



# C3VA for Automotive Applications

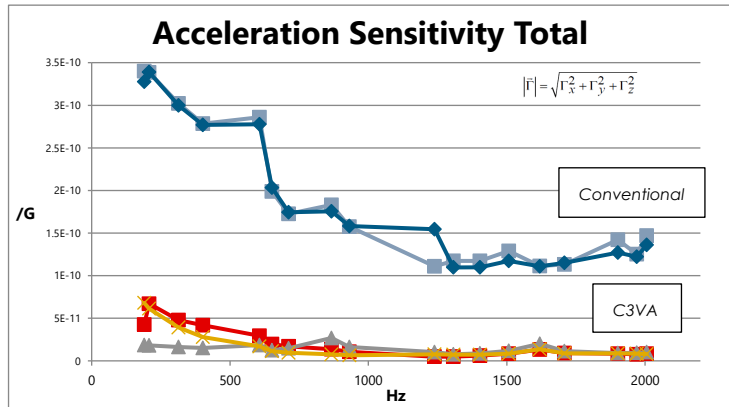
5570 Enterprise Parkway, Fort Myers, FL 33905 - www.Foxonline.com

White Paper - 9 June 2020

## Background

Rectangular shaped quartz crystals mounted in hermetic ceramic packages are currently the most widely used in timing sources or as a frequency source in the MHz frequency range in commercial electronic assemblies. AT cut quartz crystals are used due to favorable frequency accuracy over a wide temperature range. Conventional rectangular quartz crystal resonators in ceramic packages have been used as a frequency source in modern systems for the last 3 decades.

The dynamic performance of a quartz crystal resonator will degrade under adverse environmental conditions such as G forces (acceleration) or vibration. The most popular rectangular, ceramic packaged, quartz resonators have one axis (X, Y, Z) that performs up to 10 times worse for acceleration/vibration performance than the other two axes.



Fox Electronics has introduced the C3VA to improve Customer system performance when exposed to modern world environmental conditions. The state-of-the-art resonator incorporates patented technology that allows the FOX C3VA Product Series to hold system performance nearly uniform on all axes.

## Low G Sensitivity Crystal

Automotive applications could benefit from a vibration resistant crystal. The improvement under discussion is not about survivability, that is already satisfactory. The C3VA is equal to the conventional devices for these conditions. Instead, it is about dynamic performance under vibration, specifically phase noise.

The modern automobile and the autonomous vehicles being developed have numerous examples of communication systems, from In-Vehicle Networking to Driver Assistance Transceivers, CAN Transceivers, Radar Transceivers, DSRC Safety Modems and 802.11p V2X (vehicle to everything), LTE-V2X, and 5G V2X, all have performance that is impacted by phase noise. An



improvement in phase noise can mean less distortion, higher reliability, better overall system level performance. Even automotive microprocessors and microcontrollers can see some benefit when vibration induced phase noise falls in band for jitter performance.

The familiar AT cut quartz crystal is most typically designed to operate as a bulk acoustic wave resonator (BAW). Acoustics are the coupling mechanism that can make them sensitive to environmental vibration. The path for the mechanical coupling is through the solder joints into the package and into the crystal mounting structure. The external vibration energy mixes with the piezoelectric vibration energy and is upconverted to the crystals operating frequency.

If the external vibration energy is a single tone, a single sine wave at a given frequency, and this couples to a quartz crystal that is in an oscillator circuit, the phase noise of the oscillator will include a spurious response at an offset frequency (sidebands) equal to the external vibration frequency. The magnitude of the spurious response is related to the crystals' acceleration sensitivity by the following equation:

$$\Gamma_i = \frac{2 * f_v}{a_i * f_o} * 10^{\frac{\mathcal{L}(f_v)}{20}}$$

---

*Instead, it is about dynamic performance under vibration, specifically phase noise.*

---

Where:

