June 2011

NASA Electronic Parts and Packaging Program

Operation of a new COTS Crystal Oscillator - CXOMHT over a Wide Temperature Range

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Background

Crystal oscillators are extensively used in electronic circuits to provide timing or clocking signals in data acquisition, communications links, and control systems, to name a few. They are affordable, small in size, and reliable. Because of the inherent characteristics of the crystal, the oscillator usually exhibits extreme accuracy in its output frequency within the intrinsic crystal stability. Stability of the frequency could be affected under varying load levels or other operational conditions. Temperature is one of those important factors that influence the frequency stability of an oscillator; as it does to the functionality of other electronic components.

Electronics designed for use in NASA deep space and planetary exploration missions are expected to be exposed to extreme temperatures and thermal cycling over a wide range. Thus, it is important to design and develop circuits that are able to operate efficiently and reliably under in these harsh temperature environments. Most of the commercial-off-the-shelf (COTS) devices are very limited in terms of their specified operational temperature while very few custom-made commercial and military-grade parts have the ability to operate in a slightly wider range of temperature than those of the COTS parts. These parts are usually designed for operation under one temperature extreme, i.e. hot or cold, and do not address the wide swing in the operational temperature, which is typical of the space environment. For safe and successful space missions, electronic systems must therefore be designed not only to withstand the extreme temperature exposure but also to operate efficiently and reliably. This report presents the results obtained on the evaluation of a new COTS crystal oscillator under extreme temperatures.

Test Procedure

The device selected for evaluation comprised of an 8 MHz, CXOMHT-series crystal oscillator. This type of device was recently introduced by Statek Corporation and is designed as high temperature/high shock oscillator [1]. These parts are designed to operate under high temperatures up to 200 °C providing a frequency stability of 200 ppm between 25 °C and 200 °C. They have fast start-up, are CMOS and TTL compatible, and come in hermetically sealed ceramic package [1]. The 4-pin device includes an optional output enable/disable feature, and it consumes little power. Table I shows some of the manufacturer's specifications for this device [1].

Table I. Manufacturer's specifications of CXOMHT crystal oscillator [1].

Parameter	
Operating voltage (V)	3.3 to 5.0
Frequency (MHz)	8
Input current (mA)	3
Operating temperature (°C)	-55 to +200
Duty cycle (%)	40 to 60
Frequency tolerance (ppm)	±50
Output rise/fall time, max (ns)	6
Pb-free hermetically-sealed ceramic Package	4-pin 6.5 mm x 5.0 mm
Part #	CXOMHT4E-8.0M200H
Lot number	0010-RFR-14715

Operation stability of this crystal oscillator was investigated under exposure to extreme temperatures. Performance characterization was obtained in terms of the oscillator's output frequency, duty cycle, rise and fall times, and supply current at specific test temperatures. Re-start capability at extreme temperatures, i.e. power switched on while the device was soaking at extreme (hot or cold) temperature, was also examined. The effects of thermal cycling under a wide temperature range on the operation of the crystal oscillator were also investigated. The oscillator was subjected to a total of 12 cycles in the temperature range of -190 °C to +200 °C at a temperature rate of 10 °C/minute and a soak time of 20 minutes at the temperature extremes. Figure 1 shows the test circuit board populated with the CXOMHT oscillator along with three filter capacitors.

