SENSYLINK Microelectronics

(CT1720)
S-Wire Digital Temperature Sensor

CT1720 is a Low Cost Digital Temperature Sensor with ±0.5°C Accuracy over -30°C to 80°C with S-Wire Interface.

It is ideally used in General Temperature Monitor, White Appliance and Smoke / Heater Detector etc.

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±0.5 °C Accuracy Digital Temperature Sensor with S-Wire Interface

Description

CT1720 is a low cost digital temperature sensor with ±0.5°C(Max.) accuracy over -30°C to 80°C Temperature data can be read out directly via S-Wire interface by MCU.

It includes a high precision band-gap circuit, a 14-bit analog to digital converter that can offer 0.03125°C resolution, a calibration unit with non-volatile memory and a digital interface block.

The chip is calibrated for ±0.5 °C(Max.) accuracy in factory before shipment to customers.

Available Package: SOT-23, TO-92S package

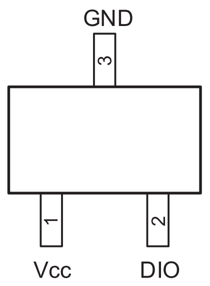
Features

- Operation Voltage: 1.8V to 5.5V
- Operating Current: 36uA(Typ.) during Temperature Conversion;
- Average Current Consumption: 0.6uA(Typ.) with reading once temperature per second
- Standby Current: 10nA (Typ.), 50nA (Max.<50°C)
- Temperature Conversion time: 33ms(Typ.)
- Temperature Accuracy:
  ±0.5°C(Max.) from -30°C to 80°C
- 14 bit ADC for 0.03125°C resolution
- S-Wire Digital Interface (single-wire lite version)
- Temperature Range: -50°C to 150°C

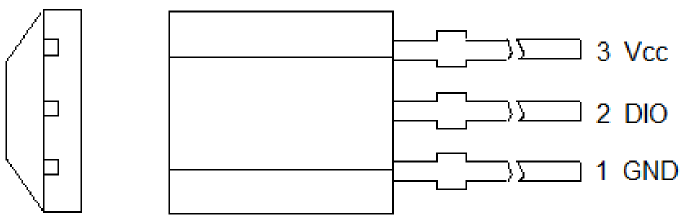
Applications

- General Temperature Monitor
- White Appliance
- Smoke / Heater Detector

PIN Configurations (Top View)



SOT-23 (package code K)



TO-92S (package code Z3)

Typical Application

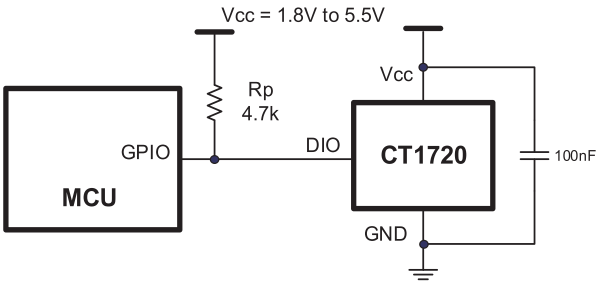


Figure 1. Typical Application of CT1720

Pin Description

PIN No.			PIN Name	Description
TO-92S	SOT-23	DFN1.2x1.2-6		
3	1	4	Vcc	Power supply input pin, it should connect a 100nF to 1.0uF ceramic cap at least to ground.
2	2	3	DIO	Digital interface data input and output pin, Generally it needs a pull-up resistor to Vcc in most applications, between 4.7k and 10k.
1	3	1	GND	Ground pin.
		2,5,6	NC	No connection

Function Block

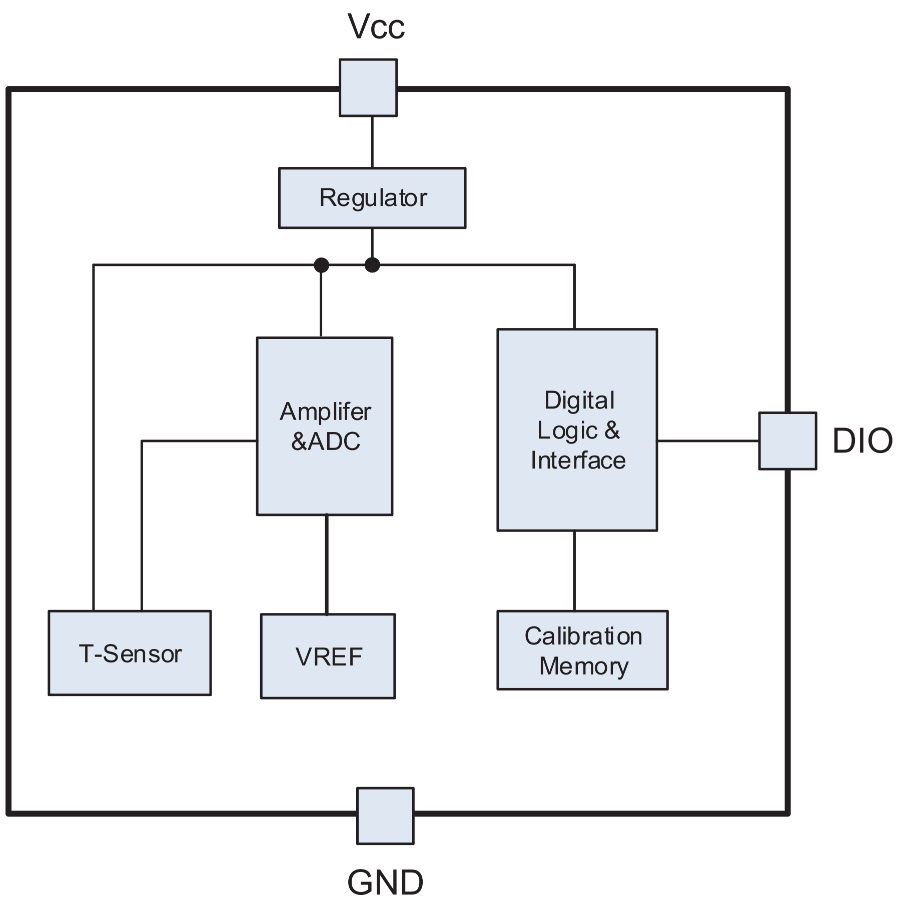
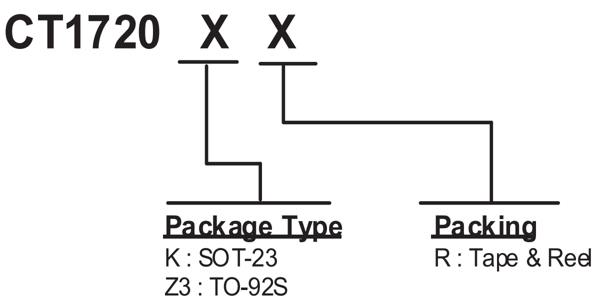