**r** = acceleration sensitivity in direction i, (i = x, y or z) in ppb/G (or smaller).

**f<sub>v</sub>** = vibration frequency (sinusoidal) in Hertz.

**a<sub>i</sub>** = acceleration magnitude in G, (G = 9.8 meters/sec<sup>2</sup>)

**f<sub>o</sub>** = oscillator (crystal) frequency in Hertz (ex. 40e6 Hz)

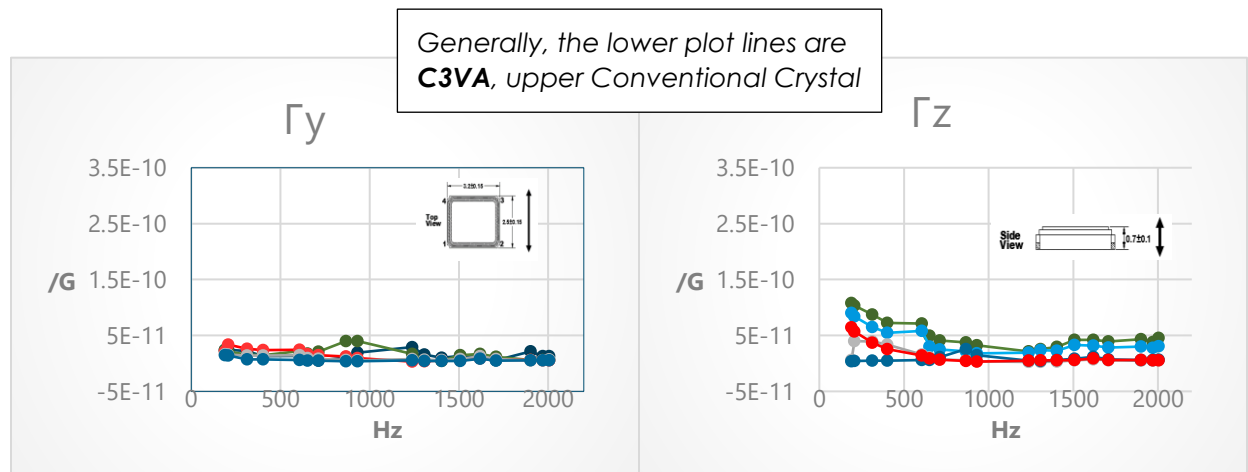
**ℒ(f<sub>v</sub>)** = phase noise magnitude of spur in dBc/Hz.