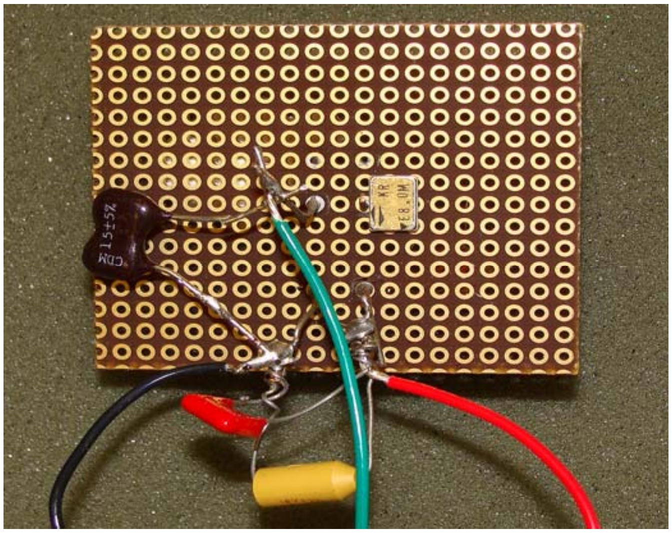


Figure 1. Oscillator chip and capacitors mounted on circuit board.

Test Results

Temperature Effects

The output frequency of the CXOMHT crystal oscillator as a function of temperature is shown in Figure 2. The oscillator operated successfully throughout the entire test temperature range with very slight variation in its output frequency that was confined to two regions within the temperature regime. First, the frequency of the oscillator exhibited a decrease between +50 °C and +175 °C but recovered as temperature was raised further, as depicted in Figure 2. The other trend observed consisted of a gradual decrease in frequency as test temperature was lowered below -100 °C. In the latter case, the frequency decreased to about 7.9985 MHz from its nominal room temperature of 8.0 MHz. This reduction in frequency was infinitesimal as it amounted to only 0.019%. In the low temperature region, the gradual decrease exhibited by the frequency which began to occur at -120 °C was also very slight as it reached a value of 7.9950 at the extreme cryogenic temperature of -190 °C; a mere 0.063% change. Given the fact that these changes were very negligible, it is very reasonable then to conclude that this CXOMHT oscillator displayed excellent stability in its output frequency throughout the entire test temperature range from -190 °C to +200°C. It should be pointed out that the crystal oscillator was allowed to soak for at least one hour at the extreme high and low test temperatures in the environmental chamber prior to recording the data. At the other intermediate temperatures, the soak time was 30 minutes. This was done in order to ensure thermal stabilization of the device under test and to account for any thermally-induced stresses emanating for expansion/contraction of contacts, solder joints, and interfaces. A typical waveform of the frequency output at 23 °C is shown in Figure 3.

