TEMPERATURE INDICATOR CALIBRATION

Product Family: **BLE SOC**

Part Number: EM9305
Keywords: Temperature, indicator, calibration

PURPOSE

The purpose of this application note is to explain the goal of the temperature indicator calibration and how to achieve it from an end user perspective.
It gives some clues on what important points shall be considered to achieve the best temperature accuracy using this embedded temperature indicator.

OVERVIEW

The EM9305 SOC comes with a temperature indicator that can be used to get the temperature of the SOC and its direct environment with an accuracy of ±5°C.
This indicator shall not be confused with a real temperature sensor that would provide a far better accuracy.
The indicator relies on the LF-RC LP frequency oscillator measurement from which the temperature is computed through a linear regression.
To achieve a better accuracy, a calibration process shall be done and is based on the use of two calibration points measurements.

REFERENCE DOCUMENTS

Not applicable.

GLOSSARY

BLE	Bluetooth Low Energy
LF-RC LP	Low frequency RC low power
SOC	System On Chip

1. TEMPERATURE CALIBRATION

A better accuracy for the temperature indicator can be reached if the calibration is done with two points.
This leads to define a line which is depicted in Figure 1-1.

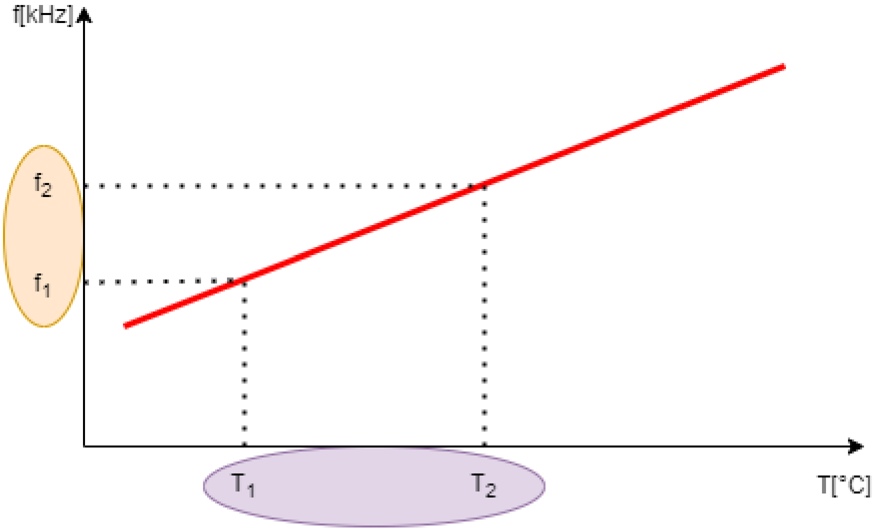

Figure 1-1: Linear regression for temperature calibration

The two T_1 and T_2 temperature shall be defined based on the specific use case in which the calibration will provide the best accuracy. These values are use-case dependent.

Once they are defined, it is the end user responsibility to bring the device environment at these temperatures to make the LF-RC LP frequency measurement. Consequently, an external temperature sensor shall be used to know exactly when the two temperatures are reached and when doing the frequency measurement.

With this calibration, the measured frequency can easily be translated to the temperature with the following formulae:

$$T_{indicator} = k \times f_{measured} + offset$$

where

$$k = \frac{T_2 - T_1}{f_2 - f_1}$$

and

$$offset = T_1 - k \times f_1$$

With a two points calibration, the *k* coefficient and the offset are device dependent. Thus, they must be determined for each device.

2. FREQUENCY MEASUREMENT

2.1 OVERVIEW

As said earlier, the two temperature points at which the LF-RC LP frequency shall be measured to get the best temperature accuracy is user application dependant.

The following figures shows the achieved accuracy depending on the two temperature points. It is then recommended that the end user picks-up the two points according to the reference measurement that is closer to its real use-case. The following scenarios are an attempt to cover or to get close to the end user real case.

As an example, if the final environment in which the end user device will be used is at ambient temperature, then it can be considered that the two temperature points at which the LF-RC LP frequency shall be measured can be the lower and the higher range. This can be [+10°C…+40°C] for example if the accuracy exposed in Figure 2-2 is suitable for the end user application.

However, since the two points calibration is done on a per device basis, the two points do not need to be the same for all the devices. This really depends on the device for which the calibration is done. Otherwise said, this process is fully on the end user responsibility.

