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Immunity of MEMS Oscillators to Mechanical Stresses

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ABSTRACT

MEMS oscillators have become very popular and have been steadily replacing crystal oscillators in many applications. MEMS oscillators offer some significant advantages against crystals, such as improved reliability and resistance to mechanical stress as well as flat stability performance over a wide temperature range. MEMS oscillators also offer flexibility in the way they can be programmed and configured for multi-output clock generation.

INTRODUCTION

Crystal-based oscillators have been used for decades whenever a given application has had a need for a stable and low-jitter clock source.

In recent years, a new technology has emerged that uses MEMS to build a resonator. MEMS oscillators offer some significant advantages over crystals. First, they are strong and reliable because they can withstand mechanical shocks, vibrations, flexing, and falling thanks to their encapsulated structure that creates a sort of natural protection for the resonator. Second, the MEMS resonator has a pseudo linear temperature coefficient that makes it easy to compensate for; this guarantees a stable clock frequency (meaning low ppm) over the entire temperature range up to +125°C and beyond.

It is easy to see how these two features make MEMS oscillators perfectly suitable for some harsh industrial, as well as automotive, applications.

Furthermore, the MEMS structure is compact and that enables the production of oscillators that can fit in tiny packages, as small as 1.6 mm x 1.2 mm.

The MEMS resonator works at a fixed and stable frequency that cannot be programmed. Therefore, a PLL is always required in order to generate a programmable output frequency. Even though this generally results in higher phase noise compared to crystal oscillators, the PLL offers the advantage of flexibility in terms of generating a wide range of frequencies, as well as the possibility of offering multi-output clocks in the same device. Many clocks can be generated from the same PLL or more than one PLL can be placed in the same device to generate completely independent outputs. MEMS oscillators are therefore flexible and programmable in many parameters. One further example of that is the possibility of programming the output driving strength which is related to the rise and fall time of the clock signal. Slower rise and fall times can be programmed for applications that are sensitive to EMI.

MEMS oscillators have become very popular and have been steadily replacing crystal oscillators in many applications in consumer, industrial, automotive, and partially in networking and telecom.

The following sections will focus more in detail about the MEMS oscillators' resistance against various types of mechanical stress.

RESISTANCE VS. FALL

Experiments have been conducted by placing the MEMS oscillators on a PCB with an additional weight of 200g and letting the system fall ten times from a height of 180 cm onto a concrete surface. In between each fall, the oscillator output clock was measured with a high resolution frequency counter for three minutes to check the clock stability over time. The results are presented in Figure 1 that shows the frequency deviation versus the initial frequency value that had been measured.

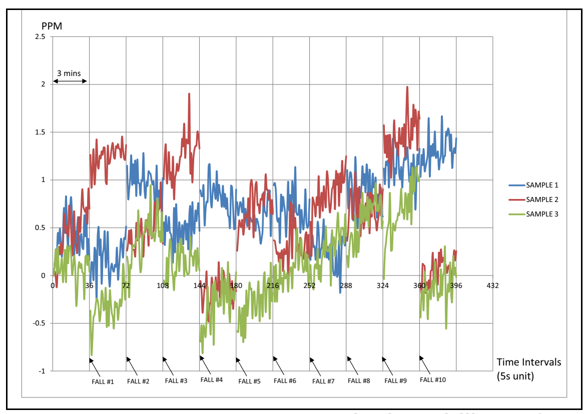

FIGURE 1: *Output Clock Stability Before and After Each of the 10 Falls Compared to the Initial Frequency Value.*

The MEMS oscillators output clock variation is less than 3 ppm maximum, which highlights how MEMS oscillators are robust and resilient to a mechanical shock such the one caused by a repeated fall on a hard surface like concrete.

