SENSYLINK Microelectronics

(CT1711)

S-Wire Digital Temperature Sensor

CT1711 is a Low Cost Digital Temperature Sensor with ±0.1°C accuracy over 30°C to 45°C with S-Wire Interface.

It is ideally used in Human Body Temperature Measurement.

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Figures and Tables

$\pm$0.1 °C Accuracy Digital Temperature Sensor with S-Wire Interface

Description

CT1711 is a low cost digital temperature sensor with $\pm$0.1°C(Max.) accuracy over 30°C to 45°C Temperature data can be read out directly via S-Wire interface by MCU.

It includes a high precision band-gap circuit, a 17-bit analog to digital converter that can offer 0.00390625°C resolution, a calibration unit with non-volatile memory and a digital interface block.

The chip is calibrated with $\pm$0.1 °C(Max.) accuracy over 30°C to 45°C range in factory before shipment to customers.

Metal Can package is specially designed to improve heat conduction performance from skin to sensor in human body measurement application.

Available Package: MCLGA3x3-4 package

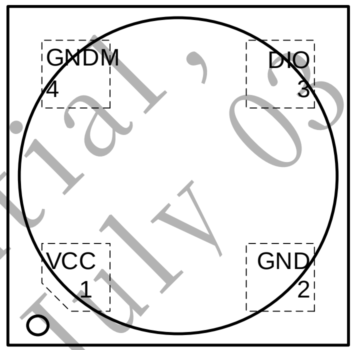
Features

- Operation Voltage: 1.8V to 5.5V
- Operating Current: 36uA(Typ.) during Temperature Conversion;
- Average Current Consumption: 4.5uA(Typ.) with reading once temperature per second
- Standby Current: 10nA(Typ.), 30nA(Max. <50 °C)
- Temperature Conversion time: 120ms(Typ.)
- Temperature Accuracy: $\pm$0.1°C(Max.) from 30°C to 45°C
- 17 bit ADC with 0.00390625°C resolution
- S-Wire Digital Interface (single-wire lite version)
- Compatible with ISO10993.5/10 (testing)
- Temperature Range: -50°C to 150°C

Applications

- General Temperature Monitor
- Human Body Temperature Monitor

PIN Configurations (Top View)



MCLGA3x3-4(package code MC)

Typical Application

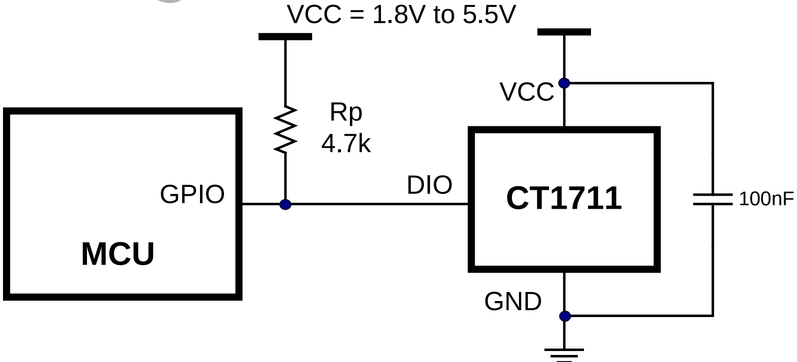


Figure 1. Typical Application of CT1711

Pin Description

PIN No.	PIN Name	Description
1	VCC	Power supply input pin, it should connect a 100nF to 1.0uF ceramic cap to ground.
2	GND	Ground pin.
3	DIO	Digital interface data input and output pin, Generally it needs a pull-up resistor (4.7k) to VCC in most applications.
4	GNDM	Metal CAN ground pin, short to GND pin in application.

