Comparison of a Crystal Oscillator to a MEMS Oscillator

Crystal vs MEMS – Oscillator Performance

Abstract

The Selection of an oscillator for electronic devices and communications system equipment is a major factor affecting system performance.
In this application note, we have measured and will compare two different types of oscillators:

1. A fundamental Quartz Crystal oscillator and
2. A MEMS (Mirco-Electro-Mechanical System) oscillator

Structure and Characteristics of Oscillators

A Crystal oscillator consists of a basic structure using a Quartz crystal in fundamental mode and a simple oscillator circuit.

In contrast, MEMS oscillators have a complex structure consisting of a resonator, a fractional-N PLL, and temperature compensation and manufacturing calibration. A MEMS oscillator uses a silicon resonator as the oscillating source and requires a PLL circuit to correct the frequency for manufacturing tolerances and temperature coefficient.

Comparison of Properties of Crystal Oscillators and MEMS Oscillators

We measured a Crystal oscillator and a MEMS oscillator and compared four parameters from each that are considered critical for the design of communication, industrial, and consumer electronic devices.

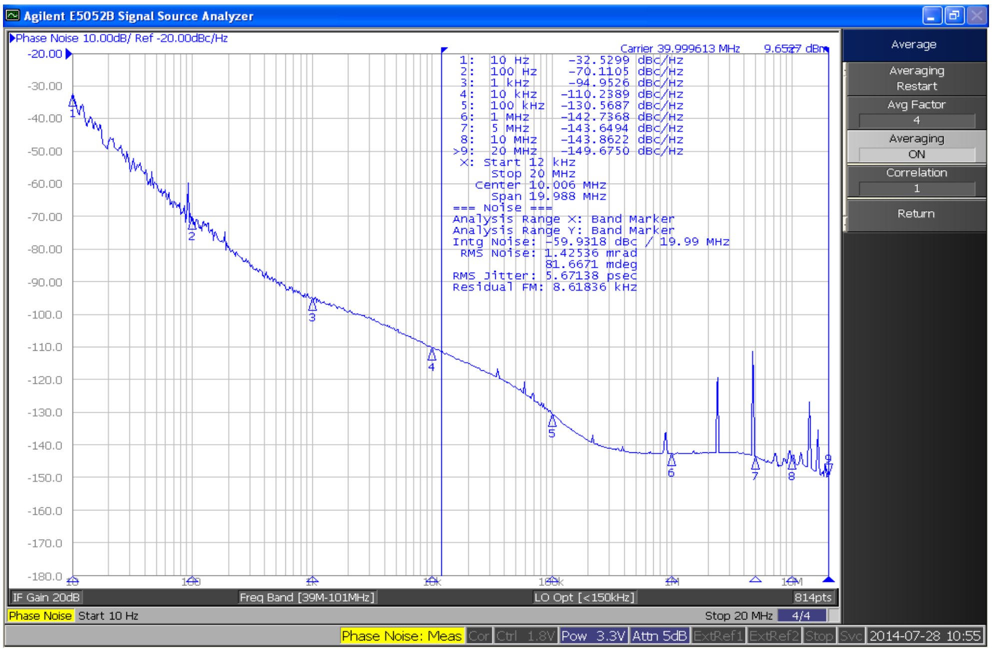
1. **Phase noise and phase jitter**
2. **Power consumption**
3. **Oscillator start up characteristics**
4. **Frequency temperature characteristics**

Comparison

1. Phase noise and phase jitter

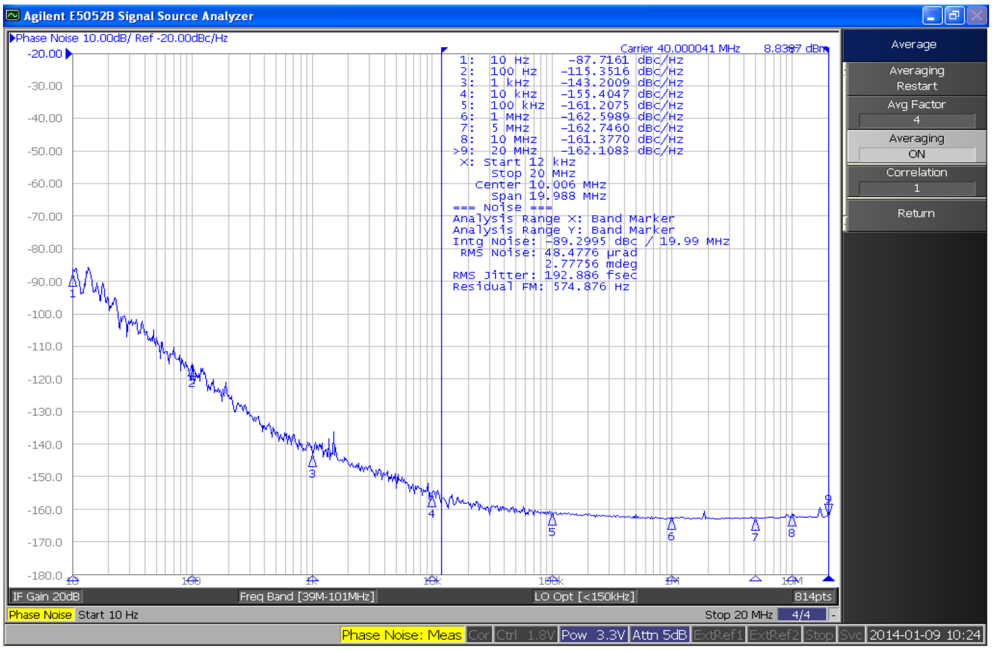
We considered three frequencies (40MHz, 100MHz and 156.25 MHz) and compared Crystal oscillators to MEMS oscillators of the same frequencies. The Laboratory measurements demonstrate that the phase noise is much better with the Crystal oscillator than the MEMS oscillator for all frequencies. The measured phase noise for both types of oscillators can be seen in illustration 1 – 6 below.

