

# AURIX™ TC3xx DTS and DTSC

## 32-bit TriCore™ AURIX™ TC3xx microcontroller

### About this document

#### Scope and purpose

This Application Note describes the integrated Die Temperature Sensor (DTS), the Core Die Temperature Sensor (DTSC) and their parameters defined in the TC39xB Data Sheet [1]. In addition, temperature sensor warning threshold configuration and related (external) safety mechanisms are discussed.

#### Intended audience

This document is intended for all TC3xx users, especially for those with a high ambient temperature for TC3xx.

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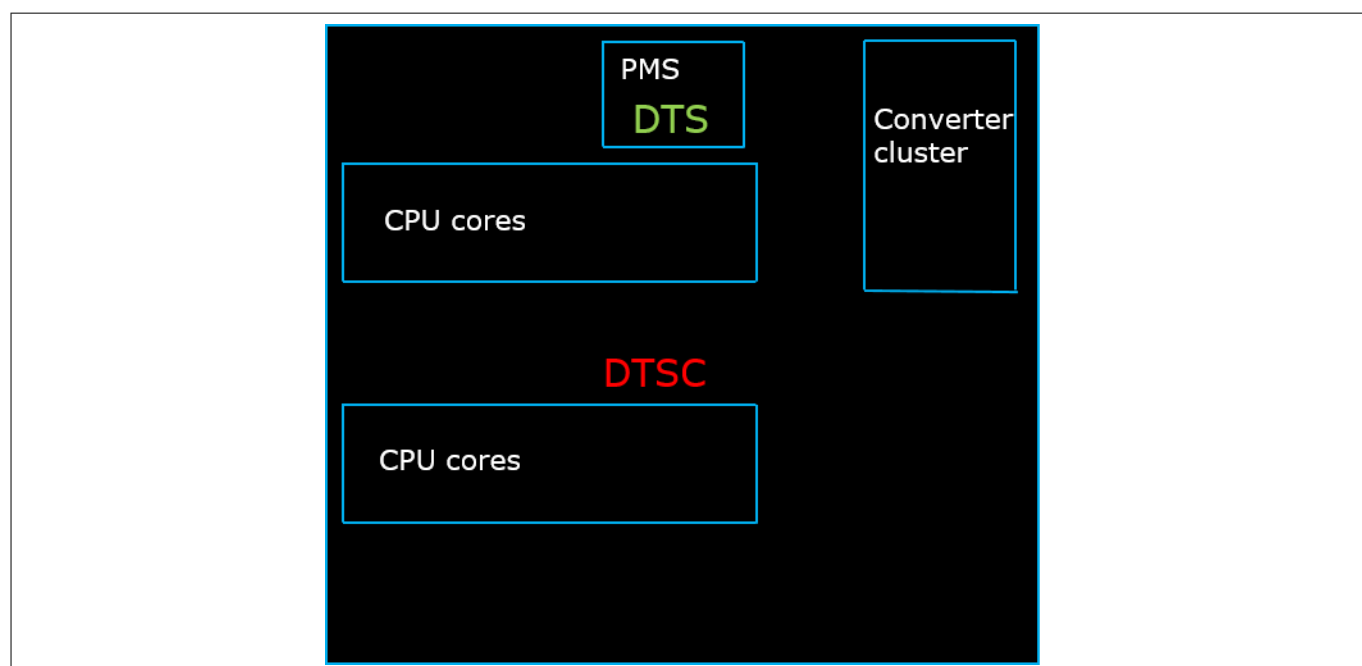
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## **1 DTS/DTSC and parameters**

