Application Note

MLX90251
Programmable Linear Hall Effect Sensor
TC – Temperature Compensation

1. Introduction

This document is intended to explain how the Thermal Compensation of the MLX90251 works and how it can be used in order to evaluate the TC of a complete system.

In the first section of this document, a theoretical approach to the thermal behaviour of the MLX90251 will be given. This section will give a general overview of the Linear Hall Sensor Transfer Function vs. Temperature and explain the item "TC – Thermal Compensation".

The second section will explain how the thermal compensation works inside the MLX90251.

The third section will show how to evaluate the TC of a system by using the MLX90251.

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2. Theory

This section is intended to give a theoretical description of the Temperature Coefficient, TC.

2.1. Linear Hall Effect Sensor Output Transfer Function vs Temperature

In a general way the output transfer characteristic of a Linear Hall Effect Sensor can be expressed by equation 1.

$$Vout(B,T) = Voq(T) + \sigma(T) \times B(T),$$

Equation 1

where:

- Vout(B,T) = Output Voltage of the IC at temperature T and when a magnetic field of strength B is applied,
- Voq(T) = Vout(0,T) = Quiescent Output Voltage (Zero Gauss Output Voltage) at temperature T,
- σ(T) = Magnetic Sensitivity of the IC at temperature T,[1]
- B(T) = Applied Magnetic Flux Density at temperature T,
- T = Ambient Temperature.

In equation 1, each parameter can be split into two parts[2]:

- one temperature independent part (value of the dedicated parameter at 25°C)
- and one temperature dependant part (proportional to [T-25°C])

By developing equation 1 in this way, equation 2 can be obtained.

$$Vout(B,T) = Voq(25°C) + \Delta Voq(T) + \sigma(25°C) \times [1 + TC_\sigma \times (T - 25°C)] \times B(25°C) \times [1 + TC_B \times (T - 25°C)]$$

Equation 2

where:

- ΔVoq(T) = Voq(T) – Voq(25°C) = Thermal Voq Drift = Thermal Offset Drift,
- TC_σ = Sensitivity Temperature Coefficient of the IC[3],
- TC_B = Magnetic Flux Density Temperature Coefficient (this TC is in general only due to the magnet, but sometimes the module can also have some influence).

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[1] $\sigma(T) = \frac{Vout(P2,T) - Vout(P1,T)}{B(P2,T) - B(P1,T)}$, where P1 and P2 are two different magnetic field positions,

[2] 25°C is taken as the reference temperature.
[3] For all temperature coefficients the unit "ppm/°C" will be used.

$$Vout(B,T) = Voq(25°C) + \sigma(25°C) \times B(25°C) + \Delta Voq(T)$$
$$+ \sigma(25°C) \times B(25°C) \times [TC_\sigma \times (T-25°C) + TC_B \times (T-25°C) + TC_\sigma \times TC_B \times (T-25°C)^2]$$

Equation 3

Since Voq(25°C) + σ(25°C) x B(25°C) = Vout(B,25°C), equation 3 becomes

$$Vout(B,T) = Vout(B,25°C) + \Delta Voq(T)$$
$$+ \sigma(25°C) \times B(25°C) \times [TC_\sigma \times (T-25°C) + TC_B \times (T-25°C) + TC_\sigma \times TC_B \times (T-25°C)^2]$$

Equation 4

which can also be written like:

$$Vout(B,T) = Vout(B,25°C) + \Delta Voq(T) + \sigma(25°C) \times B(25°C) \times \Delta TC \times (T-25°C)$$
$$+ \sigma(25°C) \times B(25°C) \times [TC_\sigma \times TC_B \times (T-25°C)^2],$$

Equation 5

where $\Delta TC = TC_\sigma + TC_B$.

Equation 5 is the general expression of the Output Transfer Function of a Linear Hall Effect Sensor versus Temperature.

2.1.1. Second order term neglected

If the second order term in equation 5 can be neglected
(i.e. valid if $|TC_\sigma \times TC_B| < 0.25ppm/°C^2$, i.e. if $TC_B < 500ppm/°C$), a simplified equation can be obtained.

$$Vout(B,T) \approx Vout(B,25°C) + \Delta Voq(T) + \sigma(25°C) \times B(25°C) \times \Delta TC \times (T-25°C)$$

Equation 6

Summary:

- **General Equation:**

$$Vout(B,T) = Vout(B,25°C) + \Delta Voq(T) + \sigma(25°C) \times B(25°C) \times \Delta TC \times (T-25°C)$$
$$+ \sigma(25°C) \times B(25°C) \times [TC_\sigma \times TC_B \times (T-25°C)^2]$$

- **Simplified Equation (i.e. TC_B < 500ppm/°C):**

$$Vout(B,T) \approx Vout(B,25°C) + \Delta Voq(T) + \sigma(25°C) \times B(25°C) \times \Delta TC \times (T-25°C)$$

2.1.1.1. Ideal case

- No Thermal Offset Drift
  => ΔVoq(T) = 0

- Perfect matching between the Temperature Coefficient of the Sensitivity (TC_σ) and the magnet (TC_B)
  => $TC_\sigma = -TC_B$ => $\Delta TC = 0$

In this case equation 6 becomes:

$$Vout(B,T) \approx Vout(B,25°C)$$

Equation 7

which means that the output voltage of the IC would only be dependant of the applied magnetic flux density.

