Application Report
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Minimizing Frequency Error Due to Soldering Process on CC2652RB Crystal-Less MCU

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ABSTRACT

This application report highlights the importance of using the correct soldering process to get the best performance out of CC2652RB crystal-less wireless MCU. CC2652RB is the industry's first wireless crystal-less microcontroller (MCU) with integrated TI Bulk Acoustic Wave (BAW) resonator technology. Various sources of errors due to improper soldering and their effects on the resonator frequency are discussed. The information presented here is relevant to the CC2652RB device due to package dependencies caused by placing the resonator within the package.

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1 Introduction

The CC2652RB is a multiprotocol 2.4 GHz crystal-less wireless MCU that uses BAW technology to remove the need for a high frequency external crystal. BAW technology is composed of a microelectromechanical (MEMs) resonator mounted onto the silicon die. It is connected to on-chip circuitry to produce an accurate clock. The accuracy and stability of the BAW resonator allows it to replace an external quartz crystal traditionally needed for 2.4 GHz radio operation. Removing the external quartz crystal allows optimization of the bill of material (BOM) and PCB area savings. Additionally, crystal-less BAW solutions provide superior clock performance compared to standard quartz crystals. Figure 1 shows CC2652RB package fabrication.

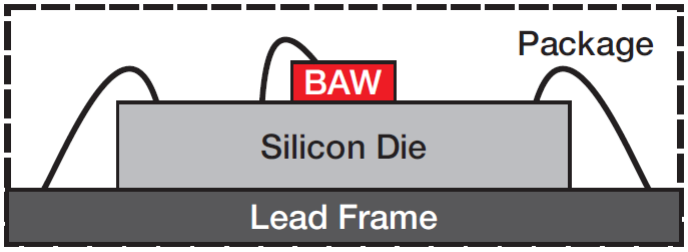

Figure 1. CC2652RB Package Fabrication

External crystal and crystal-less Simplelink™ TI devices will display no issues when being casually soldered to a board under development. However, the crystal-less CC2652RB device presents additional opportunities for optimization due to the effect solder process has on integrated resonators. An integrated resonator is affected by package stress and package grounding. When solder process is properly controlled the CC2652RB is able to demonstrate superior frequency accuracy compared to its external crystal solution.

A predetermined level of stress is expected when the CC2652RB device is soldered. The TI recommended solder profile is the JEDEC J-STD-020D.1 Pb-Free reflow profile. Deviation from this solder profile is capable of increasing or decreasing the stress seen by the BAW resonator. These differences effect the performance of the resonator in the form of a frequency offset of the carrier wave. This frequency offset is converted to Parts Per Million (PPM) deviation from the desired frequency. The CC2652RB spec states that all devices will maintain accuracy within 40 ppm across operating temperature. Under typical conditions both crystal-less and external crystal solutions have no difficulty fulfilling this requirement. However, special care should be taken in following recommended solder procedure to get the best performance across temperature and throughout the life of the device.

For this application report, information has been compiled on the different sources of errors that one could encounter in the soldering process that could lead to frequency inaccuracies if the right solder process (as per the device-specific data sheet) is not followed.

2 Error Source 1 – Solder Amount

Whenever there is a vendor, assembly, or PCB design change, it is possible soldering process is affected. The first source of error could be amount of solder. Figure 2 shows 2440 MHz radio accuracy of CC2652RB using solder amount specified as per JEDEC standard (shown as typical condition in legend) vs using extra and reduced solder. It can be seen that both increasing and decreasing the amount of solder applied resulted in a small negative frequency shift. A verification of the carrier wave frequency and a validation of production solder process should be able to prevent any such errors.

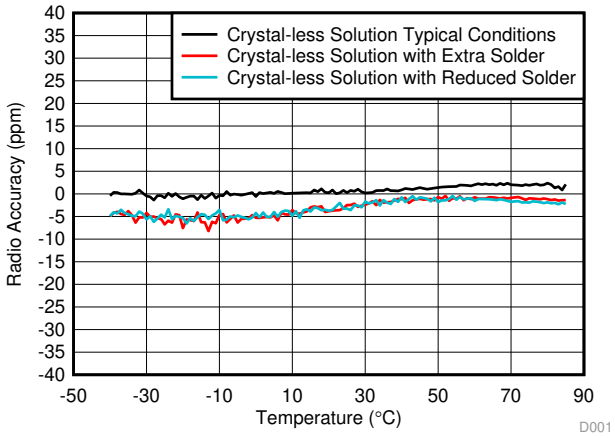

Figure 2. Crystal-Less Device With Varying Solder Amounts

3 Error Source 2 – Different Solder Profile

CC2652RB compensation parameters are fine tuned for the JEDEC J-STD-020D.1 Pb-Free reflow profile. A deviation in this profile is capable of affecting the stress on the package. For testing, a solder profiler was created 10°C colder than the Jedec profile called Low-JEDEX and one 10°C higher called High-JEDEX. Both of these profiles resulted in a slight shift at room and high temperatures of 2440 MHz radio frequency accuracy as shown in Figure 3.