Figure 2. CT1720 function block

Ordering Information



Order PN	Accuracy	Green[1]	Package	Marking ID[2]	Packing	MPQ	Operation Temperature
CT1720KR-A	±0.35°C	Halogen free	SOT-23	ANWX	Tape&Reel	3,000	-50°C~+150°C
CT1720KR	±0.5°C	Halogen free	SOT-23	ANWX	Tape&Reel	3,000	-50°C~+150°C
CT1720Z3	±0.5°C	Halogen free	TO-92S	1720 YWWAXX	Bulk	1,000	-50°C~+150°C

Notes

1. Based on ROHS Y2012 spec, Halogen free covers lead free. So most package types Sensylink offers only states halogen free, instead of lead free.

2. Marking ID includes 2 rows of characters. In general, the 1st row of characters are part number, and the 2nd row of characters are date code plus production information. For very small outline package, there's 4 digits to stands for product information and date code, first 2 digits represent product code, and the other 2 digits stands for work week and trace code.

Absolute Maximum Ratings (Note 3)

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC} to GND	-0.3 to 5.5	V
I/O pin Voltage	V_{IO} to GND	-0.3 to 5.5	V
Operation junction temperature	T_J	-50 to 150	ºC
Storage temperature Range	T_{STG}	-65 to 150	ºC
Lead Temperature (Soldering, 10 Seconds)	T_{LEAD}	260	ºC
ESD MM	ESD_{MM}	600	V
ESD HBM	ESD_{HBM}	6000	V
ESD CDM	ESD_{CDM}	1000	V

Note 3

1. *Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at the "Absolute Maximum Ratings" conditions or any other conditions beyond those indicated under "Recommended Operating Conditions" is not recommended. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability.*
2. *Using 2oz dual layer (Top, Bottom) FR4 PCB with 4x4 mm^2 cooper as thermal PAD*

Recommended Operating Conditions

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC}	1.8 ~ 5.5	V
Ambient Operation Temperature Range	T_A	-50 ~ +150	°C

Electrical Characteristics (Note 4)

Test Conditions: V_{CC} = 3.3V, T_A = -50 to 150°C unless otherwise specified. All limits are 100% tested at T_A=25°C.

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Supply Voltage	V_{CC}		1.8		5.5	V
Temperature Accuracy	T_{AC}	T_A = 10°C to 40°C	-0.25		0.25	°C
		T_A = -30°C to 80°C	-0.5		0.5	°C
		T_A = -50°C to 150°C, Vcc=1.8 to 5.5V	-2.0		2.0	°C
Temperature Resolution		14-bit ADC		0.03125		°C
Operating Current	I_{OC}	during Temperature conversion		36		uA
Shutdown Current	$I_{SHUTDOWN}$	Idle, not temperature conversion		10	30	nA
Average Operating Current	I_{AOC}	1 time reading temperature per second		0.6		uA
Conversion time	t_{CON}	From active to finish completely		33	42	ms
Digital Interface						
Logic Input High Voltage	V_{IH}	I/O pin	0.7*Vcc		Vcc	V
Logic Input Low Voltage	V_{IL}	I/O pin	0		0.3*Vcc	V
Logic Input Current	I_{INL}	I/O pin	-2.0		2.0	uA
Communication Timing						
S-Wire Communication Clock	T_{CLK}			20		us
Recovery time	t_{REC}		1.0			us
Time slot for "0" or "1"	t_{SLOT}		2*T_{CLK}+ t_{REC}			us
Initialization Low Time	t_{INIT}		16*T_{CLK}			us
Host Read bit '0' Low Time	t_{RL}			2*T_{CLK}		us
Host Read bit '0' sampling Time	t_{HSR0}		2.5	1*T_{CLK}	2*T_{CLK}	us
Host Read bit '1' High Time	t_{RH}			2*T_{CLK}		us
Host Read bit '1' sampling Time	t_{HSR1}		3.0	2*T_{CLK}		us

Note:

Maxim Idle current is test under Ta < 50°C.

Part 1 **Initialization**	Part 2 **Temperature Conversion**	Part 3 **Read out Temperature Data**
Initialize the slave device by pulling-low DIO pin with 16*t_{CLK}, for example, 400us duration time.	Waiting for A-D Conversion for Temperature Measurement with t_{CON} time (33ms Typ.) at least, for example 40ms.	Then the chip will output 16 bits data, 1). 2 bits for conversion check; 2). 14 bits for temperature data.