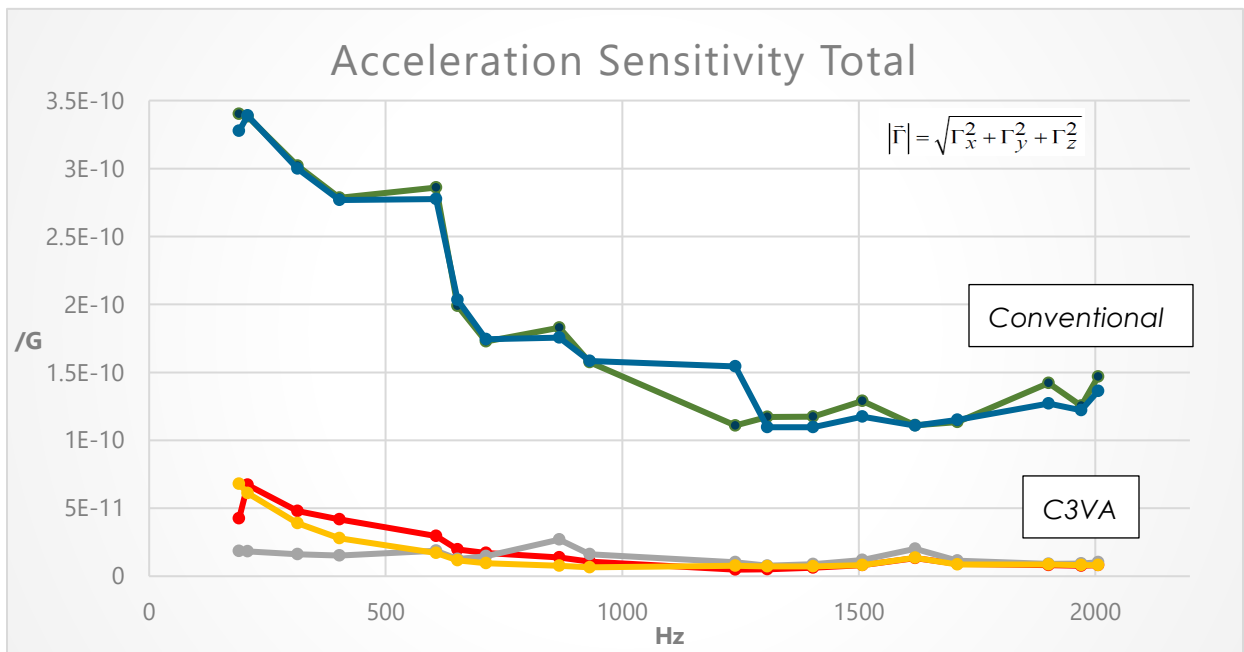
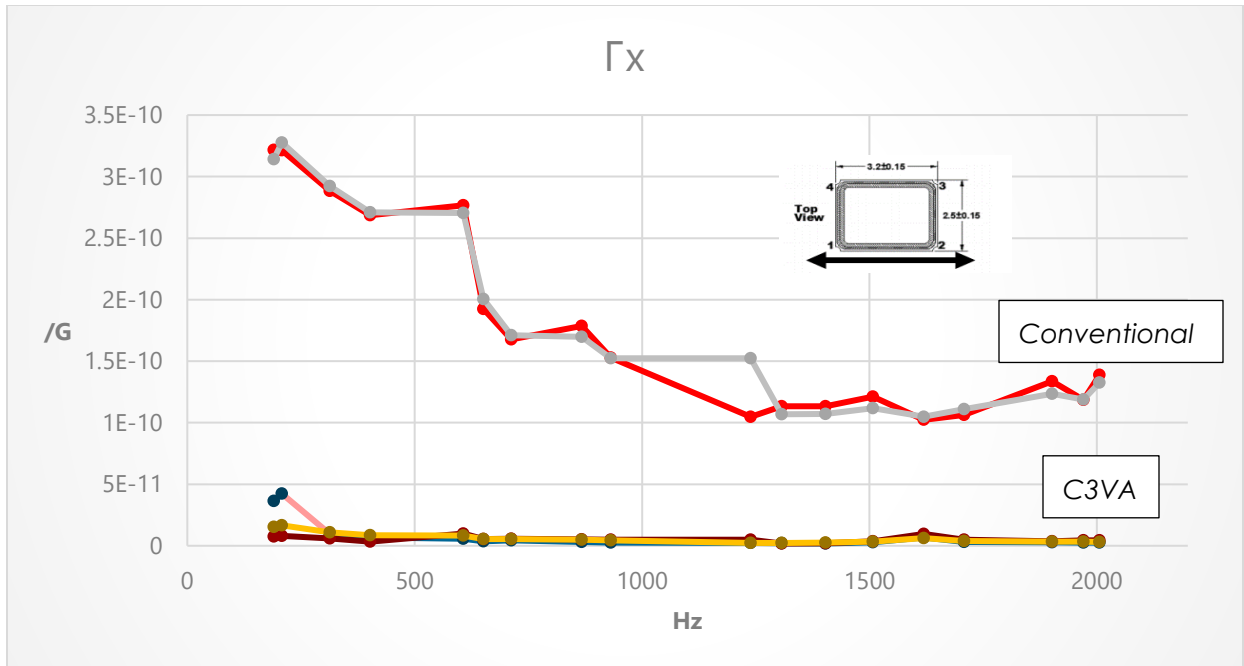
If the vibration energy is characterized as a profile, as in the case of random vibration testing, it has an analog (by way of Fourier) to a series of sine waves each at different frequencies each causing a separate spur and the envelope of the spur peaks becomes the measure of actual performance. Either method results in the same numerical value in ppb/G.