RESISTANCE VS. MECHANICAL FLEXING

Further experiments have been conducted by placing the MEMS oscillator on a 5 cm x 5 cm PCB and anchoring one side of the PCB while bending the other side with a mechanical force. The MEMS oscillator is placed 1.5 cm from the side that gets bent. The PCB is flexed by 3 mm and 6 mm and the MEMS oscillator output clock is measured with a high resolution frequency counter for three minutes before, after, and during the time it is being flexed. The results are presented in Figure 2 and shows the stability versus the initial frequency value that has been measured.

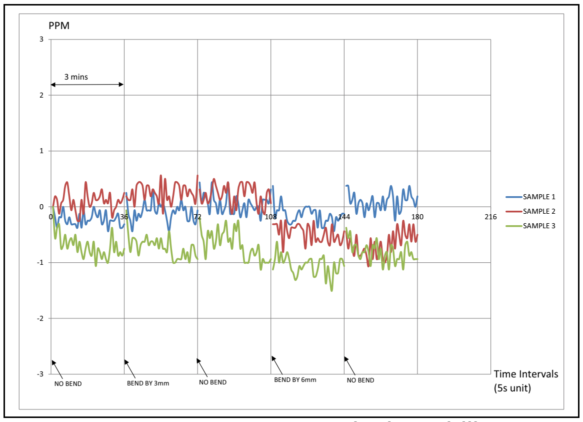

FIGURE 2: *Output Clock Stability Before, After, and During PCB Bending Compared to the Initial Frequency Value.*

The MEMS oscillators' output clock variation is less than 2 ppm maximum, which highlights how MEMS oscillators are robust and resilient to a mechanical stress such the one caused by a flexing of the PCB.

RESISTANCE VS. MECHANICAL SHOCK

MEMS oscillators have been tested for mechanical shocks by following the guidelines provided by the military and aerospace standard MIL-STD-883. The mechanical shock test follows the rules of Method 2002, test condition E: the device is subjected to five shock pulses up to 10,000g each for the duration of 0.2 ms.

The result is presented in Figure 3 where the frequency deviation in ppm is compared to the initial frequency value prior to the shock test. Assuming minimum and maximum are calculated over ±3 sigma (99.73%), it is noticeable that the maximum frequency variation is only 3.85 ppm.

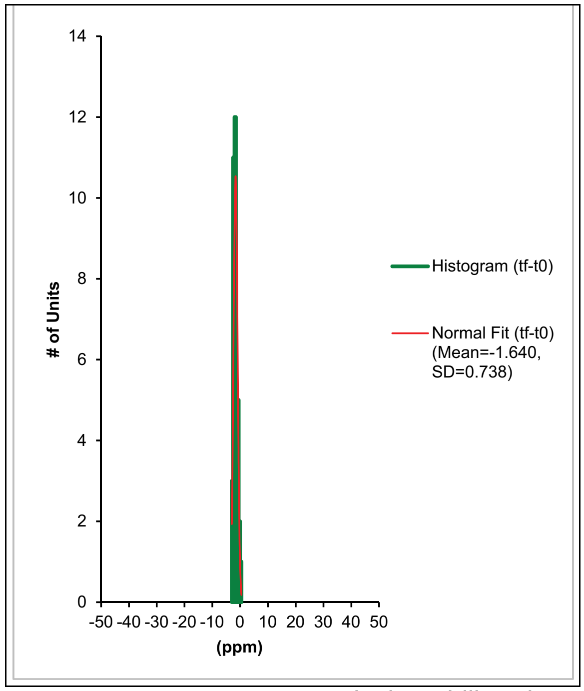

FIGURE 3: *Output Clock Stability Histogram After Mechanical Shock Test MIL-STD-883, Method 2002.*

RESISTANCE VS. MECHANICAL VIBRATION

MEMS oscillators have been tested for mechanical vibration by following the guidelines provided by the military and aerospace standard MIL-STD-883. The mechanical vibration test follows the rules of Method 2007, test condition C: the device is rigidly fastened on the vibration platform by keeping the connecting cables adequately secured. The device is vibrated with simple harmonic motion with a peak acceleration of 70g. The vibration frequency is varied logarithmically between 20 Hz and 2,000 Hz for the duration of four minutes. The test is repeated four times in each of the orientation X, Y, Z (total of 12 times) for a total time of 48 minutes.