Function Block

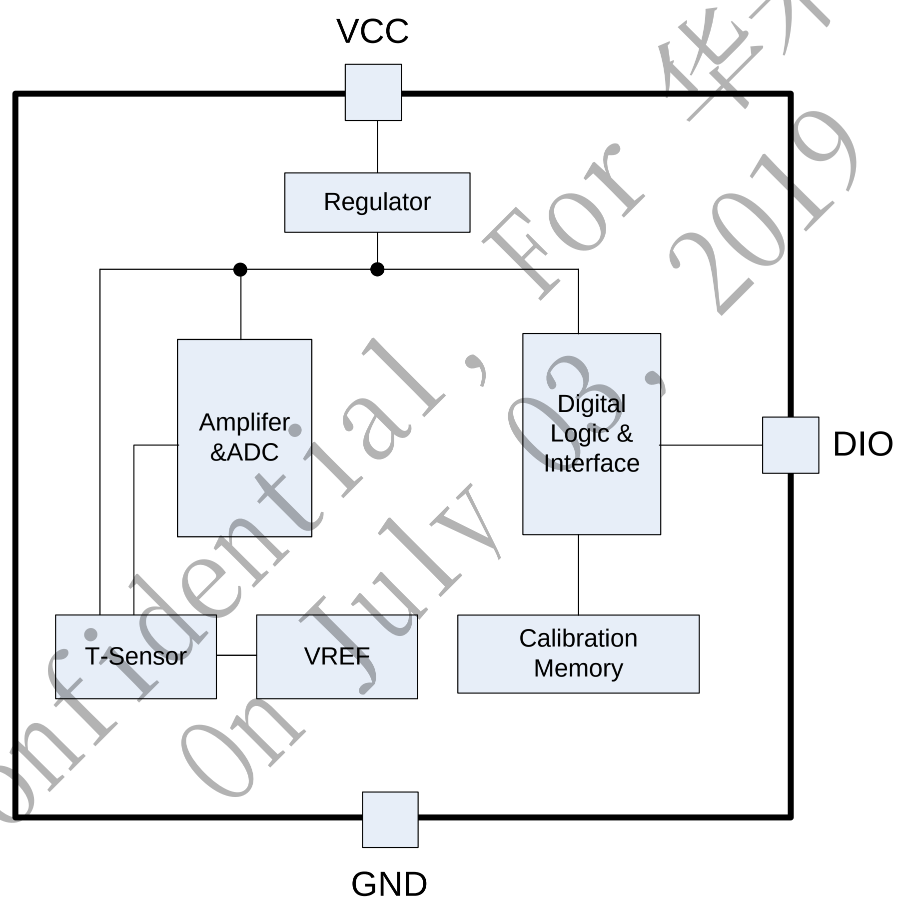


Figure 2. CT1711 function block

Ordering Information

CT1711 X X

Package Type
MC：MCLGA3x3-4

Packing
R : Tape & Reel

Order PN	Accuracy	Green[1]	Package	Marking ID[2]	Packing	MPQ	Operation Temperature
CT1711MCR	±0.1°C	Halogen free	MCLGA3x3-4	1711 YWWAXX	Tape&Reel	3,000	-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.

1) *Generally, date code is represented by 3 numbers. The number stands for year and work week information. e.g. 501stands for the first work week of year 2015;621 stands for the 21st work week of year 2016.*
2) *Right after the date code information, the next 2-3 numbers or letters are specified to stands for supplier or production location information.*
3) *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*

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}	500	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 = 30°C to 45°C, V_{CC} = 2.0V to 5.0V	-0.1		0.1	°C
		T_A = -50°C to 150°C, V_{CC} = 1.8V to 5.5V	-0.8		0.8	°C
Temperature Resolution		17-bit ADC		0.00390625		°C
Operating Current	I_{OC}	during Temperature conversion		36		uA
Shutdown Current	$I_{SHUTDOWN}$	Idle, not temperature conversion		10	30(1)	nA
Average Operating Current	I_{AOC}	1 time reading temperature per second		4.5		uA
Temperature Conversion time	t_{CON}	17-bit ADC		120		ms
Digital Interface						
Logic Input Capacitance	C_{IL}	I/O pin		20		pF
Logic Input High Voltage	V_{IH}	I/O pin	0.7*VCC		VCC	V
Logic Input Low Voltage	V_{IL}	I/O pin	0		0.2*VCC	V
Logic Input Current	I_{INL}	I/O pin	-1.0		1.0	uA
Communication Timing						
S-Wire Communication Clock	T_{CLK}		18	20	22	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

(1) The max shutdown current is tested at the temperature <50°C.