2.1.1.2. Non ideal case

From equation 6, we can define the Thermal Error as follows:

$$Thermal\ Error = \Delta Voq(T) + \Delta TC \times \sigma(25°C) \times B(25°C) \times (T - 25°C)$$

Equation 8

If we focus on the TC (i.e. suppose that ΔVoq = 0), it can be observed that for this simplified situation it is sufficient to chose $TC_\sigma = -TC_B$ in order to compensate the temperature coefficient of the magnet (TC_B).

For a numerical and graphical example, please refer to Appendix I.

2.1.2. Second order term not neglected

If the second order term in equation 5 cannot be neglected
(i.e. valid if $|TC_\sigma \times TC_B| > 0.25\text{ppm}/°C^2$, i.e. if $|TC_B| > 500\text{ppm}/°C$), Vout(B,T) follows equation 5.

$$Vout(B,T) = Vout(B,25°C) + \Delta Voq(T) + \sigma(25°C) \times B(25°C) \times \Delta TC \times (T - 25°C)$$
$$+ \sigma(25°C) \times B(25°C) \times [TC_\sigma \times TC_B \times (T - 25°C)^2].$$

Even for ΔVoq(T) = 0, there is a non negligible amount of drift coming from the sensitivity. In this case, the whole term

$$\sigma(25°C) \times B(25°C) \times [(TC_\sigma + TC_B) \times (T - 25°C) + TC_\sigma \times TC_B \times (T - 25°C)^2]$$

has to be minimized over the whole temperature range.

In order to get the optimal temperature compensation, the Sensitivity Temperature Coefficient TC_σ has to be defined by:

$$TC_\sigma = \frac{-TC_B}{1 + TC_B \times (T - 25°C)}$$

Equation 9

From equation 9, it can be seen that the Sensitivity Temperature Coefficient TC_σ has to vary with temperature (it can be assumed that TC_B is constant over the temperature range).

This behavior is more or less implemented in the MLX90251. That is why the “TC vs TC Code” specification can be written in such a way that the TC codes refer to the **“to-be-compensated”** temperature coefficient instead of the “pure IC sensitivity” temperature coefficient.

However, we have (see equation 2):

$$TC_\sigma = \frac{\sigma(T) - \sigma(25°C)}{\sigma(25°C) \times (T - 25°C)}$$

Equation 10

and

$$TC_B = \frac{B(T) - B(25°C)}{B(25°C) \times (T - 25°C)}$$

Equation 11

Based on equation 9, we have also:

$$TC_B = \frac{-TC_\sigma}{1 + TC_\sigma \times (T - 25°C)}$$

Equation 12

If TC_σ is replaced in equation 12 by equation 10, TC_B can be expressed as:[4]

$$TC_B = \frac{(\frac{1}{\sigma(T)}) - (\frac{1}{\sigma(25°C)})}{(\frac{1}{\sigma(25°C)}) \times (T - 25°C)}$$

Equation 13

[4] To get the complete development of this formula, please refer to Appendix II.

If $\sigma_1(T) = 1/\sigma(T)$, equation 13 can also be written as follows:

$$TC_B = \frac{\sigma_1(T) - \sigma_1(25°C)}{\sigma_1(25°C) \times (T - 25°C)},$$

Equation 14

which is similar to equation 10. The only difference is, that TC_B is a function of $1/\sigma$ whereas TC_σ is a function of σ.

2.1.3. Summary

- **General Output Transfer Characteristic:**

$$Vout(B,T) = Vout(B,25°C) + \Delta Voq(T) + \sigma(25°C) \times B(25°C) \times \Delta TC \times (T - 25°C)$$
$$+ \sigma(25°C) \times B(25°C) \times [TC_\sigma \times TC_B \times (T - 25°C)^2],$$

- **IC Temperature Coefficient:**

$$TC_\sigma = \frac{-TC_B}{1 + TC_B \times (T - 25°C)}$$

$$TC_\sigma = \frac{\sigma(T) - \sigma(25°C)}{\sigma(25°C) \times (T - 25°C)}$$

- **Magnet Temperature Coefficient (or Magnet + Module Temperature Coefficient):**

$$TC_B = \frac{\sigma_1(T) - \sigma_1(25°C)}{\sigma_1(25°C) \times (T - 25°C)}$$

with $\sigma_1(T) = 1/\sigma(T)$.

2.2. Approximations

Some simplified equations exist in order to determine the TC of a magnet/system.

Those simplified equations are based on equation 10:

$$TC_\sigma = \frac{\sigma(T) - \sigma(25°C)}{\sigma(25°C) \times (T - 25°C)}.$$

Also remember that the sensitivity σ is defined as follows:

$$\sigma(T) = \frac{Vout(P2,T) - Vout(P1,T)}{B(P2,T) - B(P1,T)}.$$

Therefore, TC_σ can also be expressed like in equation 15.

$$TC_\sigma = \frac{\frac{Vout(P2,T) - Vout(P1,T)}{B(P2,T) - B(P1,T)} - \frac{Vout(P2,25°C) - Vout(P1,25°C)}{B(P2,25°C) - B(P1,25°C)}}{\frac{Vout(P2,25°C) - Vout(P1,25°C)}{B(P2,25°C) - B(P1,25°C)} \times (T - 25°C)},$$

Equation 15

where P1 and P2 are two different positions with different magnetic flux densities.