Test 1:



MEMS OSC 3225
40,0MhZ
3,3V
Phase Jitter:
5.67ps

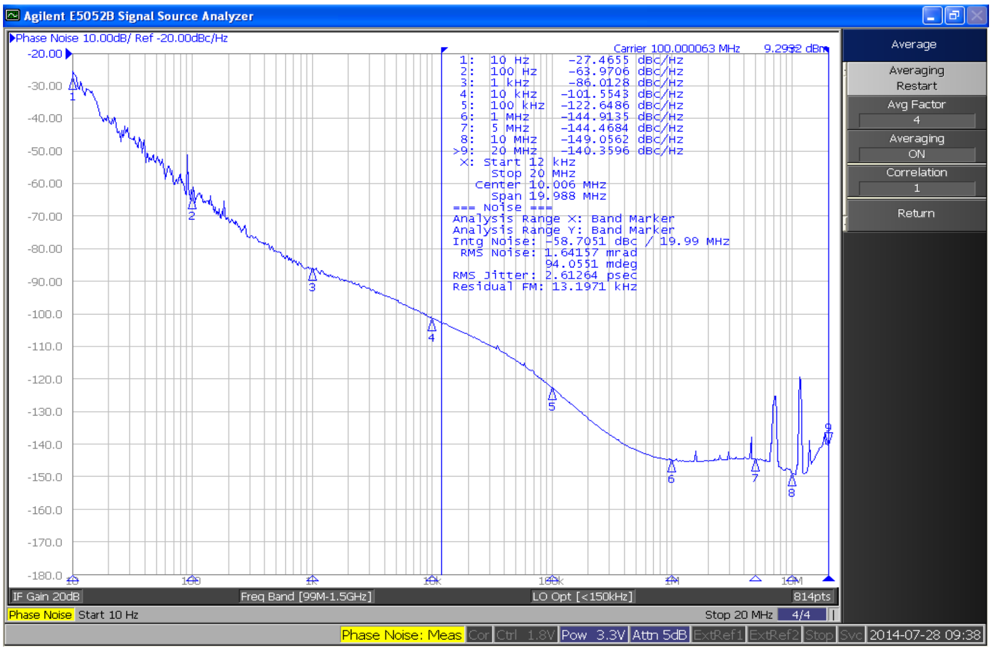
Illustration 1



Crystal OSC 3225
40,0MhZ
3,3V
Phase Jitter:
0.19ps

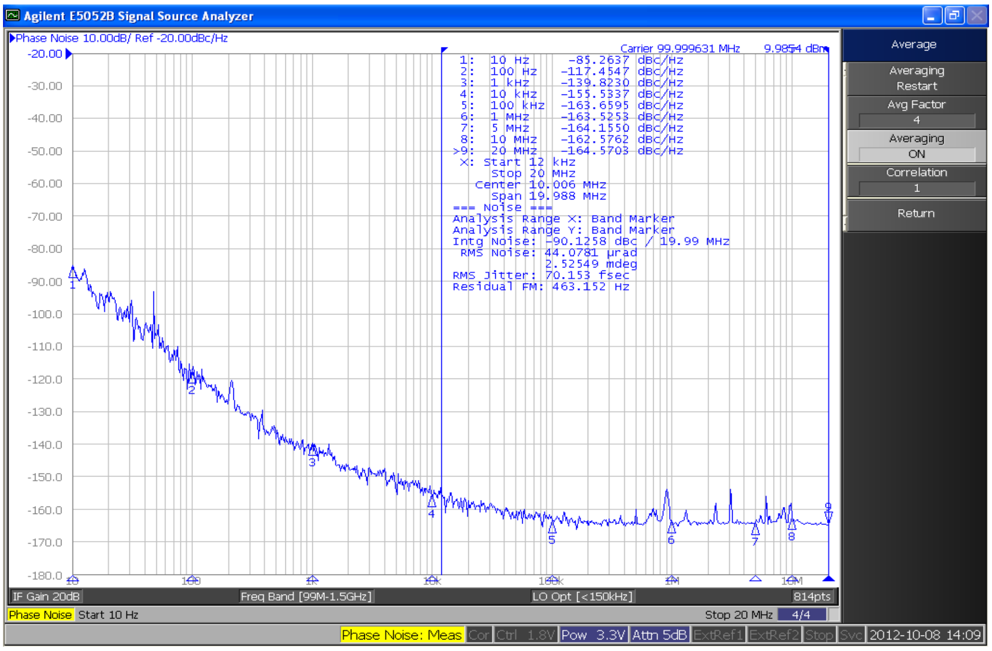
Illustration 2

Test 2:



