AN11657

NHS3xxx Temperature sensor calibration

Rev. 2 — 12 September 2016 Application note

Document information

Info	Content
Keywords	Temperature sensor, calibration
Abstract	This application note describes the user calibration of the temperature sensor.

Revision history

Rev	Date	Description
v.2	20160912	Changed security status
v.1	20160421	Initial version

Contact information

For more information, please visit: **http://www.nxp.com**

For sales office addresses, please send an email to: **salesaddresses@nxp.com**

1. Introduction

This Application note describes the user calibration of the temperature sensor, as used in the NHS3100 Temperature logger and other members of the NHS3xxx family.

1.1 Temperature sensor description

1.1.1 General operation

The temperature is measured using a high-precision zoom-ADC. The analog part is able to measure a strongly temperature-dependent $X = V_{be} / \Delta V_{be}$. It determines the value of X by first applying a coarse search (successive approximation), and then a sigma-delta in a limited range. For calibration purposes, one should always use the highest resolution.

The initial temperature sensor calibration values are determined during manufacturing. For (even) higher accuracy, the user can provide custom parameters A, B, and alpha. For calibration, the raw value X is needed, and high accuracy measurement is recommended. Internally, the following formula is then used to obtain the calibrated temperature output:

$$T = A \times \frac{\alpha}{\alpha + X} + B \quad (1)$$

The default calibration values A, B, and alpha for the default resolution settings are stored in the EEPROM memory. The user can load their own calibration values into the TSENSP1, TSENSP2 and TSENSP3 registers before starting a conversion.

1.1.2 Specifications

Table 1. Temperature sensor specifications

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$I_{CC(pd)}$	power-down mode supply current	TSENS disabled	-	-	1	nA
I_{stb}	standby current	TSENS enabled	-	6	7	µA
$I_{CC(oper)}$	operating supply current	TSENS converting	-	10	12	µA
T_{acc}	temperature accuracy	T_{amb} = 0 °C to +40 °C	–0.3	-	+0.3	°C
		T_{amb} = –40 °C to +85 °C	–0.5	-	+0.5	°C
T_{res}	temperature resolution	12-bit mode	-	0.05	-	°C
		8-bit mode	-	0.4	-	°C
T_{conv}	conversion period	12-bit mode	-	100	-	ms
		8-bit mode	-	7	-	ms

2. Calibration procedure

2.1 Calibration system requirements

Both single- and multipoint calibration have common requirements for calibrating the system.

- High-accuracy reference sensor which should be placed close to the DUT. The absolute accuracy of the reference sensor should be at least 2 × better than the desired absolute accuracy of the NHS temperature sensor after calibration
- The NHS sensor to be calibrated should be in thermal equilibrium with the reference sensor
- Hold the samples at a temperature representing the middle of the target application range

2.2 Single-point offset correction

Single-point calibration is equivalent to finding a new value for the offset parameter B. It is sufficient for most application cases. This calibration is easily accomplished as follows:

1. Set the temperature sensor to 12-bit conversion (default)
2. Use the default/boot parameters
3. Start a conversion
4. At the same time, determine the temperature using the external reference sensor of the calibration system
5. The new value of parameter B is equal to the old value plus the difference between the value of the NHS sensor and the reference sensor. Note: the output of the NHS temperature sensor is in Kelvin

Example:

NHS3xxx returns 298.7 K and the reference sensor returns 300.3 K. The new value for parameter B is the old value (found in register TSENSP2) + (300.3−298.7) = 1.6. This value should then be stored in register TSENSP2.

2.3 Multi-point calibration

Multi-point calibration is more complex.

1. To output raw data (X), set the temperature sensor by setting the TOUTMODE bit in the TSENSP0 register to 0
2. Start a conversion
3. At the same time, determine the temperature using the external reference sensor of the calibration system
4. Determine parameters A, alpha and B by curve-fitting the conversion formula to the measured temperature using the NHS3xxx output for X

The calculated parameters A and alpha are expected to be close to the factory defaults as they fundamentally depend on material parameters

3. Abbreviations

Table 2. Abbreviations

Acronym	Description
ADC	Analog-to-Digital Converter
DUT	Device Under Test

4. Legal information

4.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

4.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the *Terms and conditions of commercial sale* of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

Evaluation products — This product is provided on an "as is" and "with all faults" basis for evaluation purposes only. NXP Semiconductors, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this product remains with customer.

In no event shall NXP Semiconductors, its affiliates or their suppliers be liable to customer for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out the use of or inability to use the product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages.

Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

Translations — A non-English (translated) version of a document is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

4.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

5. Tables

6. Contents

For more information, please visit: http://www.nxp.com
For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: 12 September 2016
Document identifier: AN11657