2.2 CALIBRATION SCENARIOS

2.2.1 Calibration @(+20°C/+30°C)

The Figure 2-1 shows the temperature measurements on 10 different devices where the LF-RC LP frequency has been measured at +20°C and at +30°C.

It clearly appears the best accuracy is achieved when the temperature is within this range. Otherwise, it quickly diverges and at the edges of this graph, the computed accuracy goes beyond the specification value of 5°C.

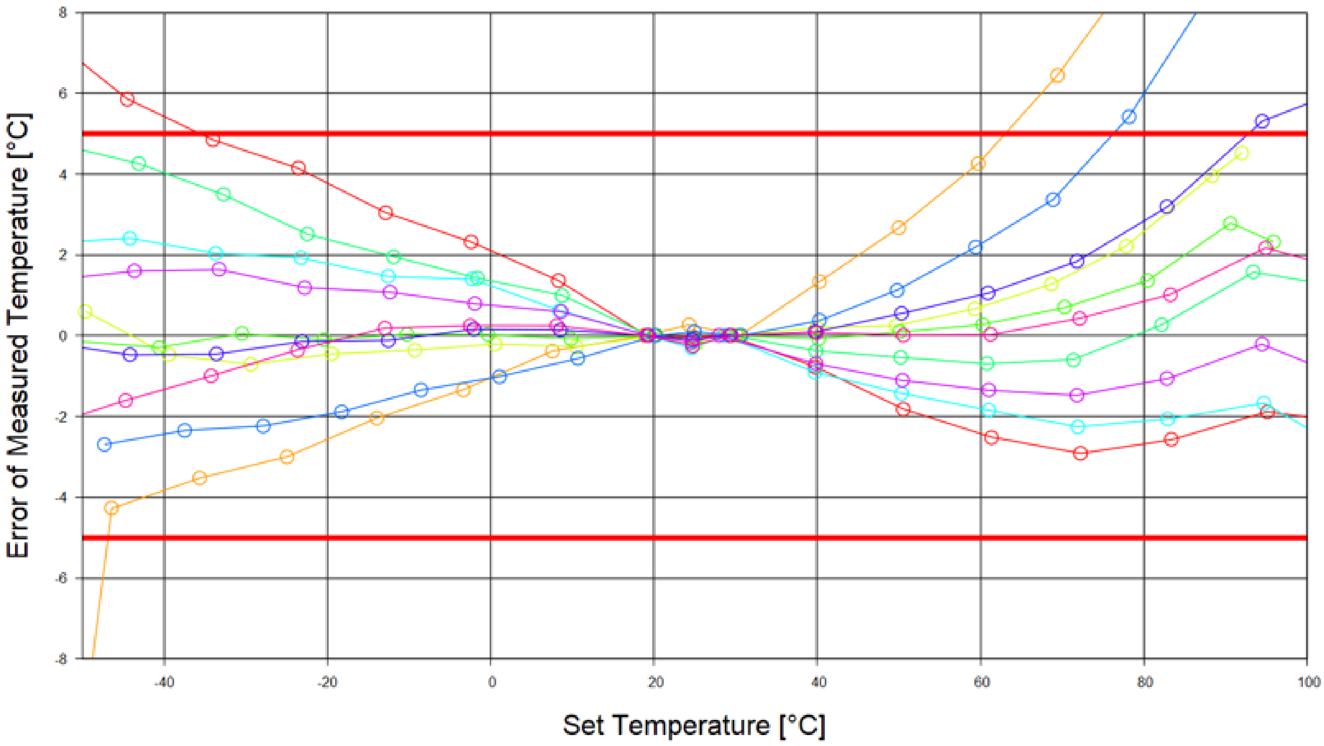

Figure 2-1: Calibration @+20°C/+30°C

2.2.2 Calibration @(+10°C/+40°C)

The Figure 2-2 shows that the maximum accuracy is achieved around the two calibration points. Inside and outside this range, it quickly diverges.