It is not unusual to see an oscillator at rest, (no external vibration), outperform one under vibration by 30dB at 1G. The acceleration sensitivity is linear from zero to about 50G's. It is possible to see the spurs become larger than the carrier (crystal oscillation frequency) at high acceleration. For systems that use phase lock loops, even temporary loss of the reference lock is a reliability concern. For systems that use phase lock loops and other frequency multiplication methods, the noise at the upconverted frequency has the additive term of  $20 \log(M)$  where M is the multiplication factor. This includes any vibration induced spur from a single tone or vibration induced envelope from a random profile of tones.

## Acceleration Sensitivity Comparison

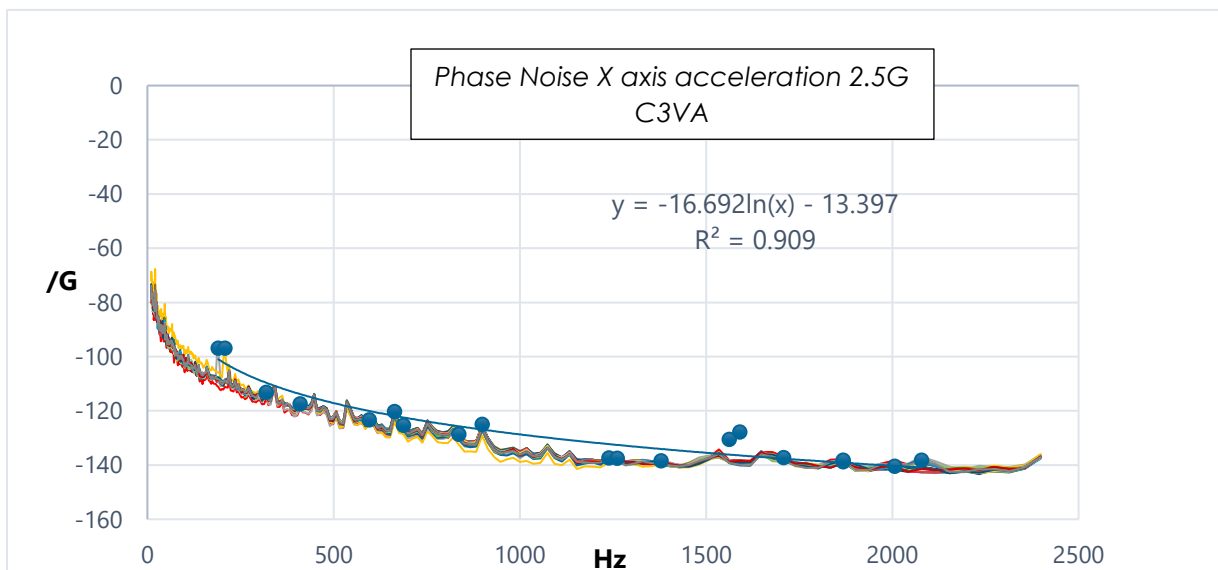
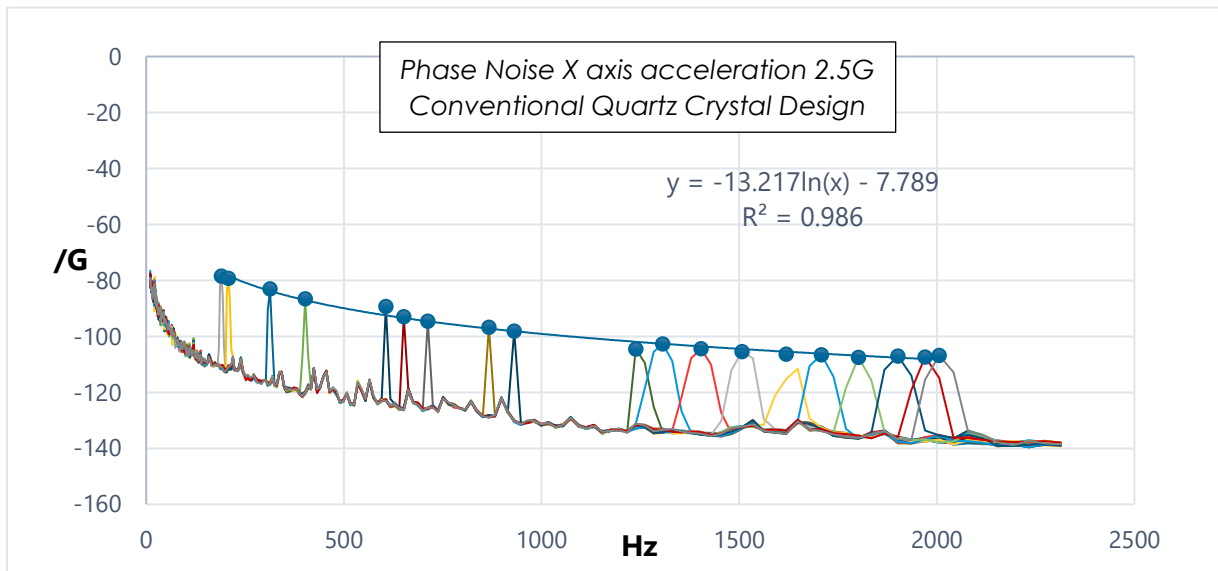
Below shows the Acceleration test results, comparing a conventional crystal to the C3VA. As you can see in the Y and Z Axes there is minimal improvement but in the X Axis there is significant improvement when going from the conventional crystal to the C3VA, which translates to a substantial difference when looking at total acceleration sensitivity.





