Application Report
SWRA499C–June 2016–Revised September 2019

Running Bluetooth® Low Energy on CC13x2/CC26xx Without a 32 kHz Crystal

Christin Lee and Fredrik Kervel *Bluetooth low energy Solutions*

ABSTRACT

This application report explains how you can configure the Bluetooth Low Energy (BLE) software stack to operate without the need for a 32 kHz crystal on the SimpleLink™ CC13x2 and CC26xx devices.

This application report explains how to configure this mode of operation, what considerations have to be taken to use the internal RC low frequency oscillator (RCOSC_LF) for the Bluetooth Low Energy peripheral and broadcast (beacon) role devices instead of the 32 kHz crystal, and what impact it has on current consumption. This document assumes the reader is familiar with the concepts described in the BLE5-Stack Users Guide and the CC13x2, CC26x2 Simplink™ Wireless MCU Technical Reference Manual.

Removing the 32 kHz crystal from a design decreases the required board space, reduces the bill of material (BOM) costand simplifies procurement.

Contents

1 Introduction 2
2 Requirements 2
3 Configuration 2
4 Performance 3
5 Recommendations 4
6 References 5

List of Figures

1 Current Consumption vs Connection Interval 4

List of Tables

1 Current consumption for Connection Event from simplePeripheral 4

Trademarks

SimpleLink is a trademark of Texas Instruments.
Bluetooth is a registered trademark of Bluetooth SIG, Inc.
All other trademarks are the property of their respective owners.

1 Introduction

The Bluetooth specification puts a strict requirement on the accuracy of the sleep clocks for Bluetooth Low Energy devices that are intended to enter (and stay) in a connection. The specification requires that devices have a sleep clock accuracy (SCA) that meets ± 500 ppm. For more details on the SCA requirement, see the *Sleep Clock Accuracy* section in the Bluetooth core specification 4.0, Volume 6. that can be downloaded from the following URL: https://www.bluetooth.com/specifications/adopted-specifications.

This sleep clock accuracy (SCA) requirement is valid for both the master and slave side of the Bluetooth Low Energy connection; however, devices such as Bluetoooth Low Energy beacons do not require such accuracy as the advertising interval is intentionally varied to prevent collisions. The intention of the SCA requirement is to ensure low power consumption while maintaining flexibility in the component selection. The amount of time a slave device must stay in active RX mode, referred to as the receive window, is dependent upon the sleep clock tolerance; a less accurate sleep clock requires the receive window time to be increased, thus, increasing the average current consumption.

2 Requirements

2.1 Bluetooth Low Energy (BLE)-Stack Software Versions

Using the internal 32 kHz RC oscillator (RCOSC_LF) as Bluetooth Low Energy sleep clock requires performing a periodic, software-based calibration of the RCOSC_LF oscillator. This functionality is included in the royalty-free TI Bluetooth Low Energy software protocal stack (Bluetooth Low Energy Stack) included in SimpleLink SDK 1.0 and onwards.

2.2 Constraints

The RCOSC_LF calibration is supported for the whole CC13x2/CC26xx temperature range, but care must be taken regarding temperature gradients. To stay within the sleep accuracy requirement of ± 500 ppm, the maximum temperature change per calibration interval cannot be higher than 1°C, with the default calibration interval being 1 second.

The calibration routine will be enabled when selecting RCOSC_LF build configuration as the sleep clock source or modify the project according to the software configuration section (for applications not requiring sleep clock accuracy, the calibration can be manually disabled. For example, non-connectable advertisement used by beacon applications). The calibration will then run automatically every time when the more precise high frequency (24 or 48 MHz) oscillator starts.

To maintain ± 500 ppm accuracy, the calibration must run at least every second assuming the temperature variation does not exceed 1°C per second. In applications with effective Bluetooth Low Energy connection intervals higher than 1 s (time in Standby mode > 1 s), wake-ups must be scheduled at least every second to perform the RCOSC_LF calibration. Similarly, if the application is active for longer time periods than 1 s, the calibration must be triggered by the application. Using the supported build configurations in Section 3.2, the BLE-Stack software will automatically handle these calibration requirements.

NOTE: The 32 kHz crystal-less feature is supported on CC13x2/CC26xx wireless MCUs implementing the Bluetooth Low Energy peripheral, observer and broadcast (beacon) roles only. Thus, all central role or master devices must use the 32 kHz crystal oscillator.

3 Configuration

3.1 Hardware Configuration

No specific hardware configuration is required to run on the internal 32 kHz RC oscillator (RCOSC_LF). The 32 kHz crystal pins will be in a Hi-Z state when not used and can safely be tied to any logic level, or left unconnected.

3.2 Software Configuration

Refer to the BLE5-Stack Users Guide, Running the SDK on Custom Hardware - Using 32-kHz Crystal-Less Mode section, for details on SW configuration.

4 Performance

4.1 Current Consumption

Using the internal RCOSC_LF as the sleep clock has a net effect on the device current consumption as compared to board designs that utilize an external 32 kHz crystal oscillator. The difference in current consumption varies depending on the configured role of the device. For peripheral (slave) devices in a Bluetooth Low Energy connection, the current consumption will be higher when using the RCOSC_LF as compared to using an external 32 kHz crystal; however, the increase in current consumption is dependent on a number of factors. This increase is due to:

- Performing the calibration at a certain interval
- The extended receive window due to the maximum allowed sleep clock accuracy (± 500 ppm, vs. typically ± 40 ppm with a 32 kHz crystal).

