Exploring IoT wireless connectivity in mechanical shock and vibration environments

Texas Instruments

Bill Xiobing Wu
Validation engineer

Habeeb Ur Rahman Mohammed
Validation manager

Texas Instruments

Introduction

Wouldn't it be nice to know the condition of parts in your car exposed to mechanical vibrations or shock from the engine, or to get information about the status of systems operating under severe mechanical vibration conditions in an automated factory? With this information, you could perform predictive maintenance and replace fatigued parts before they fail completely, substantially reducing car problems or factory downtime.

It can be a challenge to perform predictive maintenance on systems exposed to constant vibration and mechanical shock stresses. However, the Texas Instruments (TI) SimpleLink™ CC2652RB crystal-less wireless microcontroller (MCU) has paved the way with high-performance communication to help solve problems in such difficult operating conditions. As the first device of its kind on the market, the CC2652RB MCU provides robust wireless connectivity in challenging environments and significant resistance against acceleration forces and vibration. TI bulk acoustic wave (BAW) resonator technology helps designers improve network performance and can reduce overall bill of materials (BOM) by approximately 12 percent, while simultaneously increasing immunity to noise and temperature. This technology can be leveraged in a wide-variety of industrial and communication applications.

Figure 1 shows a simplified diagram of the CC2652RB MCU, which is based on TI BAW resonator technology. BAW belongs to the mechanical resonator family and has the advantage of compact size and its easy integration into silicon-based integrated circuits. Its inherent vibration-resistant design and smaller mass make it resistant to mechanical stresses such as vibration and shock. A tightly integrated wireless MCU with TI's BAW resonator technology provides a simplified approach for Internet of Things devices by providing robust wireless connections between gateways and wireless sensor nodes operating under mechanical vibrating surroundings.

Vibrations and mechanical shock affect clock resonators by inducing noise and frequency drift, degrading system performance over time. Two important parameters for measuring vibration and shock are the acceleration force and vibration frequency applied to the IoT connected devices. It is important for clock solutions to provide a stable clock with strong resistance to acceleration forces, vibration and shock and to assure stability

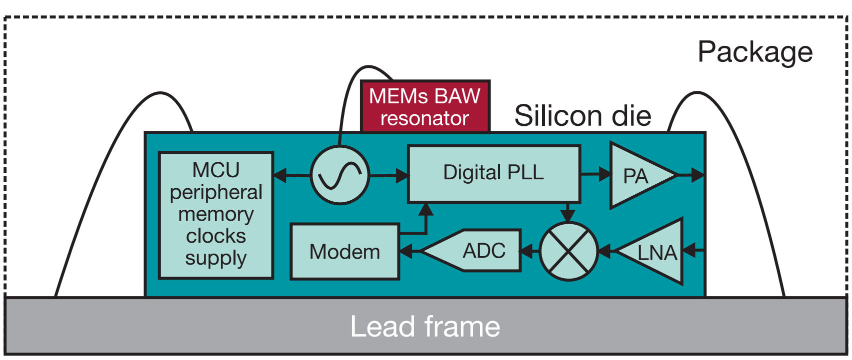

***Figure 1**. Diagram highlighting the integrated features of the SimpleLink CC2652RB crystal-less wireless MCU.*

throughout product life cycles under process and temperature variations.

The CC2652RB MCU offers ±40-ppm frequency stability across a supply voltage range from 1.8 V to 3.8 V and a –40°C to 85°C temperature range. The CC2652RB has been thoroughly evaluated against the highest possible industry standards, including those used by the military to test vibration and shock, which we'll discuss in the next sections. Compared to external crystal MCUs, the CC2652RB MCU shows substantial resistance to a variety of acceleration forces, sinusoidal vibration and mechanical shock.

Mechanical shock

Military (MIL) standard MIL-STD-883H, Method 2002 subjects semiconductor devices to moderate or severe mechanical shock caused by sudden forces or abrupt changes in motion from rough handling, transportation or field operation. Shocks of this type could disturb operating characteristics or cause damage similar to those resulting from excessive vibration, particularly if the shock pulses are repetitive. MIL-STD-883H, Method 2002 with acceleration peak 1500g has been widely adopted for testing the survivability of quartz crystal oscillators. Most commercially available quartz crystal oscillators have environmental qualification tests with acceleration levels of 100 g to 1500 g.

Figure 2 below shows the mechanical shock test setup. **Figure 3** shows the frequency variation of the CC2652RB compared to an external crystal solution. You can see that the maximum frequency deviation (measured with the device facing up and down for the CC2652RB MCU) is about 2 ppm, while the external crystal solution is about 7 ppm at 2,440 MHz.