# Phase Noise Comparison

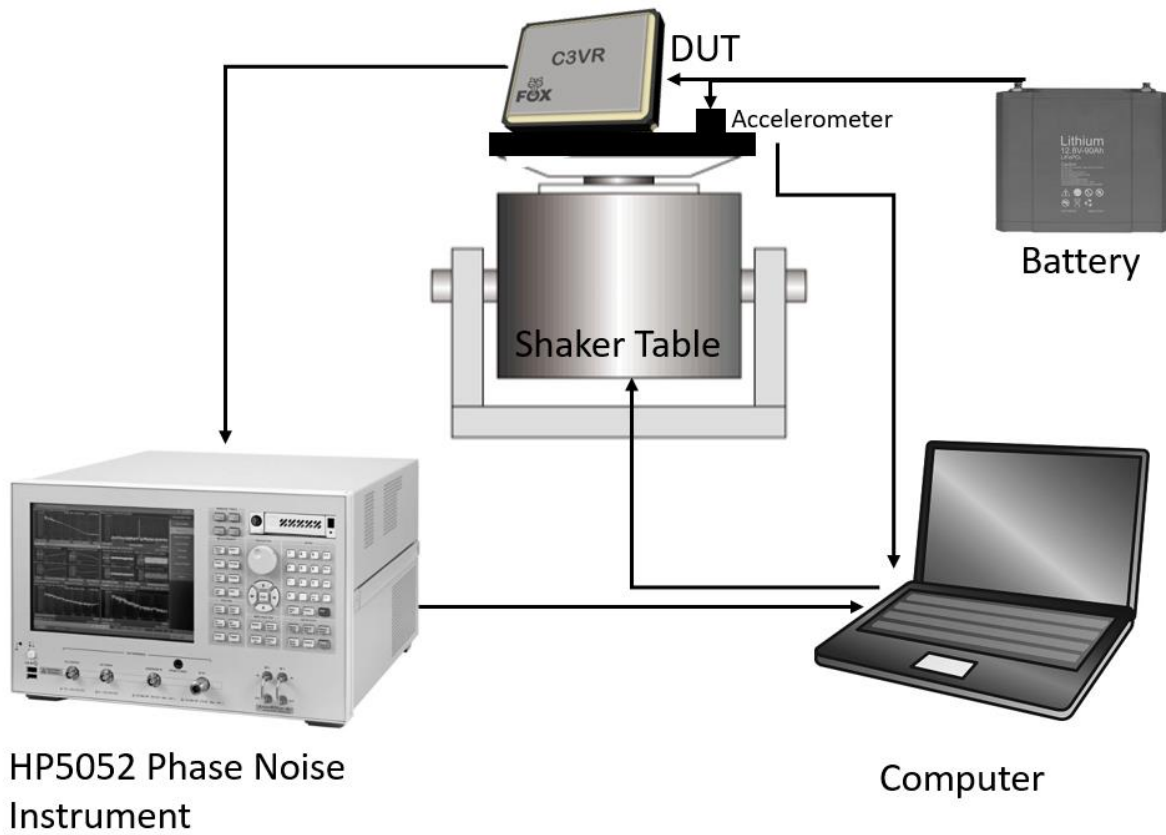
When looking at this in terms of phase noise you can see from the conventional crystal phase noise plot under acceleration spikes are created, effectively 30dB higher than what the spec sheet and phase noise plots at rest show you. With the C3VA these spikes are significantly reduced, so you have minimal phase noise difference whether at rest or under acceleration. Additionally, some of the low frequency degradation seen on the C3VA is due to the increasing contribution from wires and cables used in the test setup.