Figure 3. CT1720 S-Wire Communication Protocol Diagram

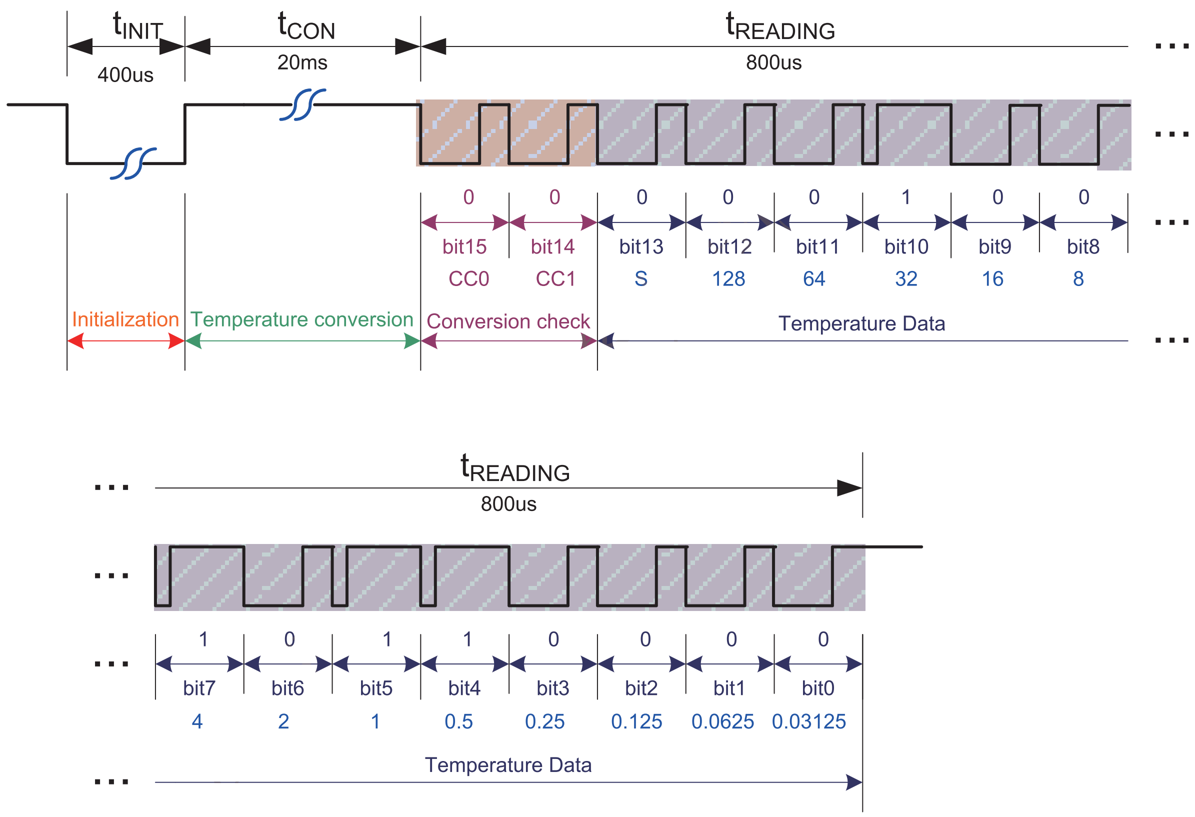


Figure 4. Complete Reading Temperature Data Diagram

**Note:*

*1. during initialization, MCU has to pull-low DIO pin with 16*tCLK, 320us at least, for example, 400us.*
2. for temperature conversion, it will spends t_{CON} (33ms Typ.) time in typical for 14 bits temperature data. MCU has to wait, for example 40ms.
3. Temperature data is valid only if both two conversion check bits (bit15 and bit14) are 0.
4. In above figure, temperature data is 37.50 oC.
5. 'S' means signature bit, to indicate if the temperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1.

1 Function Descriptions

The chip can sense temperature and convert it into digital data by a 14-bit ADC. The temperature resolution is 2^{-5} (0.03125°C). The expressed temperature range is from -255°C to +255°C. S-Wire interface is lite version of Single-Wire Bus digital interface. And its protocol is shown in Figure-3. Generally, one complete communication with host or reading temperature by host, like MCU, includes Part1, Part2 and Part3. And the time diagram is shown as Figure-4. In general, user can obtain the temperature by following below example operation procedure.

Function	Data transmission direction (host)	Data on line (LSB first)	Comments
Step 1, Initialization & temperature conversion			
Initialization	Tx	Low pulse with 400us at least duration.	The host generate valid initialization low pulse
Temperature conversion	Idle	Release DIO pin and waiting for 33ms at least, for example 40ms.	The device is busy for Temperature conversion
	Rx(option)	Checking CC0, CC1 bit	Host read the conversion check bit is '0 ', only if both CC0 and CC1 are '0', the temperature conversion is complete. or the temperature conversion has not been completed, still need to waiting till to required time of the temperature conversion (33ms in Typ.). It is ok to uncheck the conversion bits, just waiting for 33ms at least, for example 40ms.
Step 2, read temperature data from S-Wire			
Read temperature data	Rx	14 bits temperature data besides CC0 and CC1 bit	The chip sends 2 bits conversion check bits (CC0, CC1) plus 14 bits temperature data, with MSB first, then LSB.
The ends			

1.1 Digital Temperature Data

The major function of the chip is to measure temperature. The A-to-D converter resolution of the sensor is 14 bit, corresponding to 0.03125°C resolution. The CT1720 powers up in a low-power idle state. To initiate a temperature measurement and A-to-D conversion, the host has to issue an initialization and waiting for 33ms at least. After the conversion, the temperature data can be read out directly from DIO pin, total 16 bits (2 conversion check bits + 14 temperature data bits), and then the chip returns to idle state. The temperature data is stored in the temperature register as a 14-bit sign-extended two's complement format in degrees Celsius. The sign bits(S) indicate if the temperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1. Table 1 and Table 2 show examples of digital output data and the corresponding temperature (°C).

