AS3213C.4 Application Note – AN09

Use of embedded temperature sensor

Revision History

Revision	Date	Comment
1.0	2023-02-10	Initial version

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1. Description

The purpose of this document is to guide users of ASYGN **AS3213C.4** integrated circuits for the conversion of temperature sensor data into a temperature in °C. **During probing of the wafers, a calibration of each IC is carried out at 30°C.** If this calibration fits the needs of the user, he can refer to section 2. If the user wants to perform his own calibration (at a temperature different from 30°C for instance), he needs to refer to section 3.

2. Temperature sensing with an AS3213C.4 IC calibrated at 30°C

The default configuration of the AS3213C.4 IC, as described in its datasheet, is a correct configuration to use in the applications:

CONFIG0 (C0) - EPC bank address 0x10 - **C0 = 0x1000**
CONFIG1 (C1) - EPC bank address 0x11 - **C1 = 0x1003**
CONFIG1 (C2) - EPC bank address 0x12 – **C2 = 0x0**

The user can refer to the datasheet of the IC to adjust this configuration according to his needs.
The information and equations below are valid if ADC_NSMPL = 0x0 (CONFIG0) and ADC_REF = '1' (CONFIG1). If the user needs to configure ADC_NSMPL or/and ADC_REF with other values, he can contact support@asygn.com.

2.1. Use of the calibration data to calculate the offset correction value for each IC

1) Reading of the calibration data, ***CALIB_ACQ_TEMP[12:0]***, at address 0x6 in the USER bank (bits 12 downto 0), and conversion of this hexadecimal data into a decimal (between 0 and 8191).

2) Calculation of the offset correction: ***CALIB_OFFSET* = 3860.27 – *CALIB_ACQ_TEMP***

   For example, if ***CALIB_ACQ_TEMP[12:0]*** = 0x0EE3 --> 3811 in decimal

   ➔ ***CALIB_OFFSET*** = 3860.27 – 3811 ~ 49.27

IMPORTANT NOTICE: if possible, it may be useful for the user to save the ***CALIB_OFFSET*** value of each chip in a table. By this way, the above calculation do not need to be made each time a temperature measurement is taken: this calculation then only have to be redone if the chips are recalibrated (for example if calibration at a different temperature is required).

2.2. Use of the offset correction value for temperature sensing

Hereunder are the two steps that the user must follow to measure the temperature sensor data of an AS3213C.4 IC and convert it into a temperature in °C.

1) Inventory of the tag and reading of the temperature sensor data ***ACQ_TEMP[9:0]*** at address 0x1 in the USER bank (bits 9 downto 0). Conversion of this hexadecimal data in decimal.

2) Conversion of the sensor data into a temperature value by the following calculation:

   - ***ACQ_TEMP_CORRECTED* = *ACQ_TEMP* + (*CALIB_OFFSET* / 8)**
   - **t° (in °C) = A x *ACQ_TEMP_CORRECTED* + B** with **A = 0.3378** and **B = -133**

   For example, if ***ACQ_TEMP[9:0]*** = 0x01EF --> *495 in decimal* and ***CALIB_OFFSET*** = 49.27

   ACQ_TEMP_CORRECTED = 495 + (49.27 / 8) = 501.16

   ➔ t° (in °C) = 0.3378 x 501.16 - 133 ~ 36.3 °C

3. Calibration and use of an AS3213C.4 IC for temperature sensing

Reminder: if the calibration carried out at 30°C during the wafer production test corresponds to the needs of the user, this section 3 is useless: the user should refer to section 2 above in this case.

3.1. Calibration of an AS3213C.4 IC

The calibration just consists in storing in the Non Volatile Memory of each IC the two following data:

- ***CALIB_TEMP***, stored in the USER Bank at address 0x5 (USER5): the temperature measured by a reference sensor during calibration process.
- ***CALIB_ACQ_TEMP***, stored in the USER Bank at address 0x6 (USER6): the temperature sensor data provided by the IC during calibration process.

To do so, the operations listed below need to be performed for each IC (please refer to the component's datasheet if needed).

1) Configuration of the IC:

   CONFIG0 (C0) - EPC bank address 0x10 - **C0 = 0x9003**
   CONFIG1 (C1) - EPC bank address 0x11 - **C1 = 0x1003**
   CONFIG1 (C2) - EPC bank address 0x12 – **C2 = 0x0**

2) Measurement of the temperature during calibration: ***CALIB_TEMP***, and storage of ***CALIB_TEMP*** in the USER Bank at address 0x5 as an integer in 1/100 degC.