MEMS OSC 7050
100,0MhZ
3,3V
Phase Jitter:
2.61ps

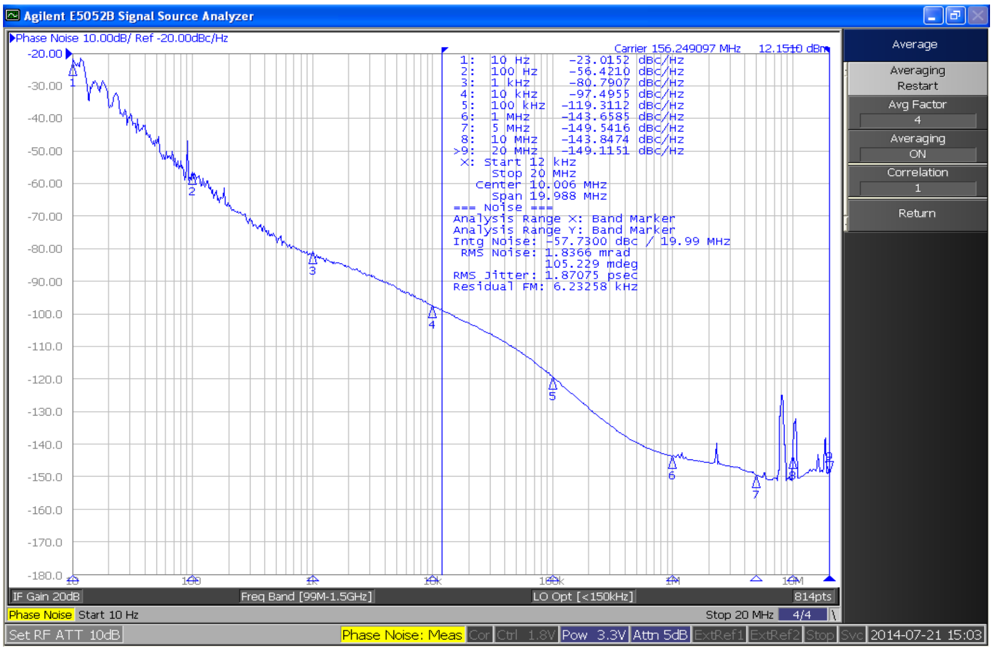
Illustration 3



Crystal OSC 7050
100,0MhZ
3,3V
Phase Jitter:
0.07ps

Illustration 4

Test 3:



MEMS OSC 7050

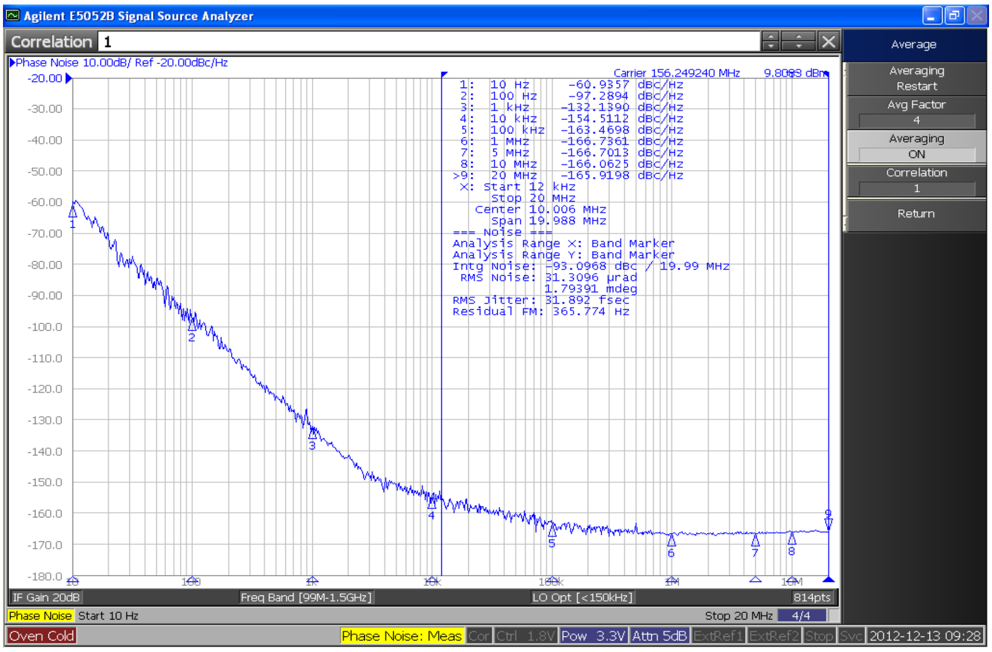
156,25MhZ

3,3V

Phase Jitter:

1.87ps

Illustration 5



Crystal OSC 7050

156,25MhZ

3,3V

Phase Jitter:

0.03ps

Illustration 6

Test result:

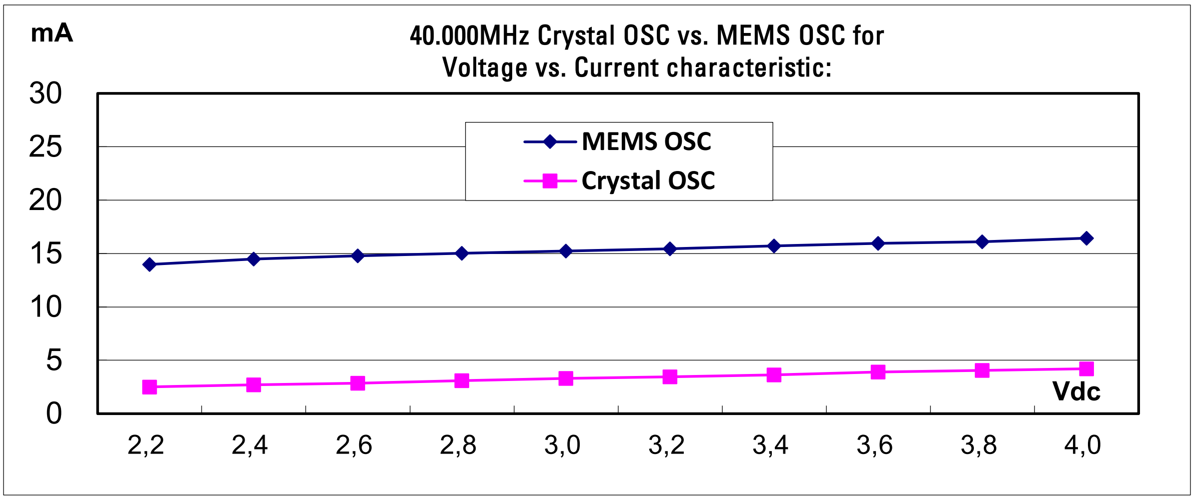
All three tested Crystal oscillators have better jitter than the three MEMS oscillators

MHz	Phase Jitter	
	MEMS Oscillator	Crystal Oscillator
40,0	5.67ps	0.19ps
100,0	2.61ps	0.07ps
156,25	1.87ps	0.03ps

2. Power consumption

The power consumption of a 40MHz Crystal oscillator and a 40MHz MEMS oscillator is shown in illustration 7 below.

Illustration 7



Vol\Num	MEMS OSC 40MHz	Crystal OSC 40MHz
2,2	13,98	2,51
2,4	14,48	2,71
2,6	14,79	2,85
2,8	15,03	3,08
3,0	15,24	3,30
3,2	15,45	3,45
3,4	15,73	3,64
3,6	15,96	3,89
3,8	16,09	4,05
4,0	16,44	4,21
		Unit : mA

The power consumption of the Crystal oscillators is much lower than that of the MEMS oscillator. This is because the Crystal oscillator benefits from a simple circuit structure and fundamental harmonic oscillation of the oscillating source.

Test results:

The increased circuitry of the MEMS oscillator raises the total power consumption of this device. The MEMS oscillator draws around 15mA of power, approximately 5x more than the Crystal oscillator, using increased current in the Silicon oscillator, PLL and LC VCO to reduce jitter.

3. Oscillator start up characteristics

Oscillator start up characteristics of a 40MHz Crystal oscillator and a 40MHz MEMS oscillator are shown in illustration 8 below.

