Extreme Temperature Operation of a 10 MHz Silicon Oscillator Type STCL1100

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Background

Electronic parts and systems geared for use in NASA deep space and planetary exploration missions must operate reliably and efficiently in extreme temperature environments. Thermal cycling over a wide temperature range is also a major concern for the spacecraft’s on-board electronics in most of the planned missions. The majority of the commercial-off-the-shelf (COTS) devices do not satisfy the operational temperature requirements and, therefore, new components have to developed and qualified for space operation. Very few custom-made commercial and military-grade components exist and are designed to operate at temperatures beyond their COTS counterparts. These special parts are usually tailored for operation under one temperature extreme, i.e. hot or cold, or under a narrow or limited range of operational temperature variation. In addition, very limited data exist on their performance under such environmental conditions. It is, therefore, essential to establish more and detailed information on parts and circuits with regard to functionality and long-term reliability under extreme temperature prior to their use in space applications.

Over the last few years, silicon oscillators began to be offered as COTS parts as potential replacement for the traditional crystal oscillators in providing timing signals in digital and analog circuits. These quartz-free oscillators cover a wide frequency range, offer great tolerance to shock and vibration, and are immune to electro-static discharge. This report presents the results obtained on the evaluation of a fixed frequency silicon oscillator under extreme temperatures.

Test Procedure

The device selected for evaluation comprised of an STMicroelectronics STCL1100 silicon oscillator chip that had a fixed frequency output of 10 MHz. This 5-pin, low cost device is designed for microprocessor and display driver applications where tight clock accuracy is not critical. Table I shows some of the manufacturer’s specifications for this device [1]. Operation stability of this high frequency silicon 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. Restart capability at extreme temperatures, i.e. power switched on while the device was soaking at extreme (hot or cold) temperature, was also investigated. The effects of thermal cycling under a wide temperature range on the operation of the silicon oscillator were also investigated. The oscillator was subjected to a total of 12 cycles between -195 °C and +130 °C at a temperature rate of 10 °C/minute and a soak time of 20 minutes at the temperature extremes.

Table I. Manufacturer's specifications of STCL1100 silicon oscillator [1].

Parameter	STCL1100
Operating voltage (V)	5.0
Frequency (MHz)	10
Operating current, unloaded (μA)	590
Operating temperature (°C)	-20 to +85
Duty cycle (%)	40 to 60
Frequency accuracy (%)	±1.5
Output rise/fall time (ns)	5
Package (RoHS compliant lead-free)	Plastic SOT23-5L
Part #	STCL1100YBFCWY5
Lot number	10A Y832

Test Results

Temperature Effects

The output frequency of the STCL1100 silicon oscillator as a function of temperature is shown in Figure 1. The oscillator exhibited very good stability in its output frequency within the temperature range of about -50 °C to +130 °C. The upper temperature of +130 °C was well above the +85 °C specification temperature. At temperatures below -50 °C, however, the silicon oscillator began to exhibit a decrease in frequency as temperature was decreased further. The intensity of this decrease in the output frequency ranged from being slight between -50 °C to -125 °C to becoming more intense as the test temperature was further lowered toward the extreme cryogenic temperature of -195 °C. For example, while the output frequency changed by only about 1.8% between -50°C and +130 °C, it decreased by about 11% between -50°C and -125 °C, and attained as much as 49% drop at -195 °C. A typical waveform of the oscillator output is shown in Figure 2.

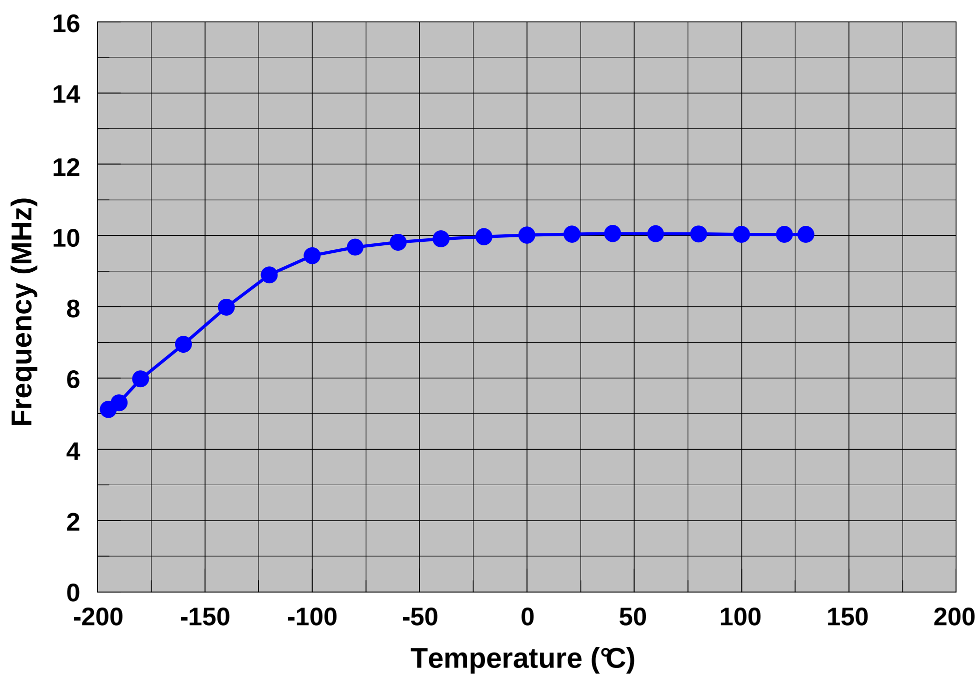

Figure 1. Variation in oscillator output frequency with temperature.