Characteristics

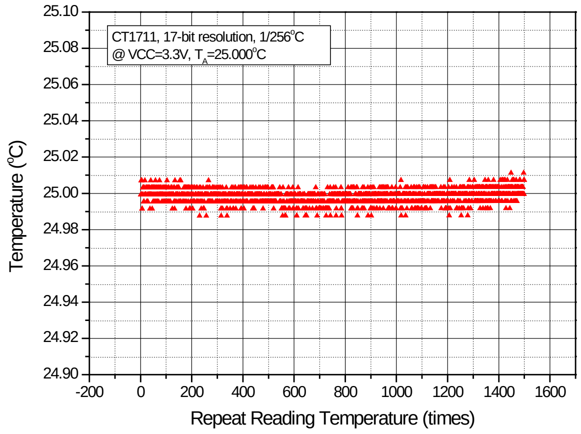


Figure 3. Repeat Reading Temperature Error

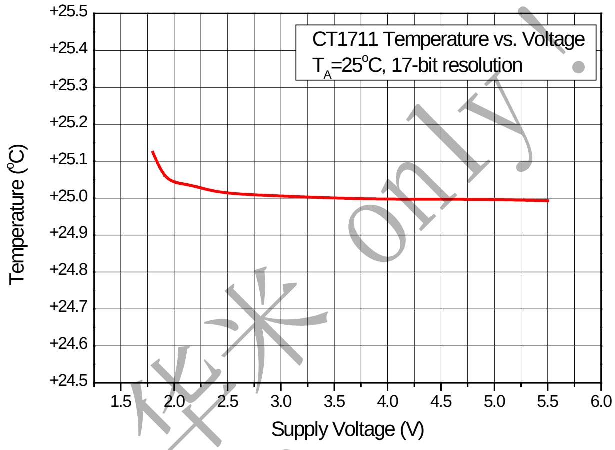


Figure 5. Temperature vs. Supply Voltage

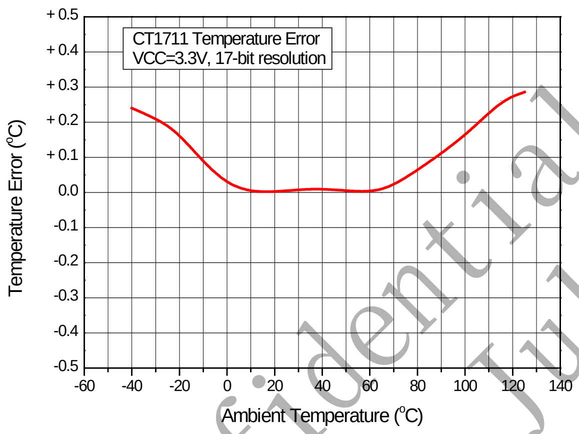


Figure 4. Temperature Error vs. Temperature

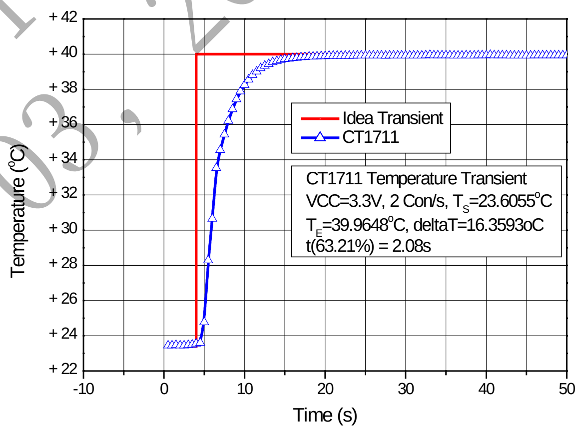


Figure 6. Temperature Transient Response

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 (120ms Typ.) at least, for example 150ms.	Then the chip will output 19 bits data, 1). 2 bits for conversion check; 2). 17 bits for temperature data.