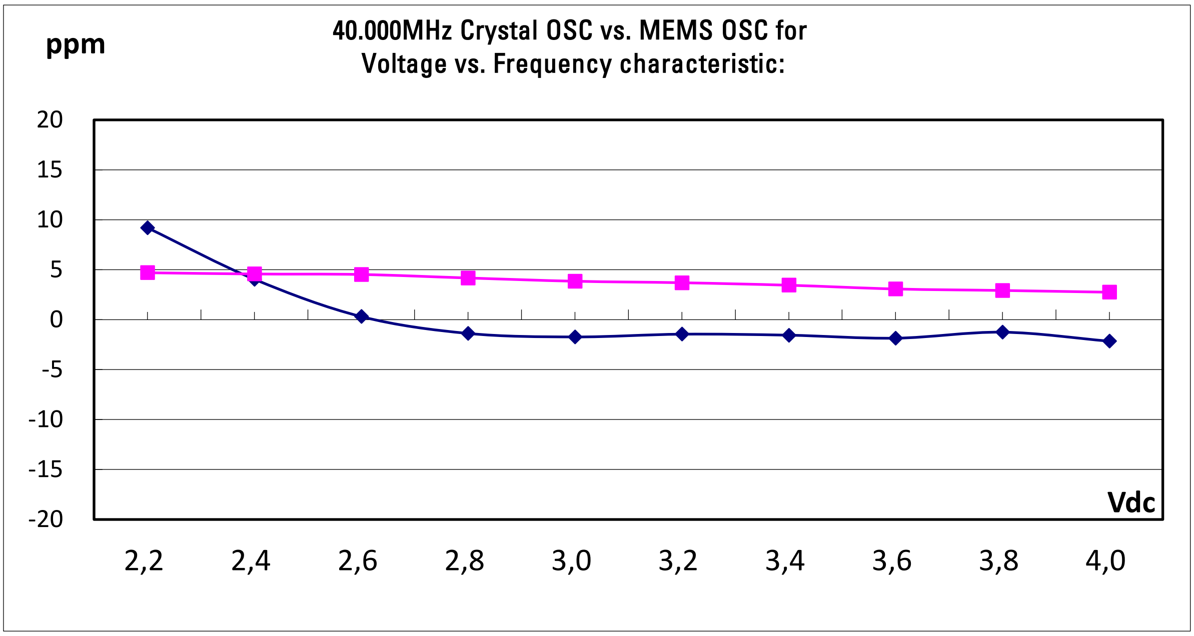


Illustration 8

Vol\ Num	MEMS OSC 40MHz	Crystal OSC 40MHz
2,2	40,000368	40,000188
2,4	40,000162	40,000183
2,6	40,000013	40,000181
2,8	39,999945	40,000167
3,0	39,999931	40,000154
3,2	39,999942	40,000148
3,4	39,999938	40,000138
3,6	39,999926	40,000123
3,8	39,999950	40,000117
4,0	39,999914	40,000110
		Unit : MHz

Vol\ Num	MEMS OSC 40MHz	Crystal OSC 40MHz
2,2	9,20	4,70
2,4	4,05	4,57
2,6	0,31	4,52
2,8	-1,38	4,17
3,0	-1,73	3,85
3,2	-1,45	3,70
3,4	-1,55	3,45
3,6	-1,85	3,08
3,8	-1,25	2,93
4,0	-2,15	2,75
		Unit : ppm

An oscillator with fast startup benefits from shorter wakeup cycles and longer battery life. This is important for consumer and home automation applications where the system is turned on and off quickly to save battery power.

Test results:
Crystal oscillators launch faster and are more constant than MEMS oscillators.

4. Frequency temperature characteristics

Frequency temperature characteristics of MEMS oscillators and Crystal oscillators with 40MHz frequency and 125MHz frequency were measured by first achieving a stable low temperature of -40°C, then increasing the temperature to +85°C at a rate of +2.0°C/ minute. The results are shown in illustration 9 – 12 below.

