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APPLICATION NOTE 5545

MEMS Technology Provides Tangible Benefits for Real-Time Clocks

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Abstract: This application note explores the benefits of MEMS (microelectromechanical systems) technology over standard crystal technology in accurate real-time clocks (RTCs).The most obvious advantage is size. Other areas where MEMS technology is superior—CMOS process and development, manufacturing and assembly, and environmental ruggedness—are also discussed.

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Introduction

MEMS (microelectromechanical systems) technology has been implemented in accurate real-time clocks (RTCs), making them extremely rugged, highly accurate over both time and temperature, and significantly smaller than clocks built using standard cylindrical crystal technology. This application note explores the significant performance enhancements that this new and exciting technology enables in accurate RTC applications.

Basic Benefits of MEMS Are Just the Beginning

With 47 times less area and 182 times less volume than that of a 32.768kHz tuning-fork cylindrical crystal (see **Figure 1**), the MEMs resonator technology used in Maxim Integrated's accurate RTC product family provides a significant advantage in size and packaging options for RTCs today.

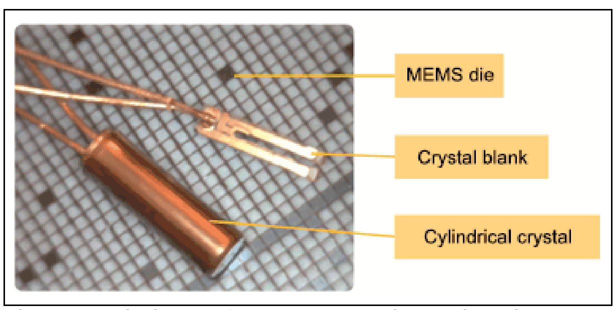


Figure 1. A single MEMS resonator occupies 47 times less area and 182 times less volume than a cylindrical crystal. This size differential allows for smaller packaging options, provides significantly enhanced ruggedness in high-vibration and shock environments, and demonstrates little to no aging (< ±1ppm total) over the life of the device.

However, the advantages that MEMS brings to this technology do not end with size. There are three distinct areas where MEMS characteristics deliver enhanced technical advantages. These areas include, but are not limited to, process and development, manufacturing and assembly, and environmental ruggedness.

MEMS in CMOS Process and Development

Let's quickly compare a MEMS process with a crystal assembly process.

The MEMS resonator technology discussed here was developed in standard complementary metal-oxide semiconductor (CMOS) fabs. CMOS fabrication is especially advantageous for meeting targeted frequency responses based on the shapes and sizes of device elements established at the photolithographic stage of development. Since MEMS is a silicon technology, the benefits of repeatability and sustainability apply to the manufacturing of MEMS wafers. The manufacturing temperatures reached while processing MEMS wafers can exceed +700°C. Subsequently, during processing, the MEMS resonator can be subjected to multiple reflow temperatures of +260°C *without* any degradation of performance. (We will talk about this in more detail below.) This durability can be attributed to its material makeup, design, and wafer processing flow.

In contrast (and well understood), crystal assembly is a less robust process and prone to sizeable variations in product-to-product output. Frequency tuning and trimming generally require the deposition or removal of material from the crystal electrode to achieve the desired frequency. Additionally, a vacuum must be established in the cylindrical carrier for the crystal resonator to vibrate once voltage is applied to the device. Consequently, to produce high-quality devices, special materials are required for attachment of the crystal to its leads. These materials help the crystal survive high-temperature (approximately 260°C) reflow operations. There is a caveat, nonetheless. Care must be taken when subjecting crystals to multiple high temperature reflow cycles. Frequency shifts can be attributed to aging of “crystal-attach” material, quality of the vacuum, and/or imperfections in the crystal blank.

MEMS in Manufacturing and Assembly

In the final manufacturing and assembly flow of an RTC, four important factors give the MEMS-based RTC its advantages over crystal counterparts.

First, MEMS is effectively an integrated circuit (IC). Therefore, when MEMS is combined with the control die/RTC, standard IC packaging technologies apply and can be used. This contrasts markedly with crystal assemblies, which require custom manufacturing flows to attach and affix the crystal and RTC die in the same package.

Secondly, wire-bonding operations are used to electrically connect the control die to the MEMS resonator. Crystal assemblies must use either a more complicated and less robust solder attachment or weld the crystal leads to connect the control die to the crystal resonator.

Third, highly efficient wire-bonding operations and standard packaging assembly flows lend themselves well to high-volume, less costly manufacturing and assembly operations.