Table 1. 16-bit Temperature Data (plus CC0, CC1)

Temperature (°C)	Digital Output (HEX)	Digital Output (BIN)
+150.0000	0x12 C0	0001, 0010, 1100, 0000
+127.96875	0x0F FF	0000, 1111, 1111, 1111
+37.8125	0x04 BA	0000, 0100, 1011, 1010
0.0000	0x00 00	0000, 0000, 0000, 0000
-10.25	0x3E B8	0011, 1110, 1011, 1000
-15.625	0x3E 0C	0011, 1110, 0000, 1100

Table 2. Temperature Data in Register

BIT	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
Define	CC0	CC1	S	2^7	2^6	2^5	2^4	2^3
Temperature[°C]	'0'	'0'	sign	128	64	32	16	8
BIT	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Define	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}
Temperature[°C]	4	2	1	0.5	0.25	0.125	0.0625	0.03125

Here bit15, conversion check bit0 (CC0), bit14 is conversion check bit1 (CC1). Only if both conversion check bits (bit15 & bit14) are '0', temperature bits (bit13 to bit0) which followed by are valid. bit13 means signature bit, '0' means positive temperature, '1' means negative temperature data.

1.2 Initialization [400us]

The host issues low pulse with 320us at least duration (for example 400us), which will initialize the chip and make sure the chip is ready for temperature conversion. Once the host release the DIO pin (DIO pin will be pulled-high by external pull-up resistor), the chip will enter into temperature conversion status, which will spend 33ms in typical. If initialization is not correct, for example the low pulse width is 100us, the chip will not enter into temperature conversion status, and be kept standby mode.

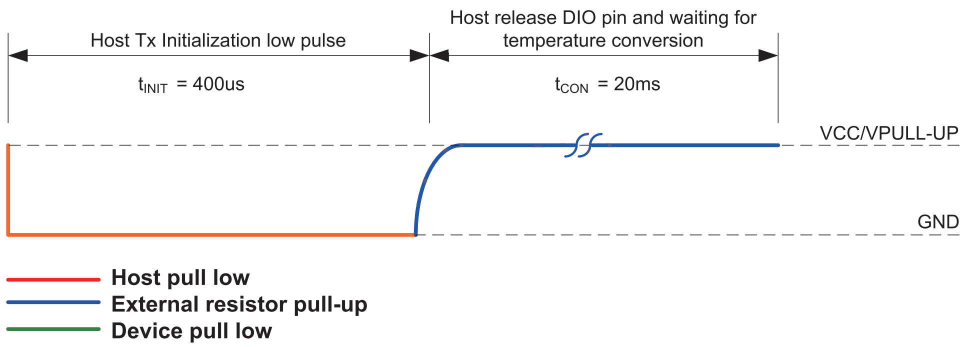


Figure 5 Initialization Timing Diagram

1.3 Temperature Conversion [33ms in Typ.]

After the host issues a valid low pulse for initialization at DIO pin, the chip will enter into working mode for temperature conversion once the host release the DIO pin (DIO pin will be pulled-high by external pull-up resistor). Temperature conversion will last 33ms in typical. And it will not be interrupted until finishing temperature conversion and save the latest temperature data into register in 14-bit (Table-2). Also user can check the chip finish temperature conversion or not by verifying conversion check bits (CC0 and CC1). Only if both CC0 and CC1 bit are '0', it does mean the chip finish temperature conversion. If user wants to terminate temperature conversion, just sending an effective initialization signal at DIO pin.

1.4 Read Out Temperature Data [16 bits, 50us/bit, 16 * 50us = 800us]

After finishing temperature conversion, the host can read out temperature data bit by bit. There is total 16 bits, start with 2 bits stand for conversion check (CC0, CC1), then followed by 14 bits stand for temperature data. The detail timing diagram is shown as above Figure-4. 16 bits definition is shown as above Table-2. Each bit starts with falling edge pulled-low by the host, shown as Figure-6.

For bit '0', the chip will pull-low the DIO pin with 40us in typical duration time, then the chip will release DIO pin, DIO pin will be pulled-high by external resistor. For example, if one bit time cycle is 50us, which means 41us (2*T + t_{REC}) of low time plus 9us of high time. If cycle is 60us, it includes 41us (2*T + t_{REC}) of low time and 19us of high time.

For bit '1', the chip will NOT pull-low the DIO pin any more, DIO pin will be pulled-high by external resistor immediately after recovery time of falling edge, 1.0us in typical. For example, if one bit time cycle is 50us, which means 1us (t_{REC}) of low time plus 49us of high time. If cycle is 60us, it includes 1us (t_{REC}) of low time and 59us of high time.

Data transmission always starts from conversion check bits (CC0 in first, then CC1), then temperature data bits (from bit14 to bit0). Also it is allowed to get partial temperature data bits, if user does not need highest temperature resolution. For example, if user just needs 1°C resolution, bit4 to bit0 can be ignored. The host does NOT sending falling edge again at DIO pin after bit5 sampling.

2 S-Wire Communication Protocol

S-Wire Protocol consists of a host and a salve device. In any case, CT1720 is used as slave device. The host could be a microcontroller or SoC. Discussion of S-Wire Protocol is divided into three parts: the hardware configuration, the operation sequence and S-Wire timing.

2.1 Hardware Configuration

S-Wire digital interface is the lite version of Single-wire, the major difference between them is that, there is only 1 host device and 1 slave device in S-Wire, multi salve devices are permitted in Single-Wire protocol. Both them have only one data line (DIO pin) physically. The slave device on the line needs to have open-drain or tri-state output, and CT1720's DIO pin uses an open-drain output.

CT1720 supports up to 22kbps communication rate. Pull-up resistor depends primarily on the distance between the host and CT1720. In most applications, it is ok to connect an external 4.7kΩ (typical) pull-up resistor. S-Wire line in idle state is high. It is ok to use another IO pin (GPIO-0) of host instead of Vcc. Both GPIO pins can be set low once finished temperature conversion & reading, which can saved power consumption further.

	S-Wire	Single-Wire
Host Device	1	1
Slave Device	1	Multi

2.2 Operation Sequence

To access CT1720 through S-Wire Line (DIO pin), the complete procedure is shown as previous Figure 3 and Figure 4, it includes:

- Part 1, Initialization.
- Part 2, Temperature Conversion.
- Part 3, Read out Temperature Data.