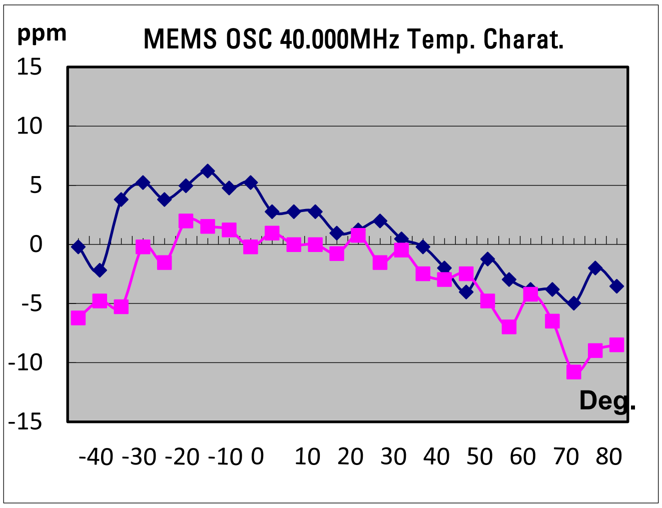


Illustration 9

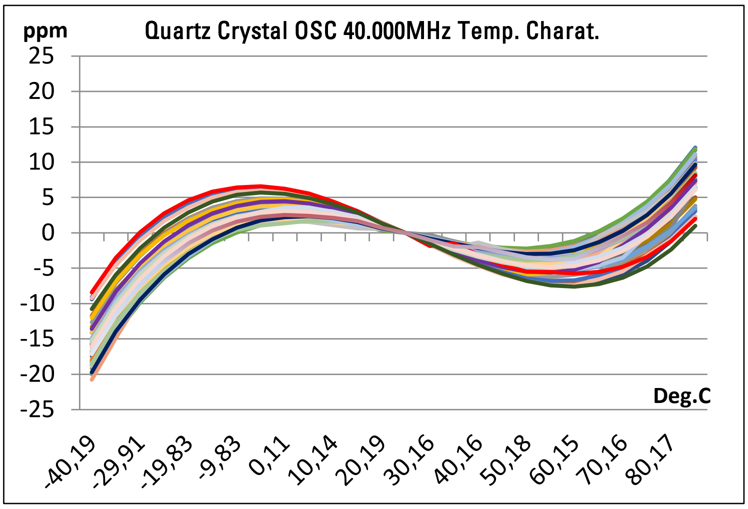


Illustration 10

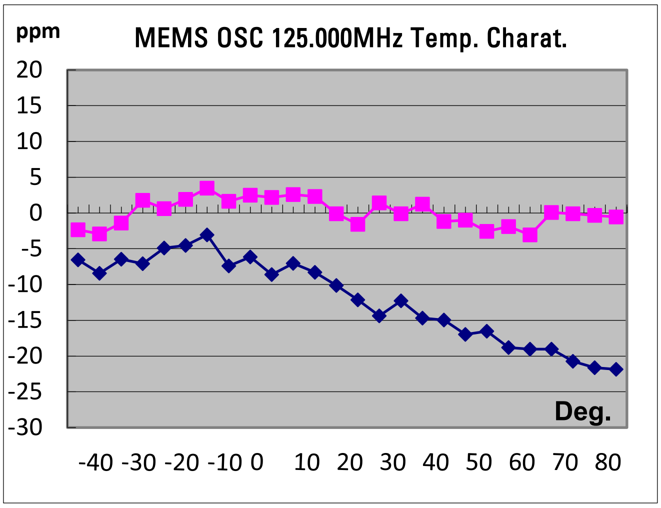


Illustration 11

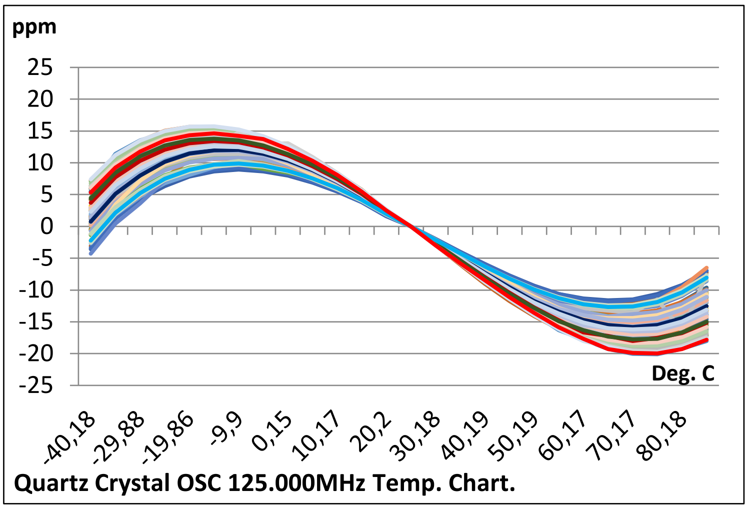


Illustration 12

The Frequency vs. Temperature of the Quartz Crystal oscillator follows the continuous cubic curve of an AT crystal, achieving ± 15ppm from -40 to +85°C. This is sufficient for most applications.

Initially the frequency vs. temperature characteristics of the MEMS oscillators appear to be better than those of the Crystal oscillator. However, the fractional –N PLL circuit of the MEMS oscillator adjusts the frequency in discrete steps to correct the very high (30ppm/ °C or 3750ppm from -40 to +85°C) temperature coefficient of the silicon resonator. This is illustrated by the jagged temperature curves of the MEMS oscillator graphs in illustrations 9 – 12 revealing frequency jumps when division ratio switches to compensate for the temperature changes.

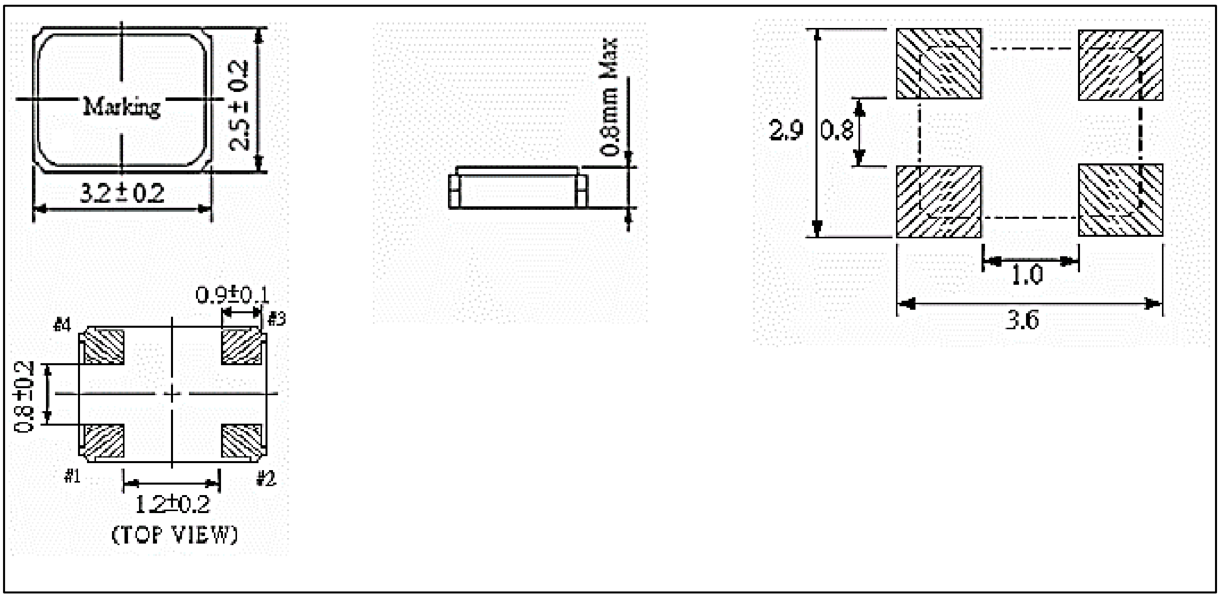
Temperature - Compensated Quartz crystal oscillators (TCXO) uses analog temperature compensation and a simple temperature compensation circuit and can achieve 1 ppm from -40 to +85°C without experiencing these frequency jumps. TCXOs are widely available at low cost and are available with temperature stability as low as ±0.1ppm.