   For example, if the temperature is 27.4°C --> 2740 --> ***CALIB_TEMP*** = 0xAB4

3) Capture of the sensor value, ***CALIB_ACQ_TEMP[12:0]***: it is the sum of 8 temperature acquisitions, read at address 0x1 in the USER bank (bits 12 downto 0).

   For example, a possible sensor data value (for one acquisition) is 478 in decimal --> 8 x 478 = 3824 --> ***CALIB_ACQ_TEMP[12:0]*** = 0x0EF0

4) Storage of ***CALIB_ACQ_TEMP[12:0]*** in the USER Bank at address 0x6.

3.2. Temperature sensing with an AS3213C.4 IC

The default configuration of the AS3213C.4 IC, as described in its datasheet, is a correct configuration to use in the applications:

CONFIG0 (C0) - EPC bank address 0x10 - **C0 = 0x1000**
CONFIG1 (C1) - EPC bank address 0x11 - **C1 = 0x1003**
CONFIG1 (C2) - EPC bank address 0x12 – **C2 = 0x0**

The user can refer to the datasheet of the IC to adjust this configuration according to his needs.
The information and equations below are valid if ADC_NSMPL = 0x0 (CONFIG0) and ADC_REF = '1' (CONFIG1). If the user needs to configure ADC_NSMPL or/and ADC_REF with other values, he can contact support@asygn.com.

3.2.1. Use of the calibration data to calculate the offset correction value for each IC

1) Reading of ***CALIB_TEMP*** (at address 0x5 in the USER bank), conversion of this data into a temperature in °C (see section 3.1 above), and calculation of the expected sensor value for this temperature, ***EXP_ACQ_TEMP***:

   ***EXP_ACQ_TEMP* ~ 1/A x (*CALIB_TEMP* – B)** with **A = 0.3378** and **B = -133**

   For example, with ***CALIB_TEMP*** = 0xAB4 --> ***CALIB_TEMP*** = 27.4°C

   ➔ ***EXP_ACQ_TEMP*** ~ 1/0.3378 x (27.4 + 133) ~ 474.84

2) Reading of ***CALIB_ACQ_TEMP[12:0]***, at address 0x6 in the USER bank (bits 12 downto 0), and conversion of this hexadecimal data into a decimal (between 0 and 8191).

   For example, if ***CALIB_ACQ_TEMP[12:0]*** = 0x0EF0 --> 3824 in decimal

3) Calculation of the offset correction, ***CALIB_OFFSET***:
   CALIB_OFFSET* = 8 x *EXP_ACQ_TEMP* – *CALIB_ACQ_TEMP

   With the examples above, we get: ***CALIB_OFFSET*** = 8 x 474.84 – 3824 ~ -25.28

IMPORTANT NOTICE: if possible, it may be useful for the user to save the ***CALIB_OFFSET*** value of each chip in a table. By this way, the above calculations do not need to be made each time a temperature measurement is taken: these calculations then only have to be redone if the chips are recalibrated (for example if calibration at a different temperature is required).

3.2.2. Use of the offset correction value for temperature sensing

Hereunder are the two steps that the user must follow to measure the temperature sensor data of an AS3213C.4 IC and convert it into a temperature in °C.

1) Inventory of the tag and reading of the sensor data ***ACQ_TEMP[9:0]*** at address 0x1 in the USER bank (bits 9 downto 0). Conversion of this hexadecimal data in decimal.

2) Conversion of the sensor data into a temperature value by the following calculation:

   - ***ACQ_TEMP_CORRECTED* = *ACQ_TEMP* + (*CALIB_OFFSET* / 8)**
   - **t° (in °C) = A x *ACQ_TEMP_CORRECTED* + B** with **A = 0.3378** and **B = -133**

   For example, if ***ACQ_TEMP[9:0]*** = 0x01B0 --> *432 in decimal* and ***CALIB_OFFSET*** = -25.28

   ACQ_TEMP_CORRECTED = 432 - (25.28 / 8) = 428.84

   ➔ t° (in °C) = 0.3378 x 428.84 - 133 ~ 11.9 °C