Figure 7. CT1711 S-Wire Communication Protocol Diagram

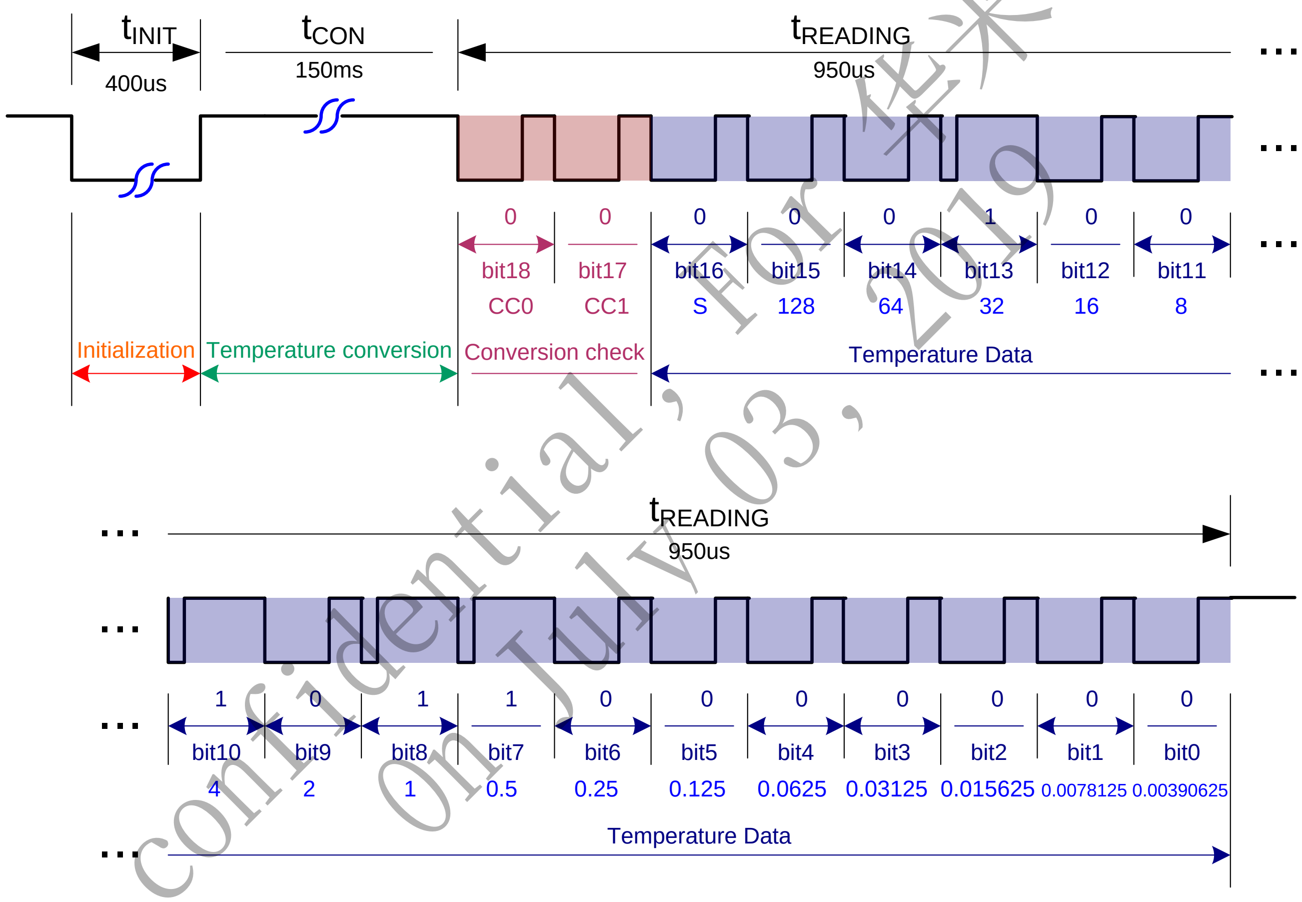


Figure 8. Complete Reading Temperature Data Diagram

Note:

*1. During initialization, MCU has to pull-low DIO pin with 16*tCLK at least, for example 400us.*
2. Temperature conversion, it will spend tCON (120ms Typ.) time for 17 bits temperature data, MCU has to wait, for example 150ms.
3. Temperature data is valid only if both two conversion check bits (bit18 and bit17) are 0.
4. 'S' means signature bit, to indicate if the temperature is positive or negative: for positive numbers S = 0 and for negative numbers S = 1
5. In above figure, temperature data is 37.5000oC.