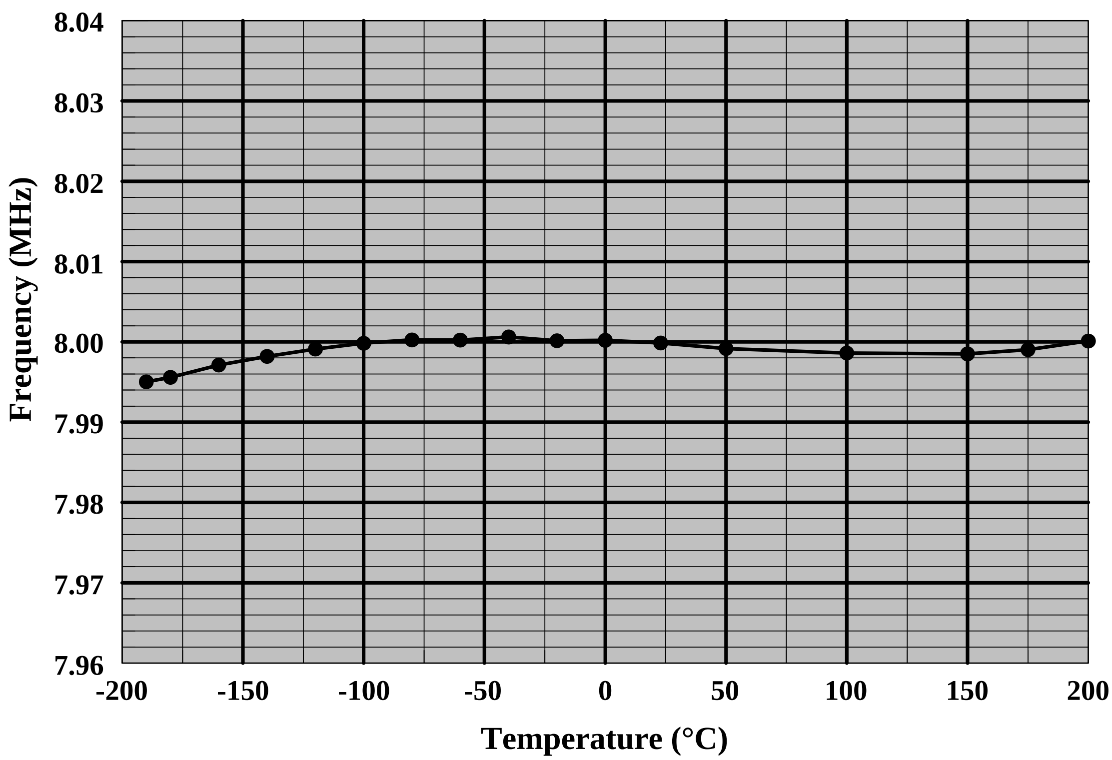


Figure 2. Variation in oscillator output frequency with temperature.

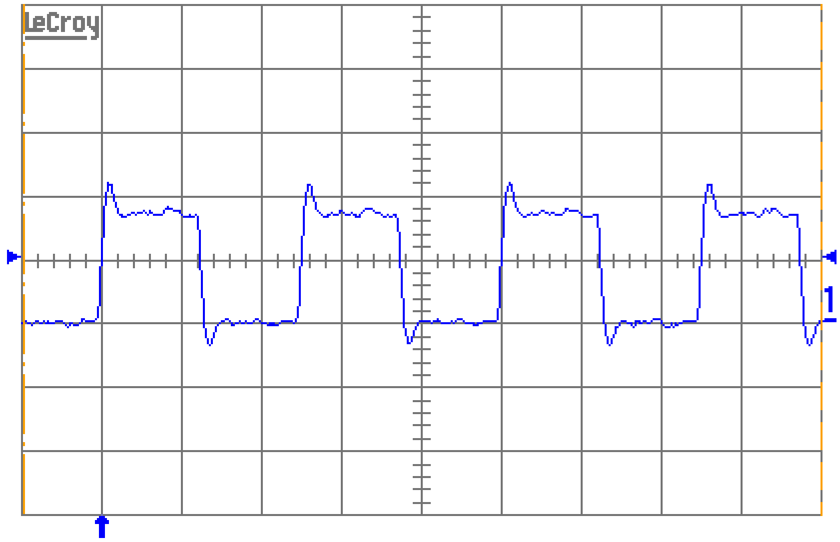


Figure 3. Typical output waveform of the CXOMHT crystal oscillator.
(Scale: Horizontal 50 ns/div, Vertical 2 V/div)

Similar to the frequency, the duty cycle of the output signal did not display any significant change over the test temperature range between -190 °C and +200 °C as it maintained a value of 50%, as depicted in Figure 4.

