Instruction

Mandatory crystal adjustment for EFR32ZG14 based products

Document No.:	INS14498
Version:	5
Description:	This document describes the mandatory adjustment of the system crystal which must be performed on a product based on the EFR32ZG14 Gateway device
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Restrictions:	

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Date	CET	Initials	Name	Justification
2019-09-17	04:28:26	JFR	Jorgen Franck	on behalf of NTJ

REVISION RECORD				
Doc. Rev	**Date**	**By**	**Pages Affected**	**Brief Description of Changes**
1	20181204	OPP	ALL	Initial version, added how to populate the CTune value as a manufacturing token
2	20181205	OPP	2, 5, 7	Type errors fixed, more correct sentences.
2	20190116	MLEDESMA	ALL	Grammar and structure (consistent format) modification
3	20190312	OPP	Section 3, Figure 1, Section 4 Table 4.1	Emphasized that only a 39MHz crystal is supported. Corrected crystal type number. Updated drawing, showing internal cap in EFR32ZG14. Rephrased wording in start of the section. Added a table-structure for CTune measurement method
4	20190819	OPP	Section 6	Added second source description
5	20190911	SCBROWN	Section 3, 4 & 6	Reviewed Sections

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1 ABBREVIATIONS

Abbreviation	Explanation
ASIC	Application Specific Integrated Circuit
PCB	Printed Circuit Board
ppm	Parts Per Million

2 INTRODUCTION

2.1 Purpose

The purpose of this document is to describe the required method to match the system crystal of an EFR32ZG14-based product to the PCB layout of the product. The procedure is required to ensure that the crystal tolerances of the product are within the specifications of the Z-Wave protocol.

2.2 Audience and Prerequisites

The intended readers of this document are:

- Product design engineers
- Production test engineers
- Z-Wave application programmers

The readers of this document are assumed to have knowledge of:

- The Z-Wave protocol
- Basic RF knowledge
- Basic RF measurement skills

Access to the bring-up software tool RailTest is required.

Knowledge and access to the following documents is essential:

- [1] “INS14283 Instruction for Bring-up/test HW development”
- [2] “AN961: Bringing Up Custom Devices for the Mighty Gecko and Flex Gecko Families”

3 ABOUT CRYSTAL TOLERANCES

The precision of the system crystal in a radio system, such as the Z-Wave radio system, is vital. If the transmitters and receivers in the Radio system are not operating with the correct clock frequency, and if the frequency difference between the parts is large, it will affect the obtainable range between the parts. This leads to customers experiencing a bad performance of the radio system. It is therefore mandatory to make sure that the system frequency of a radio product is as accurate as possible and adheres to the specifications of the radio protocol used, in this case the Z-Wave protocol.

The total tolerance of a crystal is a sum of three contributions:

1. Initial tolerances
2. Temperature tolerances
3. Aging tolerances

For the Z-Wave protocol, the required tolerances for the crystal after 5 years of operation is +/-27 ppm.

To avoid frequency harmonics in any Z-Wave frequency band, only a 39MHz crystal is supported. The recommended crystal to use for EFR32ZG14 products is a 39MHz crystal from TXC, type 8Y39072002. For the specified crystal, the total tolerances are +/-24 ppm across the temperature range -40°C – 90°C after 5 years of service, and the individual contributions are:

Initial tolerances: +/-8 ppm
Temperature tolerances: +/-13 ppm from -40°C to 90°C
Aging tolerances: +/-3 ppm after 5 years

The Initial tolerances are affected by:

- Parasitic load capacitance at the crystal component connections
- Pressure exerted on the component package

The Temperature tolerances are affected by:

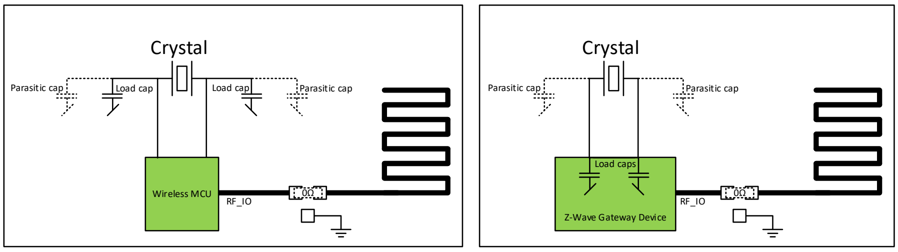
- The temperature of the environment

The Aging tolerances are affected by:

- Overdrive of the crystal
- Overheat of the component
- Mechanical stress due to normal usage

If it is assumed that the crystal is *not* stressed in any way, not mechanically nor electrically, there is only one parameter left which can give a systematic tolerance change for the crystal; i.e., change the frequency of the crystal, and that is the parasitic load capacitance added by the PCB of the product.