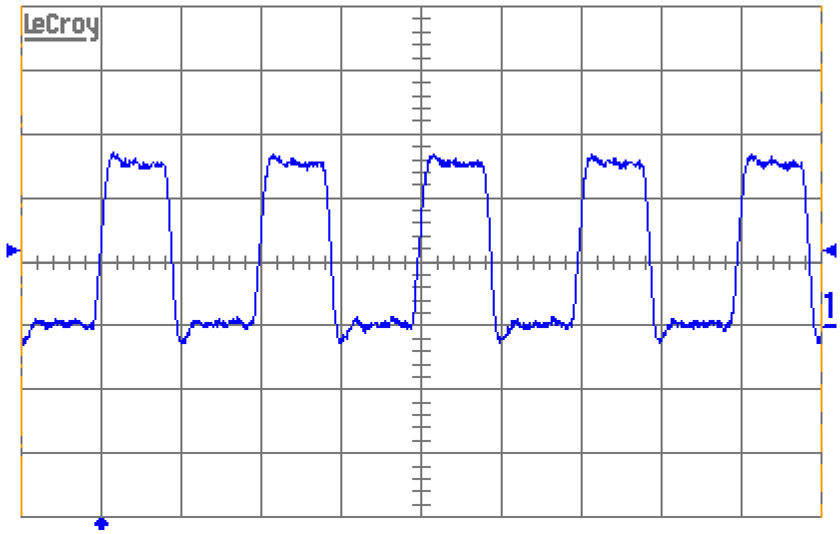

Figure 2. Output waveform of the STCL1100 silicon oscillator.
(Scale: Horizontal 50 ns/div, Vertical 2 V/div)

The duty cycle of the silicon oscillator output signal did not display any significant change over the test temperature range as its value swung between 43% and 48% at the test temperatures of +130 °C and -195 °C, respectively, as depicted in Figure 3.

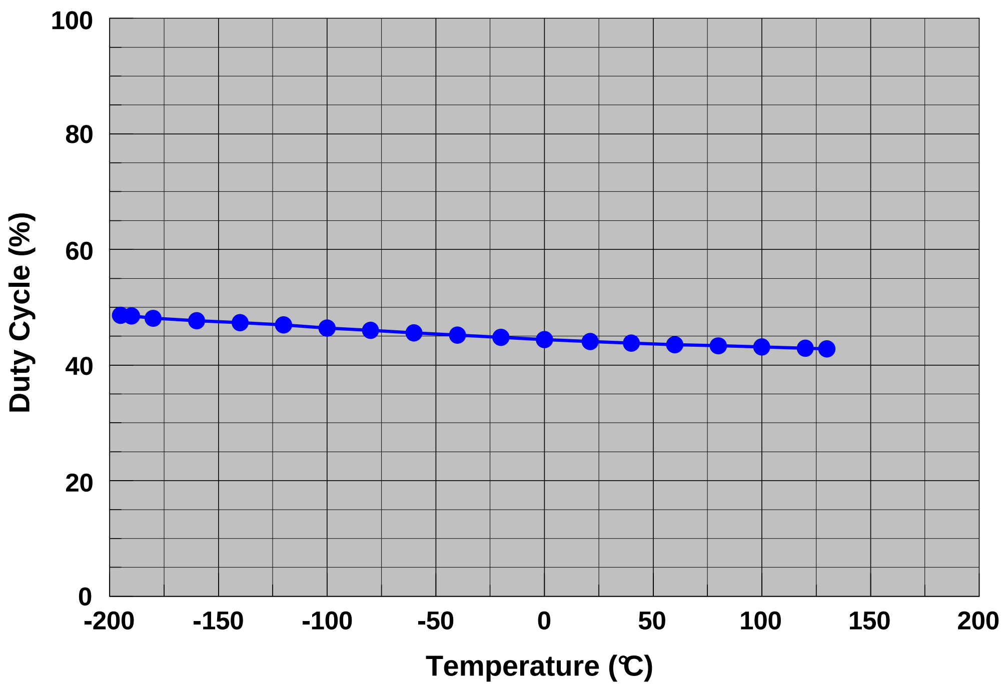

Figure 3. Duty cycle of oscillator output versus temperature.

The rise and fall times of the output signal displayed similar dependence on temperature. Both of these characteristics were found to exhibit an increase in their values as the test temperature moved away in either direction from room temperature. This increase in the rise as well as the fall time was more profound at cryogenic temperatures than at the other band as shown in Figure 4.

