

SPC58xx temperature sensor

Introduction

The aim of this document is to detail the usage of the temperature sensor on SPC58xx microcontroller family.

The document provides the necessary information about the hardware and a reference code to calculate the temperature.

All the microcontrollers (MCU) listed in [Table 1. Devices list](#) include a temperature sensor (TSENS) that monitors device junction temperature.

More details about the TSENS can be found in the device's reference manual (see [Section Appendix B Reference documents](#)).

Note: SPC582Bx MCU does not support TSENS.

Table 1. Devices list

Device	Part number
SPC584Bx	SPC584B60x, SPC584B64x, SPC584B70x
SPC584Cx/SPC58ECx	SPC584C70x, SPC584C74x, SPC584C80x, SPC58EC70x, SPC58EC74x, SPC58EC80x
SPC584Gx/SPC58EGx	SPC584G80x, SPC584G84x, SPC58EG80x, SPC58EG84x, SPC58NG80x, SPC58NG84x
SPC58EHx/SPC58NHx	SPC58EH84x, SPC58EH90x, SPC58EH92x, SPC58NH84x, SPC58NH90x, SPC58NH92x

1 Overview

SPC58xx MCUs include an onboard temperature sensor that monitors device temperature and delivers two analog outputs signals and three digital output signals. The analog outputs consist of two voltage signals which vary linearly with the internal junction temperature:

- a voltage signal that is linearly increasing (PTAT: Proportional to absolute temperature)
- a voltage signal that is linearly decreasing (CTAT: Complementary to absolute temperature).

The analog outputs are connected to an input channel of an ADC on the device. The internal junction temperature must be calculated by software based on the converted temperature values. The three digital outputs, connected to the PMC module, are used to signal under- and over-temperature operating conditions. These signals notify the device to take action to appropriately adjust the device temperature in response to an out of specification low or high temperature operating condition. Calibration parameter values, associated with the temperature threshold detection feature, are determined and stored in internal flash memory during production testing at the factory.

1.1 Linear temperature sensor (analog output generation)

The temperature sensor outputs two voltage proportional and complementary proportional to the internal junction temperature of the chip. These analog voltage signals are converted into digital values by an on-chip ADC (SAR_ADC_12bit_B0). The temperature value is obtained from a linear voltage-temperature relation with coefficients adjusted by calibration parameters. These are extracted during factory test and programmed into flash memory.

2 Temperature formula

The [Table 2. Calibration constants](#) shows the addresses of the calibration parameters associated to the temperature sensor in the internal UTEST memory.

Table 2. Calibration constants

Constant	Description	UTEST Address
P1	Code from the ADC converting PTAT output voltage at 150°C	0x400004
P2	Code from the ADC converting PTAT output voltage at -40°C	0x400000
C1	Code from the ADC converting CTAT output voltage at 150°C	0x400006
C2	Code from the ADC converting CTAT output voltage at -40°C	0x400002

In the equations below:

- Pn and Cn are the calibration constants described in [Table 2. Calibration constants](#) .
- T is the unknown device temperature in °C
- Px is the code from the ADC converting PTAT output voltage at the temperature T with any ADC reference voltage Vref
- Cx is the code from the ADC converting CTAT output voltage at the temperature T with the same ADC reference voltage Vref
- T2 = -40 °C
- T1 = 150 °C

The temperature T is calculated as:

$$T = T2 + (A * (T1 - T2)) / (A + B)$$

Where:

$$A = Px * C2 - (Cx * P2)$$

$$B = Cx * P1 - (Px * C1)$$

Please, note that it is mandatory to have the same value as the ADC reference while measuring Px and Cx.

The monitoring of on-chip analog signals coming from temperature sensor is managed by the SARADC SUPERVISOR (SAR_ADC_12bit_B0) through some specific test channels. The [Table 3. SAR_ADC analog test channels for TSENS](#) shows the test channels for temperature sensor.

Table 3. SAR_ADC analog test channels for TSENS

Test channel	Description
120	PTAT (Proportional to absolute temperature)
121	CTAT (Complementary to absolute temperature)

After the conversion is performed on a test channel the converted data is stored at two CDR locations at the end of conversion, first location is the CDR belonging to the test channel on which conversion is performed and second location is the CDR belonging to internal channel on which test channel is mapped.

3 Example code for temperature calculation

The C code below is a part of the SPC5Studio temperature sensor component and shows how to calculate the junction temperature in SPC58xx devices.

```
int16_t p1,p2,c1,c2;
uint16_t px,cx;
float a,b;
float t1 = (float)150;
float t2 = (float)-40;

/* get calibration constants from flash */
address = tsens_config.constants_address;
p2 = *((vuint16_t*)(address));
address = tsens_config.constants_address + 2UL;
c2 = *((vuint16_t*)(address));
address = tsens_config.constants_address + 4UL;
p1 = *((vuint16_t*)(address));
address = tsens_config.constants_address + 6UL;
c1 = *((vuint16_t*)(address));

/* get current vbg and tsens values from saradc channels */
cx = saradc_llc_readchannel(tsens_config.saradc_driver, tsens_config.vbg_channel);
px = saradc_llc_readchannel(tsens_config.saradc_driver, tsens_config.tsens_channel);

/*calculate and b values */
a = ((float)px * (float)c2) - ((float)cx*(float)p2);
b = ((float)cx*(float)p1) - ((float)px*(float)c1);

/* calculate temperature */
temperature = t2 + ((t1-t2)*a)/(a+b);
```

where:

```
tsens_config.constants_address = 0x00400000
tsens_config.vbg_channel = 121U
tsens_config.tsens_channel = 120U
```

Appendix A Acronyms and abbreviations

Table 4. Acronyms

Abbreviation	Complete name
MCU	Microcontroller unit
TSENS	Temperature sensor
UTEST	User test Flash
ADC	Analog to digital converter
SARADC	Successive approximation register analog to digital converter
PMC	Power management controller

Appendix B Reference documents

- SPC58xx 32-bit power architecture microcontroller reference manuals.

Revision history

Table 5. Document revision history

Date	Version	Changes
16-Jul-2020	1	Initial release.

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