# DUT Test Setup

---

Below is an illustration of the Fox Electronics vibration test set up used in the creation of the charts above.



# Popular Frequencies and Applications

While the below list shows the most requested frequencies and specs, this is in no way the only frequencies and specs available. Many more have been developed, in addition we can do custom variations to meet your requirements.

Part Number	Frequency	Package Size	Tolerance	Stability	Temperature Range	Load Capacitance	Application
FC3VAEEDM38.4	38.4MHz	3.2x2.5mm	+/-20 PPM	+/-20 PPM	-40C to +85C	8pF	IoT, DECT, WiFi, Blue Tooth
FC3VAEEEM38.4	38.4MHz	3.2x2.5mm	+/-20 PPM	+/-20 PPM	-40C to +85C	10pF	IoT, DECT, WiFi, Blue Tooth, Silicon Labs WF200 series Transceiver, BLE, Silabs Wireless Gecko SoC
FC3VAEEGM38.4	38.4 MHz	3.2x2.5mm	+/-20 PPM	+/-20 PPM	-40C to +85C	12pF	IoT, DECT, WiFi, Blue Tooth
FC3VAEEDM40.0	40 MHz	3.2x2.5mm	+/-20 PPM	+/-20 PPM	-40C to +85C	8pF	Automotive Vison Systems, NXP S32V234, 802.11p, V2X RF Transceiver, WAVE, DRSC, IoT, Qualcomm QCA4020, WiFi, Bluetooth, BLE, NFC, Simplelink, Zigbee
FC3VAEEGM40.0	40.0 MHz	3.2x2.5mm	+/-20 PPM	+/-20 PPM	-40C to +85C	12pF	802.11p WiFi, Bluetooth, BLE, NFC, Simplelink, V2X RF Transceiver, WAVE, DRSC, IoT, Qualcomm QCA4020, Zigbee
FC3VAEEDM48.0	48.0 MHz	3.2x2.5mm	+/-20 PPM	+/-20 PPM	-40C to +85C	8pF	WiFi, Bluetooth
FC3VAEEGM50.0	50.0 MHz	3.2x2.5mm	+/-20 PPM	+/-20 PPM	-40C to +85C	12pF	Ethernet, PLLs, Frequency Generators, Microcontrollers, Processors

## Conclusion

The dynamic performance of a quartz crystal resonator will degrade under adverse environmental conditions such as G forces (acceleration) and vibration. Phase noise of existing frequency control devices may meet your requirements while at rest, in real world applications that are in motion or impacted by environmental and outside forces, the C3VA really is the ideal solution. The C3VA is sampling now and is AEC-Q200 qualified and manufactured under TS16949 to meet the Automotive quality and reliability standards.