SoC Temperature Detection Module

Application Note Rev.1.3

Introduction

This document introduces the usage methods of the internal temperature detection modules (hereinafter uniformly referred to as the TD modules in subsequent sections) of the S3KM111L, S5KM312CL, ICL1112, ICL1122, and ICL111A chips (hereinafter collectively referred to as millimeter-wave sensors), facilitating users in utilizing the TD modules to detect chip temperatures.

Contents

1 Overview of TD Module Methods

The Temperature Detection (TD) module of the millimeter-wave sensor chip (hereinafter referred to as the chip) is primarily implemented by the 0x71 and 0x73 registers within the chip. Descriptions of the 0x71 and 0x73 registers are shown in Figure 1-1.

H71	0x20a1	[15:15]	i_ts_current_multi	temp sensor 1X curent mode	0
		[14:14]	i_ts_en	temp sensor enable, active high	0
		[13:12]	i_ts_mode_sel	default mode: offset mode	10
		[11:11]	i_ts_rst_n	temp sensor reset control,active low	0
		[10:10]	i_ts_start	temp sensor start contrl signal, positive edge active convertion	0
		[9 :9]	i_tx_cap_extra	reserved code for tx matching	0
		[8 :7]	i_xtal_isel_osc	xtal oscillator pmos current setting	01
		[6 :5]	i_xtal_vreg_set	xtal oscillator regulator power supply voltage setting	01
		[0]	i_pllsyn_rstn	synthesizer pll digital circuit reset signal, active low	1
H73		[10:0]	o_ts_adcdata	auxiliary adc data output	
		[11]	o_ts_datavalid	auxiliary adc data ready	
		[15]	o_pllsys_locked	pllsys lock flag	

Figure 1-1 Register description

Among them:

- The TD module's on/off and reset are controlled by the register 0x71;
- The temperature information of the TD module is obtained through the register 0x73.

2 Reading Temperature

The procedure to read the temperature information of the chip's TD module is as follows:

1) Disable the functions of modules other than the TD module. For detailed register information, refer to Chapter 6;
2) Read the value of the chip's 0x71 register and record it as the initial register value (0x71, value1);
3) Reconfigure the 0x71 register by writing the register value (0x71, 0x50A1) to reset the TD module;
4) Reconfigure the 0x71 register to disable the reset operation of the TD module, restoring the TD module to its normal operating state, by writing the register value (0x71, 0x58A1);
5) Read the value of the 0x73 register (0x73, value2), where bits [9:0] of the 0x73 register are related to temperature;
6) Define Code = HEX2DEC(value2 & 0x03ff), where the function HEX2DEC(arg) converts a hexadecimal parameter to a decimal value;
7) The relationship between the chip temperature and bits [9:0] of the 0x73 register is T = k3 * code3 + k2 * code2 + k1 * code + B. From this formula, the real-time chip temperature T can be calculated in degrees Celsius (°C), where k3, k2, k1, and B are coefficients; these coefficients require calibration. For detailed calibration methods, refer to Chapter 3;
8) Restore the initial value of the chip's 0x71 register by writing the register value (0x71, value1).

3 Calibration Methods

- The calibration of the TD module of the chip adopts a third-order piecewise curvature fitting method. Due to its high-temperature/low-temperature characteristics, the curve is divided into two segments (high-temperature segment and low-temperature segment) from a single calibration point for separate fitting. The coefficients need to be differentiated under high- and low-temperature conditions. Under low-temperature conditions, the coefficients are k3L, k2L, k1L, and B_L; under high-temperature conditions, the coefficients are k3H, k2H, k1H, and B_H.

$$T\_L = k3L * code^3 + k2L * code^2 + k1L * code + B\_L \quad (3\text{-}1)$$

$$T\_H = k3H * code^3 + k2H * code^2 + k1H * code + B\_H \quad (3\text{-}2)$$

- The Excel calculation formula is: =LINEST(B5:B29, C5:C29^{1,2,3}, TRUE, TRUE), which returns the coefficients k3L, k2L, k1L, B_L, and k3H, k2H, k1H, B_H.