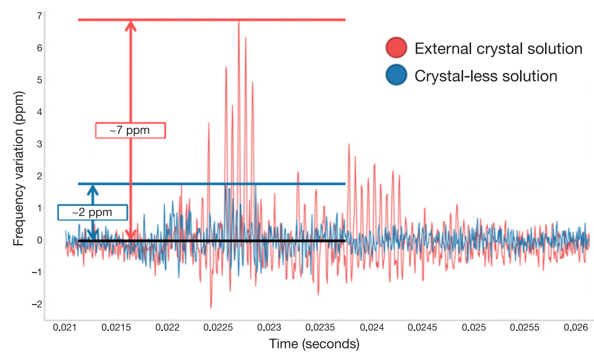

***Figure 3**. Comparing maximum radio (2,440 MHz) frequency deviation (parts per million) induced by mechanical shock on BAW and crystal devices.*

Sinusoidal vibrations

Military standard MIL-STD-202G Method 204D condition D tests sinusoidal vibration performance encountered in aircrafts, missiles and tanks. The

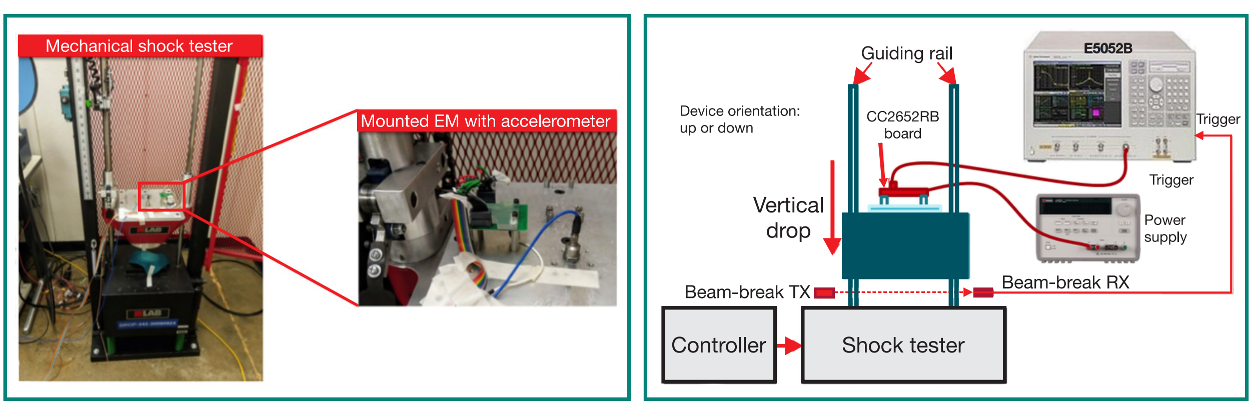

***Figure 2**. Mechanical shock test setup and test setup block diagram.*

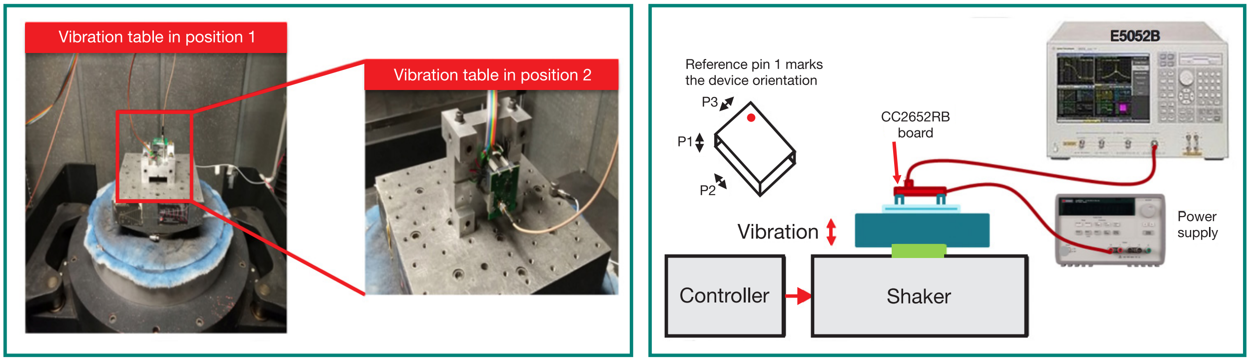

***Figure 4**. Sinusoidal vibration test setup and test setup block diagram.*

vibration frequency sweeps from 20 Hz up to 2,000 Hz and back down over a 20-minute period. Tests are repeated in three device orientations, shown with reference to pin 1 marked on the package shown in **Figure 4**.