2.3 Single-Wire Timing

It always begins with initialization for each reading temperature operation. After complete initialization successfully on S-Wire line, the next step is to waiting for temperature conversion. Once temperature conversion is finished, the host can read out temperature data bit by bit. The following section is to descript the bit transmission. The protocol defines read '0', and read '1' signal types. All these signals are synchronous signals issued by the host. During the Read Time Slot, the host reads the data from the slave device.

Read Time Slot

S-Wire device can only transmit data to the host after the host issues read time slots. After the host issues a read temperature command, a read time slot must be generated in order to read data from the S-Wire device. A complete read time slot is at least t_{SLOT} (2*T + t_{REC}), and requires at least 3us recovery time between two separate time slots. Each time slot is generated by the host to initiate falling edge and a low level period is required to be at least 1μs shown in Figure 6. Once the device detects an S-Wire line low, the device immediately sent bit "0" or "1" on the line. If S-Wire device sends "1", the line is pulled-up high by a pull-up resistor after the short low period; if sent "0", then the line is keeping low for t_{DRV} (2*T in typical). After that the device releases the line from pull-up resistors and back to idle high. Therefore, the data issued by S-Wire device after read time slot at the beginning stay effective during time 2*T in typical. During the read time slots the host must release the line, and samples the line states at 1*T after the start of one bit, falling edge.

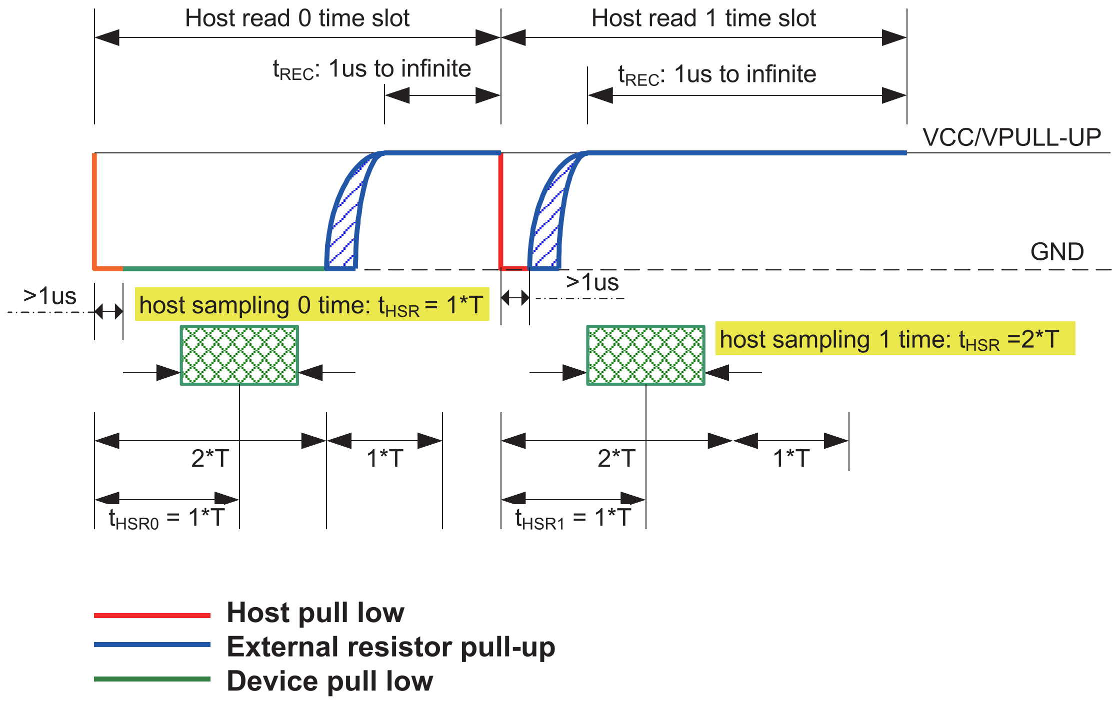


Figure 6 Read Timing Slot Diagram

There is no upper time limitation between any 2 bits (total 19 bits, including 2 conversion check bits, CC0 CC1 and 17 temperature data bits.), the bit gap time is flexible from zero to infinite. Which means it will take MCU interrupt with one bit cycle time (50us) continuously to read temperature data.