Depending on the implementation of the crystal oscillator circuit of an ASIC, external load-caps may be required. However, this is not the case for the EFR32ZG14 device, where the load-caps are integrated on the die of the EFR32ZG14, as illustrated in Figure 1:



Wireless MCU with external load capacitances EFR32ZG14 device with internal load capacitances

Figure 1. External vs. Internal Load Capacitance

The amount of parasitic capacitance seen by the crystal depends on:

- Trace length
- PCB material properties

These parameters vary from product-design to product-design.

To counteract the parasitic load capacitance of the PCB and device implementation, the Z-Wave protocol offers the possibility to adjust the internal load capacitances in such a way that the total capacitance seen by the crystal fulfills the crystal specifications.

4 HOW TO ADJUST THE SYSTEM CRYSTAL

As described in Section 3, implementing the 39MHz system crystal on a PCB will affect the crystal frequency. This is due to the parasitic load capacitance added to the crystal terminals by the traces from the EFR32ZG14 device to the crystal component.

To counteract the added parasitic load capacitance, the Z-Wave protocol offers the possibility to change the value of the internal load capacitance in such a way that the sum of the internal load capacitance and the parasitic load capacitance is equal to the nominal load capacitance of the crystal. When the crystal operates with the nominal load capacitance, the frequency of the crystal will also be the nominal frequency:

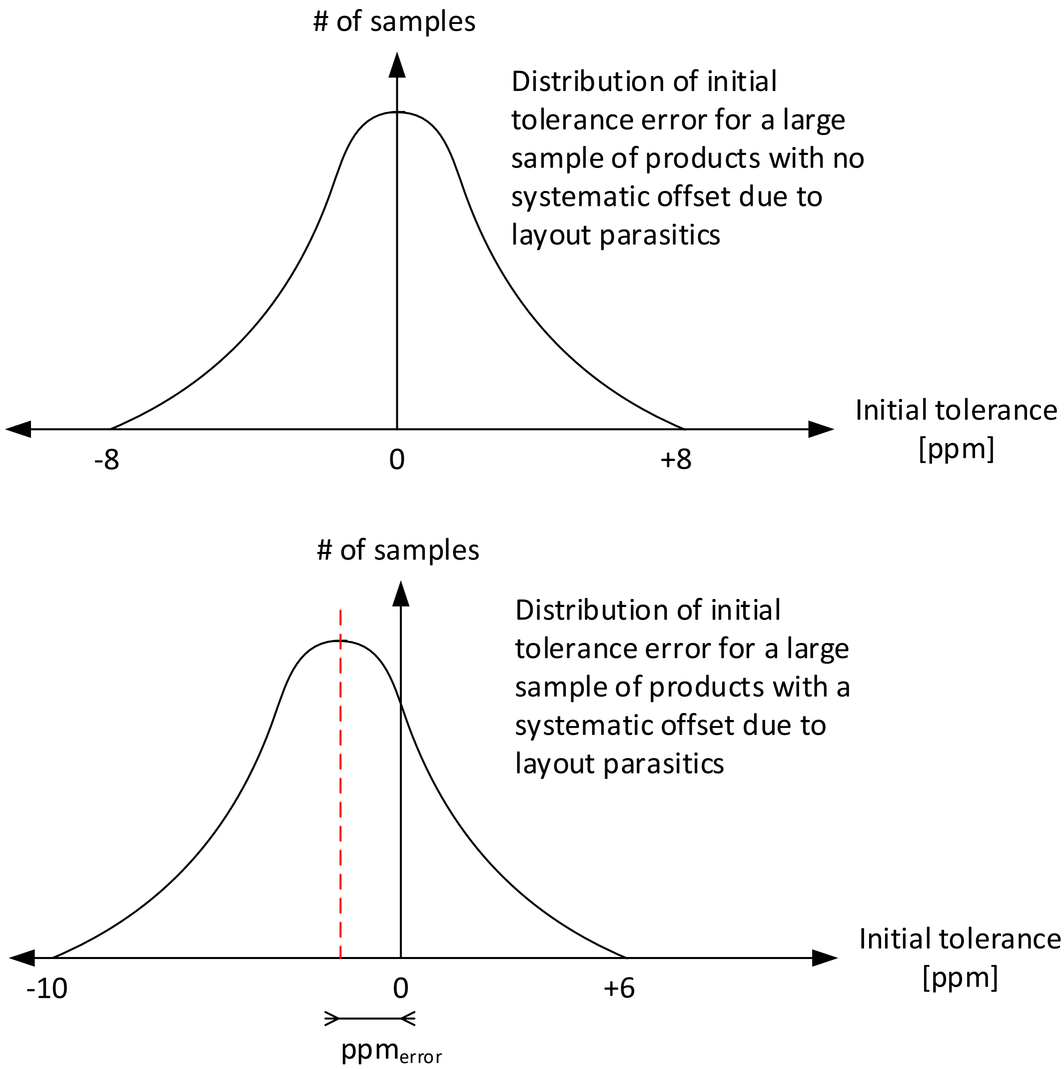


Figure 2. Offset Error Due to Parasitic Load Capacitance

Figure 2 shows how the distribution of the initial frequency errors will be for two various products: one product with the correctly adjusted load capacitance and one product with a systematic frequency offset, denoted in the figure by ppm_{error}.