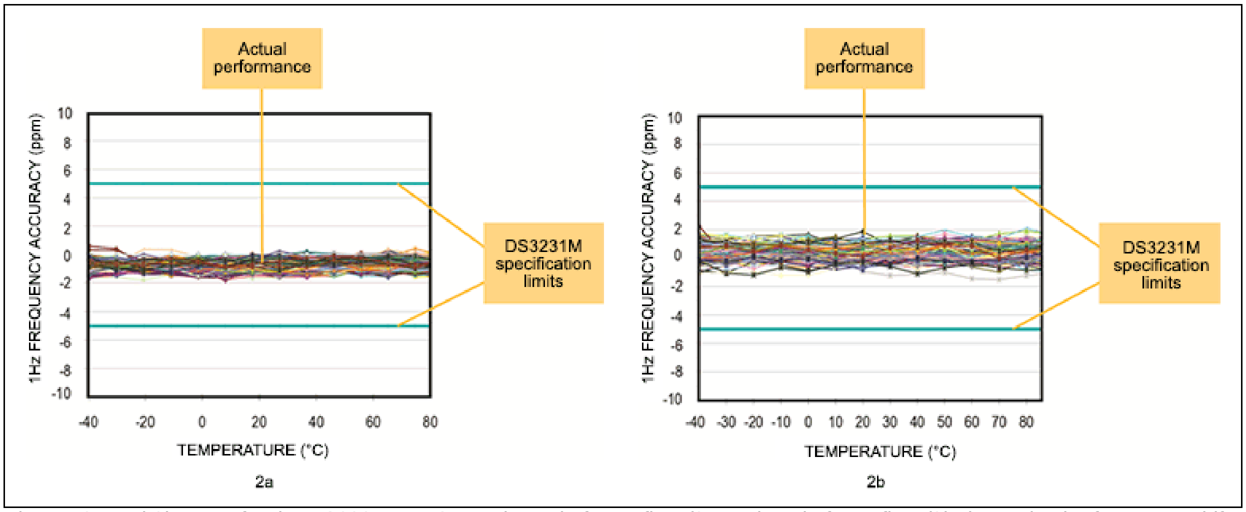
Fourth, the vast difference in size between MEMS and crystals offers smaller sized packaging options, including chip-scale assemblies that are not possible with crystals. Figure 1 demonstrates the vast size difference and resulting packaging requirements for the crystal. For comparable functionality and performance, the DS3231MZ+ RTC is assembled in an 8-pin 150-mil SO, while the previous generation crystal-based DS3231S RTC is packaged in a 16-pin 300-mil SO. The 8-pin SO package is less than half the size of the 16-pin 300-mil package.

Finally, and not to be missed, smaller packages lower cost.

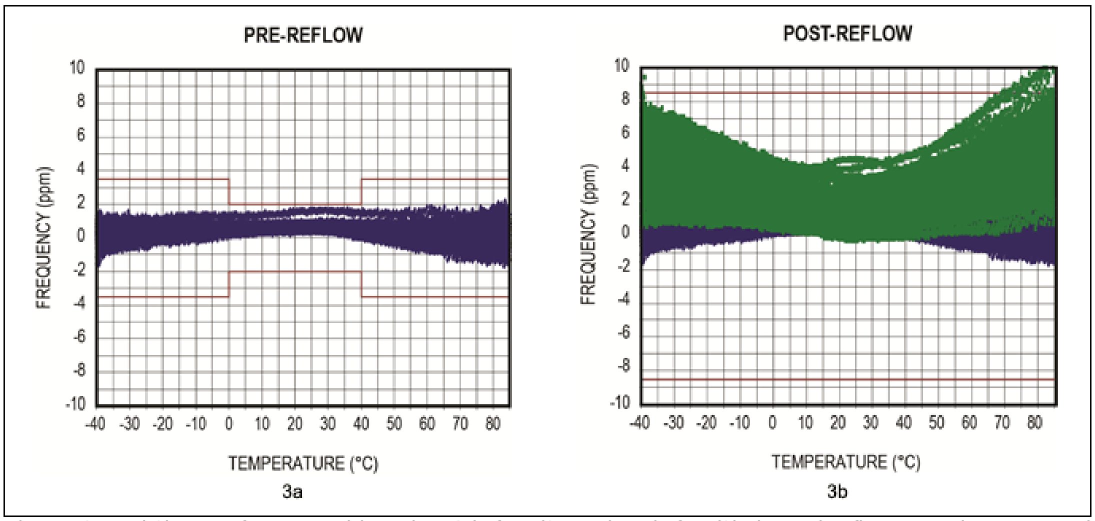
MEMS Is Environmentally Rugged

MEMS-based RTCs have proven and demonstrable performance advantages based on environmental criteria and observation.

In reflow operations (3x at +260°C) that replicate customer attachment, MEMS devices demonstrate frequency shifts of less than ±1ppm (**Figures 2a** and **2b**). Crystal-based products facing the same regiment of reflow temperature exposure demonstrate shifts as high as ±5ppm (**Figures 3a** and **3b**).



Figures 2a and 2b. Data for the DS3231M RTC are shown before reflow (2a, top) and after reflow (2b, bottom). The frequency shift is less than ±1ppm.



Figures 3a and 3b. Data for a crystal-based RTC before (3a, top) and after (3b, bottom) reflow. Data demonstrate shifts up to ±5ppm after reflow.

MEMS-based RTCs have been subjected to shock and vibration testing through the AEC-Q100 qualification. They can sustain mechanical shock in excess of 2900g (x5) (JESD22-B104C Condition-H) and variable frequency vibration in excess of 20g (JESD22-B103B Condition-1).

Summary

Performance data and processing experience prove that a MEMS-based RTC provides distinct advantages over a traditional crystal-based RTC. We spoke of the specific advantages in process and development, manufacturing and assembly, and environmental ruggedness. Additionally, frequency accuracy over time (lifetime) is less than ±5ppm with the MEMS clock. Frequency accuracy over temperature and *after* reflow is still less than ±5ppm. MEMS operate at higher temperatures. They come in smaller packaging and, finally, lower cost. It is most certainly hard to argue against designing with MEMS-based, accurate RTC products.

Related Parts		
DS3231M	±5ppm, I²C Real-Time Clock	Free Samples
DS3232M	±5ppm, I²C Real-Time Clock with SRAM	Free Samples

More Information

For Technical Support: http://www.maximintegrated.com/support
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