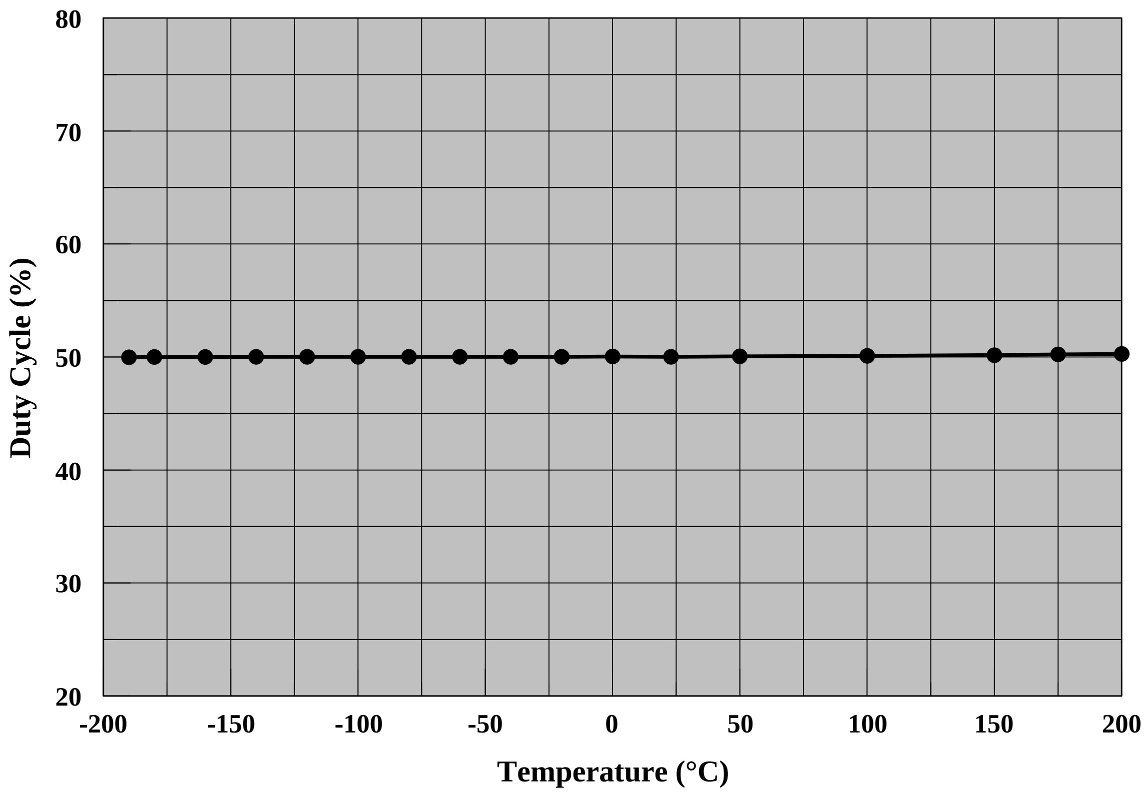


Figure 4. Duty cycle of oscillator output versus temperature.

The rise time as well as the fall time of the output signal displayed similar but weak dependence on temperature, as shown in Figure 5. Both of these characteristics were found to exhibit gradual but very small reduction in their values as temperature was decreased below room temperature; and the reverse was true when the circuit was exposed to high temperatures. The changes occurring at high temperature were more profound in the fall time property of the oscillator's output signal, as depicted in Figure 5.