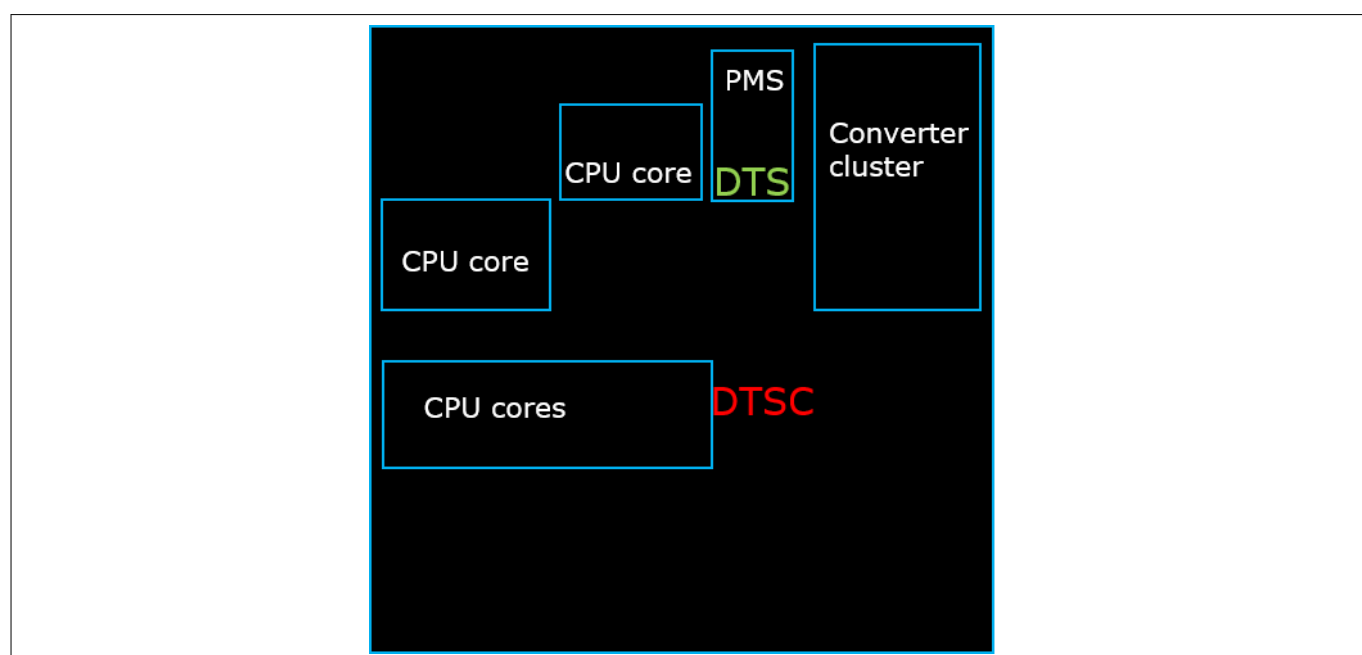
### **1.1 About DTS and DTSC**

The TC3xx has an integrated Die Temperature Sensor (DTS) and a Core Die Temperature Sensor (DTSC) on-chip. Both temperature sensors are technically the same. They are located near to hot spots on the TC3xx. The DTS is placed close to PMS (Power Management System) and AD converter cluster. The DTSC is located close to CPU core cluster. These locations are typical hot spots.

The following figures show the sensor locations on TC39x B-step and TC38x A-step.



**Figure 1 DTS and DTSC locations on TC39x B-step**



**Figure 2 DTS and DTSC locations on TC38x A-step**

## 1 DTS/DTSC and parameters

### 1.2 Parameters in the TC39xB Data Sheet

The Data Sheet defines important parameters for DTS and DTSC, including measurement time, accuracy and working range.

**Note:** *The following parameters have the same values for DTS and DTSC because they are instances of the same technology.*

**Table 1 Parameters for DTS and DTSC**

Parameter	Symbol	Remark
Measurement time	$t_M$	DTS and DTSC will output a result every $t_M$ (2.7 ms as defined in the Data Sheet)
Accuracy over temperature range	$T_{NL}$	This is the error of temperature sensors, caused by technological limitations ( $\pm 2^\circ\text{C}$ as defined in the Data Sheet)
DTS temperature range	$T_{SR}$	It defines the working range for temperature sensors ( $-40^\circ\text{C}$ to $+170^\circ\text{C}$ as defined in the Data Sheet)

For calibration reference accuracy, there is a potentially small difference between both temperature sensors due to different positions on the die.

**Table 2 Parameters with different values for DTS and DTSC**

Parameter	Symbol	Remark
Calibration reference accuracy	$T_{CALACC}$ of DTS	$\pm 1^\circ\text{C}$ , as defined in the Data Sheet
	$T_{CALACC}$ of DTSC	$\pm 2^\circ\text{C}$ , as defined in the Data Sheet

DTSC is placed more towards the center of TC3xx, therefore the real calibration temperature could differ up to  $1^\circ\text{C}$ , reflected by the different limits of  $T_{CALACC}$  for both DTS instances:  $T_{CALACC}$  of DTSC -  $T_{CALACC}$  of DTS

No run-time calibration for DTS or DTSC is needed. In production, calibration is done with high precision and a well-controlled stable temperature and test environment. In addition, calibration is done at the same time for both temperature sensors. Trimming data is stored in TC3xx and loaded by start-up software (SSW) by cold and warm PORST events.