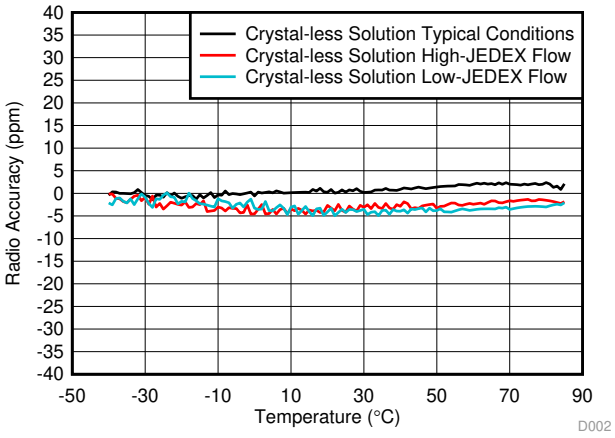

Figure 3. Crystal-Less Device With Solder Profile Changes

4 Error Source 3 – Testing Through a Socket

While JEDEC and solder levels are common error sources seen in production the development phase of a product may see additional source of frequency error. If during development a frequency offset is observed while measuring CC2652RB in socket, it will be due to improper grounding. A socket will result in improper grounding and prevent the device from seeing the expected package stress. Figure 4 shows slight shift in 2440 MHz radio frequency accuracy which operating CC2652RB in socket at low temperatures.

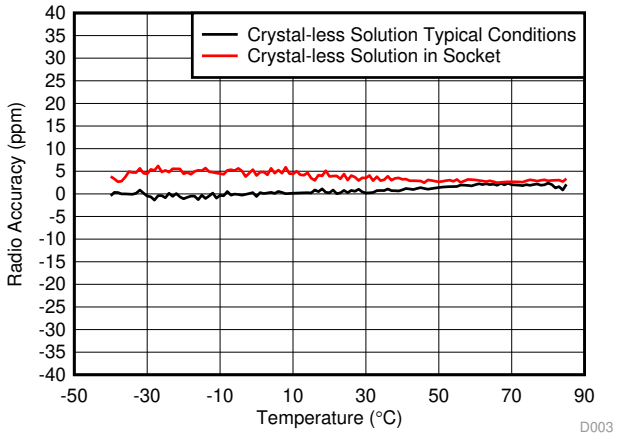

Figure 4. Crystal-Less Device Measured in Socket

5 Error Source 4 – Hand Soldering

When devices are hand soldered, the accuracy and precision of crystal-less devices will suffer. In addition to the offset shown in Figure 5, hand soldered devices will show a bigger part to part frequency distribution compared to JEDEC profile parts. This will be caused by differences in the temperature and heat distribution between devices. Figure 5 shows slight negative deviation frequency due to hand mounting. Thus, to get best possible performance from CC2652RB crystal-less radio, it is recommended to machine mount the device as per JEDEC profile.

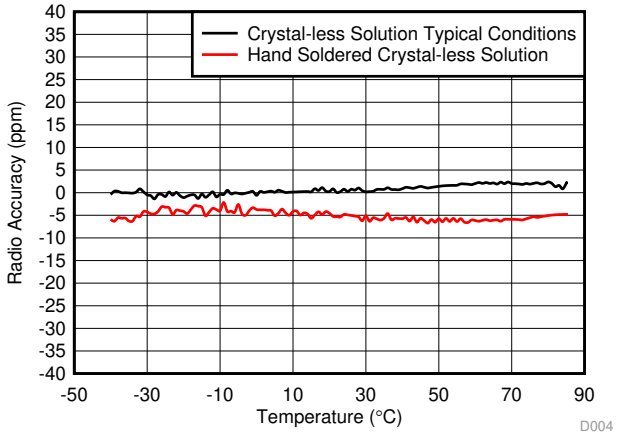

Figure 5. Hand Soldered Crystal-Less Device

6 Error Source 5 – Re-Flowing

The expected use case for a CC2625RB device is to undergo soldering one time. Additional solder work can add additional stress to the package and degrade performance. Re-flowing a soldered device can be a good first step to debug observed issues, but it is also capable of effecting slightly the frequency offset of the radio of the radio as shown in Figure 6.

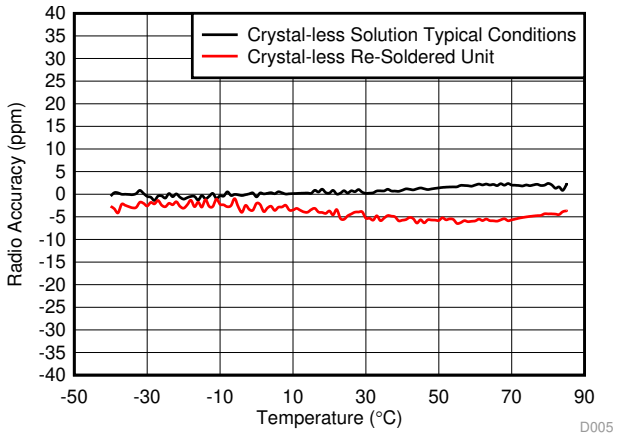

Figure 6. Re-Soldered Crystal-Less Device

7 Summary

When using a CC2652RB crystal-less wireless MCU, it is important to verify the solder process both during development and production to get the best performance. Any changes to soldering process will affect the frequency accuracy of the BLE carrier wave and lifetime of the device. As stated in the *CC2652RB SimpleLink™ Crystal-less BAW Multiprotocol 2.4 GHz Wireless MCU Data Sheet*, TI devices are designed around the JEDEC reflow profile. Verifying this process is a key step to getting the most out of your CC2652RB crystal-less, wireless MCU. The measurement results demonstrated in this application report depicts that the CC2652RB frequency is fairly robust, but there are steps customers can take to improve performance. Additionally, error sources have all been tested individually. A combination of multiple factors can be capable of summing the error. Over time the frequency of the CC2652RB device will age. The CC2652RB device is currently rated for 10 years of aging at 30°C. Taking steps to improve solder process can improve performance and extend the lifetime of a CC2652RB device.

8 References

- Texas Instruments: *CC2652RB SimpleLink™ Crystal-less BAW Multiprotocol 2.4 GHz Wireless MCU Data Sheet*
- Texas Instruments: *QFN and SON PCB Attachment*

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