checkit

# Guide to calibration certificates for CAM sensors

## Applicable Certificates

This document is applicable to the following certificates:

| | | |
|---|---|---|
| 1. | Form262 | Probe Calibration Certificate |
| 2. | Form289 | Sensor (Temperature) Calibration Certificate |
| 3. | Form327 | Sensor+ Temperature Calibration Certificate |
| 4. | Form328 | Wired Temperature Sensor (Hot) Calibration Certificate |
| 5. | Form329 | Ultra-Hot Wired Sensor Calibration Certificate |
| 6. | Form326 | Ultra-Cold Wired Sensor Calibration Certificate |
| 7. | CH-020721-TE | Sensor Temperature 100 Calibration Certificate (TMP117) |
| 8. | CH-020548-TE | Sensor Temperature 100 Calibration Certificate |

## Sensor Families

| Sensor products | Measurement technology | Duration of Certificate |
|---|---|---|
| Sensor temperature<br>Sensor + (encased sense heads)<br>Sensor temperature 100 | On-chip measurement: TE Connectivity TSYS02 | Lifetime of device |
| Sensor + wired temperature probes<br>Hand-held probe | Remote probe (platinum): TE Connectivity TSYS01 | Lifetime of device |
| Sensor temperature 100 two-battery version | On-chip measurement: Texas Instruments TMP117 | Lifetime of device |

# Introduction

The purpose of this document is to explain the Checkit calibration methodology and the resulting certificates that are issued for temperature sensors.

# Digital temperature sensors

## Manufacturers' calibration procedures

### TE Connectivity

TE Connectivity manufacture the ICs and IC-plus-probe assemblies. TE Connectivity calibrate and program each piece individually to meet calibration limits. Digital sensors are calibrated by modifying the calibration parameters to ensure they meet the calibration limits. The calibration results from TE Connectivity are made available to Checkit Ltd in order to generate the calibration certificates.

### Texas Instruments

Texas Instruments provide a statement about calibration on their datasheet with assurance that the TMP117 are 100% tested on a production setup that is NIST traceable (US National Institute of Standards and Technology) and verified with equipment that is calibrated to ISO/IEC17025 accredited standards.

## Checkit’s use of the Original Equipment Manufacturers’ calibration documents

Checkit’s calibration methodology assumes that the manufacturers’ calibration figures may be applied to the Checkit device as a whole. Checkit provides a confidence validation that the devices are measuring the appropriate temperature.

## Drift over time

### TE Connectivity

Following its own calibration, TE Connectivity advises that the only deviation from the calibrated state will be due to drift over time with temperature as based on Arrhenius equation.

TE Connectivity states that the drift per year varies with the temperature at which the probes operate and the drift increases dramatically as temperature rises. For example, both TSYS01 and TSYS02 devices show a drift of less than 0.02°C per year at 50°C and significantly less than 0.01°C at 40°C, reducing to virtually no drift for devices operating at lower temperatures.

The devices with on-chip measurement (e.g. Sealed Sensors) will be subjected to the temperature they are measuring, whereas the devices with external probes will, in general, be able to operate with their ICs at ambient temperature. This will mean that qualitatively sensor temperatures in freezers will not drift at all while sensor temperatures in hot locations will exhibit the most drift. Importantly, at normal room temperature, devices using the remote probes technology will experience less than 0.005°C drift per year if they are operated.

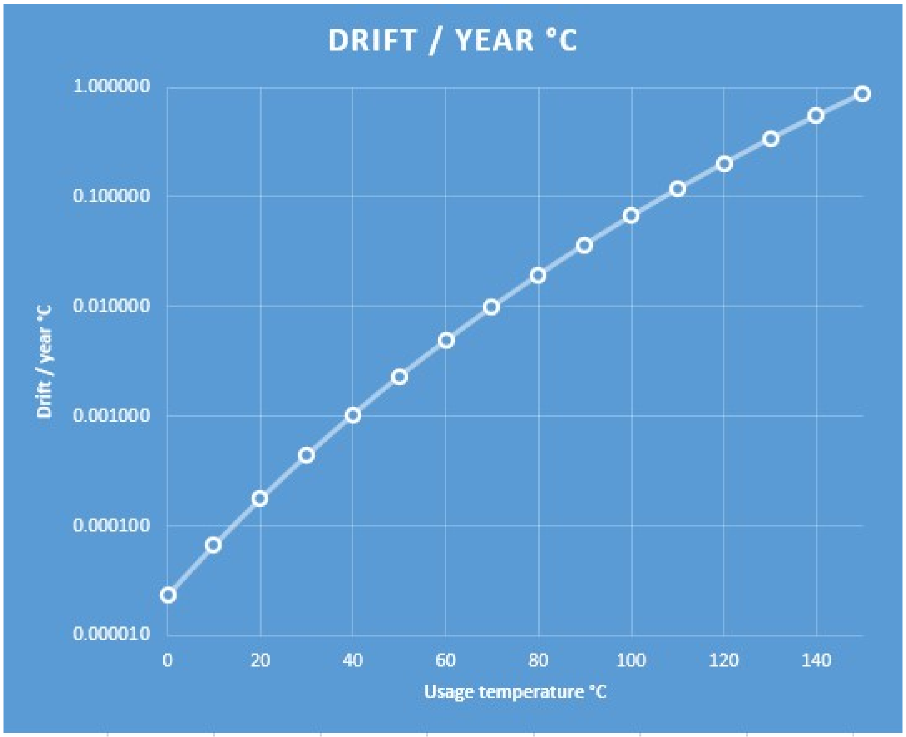
For ultra-cold and ultra-hot wired temperature probes, 0.02°C drift per year is used.