The total error ( $T_{NL} + T_{CALACC}$ ) is valid for the whole temperature range for both DTS and DTSC.

### 1.3 Heat distribution on die

Based on application specific scenarios, the actual temperature at the locations of DTS and DTSC can differ. This is because different application scenarios may have different task loads for individual components on the TC3xx. As defined in the Data Sheet, parameter “ $\Delta T$  Temperature difference between on chip temperature sensors” indicates the potential temperature difference.

**Table 3 Temperature difference between on-chip temperature sensors**

Parameter	Symbol	Remark
Temperature difference between on-chip temperature sensors	$\Delta T$	$\pm 3^\circ\text{C}$ as defined in the Data Sheet

**Note:** *The heat distribution is user specific because it is related to user application pattern, PCB design, heat dissipation methods etc.*

## 2 Consideration in application

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On the TC3xx, the Safety Management Unit (SMU) provides the possibility to generate an alarm when the device temperature reaches user configured warning level.

As there are two temperature sensors on the TC3xx, both have their individual threshold register. For DTSC, it is DTSLIM.UPPER/LOWER and for DTS it is DTSLIM.UPPER/LOWER. The upper or lower limit of each sensor has its own alarm. In case any of the configured thresholds is violated, independent alarms can be generated.

When defining the limits for UPPER and LOWER thresholds, the inaccuracy of temperature sensor defined in the Data Sheet should be taken into account ( $T_J$  is the junction temperature specified in the Data Sheet):

**Table 4 Temperature sensor threshold setting**

Threshold	Register	Value
DTS upper limit	DTSLIM.UPPER	$T_J$ upper limit - $ T_{NL} $ of DTS - $ T_{CALACC} $ of DTS
DTS lower limit	DTSLIM.LOWER	$T_J$ lower limit + $ T_{NL} $ of DTS + $ T_{CALACC} $ of DTS
DTSC upper limit	DTSLIM.UPPER	$T_J$ upper limit - $ T_{NL} $ of DTSC - $ T_{CALACC} $ of DTSC
DTSC lower limit	DTSLIM.LOWER	$T_J$ lower limit + $ T_{NL} $ of DTSC + $ T_{CALACC} $ of DTSC

If any of the alarms is triggered, the user should check the results of two sensors for plausibility to avoid latent faults in temperature sensors:

DTS and DTSC may report different measured values. This is because the two sensors are located at different places and the application specific scenario will generate different hot spots. For plausibility check criteria, the difference between DTS and DTSC reported temperatures can be up to 9°C as mentioned in external safety mechanism “ESM[SW]:DTS:DTSC\_RESULT” in AURIX™ TC3xx Safety Manual 1.10 [2].

If a larger difference is observed between DTS and DTSC, hardware failure should be considered.

The tolerance of 9°C in plausibility check is derived from following parameters:

**Table 5 Theoretical difference between two sensors**

Sources	Parameters in data sheet	Value
Total error of DTS	$T_{NL}$ of DTS and $T_{CALACC}$ of DTS	$\pm(T_{NL} + T_{CALACC}) = \pm(2^\circ\text{C} + 1^\circ\text{C}) = \pm 3^\circ\text{C}$
Total error of DTSC	$T_{NL}$ of DTSC and $T_{CALACC}$ of DTSC	$\pm(T_{NL} + T_{CALACC}) = \pm(2^\circ\text{C} + 2^\circ\text{C}) = \pm 4^\circ\text{C}$
Temperature difference between on-chip temperature sensors	$\Delta T$	$\pm 3^\circ\text{C}$ (see Table 3)
Calibration reference accuracy difference of DTS and DTSC	$T_{CALACC}$ of DTSC - $T_{CALACC}$ of DTS	1°C (see Table 2)

Overall tolerance between 2 sensors: Total error of DTS + Total error of DTSC +  $\Delta T$  – Calibration reference accuracy difference of DTS and DTSC = 3°C + 4°C + 3°C – 1°C = 9°C

For other temperature sensor related (external) safety mechanisms, please refer to AURIX™ TC3xx Safety Manual V 1.10 [2].

## **References**

- [1] TC39xB Data Sheet V 1.1
- [2] AURIX™ TC3xx Safety Manual V 1.10
- [3] AURIX™ TC3xx User Manual V 1.6

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**Revision history**

## **Revision history**

<b>Document revision</b>	<b>Date</b>	<b>Description of changes</b>
V1.0	2020-10	Initial version
V1.1	2024-04-17	Template update; no content update.

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