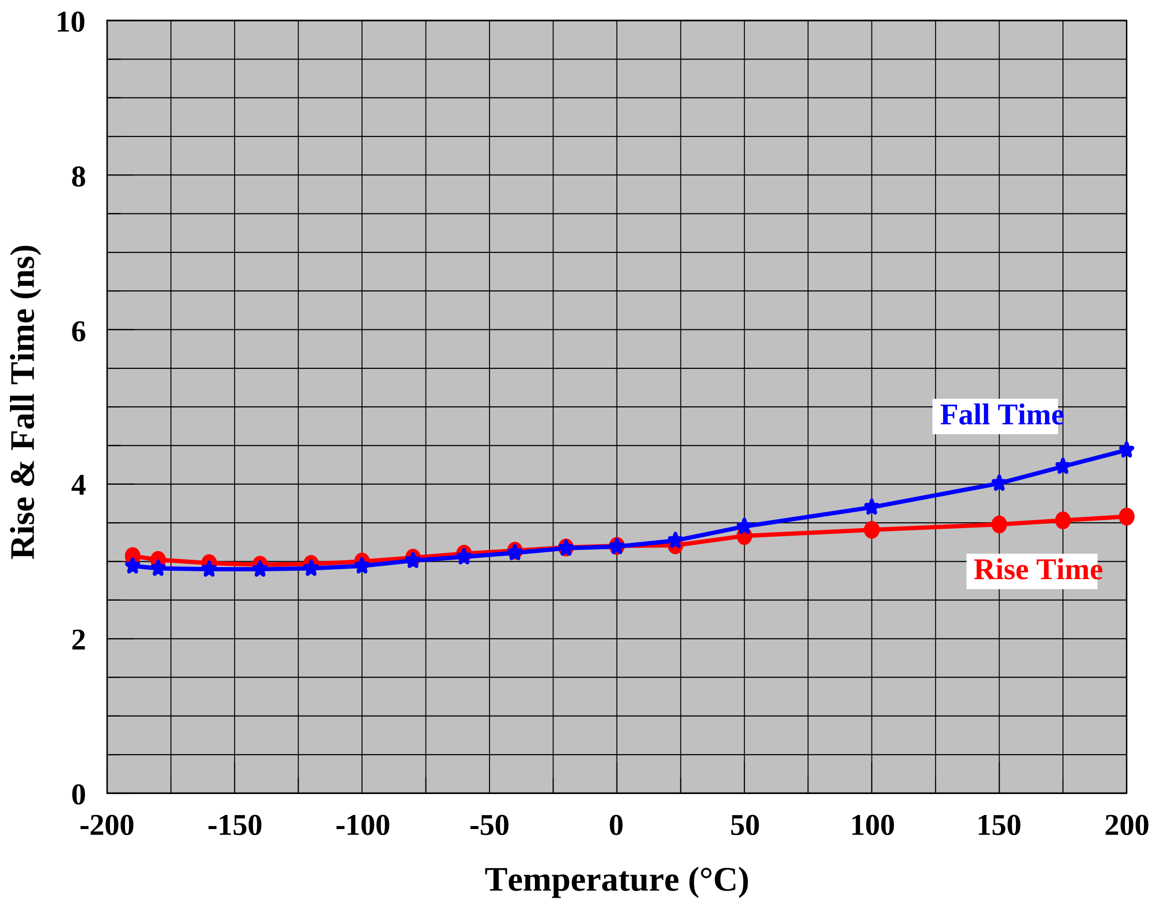


Figure 5. Rise and fall times of output signal versus temperature.

Negligible effect of test temperature on the supply current of the oscillator was observed as the value of the current hovered around 2 mA throughout the test temperature range between -190 °C and +200 °C, as shown in Figure 6.

Re-Start at Extreme Temperatures

Re-start capability of this CXOMHT crystal oscillator was investigated at the extreme test temperatures of -190 °C and at +200 °C. The oscillator chip was allowed to soak at each of those two temperatures, with electrical power off for at least 20 minutes. Power was then applied to the circuit, and measurements of the oscillator's output waveform characteristics and frequency were recorded. The oscillator circuit successfully operated under cold start at -190 °C as well as at the hot temperature of +200 °C, and the data obtained was similar to those obtained earlier at these respective temperatures.