If it is assumed that

B(P2,T) - B(P1,T) = B(P2,25°C) – B(P1,25°C),

i.e. the span of the magnetic flux density is constant over temperature, equation 15 becomes:

$$TC_\sigma = \frac{[Vout(P2,T) - Vout(P2,25°C)] - [Vout(P1,T) - Vout(P1,25°C)]}{[Vout(P2,25°C) - Vout(P1,25°C)] \times (T - 25°C)}.$$

Equation 16

where [Vout(P2,25°C) – Vout(P1,25°C)] is the output voltage span at 25°C.

If Vout(P1,T) = Voq(T) (= Offset voltage position), equation 16 becomes:

$$TC_\sigma = \frac{[Vout(P2,T) - Vout(P2,25°C)] - [Voq(T) - Voq(25°C)]}{[Vout(P2,25°C) - Voq(25°C)] \times (T - 25°C)}$$

Equation 17

Furthermore, if it could be assumed that the Thermal Offset Drift (thermal Voq drift) is compensated (Voq(T) – Voq(25°C) = 0), equation 17 can still be simplified. In this case we have:

$$TC_\sigma = \frac{Vout(P2,T) - Vout(P2,25°C)}{[Vout(P2,25°C) - Voq(25°C)] \times (T - 25°C)}$$

Equation 18

Equation 18 gives the simplest expression of the IC Temperature Coefficient, TC_σ. However, it should be emphasized that this expression is only an approximation.

2.2.1. Summary

Following simplified equations can be used in order to determine the Temperature coefficient of a system:

- **1st approximation:** magnetic field span is constant vs temperature

$$TC_{\sigma} = \frac{[Vout(P2,T) - Vout(P2,25°C)] - [Vout(P1,T) - Vout(P1,25°C)]}{[Vout(P2,25°C) - Vout(P1,25°C)] \times (T - 25°C)}$$

- **2nd approximation:** ΔVoq(T) = Voq(T) – Voq(25°C) = 0

$$TC_{\sigma} = \frac{Vout(P2,T) - Vout(P2,25°C)}{[Vout(P2,25°C) - Voq(25°C)] \times (T - 25°C)}$$

3. MLX90251 – TC Table

This section is intended to give a description of the TC Table implemented into the MLX90251.
In fact, the MLX90251 is a Programmable Linear Hall Effect Sensor, whose Temperature Coefficient, TC_σ, is also programmable. This allows the user of this IC to program a TC into the chip so that he can compensate - at least partially – the thermal drift of the applied magnetic flux density. This former drift can be due either only to the magnet which is used in the application or even to the interaction of magnet and module.

The TC_σ (TC of the IC) is defined through three programmable parameters: TCW (3 bits), TC (5 bits) and TC2ND (6 bits).
All three parameters can be programmed in the final application and are stored in the EEprom of the IC.
In order to determine which triplet [TCW, TC, TC2ND] has to be programmed into the IC to compensate a pre-defined TC_B (see equation 9 to get the relationship between TC_B and TC_σ) a kind of look-up table is used. This table is what we call the TC Table.

The following paragraph gives more details about the implementation of this TC Table.

The TC Table of the MXL90251 is based on two equations, equation 19 and equation 20.

$$TChot = (K2 + A1\times TC + A2\times TCW)\times TC2ND + (K3 + A3\times TC + A4\times TC^2)\times TCW + K4\times TC + A5\times\frac{TC^2}{2} + K5$$

Equation 19

$$TCdiff = K1\times TC2ND + (K7 + A6\times TC)\times TCW + A7\times\frac{TCW^2}{2} + K8\times TC + A8\times\frac{TC^2}{2} + K9$$

Equation 20

where:

- TChot = TC between 25°C and 125°C
- TCdiff = TChot – TCcold, with TCcold = TC between -40°C and 25°C.

Both equations have been evaluated through a statistical analysis performed on the MLX90251.

It should also be emphasized to the fact, that TChot equals TC target, i.e. the “to-be-compensated” temperature coefficient (the TC of the magnet).