The frequency error of an RF-enabled product can be measured by measuring the RF frequency of a Carrier Wave (CW) transmitted by the product. If the product is designed for the EU region, and a CW is enabled for, as an example, channel 2, then any measured average frequency offset from 868420000 Hz is an RF frequency error that must be corrected.

Refer to [1] to see how a CW is set up in connection with the usage of the test software RailTest.

According to [1], the measurement of the frequency offset for the product must be performed as part of the bring-up process for the product.

Once the general frequency offset is found, a value for the required load capacitance setting can be derived, this value is called CTune. With the derived CTune-value, it must be remeasured, so that the average frequency offset is zero when applied to the product samples. Please refer to Table 4.1.

It is recommended to one perform the measurement on a larger number of samples. To further strengthen the confidence of the procedure, “process corner crystals” can be used. A “process corner crystal” is a crystal which during its manufacturing is forced to be at an extreme value, but still within the overall tolerances given for the device.

The determination of the CTune value is an iterative process and can be described as shown below:

Table 4.1, CTune Measurement Method

1	Program RailTest to a larger number of product prototypes. Refer to [1] for more information.
2	For each product, follow the procedure described in [1] and measure and record the CW frequency.
3	Calculate the average frequency measured for the prototypes: $f_{average\_1} = (f_{product\ 1\_1} + f_{product\ 2\_1} + f_{product\ X\_1}) / X$
4	Calculate the frequency offset: $f_{offset\_1} = f_{target} - f_{average\_1}$.
5	Take a sample with a measured frequency close to $f_{average\_1}$.
6	Using the method described in [1], adjust the CTune value for this product until $f_{measured} = f_{target}$.
7	Re-measure all the prototypes using the value CTune.
8	Re-calculate the average frequency measured on the prototypes: $f_{average\_2} = (f_{product\ 1\_2} + f_{product\ 2\_2} + f_{product\ X\_2}) / X$
9	Re-calculate the frequency offset: $f_{offset\_2} = f_{target} - f_{average\_2}$.

The process should stop when the $|f_{offset_2}| < 1000$Hz. That is, the average frequency error should be within +/-1 ppm.

The CTune found is valid for the specific product. If the layout of the product changes, the procedure must be repeated. If the stackup of the PCB changes, the procedure must be repeated. If the firmware is updated, the new firmware must contain the found CTune value. In other words, the CTune value must follow the product during its entire lifecycle.

The found CTune value is incorporated into the Z-Wave protocol by setting the token TOKEN_MFG_CTUNE equal to the CTune value found. For handling of manufacturing tokens, refer to [2].

5 HOW TO PRODUCTION CALIBRATE THE SYSTEM CRYSTAL

Section 4 describes how to remove the systematic frequency offset of a product. This will ensure, that the system frequency error is identical to the nominal tolerances of the crystal.

If a more precise system frequency is desired, another approach is required: production calibration at manufacturing time.

If each product is to be production calibrated, the net result will be as shown below:

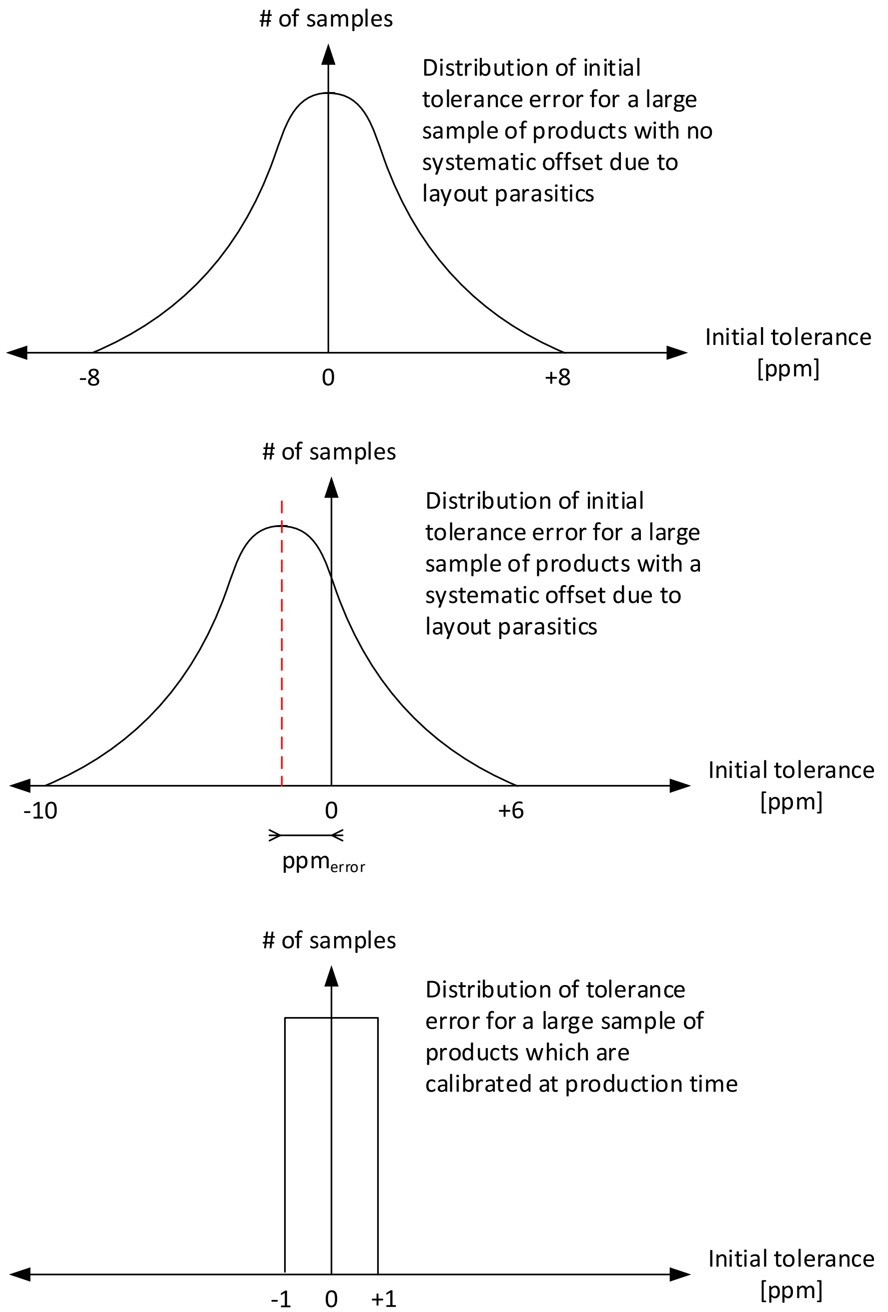


Figure 3. Effect of Production Calibration

As seen from Figure 3, the initial crystal tolerance is at +/-8 ppm and the offset due to layout parasitics is reduced to e.g., +/-1 ppm, since each product is individually measured and calibrated.

To individually calibrate each product, one must:

1. Be able to download RailTest during the manufacturing of the product
2. Be able to control RailTest during the manufacturing of the product
3. Be able to precisely measure a CW from the product with a precision of +/- 1 ppm
    a. With the aid of a spectrum analyzer or an RF frequency counter
4. Be able to derive a CTune value from the frequency measured
5. Be able to incorporate the CTune value found into the Z-Wave protocol code to download

As seen in the procedure description above, the CTune value found must be incorporated into the Z-Wave protocol. This is done in the form of a TOKEN_MFG_CTUNE value, with value = Ctune, which is programmed into memory according to the description given in [2].

6 SECOND SOURCE CRYSTAL COMPONENT

In case a second source component for the TXC, type 8Y39072002, is needed, the following component is suggested:

Table 6.1, Second source crystal component

Part Number	Supplier
XTL501140-S315-020	Siward

Other crystal vendors that meet these requirements can be used:

Crystal minimum requirements:

- Fundamental mode crystal
- +/- 25ppm after 5 years across temperature range of the product
- Load capacitance 10pF (range: 8pF – 12pF)
- ESR : Max 50Ω
- C_0 : 2pF – 7pF (C_0 for first source and second source components: 2pF and 3pF)

NOTE: The “CTune” value must be measured and applied to each unit depending on the crystal vendor being used.

NOTE: Selecting a crystal is an important step in the design of an end-product. Once an end-product has obtained RF regulatory certifications, the RF regulatory authorities does not allow the change of the crystal without re-certification.

REFERENCES

[1] INS14283, Instruction for Bring-up/test HW development.
[2] AN961, Bringing Up Custom Devices for the Mighty Gecko and Flex Gecko Families.