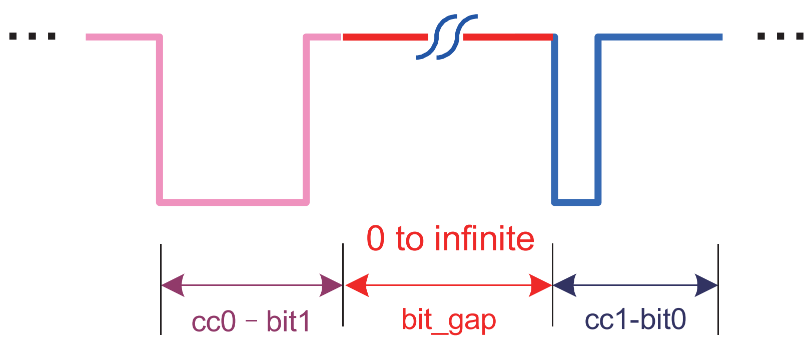


Figure 7 bit gap during Read Timing Slot

3 Software Reference Code

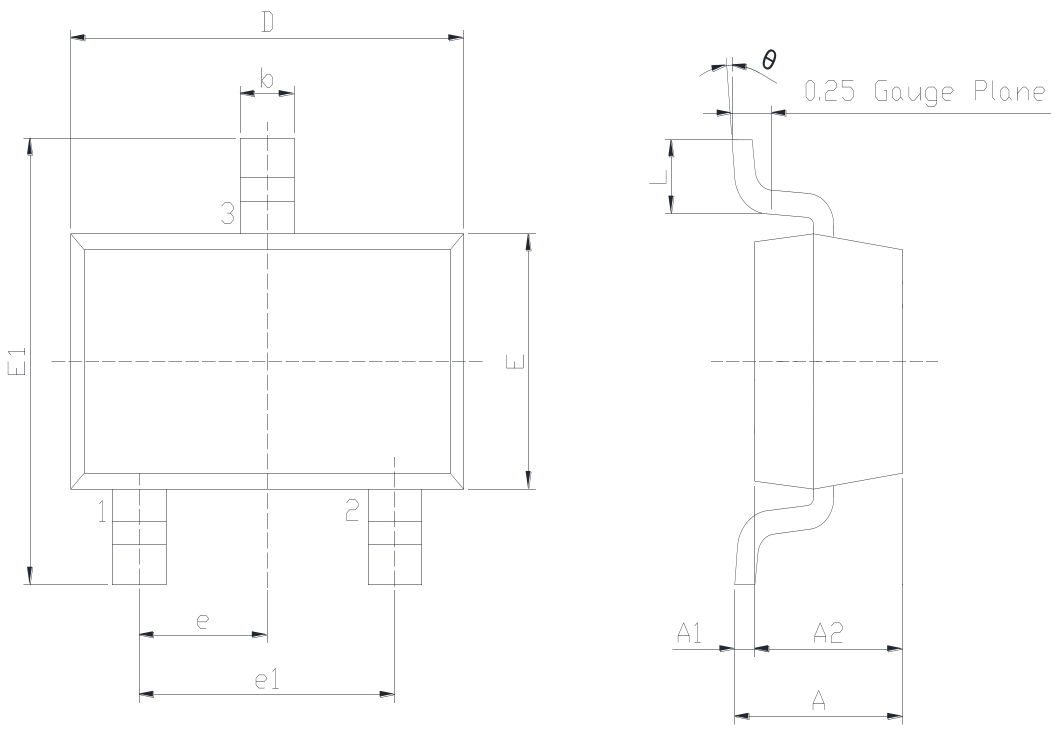
Below is reference C++ code based on 51 MCU.

```
#include <stdio.h>
sbit DIOPORT = P0 ^ 0;
/**********************************************/
void CT1720_Init(void)
{
    DIOPORT = 0;            //pull-low DIO pin
    delay500us();           //setup delay >400us
    DIOPORT = 1;           //pull-high line
}

bit CT1720_Read_Bit(void)
{
    bit bi_data;
        DIOPORT = 0;     //pull-low DIO pin with 1us
         _nop_();
        DIOPORT = 1;     //then release DIO pin
        delay20us();     //delay 20us
        bi_data = DIOPORT;     //Read 1-bit Data from DIO pin
         _nop_();
         DIOPORT = 1;     //then release DIO pin
        delay30us();     //delay 30us
    return bi_data;
}

U8 CT1720_Read_Byte(void)
{
    U8 byte = 0;
    int i;
    for(i = 8; i > 0; i--)
    {
        byte <<= 1;
        byte |= CT1720_Read_Bit();
    }
    return byte;
}
 float CT1720_Read_Temp_Degree(void)
{
    float temp = 0.00;
    unsigned char bit_cc0, bit_cc1, bit_sign;
    char temp_byte0, temp_byte1, temp_byte2;
    int  temp_val;
```

```
    CT1720_Init();               //Initialization
    Delay40ms();                 //delay 40ms
    bit_cc0 = CT1720_Read_Bit();  //get CC0 bit;
    delay10us();                 //delay 10us
    bit_cc1 = CT1720_Read_Bit();  //get CC1 bit;
    delay10us();                 //delay 10us
    bit_cc0 = bit_cc0 & 0x01;
    bit_cc1 = bit_cc1 & 0x01;
    if((bit_cc0 == 0x00) && (bit_cc1 == 0x00))
    {
       bit_sign = CT1720_Read_bit();   //get signature bit
       delay10us();                   //delay 10us
       temp_byte0 = CT1720_Read_Byte();  //Read 1st byte of Temperature, exclude cc0,cc1 and S bit, MSB is 128oC, LSB is 1.0oC of this byte.
       delay10us();      //delay 10us
       temp_byte1 = CT1720_Read_Byte();  //Then read 2nd Byte of Temperature, MSB is 0.5oC, LSB bit stands for 0.03125oC(1/32)
       delay10us();      //delay 10us
       temp_val = (temp_byte0 << 5) + (temp_byte1 >> 3);
       if(bit_sign == 0x01)
       {
          temp_val =~ temp_val;
          temp_val &= 0xFFFF;
          temp_val++;
          temp = -3.125 * temp_val / 100.00;
       }
       else
       {  temp = 3.125 * temp_val / 100.00; }
      return temp;
    }
}
void main()
{
    float  CT1720_temp = 0.00;
    Init_io_port();
    while(1)
    {
       CT1720_temp = CT1720_Read_Temp_Degree();
       printf("Temperature is: %.8f\n", temp);
    }
```

Package Outline Dimensions (SOT-23)