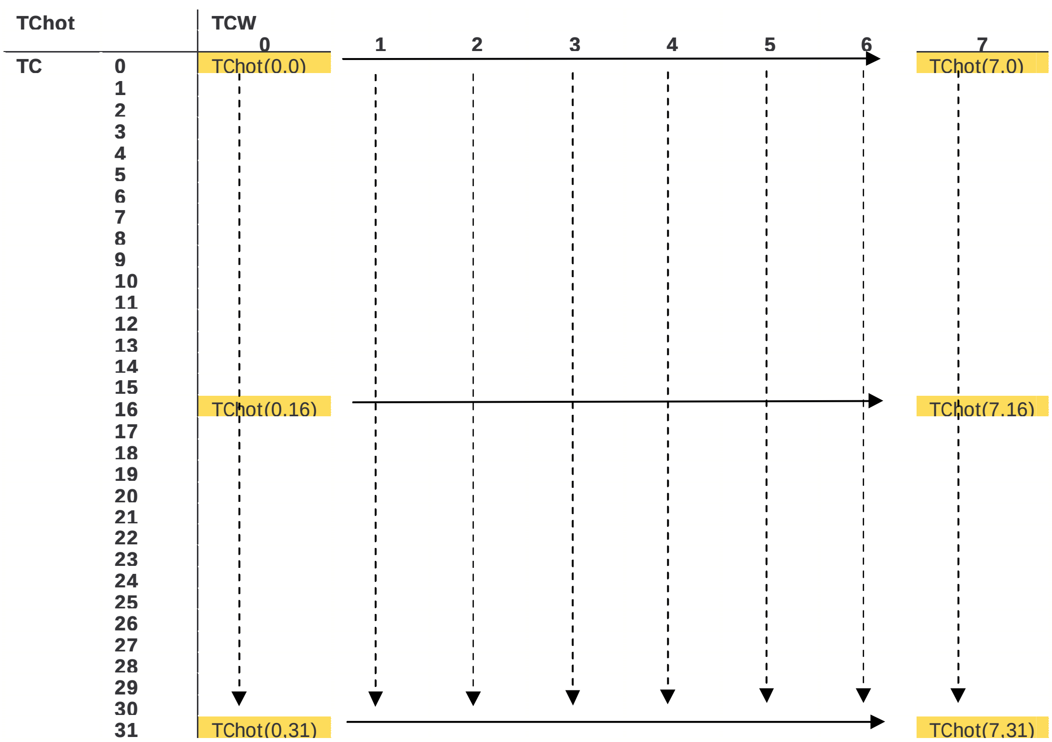
Normally, the concept of this TC Table would require the coding of all the information needed to calculate the TChot at any point of the space defined by the triplet [TCW, TC, TC2ND]. Therefore, the 16 parameters which define the previous 2 expressions should be stored into the EEprom. However, this storage would require too much memory-space.
This is why a simplified method for calculating the value of TChot as a function of (TCW, TC) only has been evaluated. In a similar way, a simplified equation for calculating the value of TC2ND as a function of (TCW, TC) only has been defined. This former one is defined in such a way to minimize TCdiff, i.e. to compensate the difference between TChot and TCcold. Therefore, this parameter is called TC2ND; it

compensates the second order effect, which normally would imply a little difference between the TChot and the TCcold of the IC.

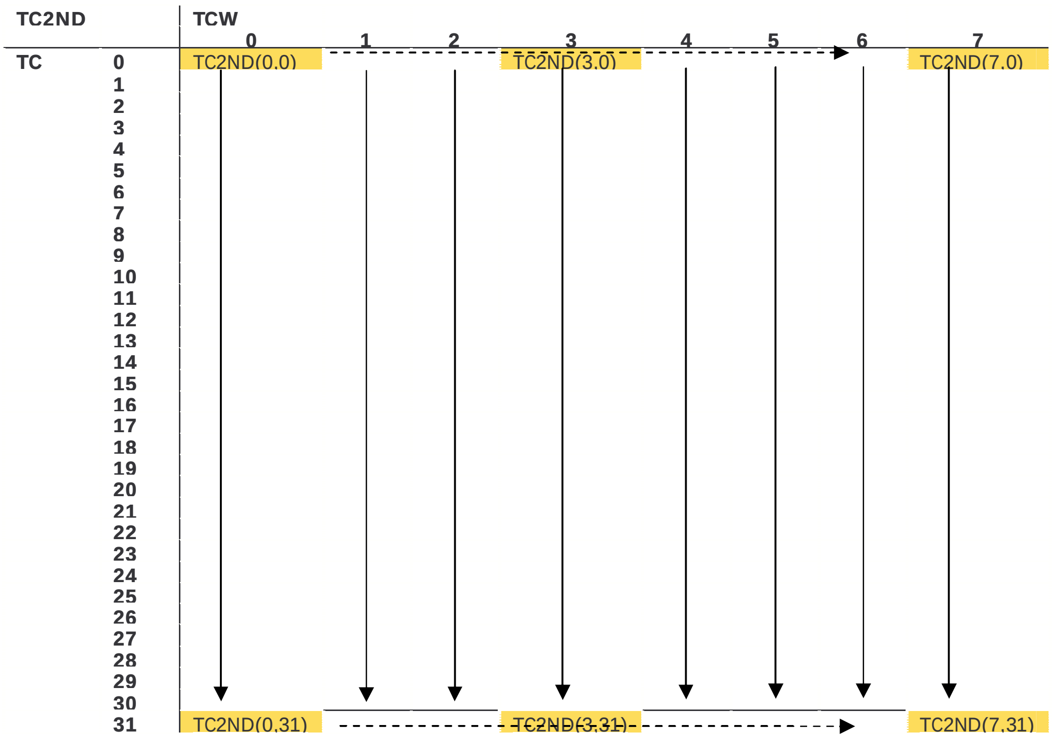
Finally, the TC_{σ} is based on two TC Tables: one table, which gives TChot as a function of TCW and TC and a second one which gives TC2ND as a function of TCW and TC, **where TC2ND is chosen in order to minimize TCdiff**.