During periods where the CC13x2/CC26xx is advertising (for example, as a beacon or waiting for a connection request) or in standby (while idle), current consumption using the internal RCOSC_LF will be less (better) than using a 32 kHz crystal oscillator.

The calibration process itself takes approximately 1 ms, and for a typical Bluetooth Low Energy connection event the calibration will happen in the background while the radio operates. In most cases, the added current consumption from performing the calibration will thus be negligible. In configurations with longer effective Bluetooth Low Energy connection intervals, that is the connection interval with the maximum slave latency applied is greater than 1 second, there will be additional power consumption because the device has to wake up from standby (sleep) between the connection events to perform the RCOSC_LF calibration. In a board design that uses a 32 kHz crystal, these calibration wakeups would not be required.

The average current consumption using the 32 kHz crystal as compared to using the internal RCOSC_LF for some Bluetooth Low Energy effective connection intervals can be seen in Table 1 and Figure 1. To get actual current consumption for any given configuration, follow the measurement procedure in Measuring CC13xx and CC26xx current consumption.

Table 1. Current consumption for Connection Event from simplePeripheral

Connection Interval [ms]	Average Current w. RC OSC [µA]	Average Current w. XOSC [µA]
10	963.3	897
50	194.5	180
100	98.3	90.8
500	23.9	19.7
1000	15.4	10.8
4000	11.7	4.2

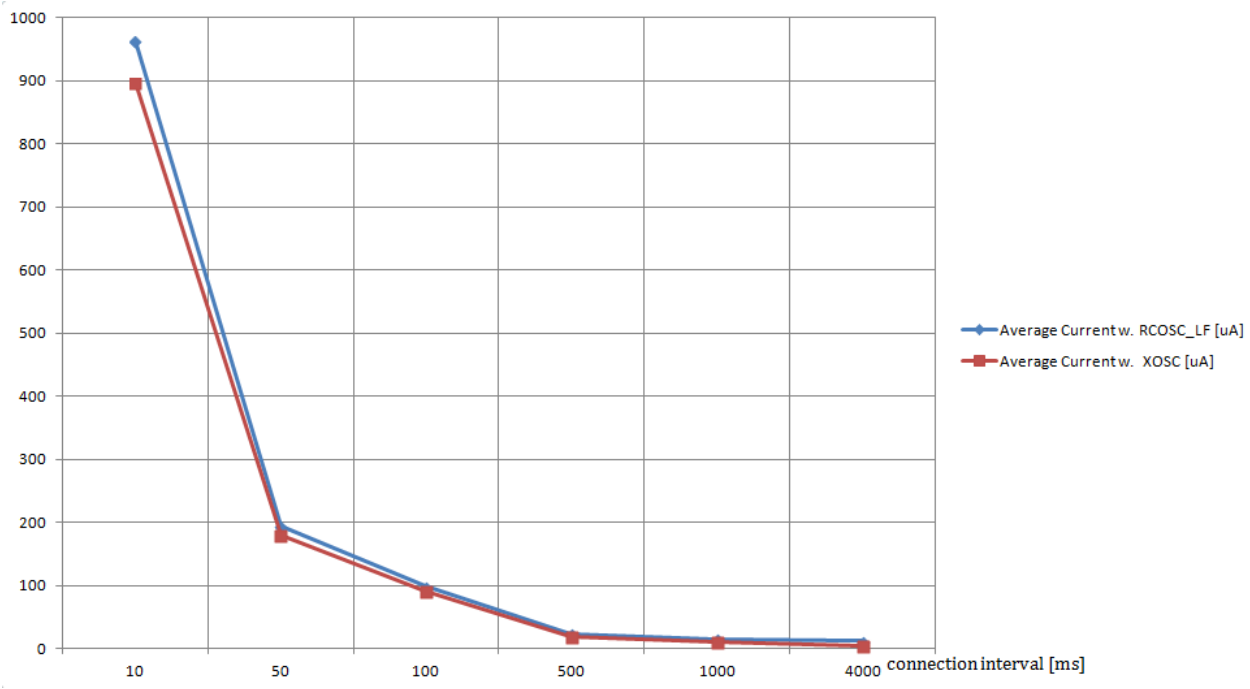

Figure 1. Current Consumption vs Connection Interval

5 Recommendations

Use of the 32 kHz crystal-less feature should be considered for the following Bluetooth Low Energy operating conditions:

- Where the lowest possible BOM cost is desired or when board layout space is limited.
- Peripheral role devices (slave) that maintain short (fast) connection intervals or enter Bluetooth Low Energy connections infrequently and remain idle or advertising most of the time. Example devices include door locks, light bulbs, blood glucose meters (BGMs) and fitness/activity trackers.
- Beacon or broadcast role devices. These devices do not typically form connections and spend most of the time performing Bluetooth Low Energy advertising. These devices will achieve better (lower) current consumption with the RCOSC_LF than using an external 32 kHz crystal.

6 References

- BLE5-Stack Users Guide
- CC13x2, CC26x2 SimpleLink™ Wireless MCU Technical Reference Manual
- Measuring CC13xx and CC26xx current consumption

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from B Revision (April 2017) to C Revision	Page
• Updates made to the Abstract.	1
• This version includes support for CC13x2 and CC26x2 devices.	1
• Updates were made in Section 1.	2
• Updates were made in Section 2.1.	2
• Updates were made in Section 2.2.	2
• Updates were made in Section 3.2.	3
• Updates were made in Section 4.1.	3
• Updates were made in Section 5.	4
• Updates were made in Section 6.	5

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265