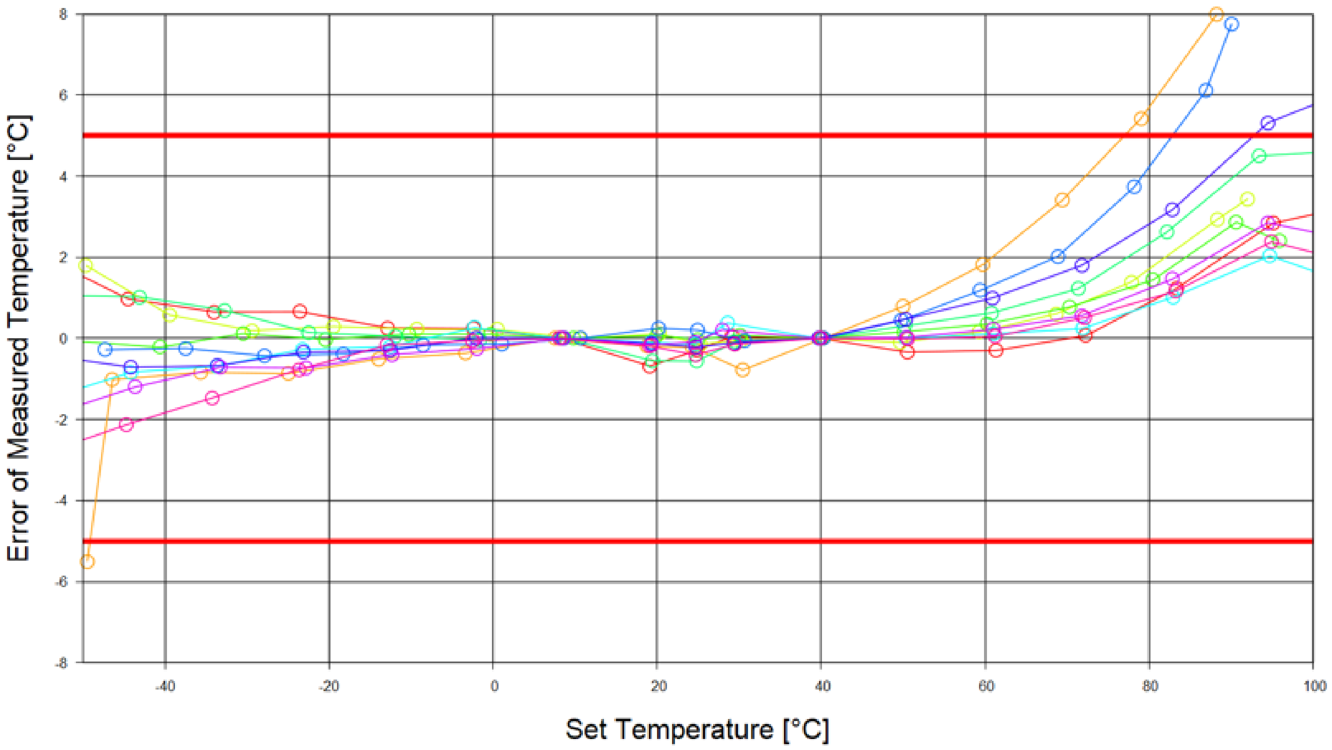

Figure 2-2: Calibration @+10°C/+40°C

2.2.3 *Calibration @(0°C/+50°C)*

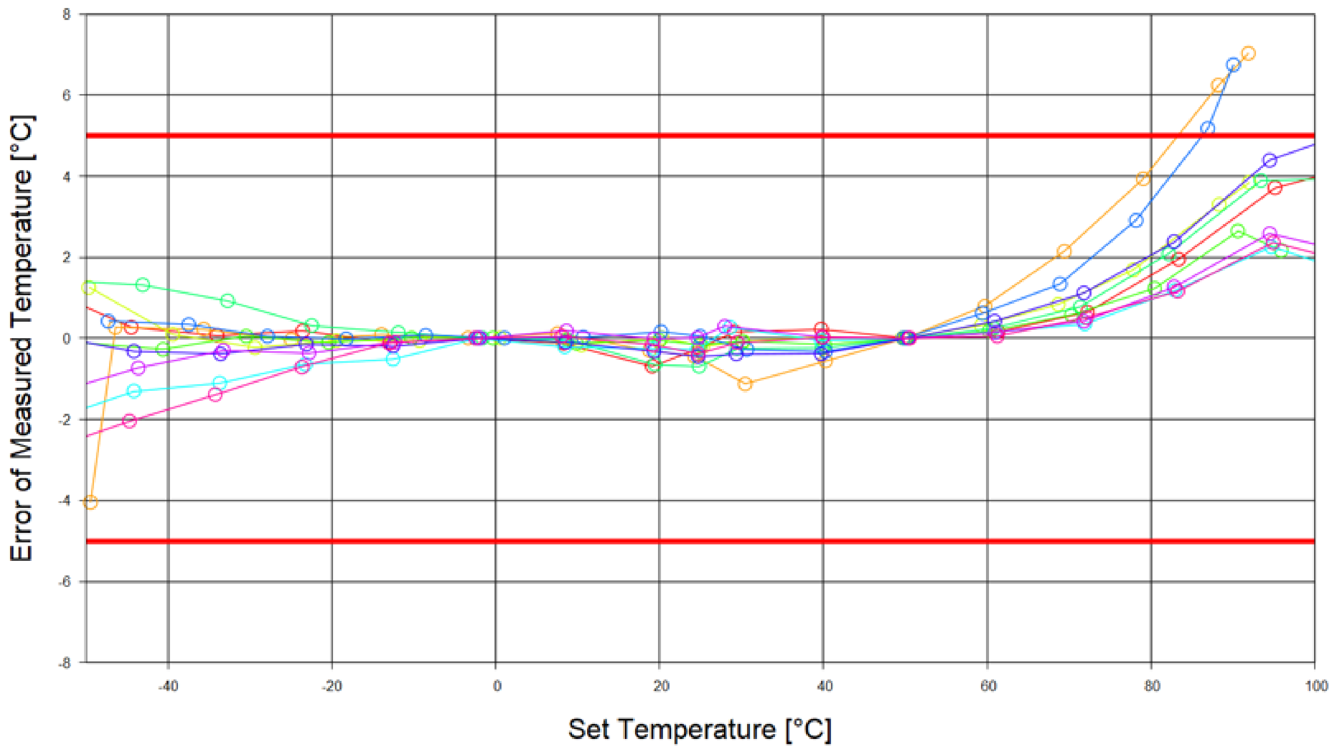

Figure 2-3: Calibration @0°C/+50°C

2.2.4 Calibration @(-10°C/+60°C)

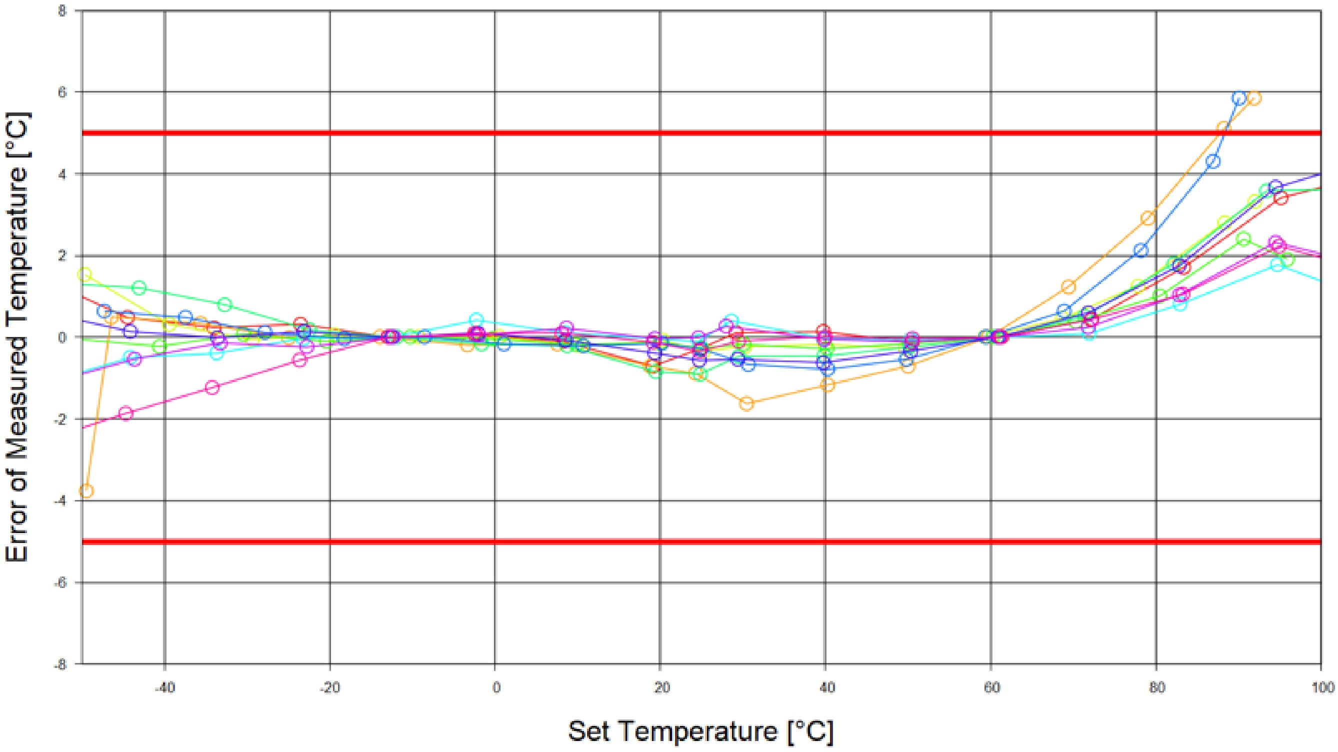

Figure 2-4: Calibration @-10°C/+60°C

2.2.5 Calibration @(-20°C/+70°C)

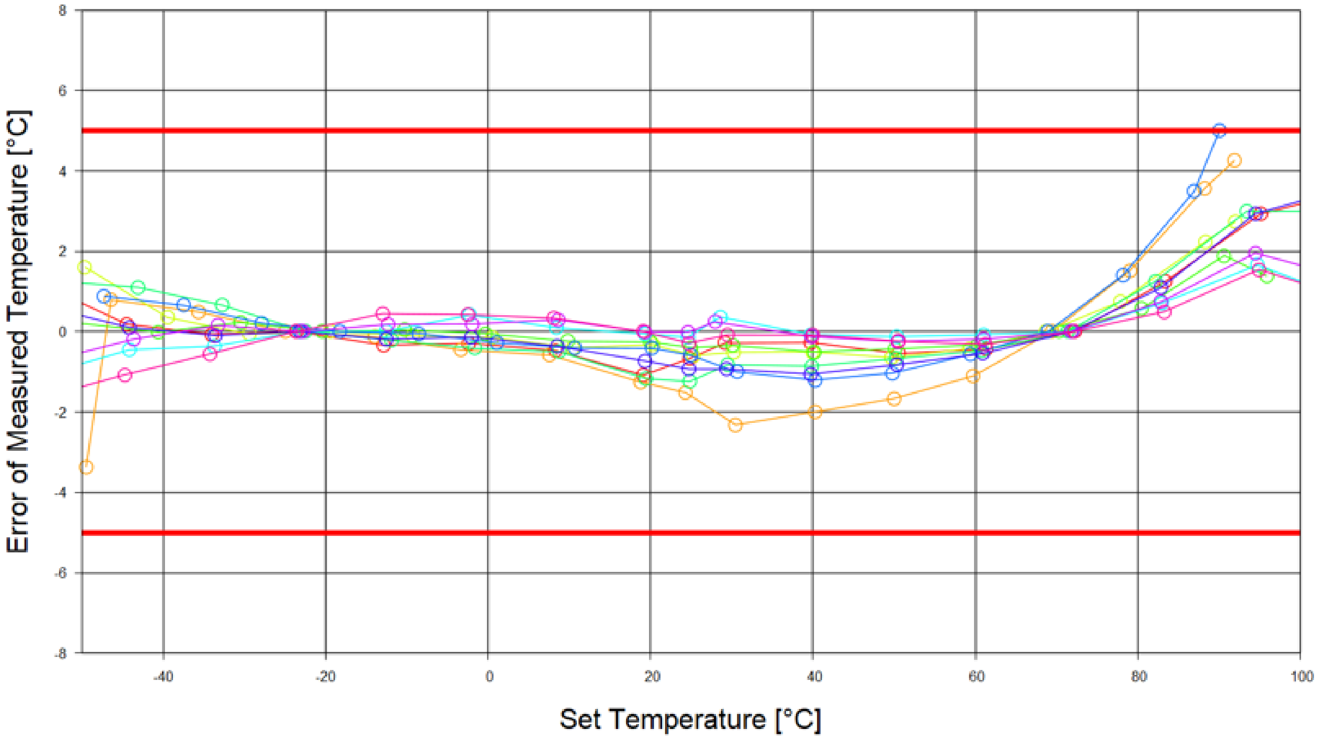

Figure 2-5: Calibration @-20°C/+70°C

2.2.6 Calibration @(-30°C/+80°C)

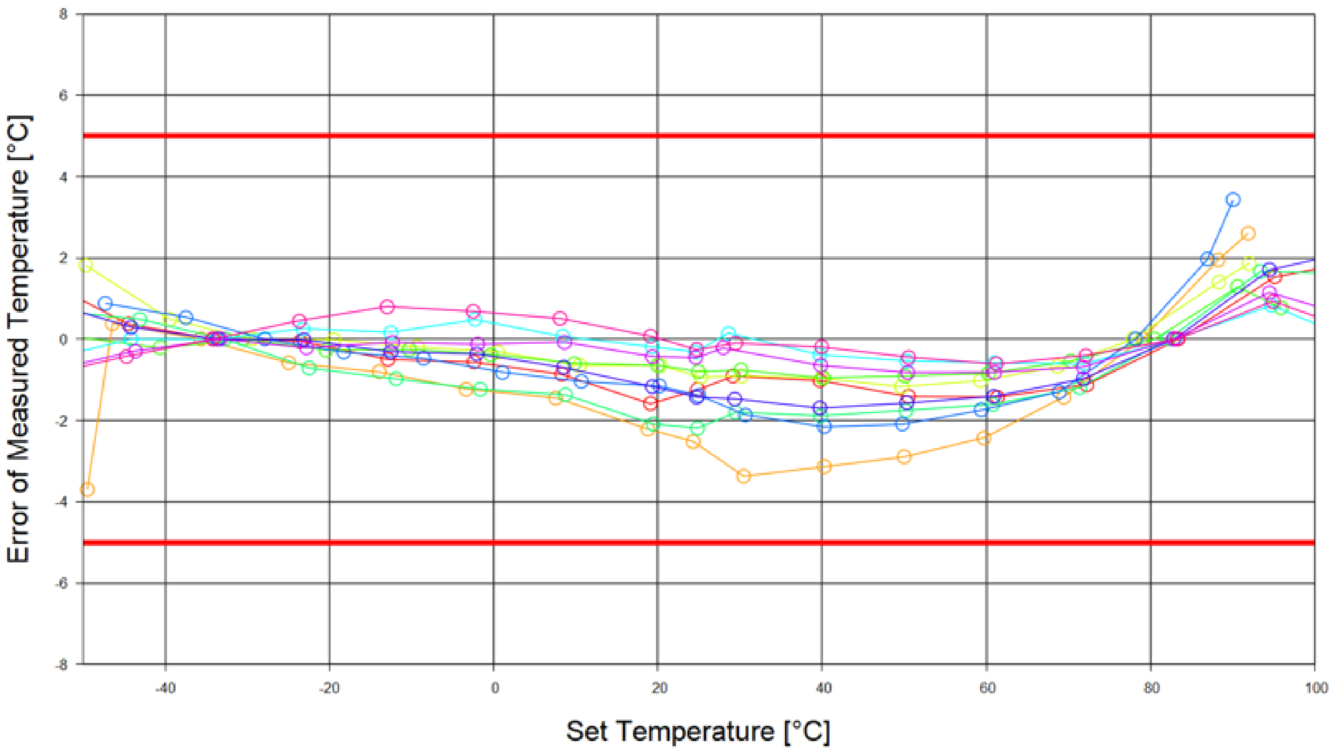

Figure 2-6: Calibration @-30°C/+80°C

3. LF-RC LP FREQUENCY MEASUREMENT

Measuring the LF-RC LP frequency can only be done by software. To achieve this operation, the `ti_example` sample application is provided in the SDK and showcase how to implement a code that make such measurement. Moreover, it can also be directly used by an end user to show the measured frequency on a host terminal connected to the EM9305 through the serial line.

Since the temperature measurement is an asynchronous operation, this sample application does the following operations at startup:

1. register a callback function to catch the end of the temperature indicator measurement
2. start the temperature measurement
3. do something else in the meantime

Measuring the temperature takes a little bit of time and within this operation fully handled by the temperature indicator driver, the LF-RC LP frequency is measured and stored. Remember that the temperature is computed from the measured LF-RC LP frequency measurement.

When this operation is completed, the previously defined callback function is called. In this callback, the `SIG_TEMP_INDICATOR_ISR` QP/C event is posted along with the measured temperature as a parameter of this event.

Then, this event is processed in the `idle` task. The latest stored frequency value is retrieved and sent to the serial line so it can be displayed on the host computer terminal.

Note that the frequency is first converted from fixed point to floating point and then displayed in Hz.

Once the two frequencies are measured for T_1 and T_2, it is the end user responsibility to compute the `k` and `offset` calibration value and to write them into the user information page 2 from where they will be used for any further temperature measurement.