By using this approach, only six TChot values and six TC2ND values must be stored inside the EEprom in order to be able to restore the whole TC characteristic of the IC. All intermediate values can be calculated either via a linear interpolation or via a quadratic interpolation.
Those 12 values, which have to be stored, are determined individually for each IC during the three temperature Final Test at Melexis.

The following figure illustrates the interpolation scheme.[5]



[5] TChot(x,y) represents the value of TChot stored in the EEprom for TCW = x and TC = y.
TC2ND(x,y) represents the value of CT2ND stored in the EEprom for TCW = x and TC = y.



The yellow colored cases are recorded TChot or TC2ND values.
The solid arrows are representative for a linear interpolation (along the TCW axis for TChot and along the TC axis for TC2ND), whereas the dashed arrows are representative for a quadratic interpolation (along the TC axis for TChot and along the TCW axis for TC2ND).

4. TC Determination

This section is intended to describe how the Temperature Coefficient of a system can be determined by using a chip like the MLX90251.

First of all it should be specified what the denomination "system" does mean. In the following section, when speaking about the "system" we refer either to a simple magnet or to a magnet implemented in a module (w/o IC, if not otherwise specified).

Each part of the system can have a certain temperature coefficient. Therefore, we have the general equation:

$$TC_{measured} = TC_{IC} + TC_{system} = TC_{IC} + TC_{M} + TC_{module}$$

Equation 21

,

where:

- TC_{IC} represents the temperature coefficient of the IC
- TC_{M} represents the temperature coefficient of the magnet
- TC_{module} represents the temperature coefficient of the module (w/o magnet and w/o IC)
- $TC_{system+IC}$ represents the temperature coefficient of the complete system (module + magnet + IC).
- $TC_{measured}$ represents the measured temperature coefficient, which will be measured via the MLX90251.

All our measurement results will be based on measurements made by using the MLX90251. In order to determine the TC of the system we should know/characterize the TC of the MLX90251. To do so, the TC of the MLX90251 should be programmed to 0ppm/°C. In this way equation 21 becomes:

$$TC_{measured} = TC_{IC} + TC_{system} = 0 + TC_{M} + TC_{module} = TC_{M} + TC_{module}$$

Equation 22

This means that we can directly evaluate the TC of the system (magnet + module). However, in order to get accurate estimations of this TC, we need first to characterize the TC of the IC. To do so, the following procedure should be applied.

4.1. Characterize TC of the MLX90251

As mentioned before, the TC of the MLX90251 should be programmed to 0ppm/°C. However, due to the limited accuracy of the chip, the perfect 0ppm/°C behavior will never been achieved. Therefore, the TC of the IC has to be characterized. This should be done by performing the following procedure:

1. Program the TC of the IC to 0ppm/°C via the PTC-03/PTC-04
2. Evaluate the real thermal behavior of the IC

In order to evaluate the TC of the IC, the output voltage should be measured at at least three different temperatures (Cold, Ambient, Hot) and per temperature for two different positions, i,e, for two different magnetic fields.
Concerning the two different positions, the best approach would be to measure Vout for a positive magnetic field and for the corresponding negative magnetic field, i.e. Vout(+B Gauss, T) and Vout(-B Gauss, T).

To calculate the TC of the IC equation 15 should be used.[6]

$$TC_\sigma = \frac{\dfrac{Vout(P2,T) - Vout(P1,T)}{B(P2,T) - B(P1,T)} - \dfrac{Vout(P2,25°C) - Vout(P1,25°C)}{B(P2,25°C) - B(P1,25°C)}}{\dfrac{Vout(P2,25°C) - Vout(P1,25°C)}{B(P2,25°C) - B(P1,25°C)} \times (T - 25°C)}$$

If however, the magnetic field strength is not known one of the approximating equations can be used (see equation 16 and equation 18).

In order to represent the TC of the IC (and even the TC of a system) a nice method is to use the normalized sensitivity, i.e. Sensitivity(25°C)/Sensitivity(T °C). This approach will be explained in Appendix III.

4.2. Determine TC of the system

Once the thermal behavior of your IC is fully characterized you can use it to characterize your system (magnet or magnet + module).
To do so you only need to implement the characterized IC into your system and to perform the same measurements as explained in the previous section, i.e. measure the output voltage at at least three different temperatures (Cold, Ambient, Hot) and per temperature for two different positions.

Once those measurements have been performed you can evaluate the TC of your system by using equation 13.

$$TC_{system} = \frac{(\dfrac{1}{\sigma(T)}) - (\dfrac{1}{\sigma(25°C)})}{(\dfrac{1}{\sigma(25°C)}) \times (T - 25°C)}.$$

In order to compensate this thermal TC of your system you should program the corresponding value into your IC.

[6] If the strength of the magnetic field B is not known you can also use one of the approximating formulas (see section 2.2.1.). However, in this case you will loose on accuracy.

Example:
Assume that TC_{system} = -450ppm/°C.

Your IC should compensate the TC of your system. Therefore, the IC should have a TC of +450ppm/°C. However, it should be emphasized that by using the User Interface of the PTC-03/PTC-04 you have to define the "To-Be-Compensated TC", TC_{system}, and not the TC that your IC should have.
This means that in this case you should define as Target TC -450ppm/°C. The software of the PTC-03/PTC-04 will then automatically calculate the corresponding TC, i.e. +450ppm/°C, and program the corresponding TC-triplet [TCW, TC, TC2ND] into the IC.