1 Function Descriptions

The chip can sense temperature and convert it into digital data by a 17-bit ADC. The temperature resolution is 2^{-8} (0.00390625°C). The expressed temperature range is from -255°C to +255°C. S-Wire interface is the lite version of Single-Wire Bus digital interface. And its protocol is shown in Figure-7. 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-8. 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 duration.	The host generate valid initialization low pulse
Temperature conversion	Idle	Release DIO pin and waiting for 120ms at least, for Example 150ms.	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 (120ms in Typ.). It is ok to uncheck the conversion bits, just waiting for >120ms.
Step 2, read temperature data from S-Wire			
Read temperature data	Rx	17 bits temperature data besides CC0 and CC1 bit	The chip sends 2 bits of conversion check (CC0, CC1) plus 17 bits of 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 17 bit, corresponding to 0.00390625°C resolution. The CT1711 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 120ms at least. After the conversion, the temperature data can be read out directly from DIO pin, total 19 bits (2 conversion check bits + 17 temperature data bits), and then the chip returns to idle state. The temperature data is stored in the temperature register as a 17-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. 19-bit Temperature Data (including CC0, CC1)

Temperature (°C)	Digital Output (HEX)	Digital Output (BIN)
+150.99609375	0x0 96 FF	000, 1001, 0110, 1111, 1111
+127.96875	0x0 7F F8	000, 0111, 1111, 1111, 1000
+37.046875	0x0 25 0C	000, 0010, 0101, 0000, 1100
0.0000000	0x0 00 00	000, 0000, 0000, 0000, 0000
-10.234375	0x1 F5 C4	001, 1111, 0101, 1100, 0100
-15.6640625	0x1 F0 56	001, 1111, 0000, 0101, 0110

Table 2. Temperature Data in Register

BIT						Bit18	Bit17	Bit16
Define						*CC0*	*CC1*	*S*
Description						'0'	'0'	sign
BIT	**Bit15**	**Bit14**	**Bit13**	**Bit12**	**Bit11**	**Bit10**	**Bit9**	**Bit8**
Define	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Temperature[°C]	128	64	32	16	8	4	2	1
BIT	**Bit7**	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
Define	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}	2^{-8}
Temperature[°C]	0.5	0.25	0.125	0.0625	0.03125	0.015625	0.0078125	0.00390625

Here bit18, conversion check bit0 (CC0), bit17 is conversion check bit1 (CC1). Only if both conversion check bits (bit18 & bit17) are '0', temperature bits (bit16 to bit0) followed by are valid.
bit16 means sign bit, '0' means positive temperature, '1' means negative temperature data.

1.2 Initialization [400us]

The host issues low pulse with 16*t_{CLK} (320us Typ.) at least, for example 400us duration, 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 1*t_{CON} time (120ms Typ.). 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.

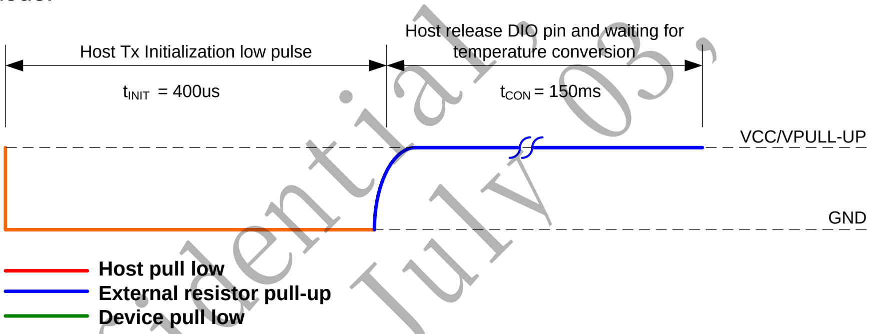


Figure 9 Initialization Timing Diagram

1.3 Temperature Conversion [120ms at least]

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 1*t_{CON} time (120ms Typ.), for example 150ms. And it will not be interrupted until finishing temperature conversion and save the latest temperature data into register in 17-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 again.

1.4 Read Out Temperature Data [19 bits, 50us/bit, 19 * 50us = 950us]

After finishing temperature conversion, the host can read out temperature data bit by bit. There is total 19 bits, start with 2 bits stand for conversion check (CC0, CC1), then followed by 17 bits stand for temperature data. The detail timing diagram is shown as Figure-8 and Table-2. Each bit starts with falling edge pulled-low by the host, shown as Figure-11.