### Texas Instruments

Texas Instruments provide estimates of long term drift for the TMP117 based on the Arrhenius equation. For further information, Texas Instruments has published two informative papers: [TMP117: Long term stability and drift parameter interpretation]() and [Calculating Useful Lifetimes of Temperature Sensors]().

The chart below shows the expected drift per year based on the operating temperature.

In conclusion, at fridge temperatures, the drift per year is expected to be negligible. For hot hold sensors working at around 85°C, the drift is less than 0.03°C per year.

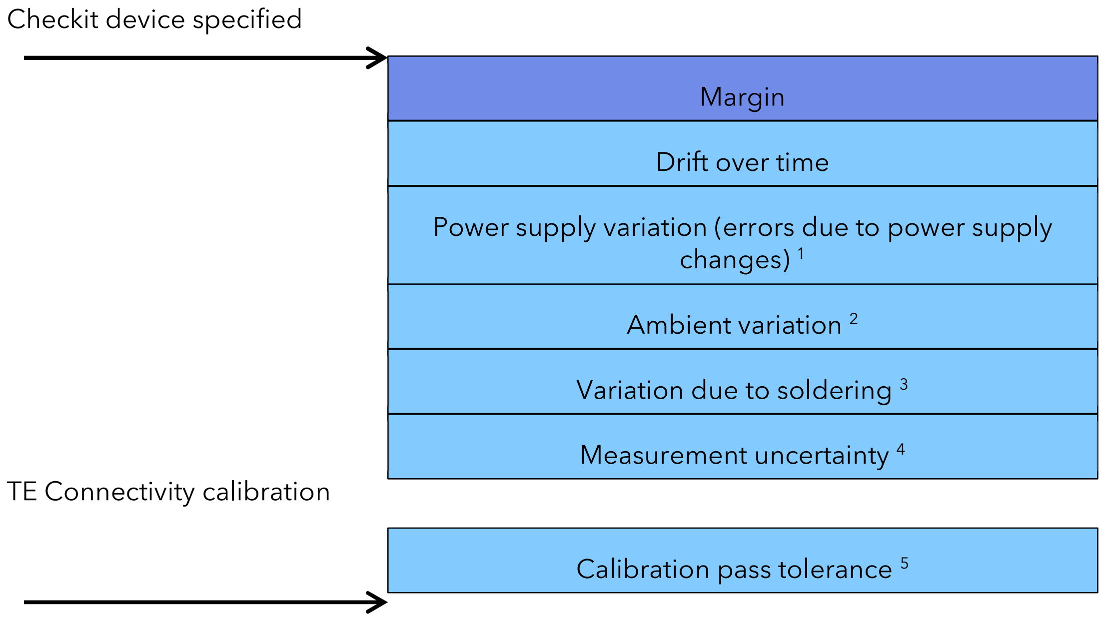



## Calibration certificates for ultra-cold and ultra-hot products

### Explanation

The tolerance stack is defined as the total of the limits applied by TE Connectivity and all uncertainties and drift combined. This represents the maximum error that could be permitted in the calibration measurements to guarantee that the device would remain within its specification.

In more detail, the tolerance stack is illustrated below:



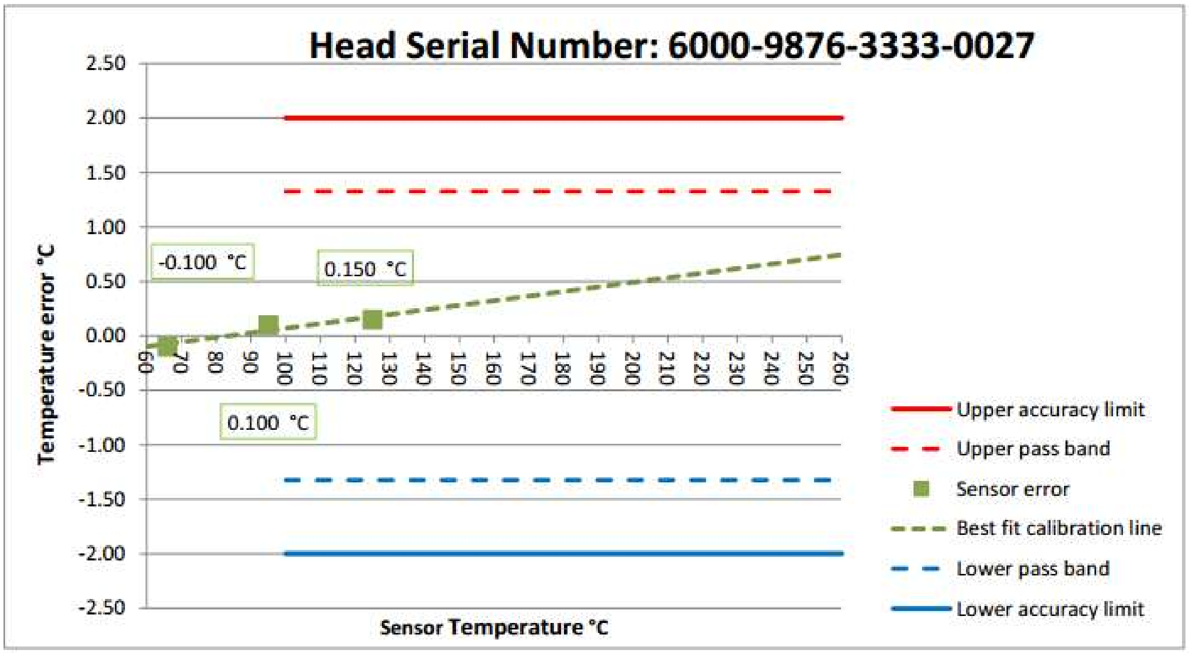

## Notes to diagram

| | |
|---|---|
| *1* | *Power supply variation – if the power supply to the measurement IC is well regulated, this error is small, but if the power supply is directly from the battery, for example, this is more significant as the battery voltage changes over time. The hand-held probe is well-regulated. Other devices are straight from the battery.* |
| *2* | *Ambient variation – this is only relevant to devices with remote elements and describes how the change in ambient on the IC can affect its reading.* |
| *3* | *Variation due to soldering – some elaborate experiments were used to try to assess this. The concluding value was so small that it is really negligible.* |
| *4* | *Measurement uncertainty – within the calibration process, the equipment, for example an Adsotech MilliK will have an element of uncertainty in the figure it presents.* |
| *5* | *Calibration pass tolerance – the tolerance around the calibration measurement that is permitted by TE Connectivity for the device to be within its accuracy limits. It could be argued that the tolerance stack should be on top of this, rather than it being explicitly part of the tolerance stack. Keeping it as part of the tolerance stack is a more conservative approach.* |

## Calibration Certificate Chart

The Checkit calibration certificates show a chart of the calibration points and the limit lines of the tolerance stack.

Example of the ultra-hot wired temperature probe below.




This chart has an extrapolated best-fit calibration line to illustrate that the calibration process is satisfactory for the full range of the device.

This particular sensor product has a number of regions with different accuracies, hence the steps in the limits. Taking the middle, most accurate range, the Checkit specification is ±0.4°C. The tolerance stack is:

| Tolerance name | Value (°C) |
|---|---|
| Calibration pass tolerance | 0.2 |
| Measurement uncertainty | 0.02 |
| Variation due to soldering | assumed very small |
| Ambient variation | 0.215 |
| Power supply variation 2.7V to 3.6V | 0.2 |
| Drift over 2 years at 0.02°C / year | 0.06 |
| Total tolerance stack | 0.70 |

So, given the tolerance stack total of ±0.70 and published device accuracy of ±2°C, the calibration must be within the limits of ±2 - ±0.70 = ±0.13°C.

## Longevity of the calibration

The longevity of the calibration depends solely on the drift calculation when in use. No significant drift is assumed while not in service.