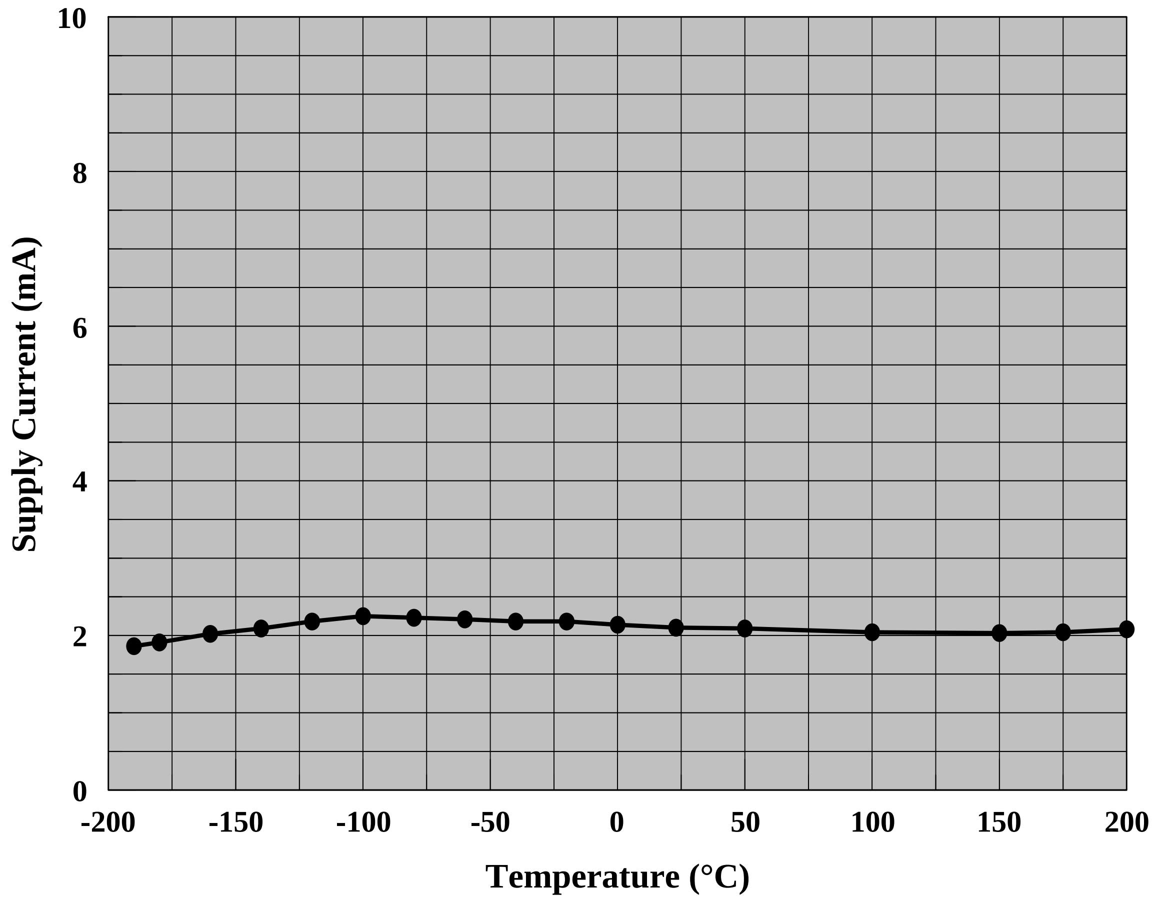


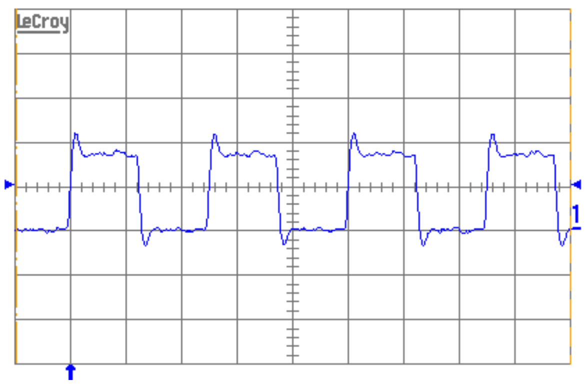
Figure 6. Supply current of oscillator as a function of temperature.