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 0.125°C resolution, bit4 to bit0 can be ignored. The host does NOT sending falling edge again at DIO pin after bit5 sampling.

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.

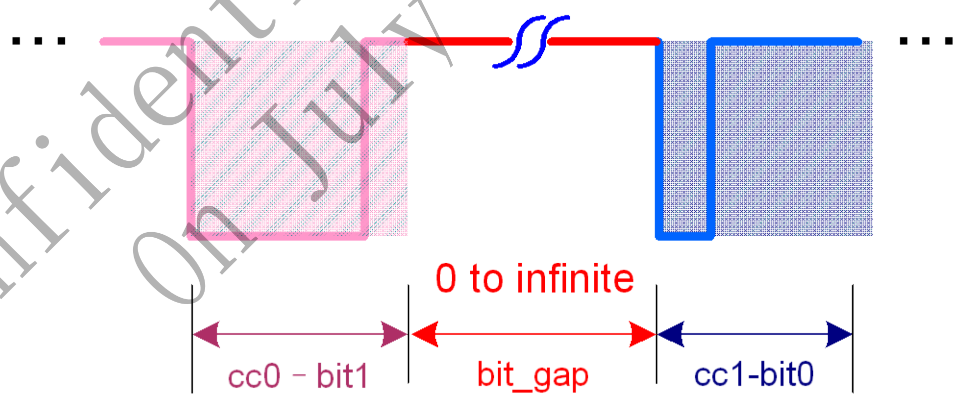


Figure 10 bit gap during Read Timing Slot

2 S-Wire Communication Protocol

S-Wire Protocol consists of a host and a salve device. In any case, CT1711 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 CT1711's DIO pin uses an open-drain output.
CT1711 supports up to 22kbps communication rate. For other communication rate, please contact Sensylink sales. Pull-up resistor depends primarily on the distance between the host and CT1711. For example with the communication distance of less than 20cm, a single node and an independent power supply condition, CT1711 requires an external 4.7kΩ (typical) pull-up resistor. If the communication distance is greater than 30m, you need a 3.3k or smaller 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 CT1711 through S-Wire Line (DIO pin), the complete procedure is shown as previous Figure 7 and Figure 8, it includes:

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

2.3 S-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 11. 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.

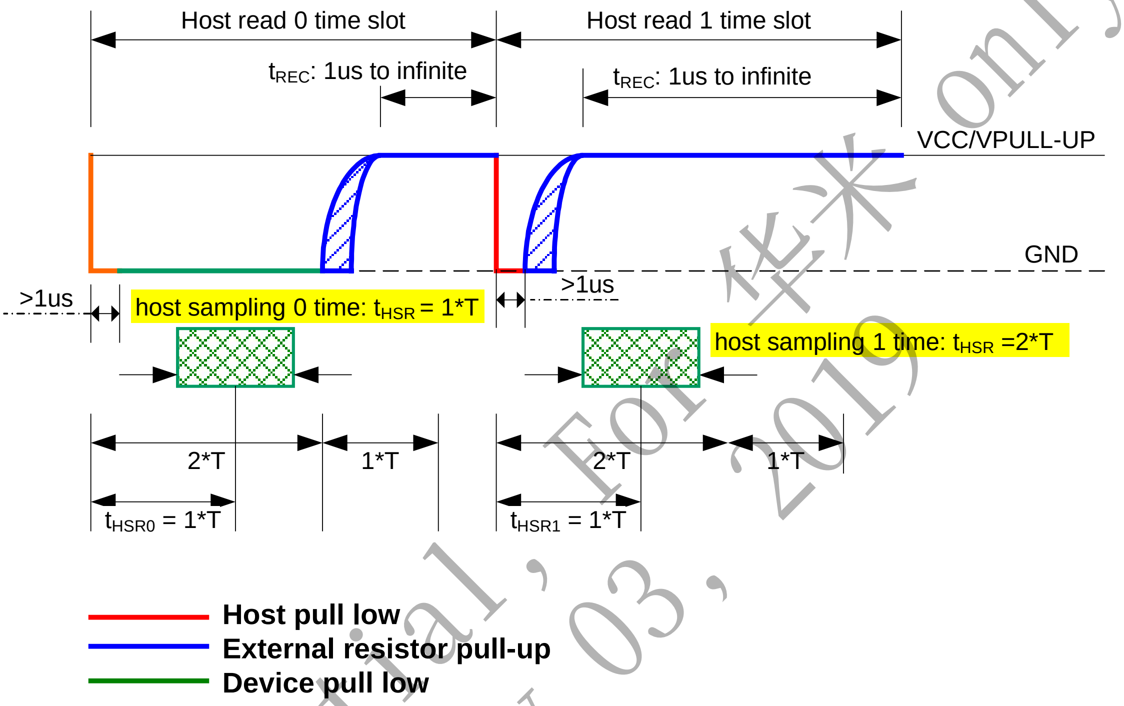


Figure 11 Read Timing Slot Diagram

3 Software Reference Code

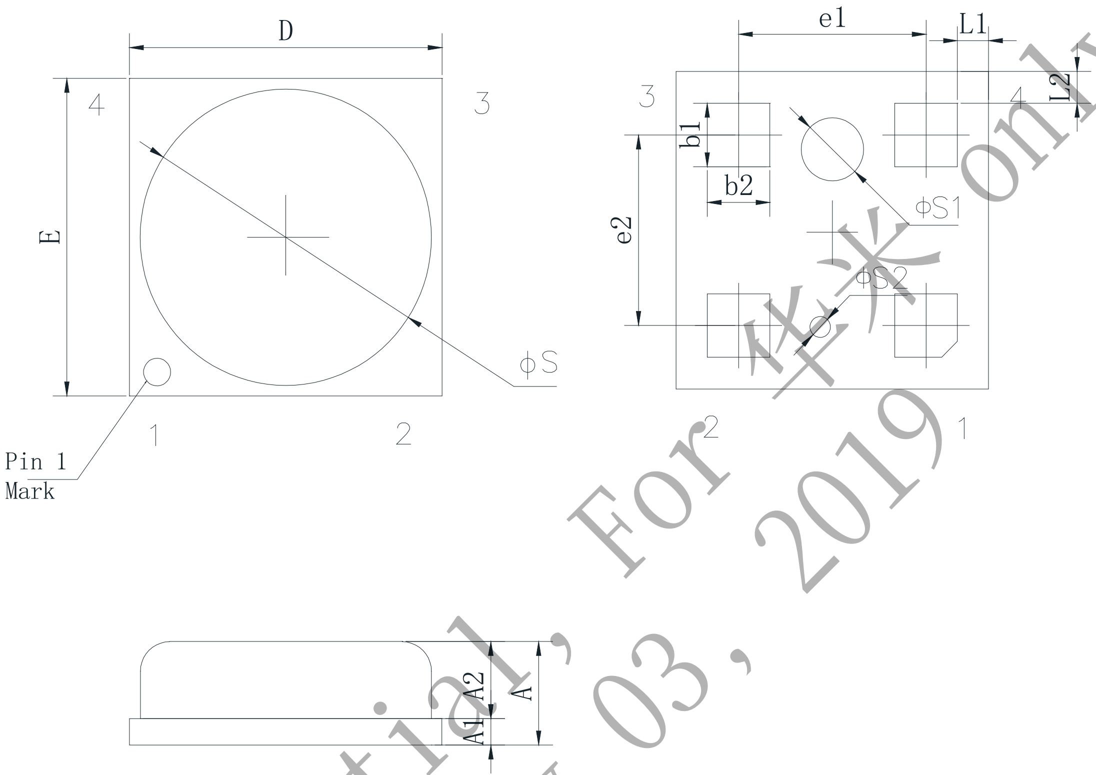
Below is C++ reference code based on 51 MCU.

```
#include <stdio.h>
sbit DIOPORT = P0 ^ 0;
/***********************************************/
void CT1711_Init(void)
{
    DIOPORT = 0;            //pull-low DIO pin
    delay500us();           //setup delay >400us
    DIOPORT = 1;           //pull-high line
}

bit CT1711_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 CT1711_Read_Byte(void)
{
    U8 byte = 0;
    int i;
    for(i = 8; i > 0; i--)
    {
        byte <<= 1;
        byte |= CT1711_Read_Bit();
    }
    return byte;
}

float CT1711_Read_Temp_Degree(void)
{
    float temp = 0.00;
    unsigned char bit_cc0, bit_cc1, bit_sign;
```

```c
    char temp_byte0, temp_byte1, temp_byte2;
    int  temp_val;
    CT1711_Init();                  //Initialization
    delay150ms();                   //delay 150ms
    bit_cc0 = CT1711_Read_Bit();     //get CC0 bit;
    delay10us();                    //delay 10us
    bit_cc1 = CT1711_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 = CT1711_Read_bit();   //get signature bit
      delay10us();                    //delay 10us
      temp_byte0 = CT1711_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 = CT1711_Read_Byte();  //Then read 2nd Byte of Temperature, MSB is 0.5oC, LSB bit stands for 0.00390625oC(1/256)
      delay10us();      //delay 10us
      temp_val = (temp_byte0 << 8) + temp_byte1;
      if(bit_sign == 0x01)
      {
        temp_val =~ temp_val;
        temp_val &= 0xFFFF;
        temp_val++;
        temp = -3.90625 * temp_val / 1000.00;
      }
      else
      { temp = 3.90625 * temp_val / 1000.00; }
     return temp;
   }
}
void main()
{
    float  CT1711_temp = 0.00;
    Init_io_port();
    while(1)
    {
      CT1711_temp = CT1711_Read_Temp_Degree();
      printf("Temperature is: %.8f\n", temp);
    }
}
```