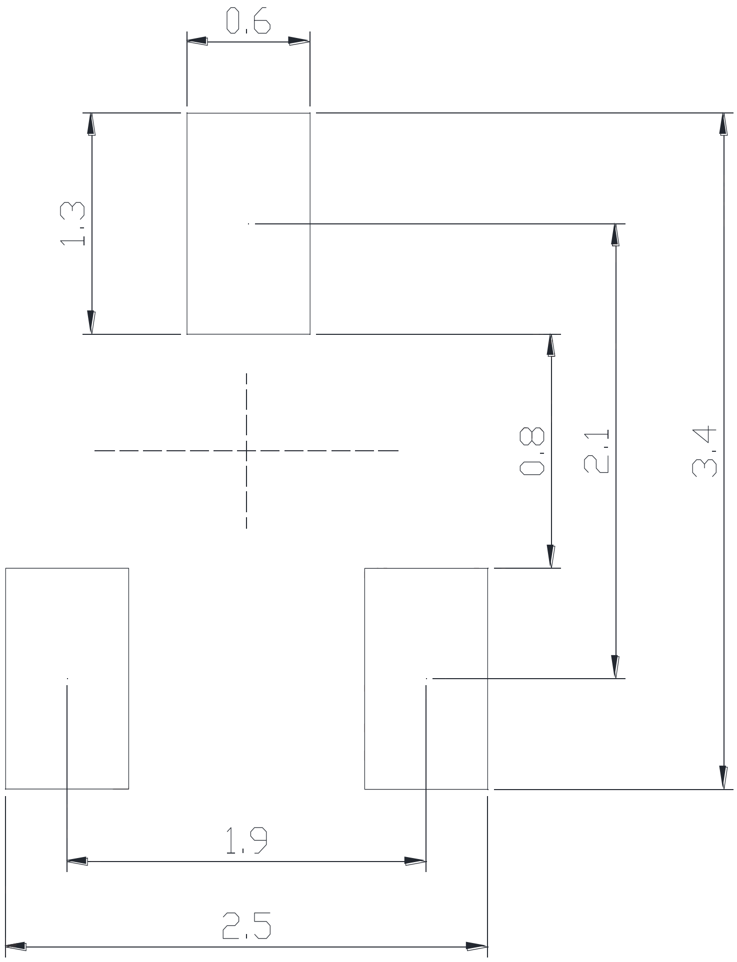
SOT-23 **Unit (mm)**



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	0.900	1.150	0.035	0.045
A1	0.000	0.100	0.000	0.004
A2	0.900	1.050	0.035	0.041
b	0.300	0.500	0.012	0.020
c	0.080	0.200	0.003	0.008
D	2.800	3.000	0.110	0.118
E	1.200	1.400	0.047	0.055
E1	2.200	2.600	0.087	0.102
e	0.950（BSC）		0.037（BSC）	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

Recommend Land Pattern Layout(SOT-23)

SOT-23 **Unit (mm)**



Note:

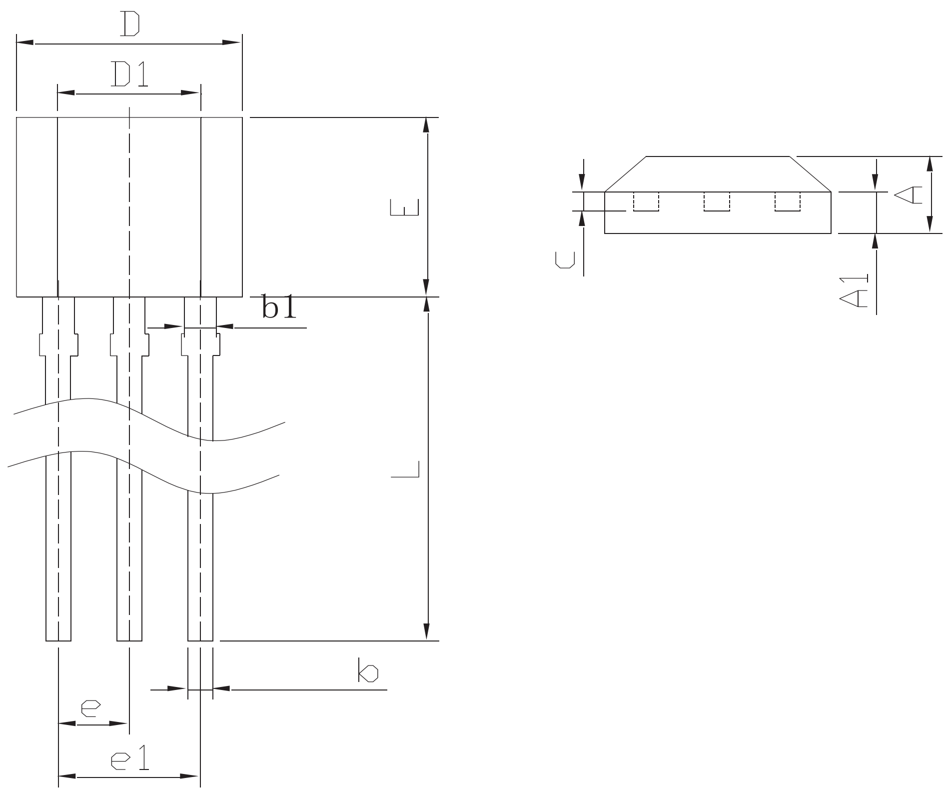
1 All dimensions are in millimeter

2 Recommend tolerance is within ±0.1mm

3 Change without notice

Package Outline Dimensions (TO-92S)

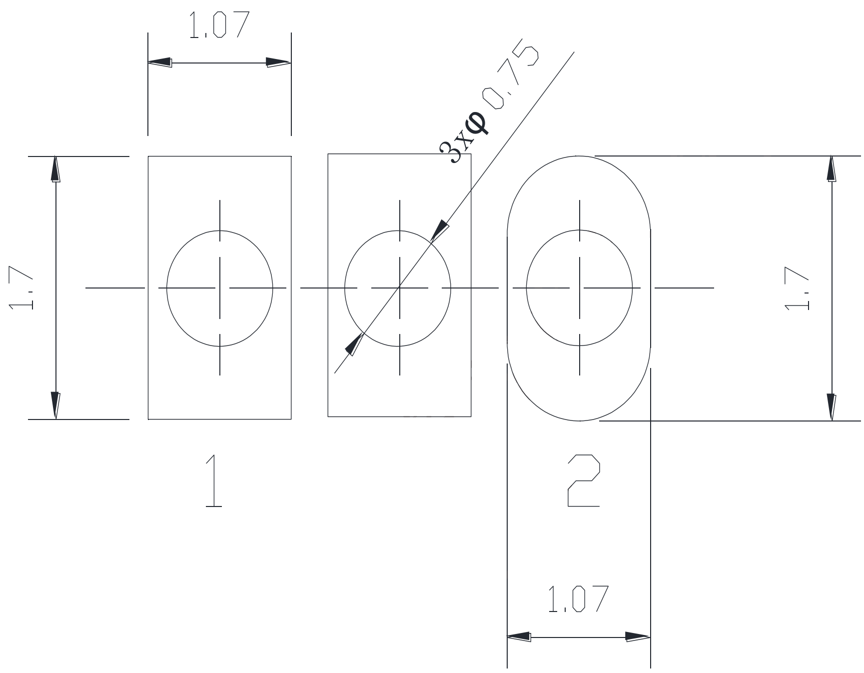
TO-92S **Unit (mm)**



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	1.420	1.620	0.056	0.064
A1	0.660	0.860	0.026	0.034
b	0.330	0.480	0.013	0.019
b1	0.400	0.510	0.016	0.020
c	0.330	0.510	0.013	0.020
D	3.900	4.100	0.154	0.161
D1	2.280	2.680	0.090	0.106
E	3.000	3.300	0.118	0.130
e	1.270（TYP）		0.050（TYP）	
e1	2.540（TYP）		0.100（TYP）	
L	15.100	15.500	0.594	0.610

