AN-B-100

System Clock Temperature Compensation

This application note describes the procedure for the customer to follow when implementing the 32 MHz XTAL oscillator temperature compensation mechanism included in the latest SDK.

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1. Terms and Definitions

ADC	Analog to digital converter
OTP	Memory inside the device containing, for example calibration values
RT	Room temperature

2. References

[1] DA14535, Datasheet, Revision, Renesas Electronics.

Note 1 References are for the latest published version, unless otherwise indicated.

3. Introduction

To support DA14535 working in a wider temperature range, a temperature compensation algorithm for the 32 MHz XTAL oscillator is implemented. This algorithm uses measurements from the internal temperature sensor and changes the TRIM setting for the 32 MHz XTAL oscillator to compensate the frequency offset introduced by temperature change.

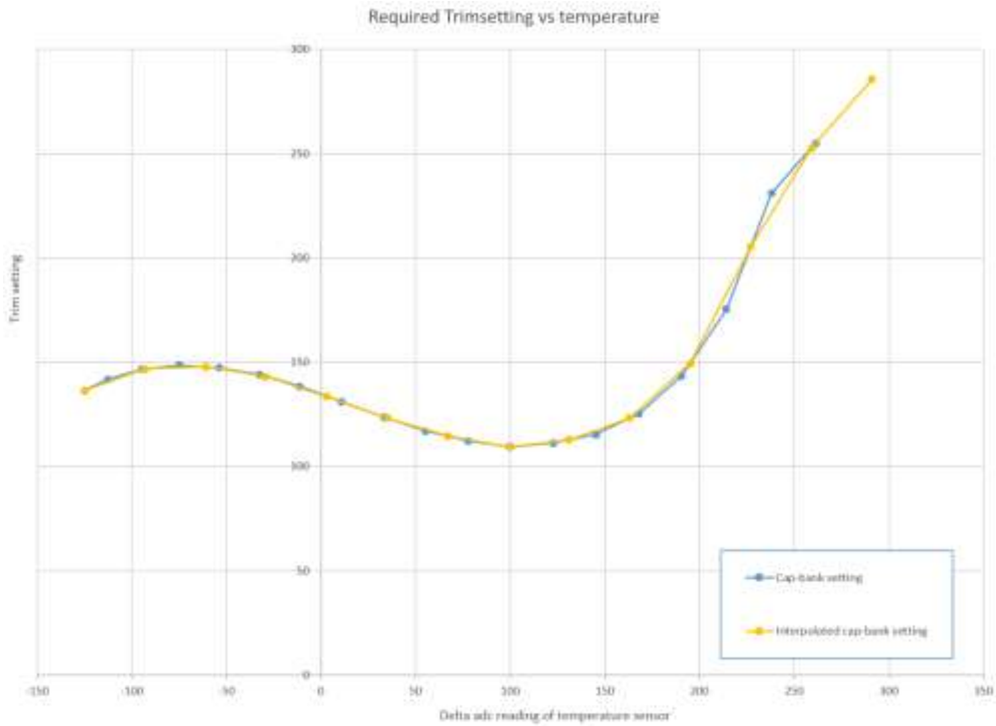

Figure 1: Comparison between measured and interpolated TRIM values

4. Interpolating over Temperature

4.1 Implementation of the interpolation

A list of datapoints (constants) is stored in the program, which allows for the routine to find a suitable trim setting. The datapoints pairs of (delta) adc (x-value) and trim settings (y-value) that are used for interpolation. The steps in the adc range are constant. So only the minimum value (adc_min), the step size (trim_delta), and the fit coefficients (trimfit_dt) are stored. This evaluates to the following list for the points pairs (for adc_min = 100, steps=8):

Table 1. Example of datapoints

Index	x-point	y-point
0	100	trimfit_dt[0]
1	164	trimfit_dt[1]
2	228	trimfit_dt[2]
3	292	trimfit_dt[3]
4	356	trimfit_dt[4]
5	420	trimfit_dt[5]
6	484	trimfit_dt[6]
7	548	trimfit_dt[7]
8	612	trimfit_dt[8]
9	676	trimfit_dt[9]
10	740	trimfit_dt[10]
11	804	trimfit_dt[11]
12	868	trimfit_dt[12]
13	932	trimfit_dt[13]

Note 1 The step distance between consecutive x points is calculated
step = 2 ^ Round((Log((XMAX - XMIN) / steps) / Log(2)), 0)
As you can see you might get the same step values for different steps values because of the rounding.

Note 2 The raw ADC value is always divided by 64.

If the raw adc temperature reading is, for example, 430*64 it is located between index 5 and 6. We are using the x and y data of this interval for the interpolation:

x5=420, x6=484 and y5=trimfit_dt[5], y6=trimfit_dt[6]

and do a linear approximation with those.

dtrim = y5 + (adcVal/64-x5)*(y6-y5)/(x6-x5)

The resulting trim value is then the sum of this delta trim value and the room temperature trim value:

Trim = RT_trimval + dtrim

4.2 How to generate the interpolation parameters

The interpolation parameters are generated from bench measurements. To get the data, do the following:

1. Sweep temperature in 10-degree steps, and in each step:
   a. Measure the temperature sensor with the internal ADC.
   b. Calibrate the xtal32m oscillator, and store the resulting trim setting.

   The result that is obtained are pairs of raw ADC readings and trim settings.
2. Fetch the adcValRT value from OTP (or use RT adc value from sweep).
3. Obtain the room-temperature trimming value (or use RT trim value from sweep).

4. Use sheet “xtal32m_temperature_compensation/AN-3081_XTAL_frequency_compensation.xlsx” to generate the constants that are needed in the program.
   a. Insert datapoints (as obtained from sweep) into column “adc_read” and “Required trim setting”.
   b. Choose “STEPS”; a higher number of steps will yield a better accuracy with the measurement.
   c. Click “Gen TC params” to find the interpolation coefficients, which are subsequently placed in the table (cell F16 in the sheet).

The coefficients from the code example are generated from an average of 3 samples, of which the data is shown in “xtal32m_temperature_compensation/TempComp_measurements.xlsx”

5. Conclusions

The 32 MHz XTAL oscillator of DA14535 is generating the system clock, which is reference of the PLL generating the 2.4 GHz carrier frequency. Usually a fixed trim value is used to calibrate the 32 MHz XTAL oscillator to achieve the wanted frequency tolerance at industrial temperature range. If a customer wants to use DA14535 in a wide temperature range or requires a better frequency tolerance, it is beneficial to use variable trim values for the 32 MHz XTAL oscillator to compensate the temperature drift.

Revision History

Revision	Date	Description
0.1	Aug 23, 2023	First Draft

Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

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