Package Outline Dimensions (MCLGA3x3-4)

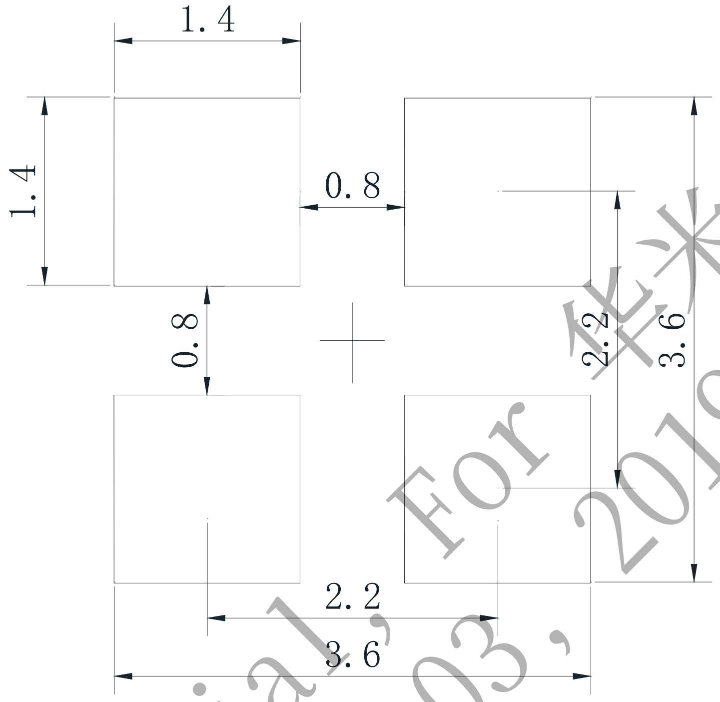
MCLGA3x3-4 Unit (mm)



Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	0.900	1.100	0.035	0.043
A1	0.200	0.300	0.008	0.012
A2	0.700	0.800	0.028	0.031
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
φS	2.700	2.900	0.106	0.114
φS1	0.550	0.650	0.022	0.026
φS2	0.150	0.250	0.006	0.010
b1	0.550	0.650	0.022	0.026
b2	0.550	0.650	0.022	0.026
e1	1.800YP.		0.072TYP	
e2	1.800YP.		0.072TYP	
L1	0.250	0.350	0.010	0.014
L2	0.250	0.350	0.010	0.014

Recommended PCB Layout Pattern (MCLGA3x3-4)

MCLGA3x3-4 Unit (mm)



Notes：All dimensions are in millimeters

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