Recommend Land Pattern Layout (TO-92S)

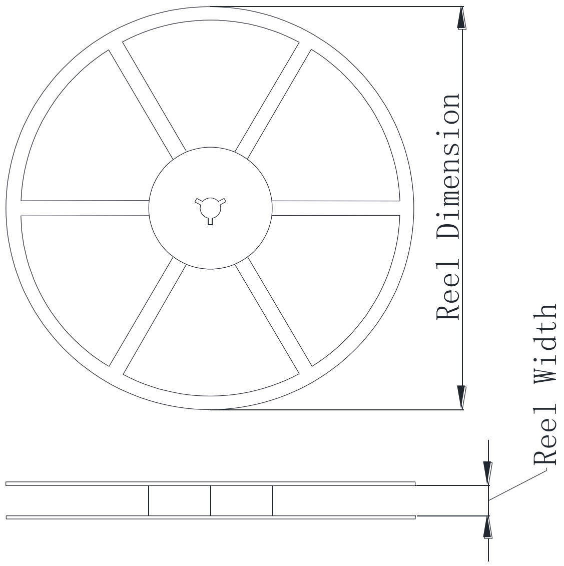
TO-92S　　Unit (mm)

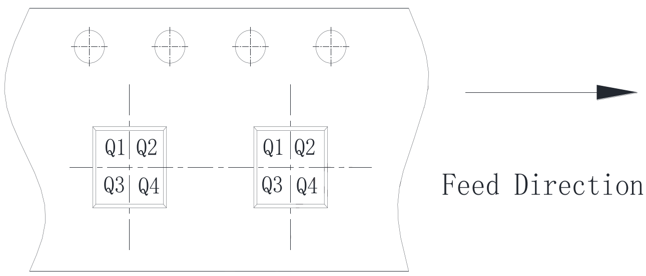


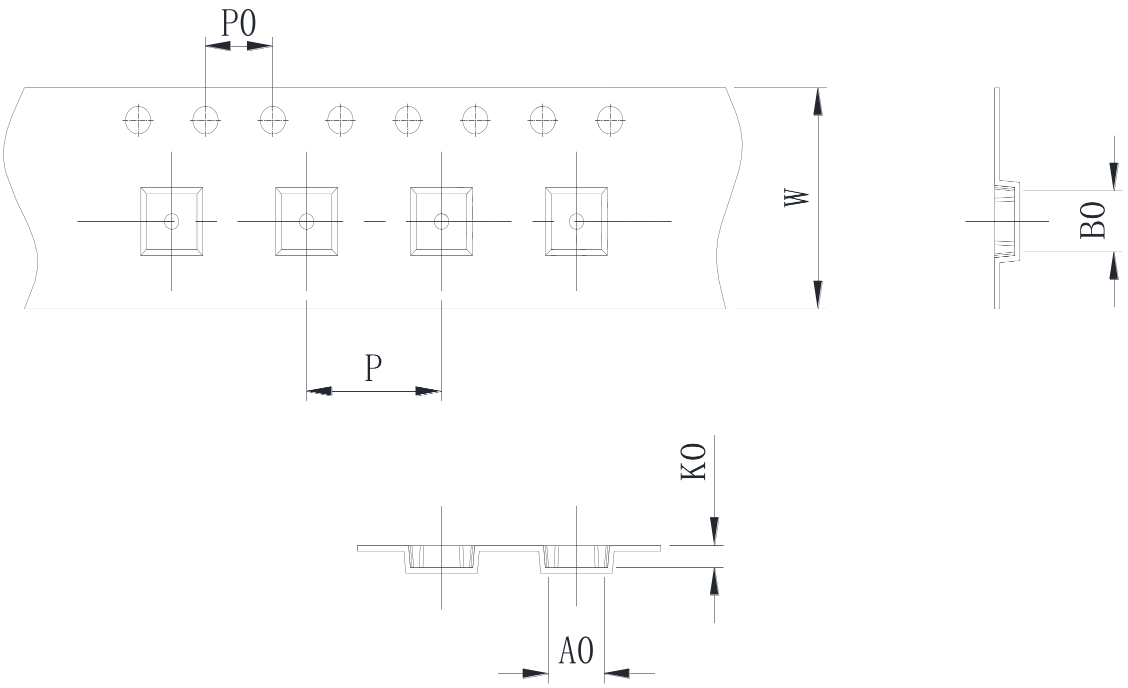
Note:

1. All dimensions are in millimeter
2. Recommend tolerance is within ±0.1mm
3. Change without notice

Packing information







Package type	Reel size	Reel dimension (±3.0mm)	Reel width (±1.0mm)	A0 (±0.1mm)	B0 (±0.1mm)	K0 (±0.1mm)	P (±0.1mm)	P0 (±0.1mm)	W (±0.3mm)	Pin1
SOT-23	7'	180	8.4	3.15	2.77	1.22	4.0	4.0	8.0	Q3

Revision History

Version	Date	Change Content
Ver1.3	2021/11	1. Update Electrical Characteristics 2. Delete DFN1.2X1.2

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IMPORTANT NOTICE