Effects of Thermal Cycling

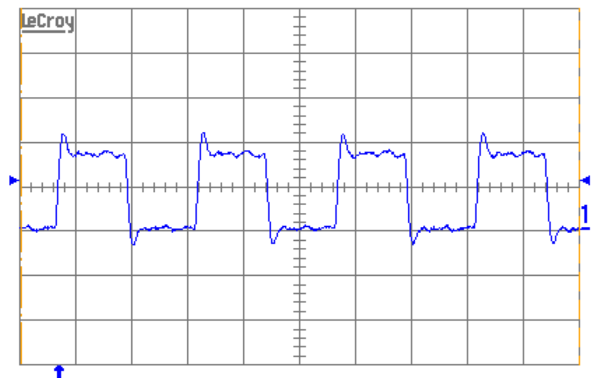
The effects of thermal cycling were investigated by subjecting the crystal oscillator chip to a total of 12 cycles between -190 °C and +200 °C at a temperature rate of 10 °C/minute. Although this short-term activity does not replace highly accelerated or life testing for reliability determination, it provides, nonetheless, some preliminary insight on the effect of thermal cycling on the device's behavior. During cycling, a dwell time of 20 minutes was applied at the extreme temperatures. Post-cycling measurements on the characteristics of the oscillator circuit were then performed at selected test temperatures. Table II lists post-cycling data along with the data obtained prior to cycling. A comparison between pre- and post-cycling data reveals that this oscillator did not undergo any significant changes in its operational characteristics due to this limited cycling; as also evidenced by the consistency in the output waveforms shown in Figure 7 that were recorded at selected temperatures before and after the cycling. The thermal cycling also appeared to have no effect on the structural integrity of the device as no packaging damage was noted upon inspection.

Table II. Pre- and post-cycling characteristics of the CXOMHT crystal oscillator.

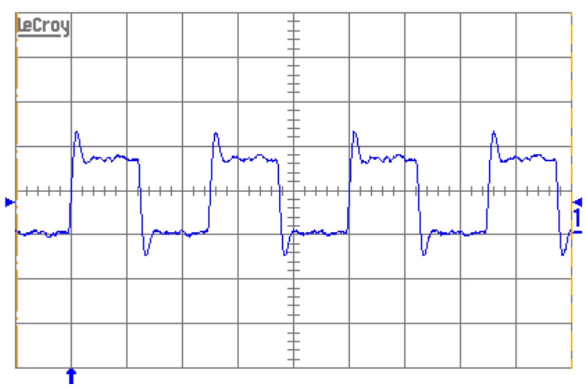
T(°C)	Cycling	f (MHz)	Duty cycle (%)	T_{rise} (ns)	T_{fall} (ns)	I_S (mA)
-190	pre	7.99502	49.98	3.07	2.94	1.86
	post	7.99455	49.98	3.04	2.91	1.84
23	pre	7.99985	50.02	3.21	3.27	2.1
	post	7.99987	50.04	3.23	3.29	2.1
+200	pre	8.0001	50.27	3.58	4.44	2.08
	post	8.00022	50.28	3.64	4.52	2.09