To verify the vibration sensitivity to package and wire bonding, CC2652RB devices underwent twelve 20-minute sweeps in three mutually perpendicular directions, totaling 36 sweeps.

Figure 5 shows phase noise with 20-g sinusoidal vibration for the CC2652B MCU compared to the external crystal solution. You can see that the CC2652RB MCU performance is on par with the external crystal solution.

Bluetooth® Low Energy 5 link performance

One of the most critical performance metrics for any wireless device is to maintain a link between the transmitter and receiver so that no data is lost within any operating environment. TI performed *Bluetooth*® Low Energy 5, 1-Mbps link test on the CC2652RB MCU under MIL-STD-883H, Method 2026, condition E: random vibrations, with the maximum frequency extended to 4 kHz. **Figure 6** on the following page shows the packet error rate results with and without vibrations. There is no substantial change in receive packets, proving that the CC2652RB MCU has robust performance under vibration conditions.

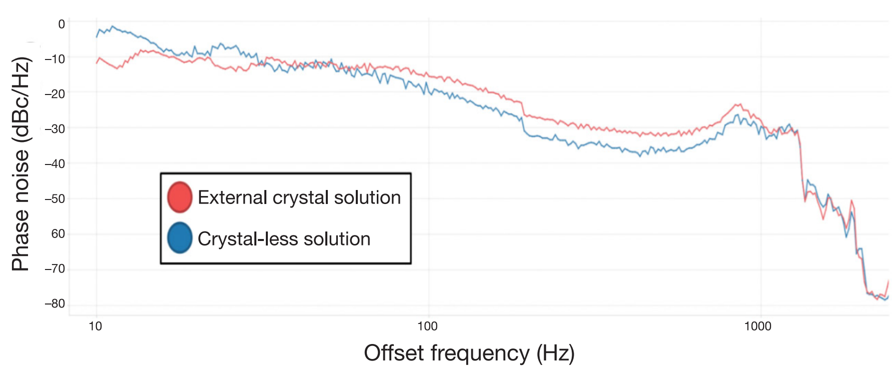

***Figure 5**. Maximum induced radio (2,440 MHz) phase noise from a 20-g sinusoidal vibration sweep.*

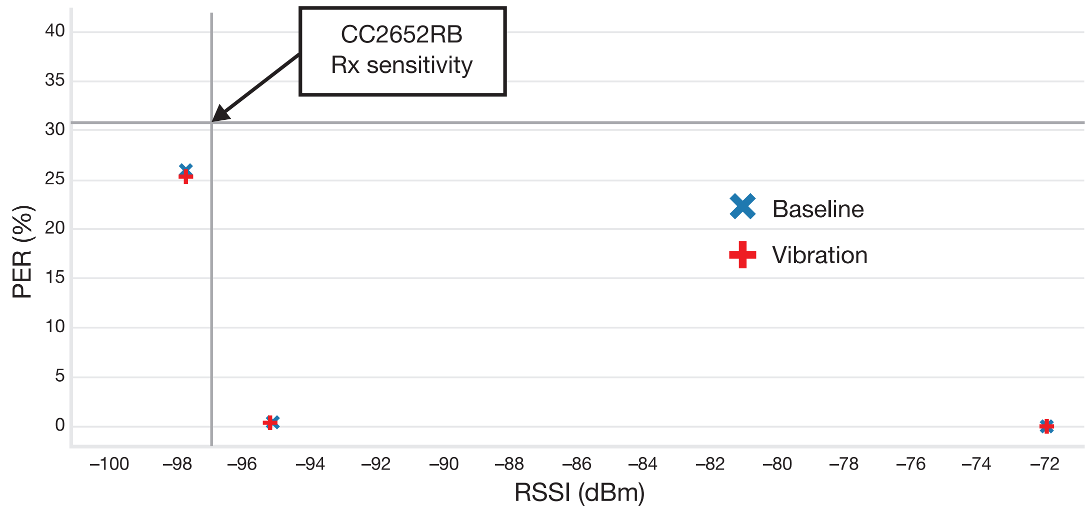

***Figure 6**. CC2652RB Bluetooth Low Energy 5 link performance under vibrations.*

Summary

TI's SimpleLink CC2652RB crystal-less wireless MCU with integrated TI BAW resonator technology provides significant performance benefits for IoT products operating under vibrating surroundings and can be leveraged in a wide variety of communications and industrial applications. The device offers an unprecedented level of integration and performance that's three times better than external crystal solutions under mechanical shock conditions.

Resources

- CC2652RB product folder, tool folder and data sheet
- "Getting started with CC2652RB for crystal-less BAW operation" application report
- SimpleLink CC13x2 and CC26x2 software development kit

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