# The approach for other products using the TSYS01 and TSYS02 devices

## Using the manufacturers' calibration pass tolerances

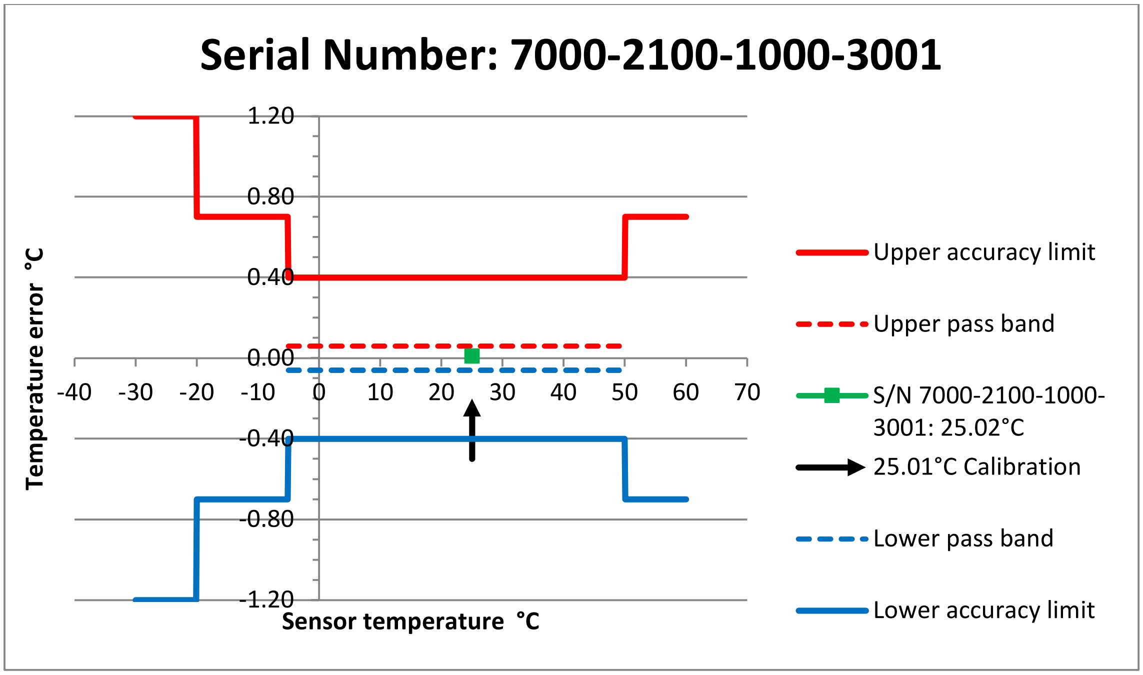
This approach is a simplified way of presenting the calibration of the device: if the calibration is within the manufacturer's calibration pass tolerance, the device's accuracy must be within the accuracy stated by the manufacturer in the datasheet for the sensing device.

There are some details where the accuracy stated by the manufacturer is decreased a little for the Checkit device itself. The contributing factors for this are:

- The manufacturer's power supply rejection ration (PSRR) which is not strictly a ratio, but is a decrease in accuracy related to having a wide power supply voltage from a battery supply rather than a regulated supply.
- Perceived self-heating – this is applied for the sealed sensor. It is estimated at only 0.1°C and is applied as ±0.1°C, although it will always be positive in practice.

## Calibration Certificate chart

The chart shows the published accuracy figures for the Checkit product and the calibration pass tolerance (referred to as a band). Below is an example:



## The approach for products using the TMP117 device (Texas Instruments)

As previously mentioned, the drift of the TMP117 is expected to be very low. Texas Instruments does not provide individual calibration data for their devices, so the calibration certificate from Checkit is based on the Texas Instruments drift calculations and the statements by Texas Instruments about their factory calibration process.

## Notes about the individual calibration certificates

### Calibration certificate start date

Checkit's convention is to make the start date for the calibration the same as the installation date, given that the drift of the sensors when in stock is negligible.

| Form 289 Sensor temperature calibration certificate | This certificate has a chart showing a number of regions of different accuracies and a single point calibration. |
|---|---|
| Form 327 Sensor+ calibration certificate | This certificate is similar to the sensor temperature form with a single point calibration. |
| Form 262 Probe calibration certificate | This has three regions for changing accuracies and a two-point calibration with a third central confirmation measurement point. |
| Forms 326 Ultra-cold and 329 ultra-hot wired temperature probe certificates | These two certificates have single regions of accuracy. Two outside calibration points and a central confirmation point are provided by the manufacturer. These are used to provide a best-fit line that is extrapolated to suggest the quality of the calibration within the published temperature range of the device. As stated previously, the pass band used for these charts is based on the tolerance stack. |
| Form 328 Hot wired temperature probe calibration certificate | This sensor has a tight accuracy, but since it has two calibration points with a central confirmation point, calibrating to meet the specification is straightforward. |
| CH-020548-TE Sensor Temperature 100 Calibration Certificate | The sensor temperature 100 products (i.e. hot holds sensors) using serial number first-fields (prefixes) of 7010 and 7020 have a single battery and use a TE Connectivity TSYS02 device. The calibrated certificates use the same approach as the standard sealed sensor. |
| CH-020721-TE Sensor Temperature 100 two-battery (TMP117) calibration certificate | The sensor temperature 100 products using the serial number first-field (prefix) of 7030 has two batteries and uses the Texas Instruments TMP117 device. The drift of the TMP117 is estimated to be very low, even at 85°C. |