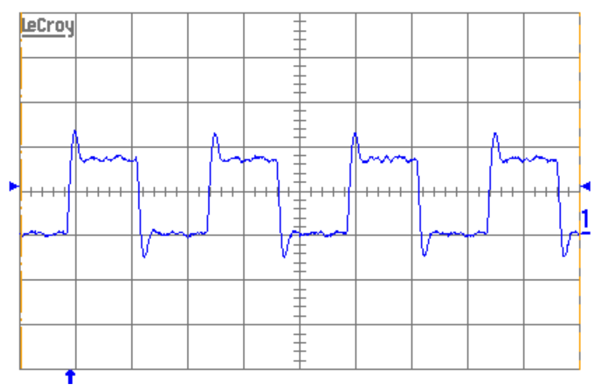
Pre-cycling at 23 °C



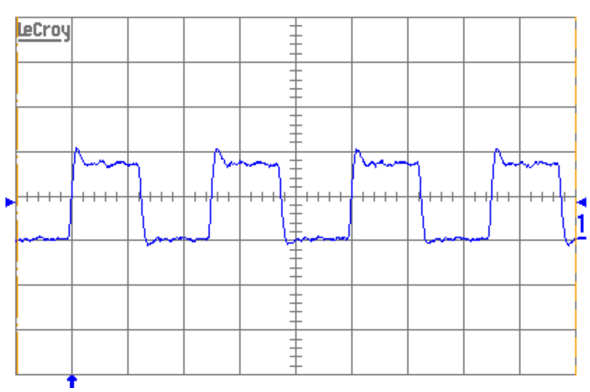
Post-cycling at 23 °C



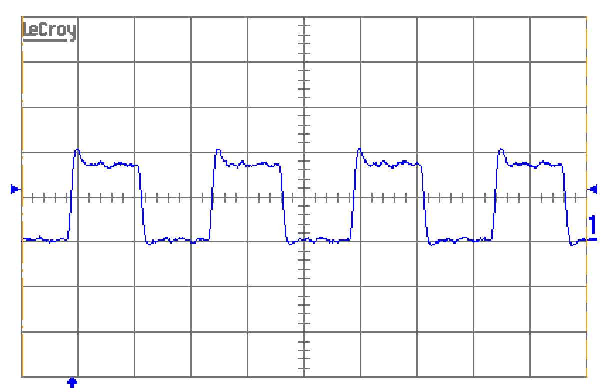
Pre-cycling at -190 °C



Post-cycling at -190 °C



Pre-cycling at +200 °C



Post-cycling at +200 °C

Figure 7. Pre- and post-cycling oscillator output waveforms at 23, -190, and +200 °C.

Short-Duration Thermal Stressing

Following the thermal cycling activity, the oscillator circuit was over-stressed thermally by exposing it to temperatures that were slightly higher than its specified rating of +200 °C for a brief duration. This was done in order to roughly establish how much of excessive high temperature the oscillator can tolerate before reaching a threshold level at which severe degradation in performance begins to occur or a catastrophic failure takes place due to circuit malfunction, interconnect damage, and metallization or packaging issues. The high-temperature stress testing comprised of exposure to +210 °C and +225 °C, whose results along with those obtained at other temperatures are listed in Table III. The data obtained indicate that oscillator withstood this short-term thermal stressing and operated quite well as no major changes were experienced in its operational characteristics as compared to those at the other temperatures, as shown in Table III.

Table III. Operational characteristics of the oscillator at selected temperatures.

T(°C)	Soak time (hr)	f (MHz)	Duty cycle (%)	T_{rise} (ns)	T_{fall} (ns)	I_S (mA)
-190	1	7.99455	49.98	3.04	2.91	1.84
+23	1	7.99987	50.04	3.23	3.29	2.10
+200	1	8.00022	50.28	3.64	4.52	2.09
+210	1	8.00084	50.30	3.67	4.64	2.13
+225	1	8.00199	50.35	3.72	4.77	2.21

Conclusions

A new COTS high temperature crystal oscillator was evaluated under exposure to extreme temperatures and wide-range thermal cycling. The Performance of the Statek CXOMHT oscillator was characterized in terms of its frequency stability, output signal rise and fall times, duty cycle, and supply current at specific test temperatures. Re-start capability at extreme hot and cold temperatures was also examined. Short-term thermal stressing beyond its high temperature rating of +200 °C was also carried out. The oscillator was found to exhibit good operation with excellent frequency stability within the temperature range of -190 °C to +200 °C. Brief over-stressing of the oscillator to temperatures as high as +225 °C had no impact on its operation. Similarly, the circuit experienced no change in its behavior after undergoing limited thermal cycling between -190 °C and +200 °C, and was able to re-start at the extreme temperatures. In addition, no damage was observed in the packaging material due to extreme temperature or thermal cycling. These preliminary results indicate that the device has the potential for operating in a temperature regime that exceeds its specified range. Additional long-term testing is, however, required to fully establish the reliability of these devices and to determine their suitability for use in space exploration missions under extreme temperature conditions.

References

[1]. STATEK Corporation, "High Temperature/High Shock Oscillators - CXOMHT Series" Data Sheet 10180 – Rev A. http://www.statek.com

Acknowledgments

This work was performed under NASA GRC GESS-2 Contract # NNC06BA07B. Funding was provided from the NASA NEPP Program.