The result is presented in Figure 4 where the frequency deviation in ppm is compared to the initial frequency value prior to the vibration test. Assuming minimum and maximum are calculated over ±3 sigma (99.73%), it is noticeable that the maximum frequency variation is only 5.23 ppm.

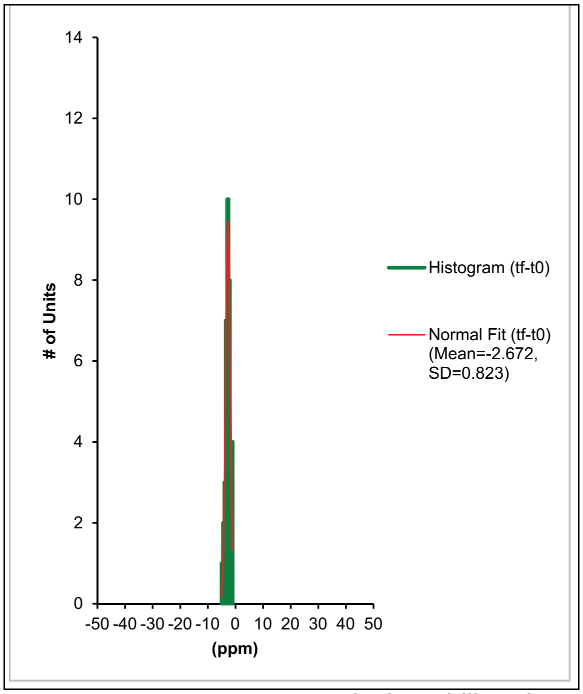

FIGURE 4: Output Clock Stability Histogram After Mechanical Vibration Test MIL-STD-883, Method 2007.

STABILITY BEFORE AND AFTER SHOCK AND VIBRATION

Figure 5 below shows the frequency stability for three samples before and after the mechanical shock and vibration tests described in the previous two sections and shown in Figure 3 and Figure 4.

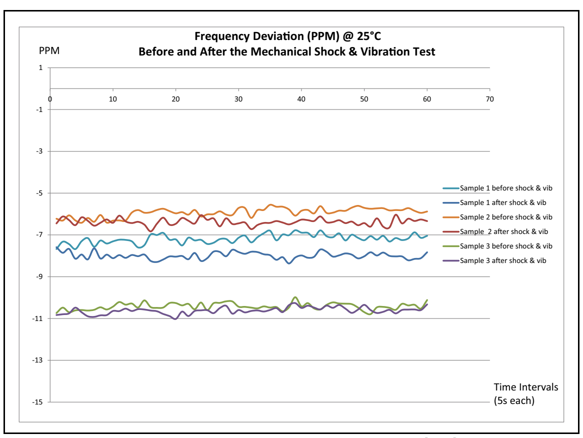

FIGURE 5: Frequency Deviation at 25°C Before and After Shock & Vibration Test.

The MEMS oscillators' output clock variation is within 1.5 ppm, which again highlights how much MEMS oscillators are robust to heavy mechanical stress such as the one created by the MIL-STD-883 shock and vibration tests.

CONCLUSION

MEMS oscillators are quite immune to mechanical stresses caused by falls, bending, shocks, or vibrations. This immunity enhances their reliability and makes them suitable for harsh environments such as the ones found in industrial and automotive applications. Due to this important property, as well as some other benefits like flat stability over a wide temperature range, flexibility, programmability, and small size, MEMS oscillators have become very popular and have been steadily replacing crystal oscillators in many applications in consumer, industrial, automotive, and telecom.

More information about Microchip MEMS oscillators can be found at: http://www.microchip.com/design-centers/clock-and-timing/oscillators.

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