Summary

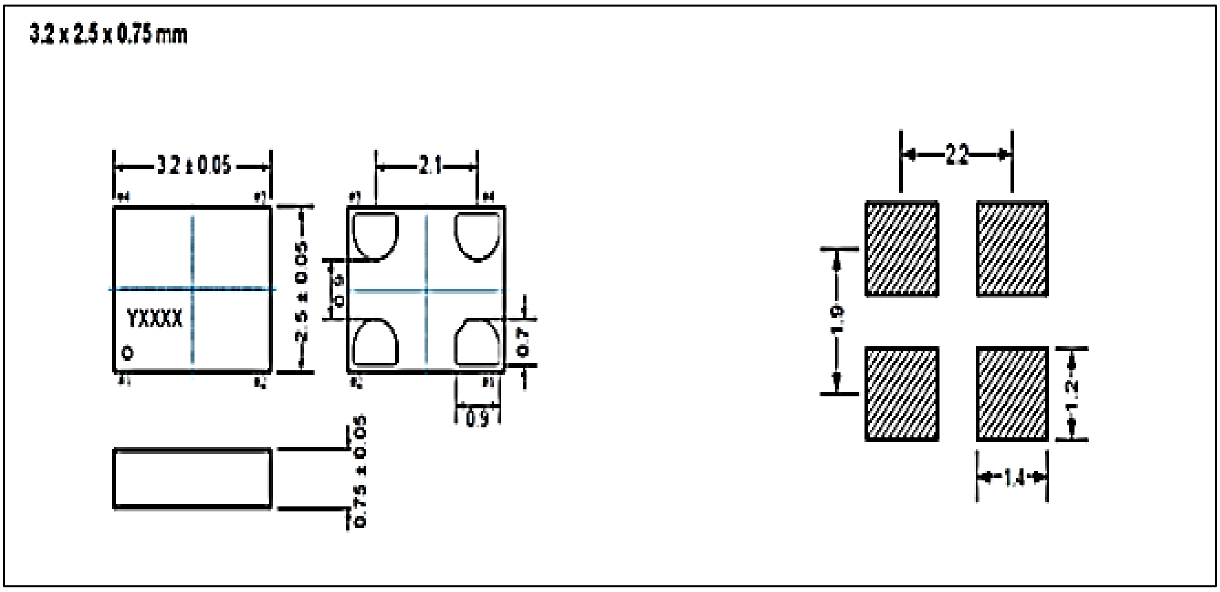
Crystal Oscillator vs. MEMS Oscillator			
		Crystal OSC	MEMS OSC
Electrical Characteristics	1. Started oscillating voltage	Started: @0.9Vdc	Started: @2.1Vdc
	2. Voltage vs. Frequency characteristics	Crystal OSC is better as MEMS OSC (pls, refer to "test data")	
	3. Voltage vs. Current characteristics	Crystal OSC is better as MEMS OSC (pls, refer to "test data")	
	4. Temperature	Crystal OSC is better as MEMS OSC (pls, refer to "test data"), that MEMS OSC is jagged in a short time	
	5. Jitter characteristics	40,0 MhZ: 0.19ps 100,0 MhZ: 0.07ps 156.25MhZ: 0.03ps	40,0MhZ: 5.67ps 100,0MhZ: 2.61ps 156.25MhZ: 1.87ps
	6. Phase noise	Crystal OSC is better as MEMS OSC (pls, refer to "test data")	
	7. Shield Effect	Crystal OSC is better as MEMS OSC (Crystal OSC have metal lid to do shield), Crystal OSC is hermetically sealed, as it has a ceramic housing, MEMS are not hermetically sealed	
	8. Reliability	MEMS OSC is better as Crystal OSC	
	9. ESD	MM: 400 Vdc HBM: over 4000 Vdc	n.A.
	10. Vibration	Freq. range: 10 ~ 2000Hz Peak to peak amplitude 1.5mm Peak value:20g`s Duration time of 3 orientations (X,Y,Z): 4hourse	n.A.
	11. Shock	5000g`s 0.3msec, 1/2 sinusoid 12 times for each direction (X,Y,Z)	Can withstand at least 50,000g shock
	12. High pressure test	100% been through 5Kg/cm² (5atm)/1.5hrs by Helium pressure and 4.5Kg/cm²/320mins (4.5atm) by Electronic test fluid pressure	n.A.
For availability		large selection available worldwide by many manufacturers	few manufacturers in the world (15% less in 2013)
Lead Time		7 – 30 days	more readily available
Temperature range		-40 - +125°C	-40 - +125°C
ROHS		yes	yes
Pin Layout		Pin and pin function can might compatible between Crystal OSC and MEMS OSC	