The detailed calibration steps are as follows:

1) Disable the functions of modules other than the TD module. For detailed register information, refer to Chapter 6;
2) Place the chip test board in a high- and low-temperature chamber and read the values of bits [9:0] of the 0x73 register at temperatures ranging from -40°C to 85°C at intervals of 5°C. Note that wait for 10 minutes at each temperature level before reading the register;
3) Select the test data from -40°C to 25°C to calculate the coefficients k3L, k2L, and k1L; select the test data from 25°C to 85°C to calculate the coefficients k3H, k2H, and k1H;
4) Select 10 chips and complete the above tests respectively. Calculate the average values of k3L, k2L, k1L, and k3H, k2H, k1H as the calibration coefficients for the chips;
5) Each chip needs to be calibrated for B_L and B_H at room temperature (25°C) before use;
6) Subsequent chips should write the above-calibrated k3L, k2L, k1L, B_L, and k3H, k2H, k1H, B_H into the corresponding code; temperature reading should be performed using the method described in Chapter 2.

4 Simple Calibration Methods

Refer to formulas (3-1) and (3-2) of the calibration methods:

$$T\_L = k3L * code^3 + k2L * code^2 + k1L * code + B\_L$$

$$T\_H = k3H * code^3 + k2H * code^2 + k1H * code + B\_H$$

1) Through the test and calibration conducted by our company, the coefficients are confirmed as follows: k3L=3.92E−06, k2L=−0.0082, k1L=5.19, k3H=5.80E−06, k2H=−0.01, k1H=5.11. With the k values confirmed, record the ambient temperature at that time with a thermometer during mass production or other test environments.
2) Disable the functions of modules other than the TD module (refer to Chapter 6 for detailed register information); Read the value of bits [9:0] of the 0x73 register.
3) Calculate B_L and B_H using Formulas 3-1 and 3-2 based on the measured ambient temperature.
4) Subsequent chips should write the above-calibrated k3L, k2L, k1L, B_L, and k3H, k2H, k1H, B_H into the corresponding code; temperature reading should be performed using the method described in Chapter 2.

5 Sample Code

The sample code to read the temperature information of the TD module is as follows:

```
uint16_t Radar_GetChipTemp(void)
{
uint16_t reg_tmp = 0;
uint16_t reg_temperature;
float tmperature_val;

I2C_Read(I2C_ADDR_RADAR_Chip0, 0x71, &reg_tmp);
I2C_Write(I2C_ADDR_RADAR_Chip0, 0x71, 0x50A1);
I2C_Write(I2C_ADDR_RADAR_Chip0, 0x71, 0x58A1);
I2C_Read(I2C_ADDR_RADAR_Chip0, 0x73, &reg_temperature);
I2C_Write(I2C_ADDR_RADAR_Chip0, 0x71, reg_tmp);

tmperature_val = 506.7 - 0.746 * (reg_temperature & 0x03ff);

return (uint16_t)tmperature_val;
}
```

6 Register List

00=0500	20=0500	31=0500
01=0500	21=0500	32=0500
02=0500	22=0500	33=0500
03=0500	23=0500	34=0500
04=0500	24=0500	35=0500
05=0500	25=0500	36=0500
06=0500	26=0500	37=0500
07=0500	27=0500	3A=0500
08=0500	28=0500	3B=0500
09=0500	29=0500	3C=0500
0A=0500	2A=0500	3D=0500
0B=0500	2B=0500	3E=0500
0D=0500	2C=0500	3F=0500
0E=0500	2D=0500	40=0207
10=0500	2F=0500	41=0000
11=0500	30=0500	42=0000

43=61A8
44=0000
45=0000
46=01F4
47=0000
48=2904
49=0000
4A=0EA6
4B=0000
4C=280A
4D=0000
4E=0001
4F=0000
50=0258
51=0000
52=0765
53=5000
54=0000
55=0000
56=0000
57=0000
58=0000
59=0000
5A=0000
5B=0022
5C=0022
5D=0601
5E=FF32
5F=2D16
61=01EF
62=016F
63=01EF
64=016F
65=0000
66=0000
67=0000
68=0000
69=1004
6A=0000
6B=6D00
6C=0000
6D=8AD0
6E=0390
6F=FF00
70=0000
71=2021
72=02D0
73=0000
74=0102
75=0004
76=0021
77=0400
78=0807
79=0003

7 Revision History

Revision	Date	Content
1.0	2021/11/12	Initial release.
1.1	2025/11/28	Added ICL1112, ICL1122 and ICL111A to the SoC series.
1.2	2026/1/20	Added Chapter 3, Calibration Methods.
1.3	2026/03/17	Added Chapter 4, Simple Calibration Methods.

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