To get a nice representation of the thermal TC behavior of your system it is also recommended to use the normalized sensitivity approach (see Appendix III).

Appendix I

Remember that the Thermal Error was defined as:

$$Thermal\ Error = \Delta Voq(T) + \Delta TC \times \sigma(25°C) \times B(25°C) \times (T - 25°C)$$

We will take the following assumptions:

- ΔVoq(T) = ±20mV i.e. 0.4%Vdd if Vdd = 5V (tolerance on the Thermal Offset Drift)
- ΔTC = ±100ppm/°C (tolerance on the mismatching between the calibrated [Melexis] Sensitivity TC and the whole magnetic and mechanical circuit TC)
- Output Span from 10%Vdd up to 90%Vdd
- 0.8%Vdd/mT i.e. 4mV/G if Vdd = 5V

The Thermal Voq Drift Error, ΔVoq(T), can be represented graphically as follows:

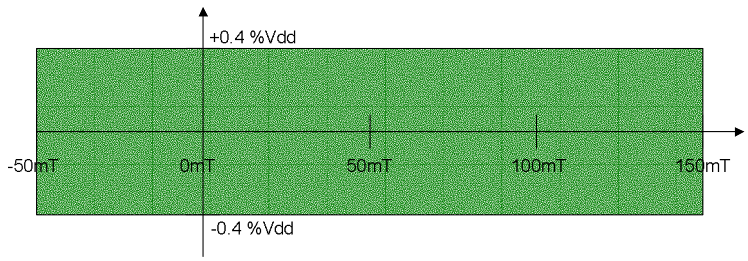


Figure 1: Error induced by the Thermal Voq Drift i.e. ΔVoq(T)

Whereas the error induced by the TC mismatch, i.e. ΔTC, can be represented like:

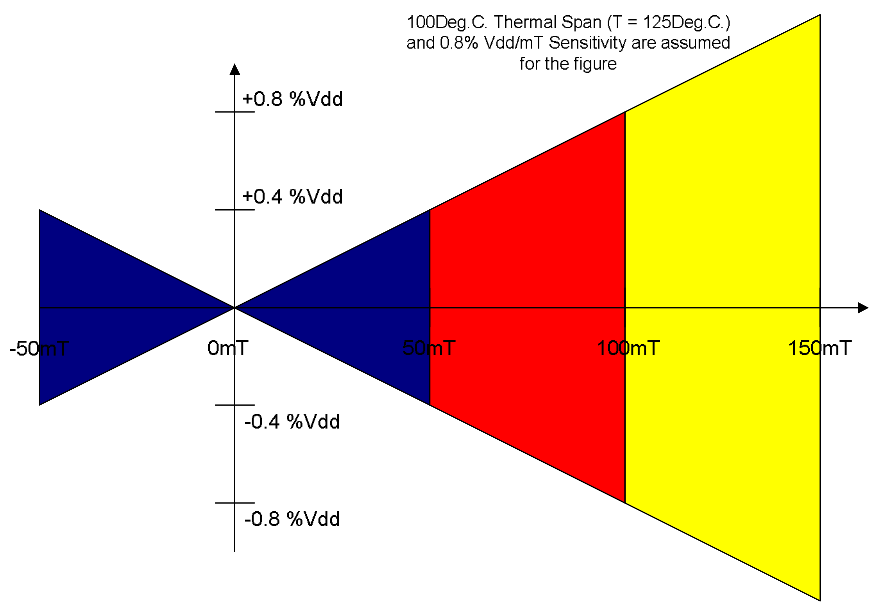


Figure 2: Error induced by the TC mismatch i.e. ΔTC

Finally, the total Thermal Error will have the following shape:

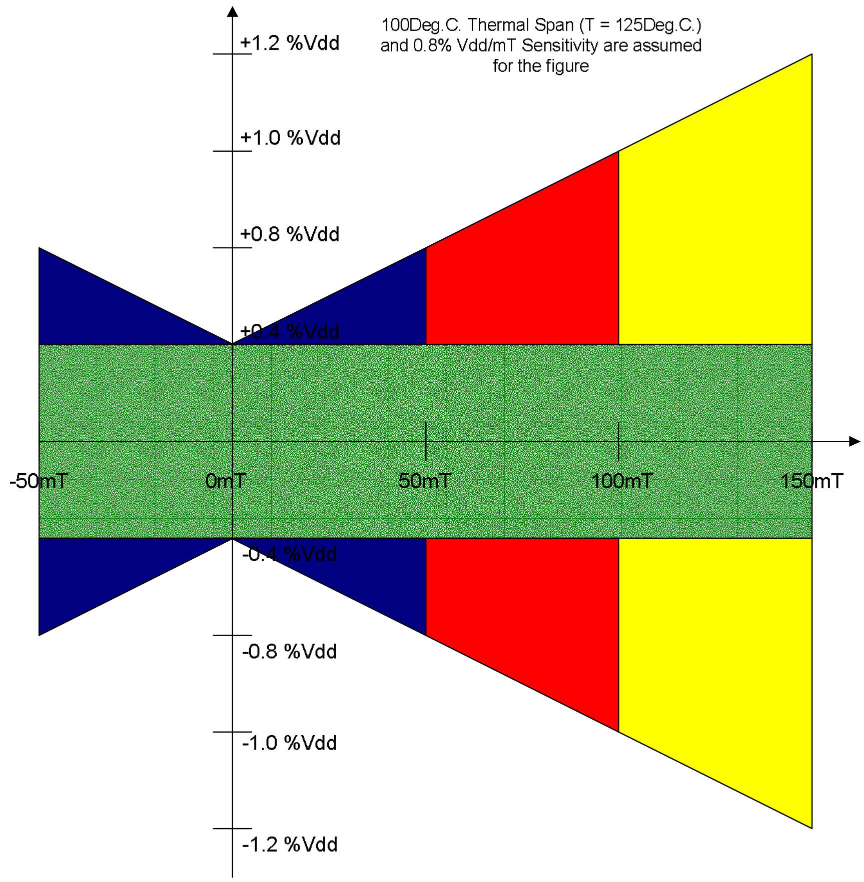


Figure 3: Total Thermal Error

Appendix II

$\sigma(T) = \sigma(25°C) \times [1 + TC_\sigma \times \Delta T]$
$B(T) = B(25°C) \times [1 + TC_B \times \Delta T]$

with $\Delta T = T – 25°C$.

- $TC_\sigma = [\sigma(T) - \sigma(25°C)] / [\sigma(25°C) \times \Delta T]$ [a]
- $TC_B = [B(T) – B(25°C)] / [B(25°C) \times \Delta T]$ [b]

Furthermore we have:

$TC\sigma = -TC_B / [1 + TC_B \times \Delta T]$ [c]
$TC_B = -TC_\sigma / [1 + TC_\sigma \times \Delta T]$ [d]

If we put [a] in [d]:

$TC_B = - \{[\sigma(T) - \sigma(25°C)] / [\sigma(25°C) \times \Delta T]\} / \{1 + [\sigma(T) - \sigma(25°C)] / [\sigma(25°C) \times \Delta T]] \times \Delta T\}$

$= - \{[\sigma(T) - \sigma(25°C)] / [\sigma(25°C) \times \Delta T]\} / \{[\sigma(25°C) + \sigma(T) - \sigma(25°C)] / \sigma(25°C)\}$

$= - \{[\sigma(T) - \sigma(25°C)] / [\cancel{\sigma(25°C)} \times \Delta T]\} / \{\sigma(T) / \cancel{\sigma(25°C)}\}$

$= - \{\sigma(T) - \sigma(25°C)\} / \{\sigma(T) \times \Delta T\}$

by multiplying nominator and denominator with $\{1 / [\sigma(25°C) \times \sigma(T)]\}$

$= - \{[\sigma(T) - \sigma(25°C)] / [\sigma(25°C) \times \sigma(T)]\} / \{[\cancel{\sigma(T)} \times \Delta T] / [\sigma(25°C) \times \cancel{\sigma(T)}]\}$

$= - \{[\sigma(T) - \sigma(25°C)] / [\sigma(25°C) \times \sigma(T)]\} / \{\Delta T / \sigma(25°C)\}$

$= - \{[\sigma(T) - \sigma(25°C)] / [\sigma(25°C) \times \sigma(T)]\} / \{\Delta T \times [1 / \sigma(25°C)]\}$

$= - \{[1 / \sigma(25°C)] – [1 / \sigma(T)]\} / \{\Delta T \times [1 / \sigma(25°C)]\}$

if $\sigma_1(T) = 1 / \sigma(T)$:

$= \{\sigma_1(T) - \sigma_1(25°C)\} / \{\sigma_1(25°C) \times \Delta T\}$.

Appendix III

The normalized Sensitivity Approach

This section will give a nice way to represent graphically the TC of a system or of an IC.
This approach is called the normalized sensitivity approach because it represents the normalized sensitivity versus the normalized temperature, where

- normalized sensitivity means:

$$NormalizedSensitivity = \frac{\frac{1}{Sensitivity(T)}}{\frac{1}{Sensitivity(25°C)}}$$

- normalized temperature means:

$$NormalizedTemperature = T - 25[°C].$$

Example:

Assume that we should have an IC with a target TC of -350ppm/°C, and that the spec is +/-150ppm/°C.

Assume the following measurements results:

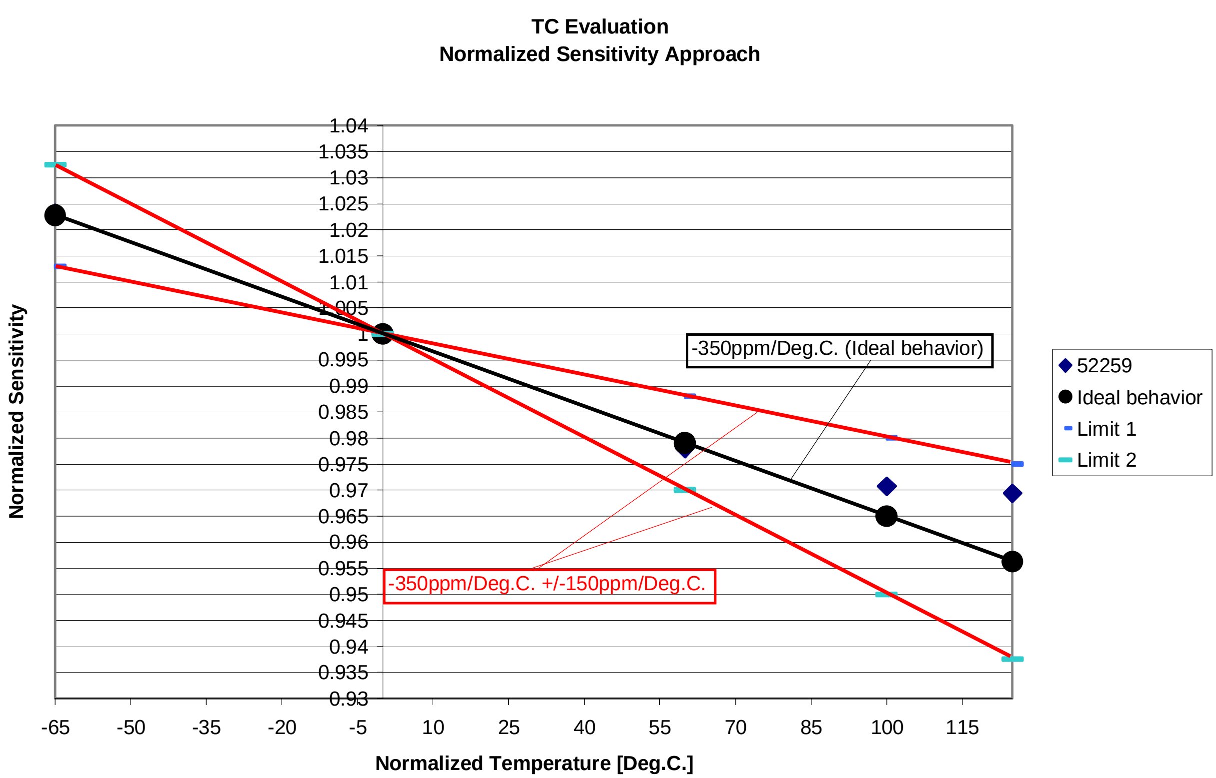
Chip ID	Temperature [Deg.C.]	Magnetic Filed [Gauss]	Output Voltage [V]
52259	-40	-500	3.259074
52259	-40	0	2.486386
52259	-40	500	1.712807
52259	25	-500	3.287673
52259	25	0	2.497092
52259	25	500	1.70554
52259	85	-500	3.31161
52259	85	0	2.503244
52259	85	500	1.693924
52259	125	-500	3.319199
52259	125	0	2.504777
52259	125	500	1.689406
52259	150	-500	3.319829
52259	150	0	2.504135
52259	150	500	1.687745

Table 1

Based on those measurements, the normalized Sensitivity and the normalized Temperature can be calculated. The results are summarized by Table 2.

Normalized Temperature [Deg.C.]	Normalized Sensitivity
-65	1.023195218
0	1
60	0.978022311
100	0.970757023
125	0.969394345

Table 2



How to determine the Normalized Sensitivity characteristic versus the normalized temperature?

This approach is based on equation 13:

$$TC_B = \frac{(\frac{1}{\sigma(T)}) - (\frac{1}{\sigma(25°C)})}{(\frac{1}{\sigma(25°C)}) \times (T - 25°C)}.$$

This equation can be transformed into:

$$TC_B = \frac{(\frac{\sigma(25°C)}{\sigma(T)}) - (\frac{\sigma(25°C)}{\sigma(25°C)})}{(T - 25°C)}$$

$$=> TC_B = \frac{(\frac{\sigma(25°C)}{\sigma(T)}) - 1}{(T - 25°C)}.$$

This equation represents the slope of the ideal behaviour line in our Normalized Sensitivity Approach.
In fact, we have:

$$NormalizedSensitivity(T) = \frac{Sensitivity(25°C)}{Sensitivity(T \ \ °C)}$$

$$= [TC_B * (T - 25°C)] + 1$$

If T = 25°C, the Normalized Sensitivity equals to 1. Therefore, at the Normalized Temperature of 0°C our Normalized Sensitivity function crosses the Y-axis at point 1.

Numerical Example:

How to determine the Ideal behavior characteristic?

Suppose that TC target = -350ppm/°C.
At T = 125°C, we have:

$$-350\,ppm/°C = \frac{(\frac{\sigma(25°C)}{\sigma(T)}) - 1}{(125 - 25°C)}$$

$$=> \frac{\sigma(25°C)}{\sigma(T)} = ([-350\,ppm/°C]*[100°C]) + 1$$
$$= -0.035 + 1$$
$$= 0.965$$

Furthermore, the Normalized Sensitivity equals to σ(25°C)/ σ(T). So we have:

Normalized Sensitivity = 0.965, at T = 125°C (Normalized Temperature = 100°C).

To calculate the specification limit lines, same procedure has to be used for -500ppm/°C (=-350ppm/°C – 150ppm/°C) and for -200ppm/°C (=-350ppm/°C + 150ppm/°C).

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