Pin compatibility between Crystal OSC and MEMS OSC

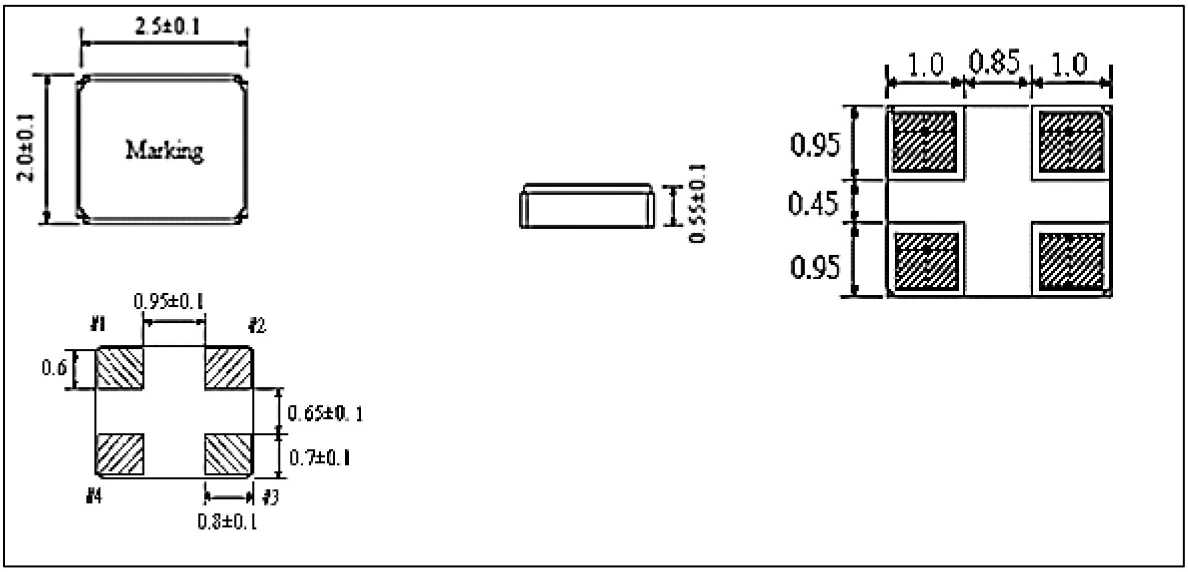
Crystal OSC (3.2 x 2.5mm) Drawing:



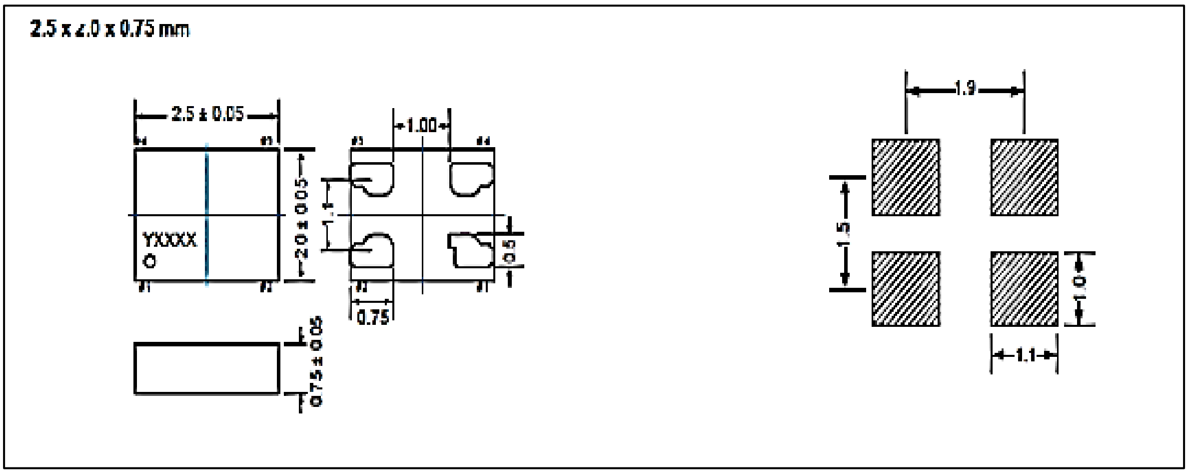
MEMS OSC (3.2 x 2.5mm) Drawing:



Crystal OSC (2.5 x 2.0mm) Drawing:



MEMS OSC (2.5 x 0.2mm) Drawing:



Conclusion

MEMS oscillators appear suited to high vibration environments, to non-critically timed applications, and to applications where the signal-to-noise ratios are not critical.
Applications that have complex modulation schemes, very high speed communication, or that require excellent signal-to-noise performance (i.e. A to D Converters) will continue to be clocked by crystal oscillators, taking advantage of the low jitter, the exceptionally high Q and excellent time and temperature stability of a quartz.

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