Application Report
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Design Considerations for High Temperature Applications Using the CC2640R2F-Q1

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ABSTRACT

When creating an application using the CC2640R2F-Q1 targeting operation in high ambient temperatures, there are a few considerations that have to be made. The goal of this application report is to make these considerations clear to the developer.

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Trademarks

1 Introduction

The CC2640R2F-Q1 is an AES Q100 qualified version of the CC2640R2F SimpleLink Wireless MCU [1] with operating temperature grade 2. This means that the device is rated for operation in ambient temperatures ranging from -40°C to +105°C.

It is recommended to follow the *SimpleLink CC2640R2F-Q1 EVM v1.0.1 Design Files* closely both regarding layout and component selection [2].

2 Hardware Considerations

2.1 Passive Components

The CC2640R2F-Q1 is dependent on several passive components for proper operation. These must be rated for the full operating range of the application. Typically, when using automotive grade components, these will have the required temperature rating. If making a non-automotive, high temperature application, it is fine to use non-automotive qualified parts as long as these are rated for the correct operating temperature range.

Using passive components outside their specified temperature range can lead to improper decoupling, instability of the built-in DCDC regulator and poor RF performance. All of these can again lead to poor performance, unexpected behavior and violation of RF regulations.

2.2 Crystals

The CC2640R2F-Q1 is dependent on several clock sources for operation. A 24 MHz crystal is required to run the internal high frequency oscillator, which again is required to operate the radio, and a 32.768 kHz crystal is required to run the internal low frequency oscillator which drives the RTC. While the latter oscillator is optional, it is required when running Bluetooth low energy due to the strict timing requirements of the Bluetooth (BT) protocol specification.

The crystal accuracy over temperature requirements are outlined in the CC2640R2F-Q1 data sheet [1], and the crystals used must meet these requirements over the entire operating temperature range. Particularly important for RF protocol interoperability are the frequency accuracy requirements. The 24 MHz crystal must be within ± 40 ppm total accuracy to fulfill the BT requirement (± 150 kHz) while still allowing for packet drift. The 32.768 kHz crystal must be within ±500 ppm to fulfill the BT requirements on RTC accuracy.

The 24 MHz crystal accuracy over temperature is typically clearly stated in the applicable crystal. For example, the crystal used in the CC2640R2F-Q1 reference design [2], Epson TSX-3225 X1E0000210048 has an initial tolerance of ± 10 ppm and a temperature tolerance of ± 20 ppm over the operating range [4].

The 32 kHz crystal accuracy over temperature can often be harder to interpret. Typically, it is rated with a turnover temperature and a parabolic coefficient. The Epson FC-13A 32.7680KA-A3 crystal used in the CC2640R2F-Q1 reference design is specified with a turnover temperature (Ti) of 25°C and a parabolic coefficient (B) of -0.04 × 10-6/ °C^2. Based on these numbers, the frequency tolerance over temperature can be calculated from:

$$f_{offset} = (T - Ti)^2 * B \quad (1)$$

Figure 1 shows the resulting frequency over temperature.

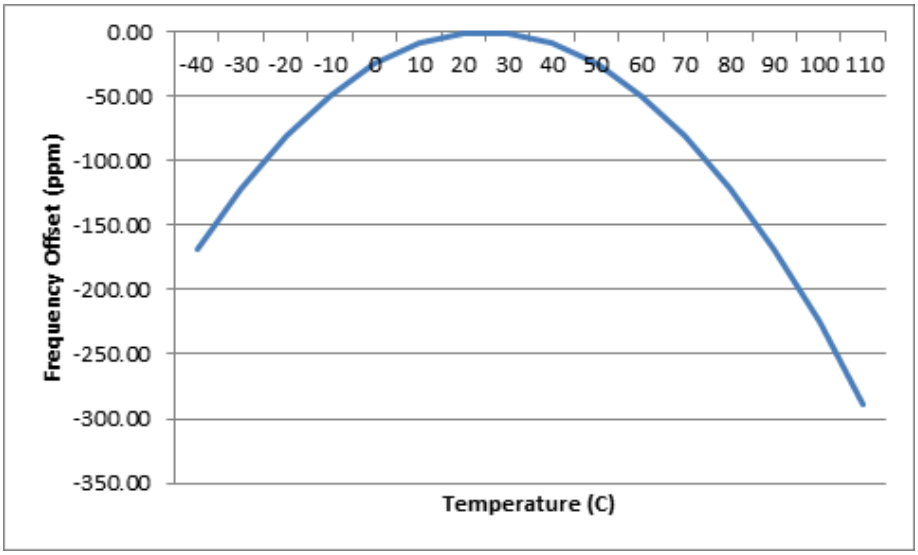

Figure 1. 32.768 Crystal Frequency Offset Over Temperature

3 Software Considerations

When a Bluetooth low energy connection is formed, the Central device reports its worst case sleep clock accuracy (SCA) to the Peripheral. The Peripheral adds this number to its own SCA and the total resulting SCA is then used to calculate when to wake up to hit a connection event. Basically, the worse the clock accuracy, the earlier the Peripheral must turn on its receiver to avoid missing the connection event. To optimize for power efficiency and assuming most applications do not operate at temperature extremes, the default SCA value in the TI Bluetooth low energy protocol Stack is set to ± 40 ppm. Considering the initial tolerance of the crystal to be ± 20 ppm, it is clear from Figure 1 that the temperature range is limited to about 5°C to 45°C when using the default setting. Thus, it is necessary to change the SCA value in the BLE Stack according to the 32 kHz crystal specification and the operating temperature. The SCA value is set through the *HCI_EXT_SetSCACmd()* function [6].

4 Summary

When designing an application that targets operating temperatures up to 105°C using the CC2640R2F-Q1, care must be taken to select appropriate passive components. Particularly, the crystal parameters must be ensured to fulfill the CC2640R2F and the RF protocol requirements for the whole operating temperature range.

When using the TI Bluetooth low energy Stack, the sleep clock accuracy value must be set according to the worst case 32.768 kHz crystal offset caused by the operating temperature.

5 References

1. *CC2640R2F-Q1 SimpleLink™ B Data Sheet*
2. *SimpleLink CC2640R2F-Q1 EVM v1.0.1 Design Files*
3. BLE Software Developer's Guide
4. Product No./Ordering code :X1E0000210048
5. Product No./Ordering code :FC-13A 32.7680KA-A3
6. BLE Modules

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