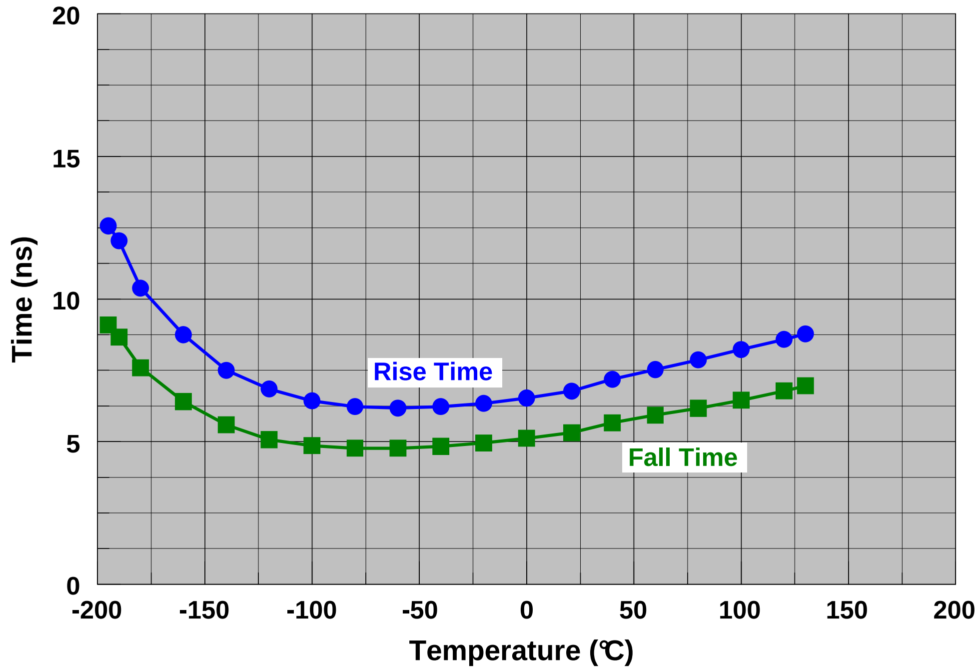

Figure 4. Rise and fall times of output signal versus temperature.

The supply current of the oscillator versus temperature is shown in Figure 5. While the current seemed to exhibit a gradual but very slight increase as the test temperature was increased from ambient to higher temperatures, it underwent a decrease in its value with temperature at the silicon oscillator was subjected to test temperaures lower than room temperature. This decrease in the supply current with temperature was more noticeable in the temperature vicinity of -125 °C to -195 °C, as depicted in Figure 5.

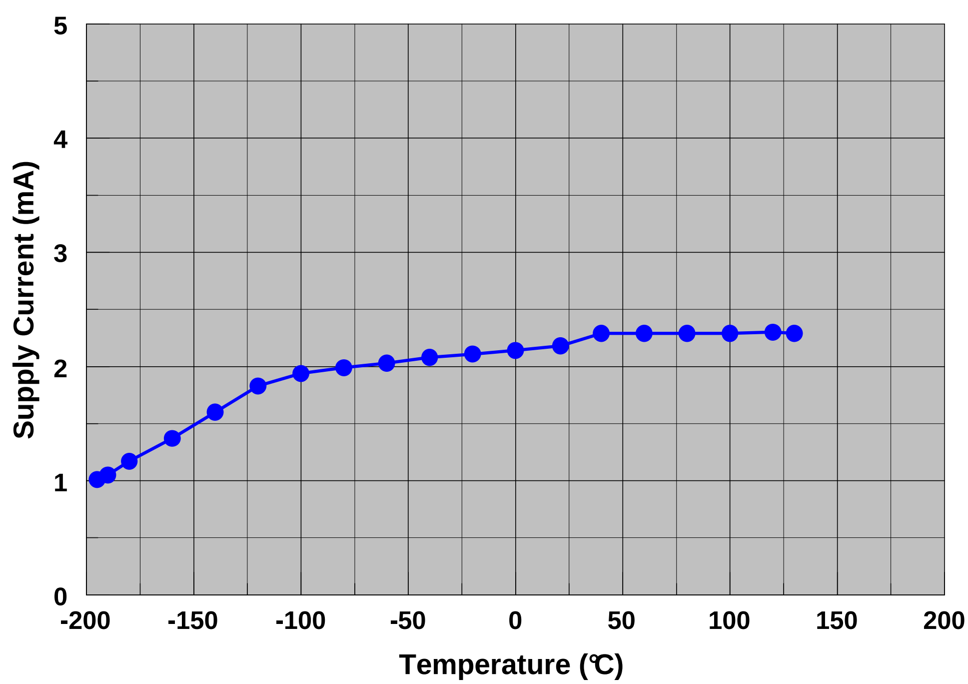

Figure 5. Supply current of oscillator as a function of temperature.

Re-Start at Extreme Temperatures

Restart capability of this STCL1100 silicon oscillator was investigated at the extreme test temperatures at which stable operation was maintained, i.e. -195 °C and +130 °C. The oscillator chip was allowed to soak separately at 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 -195 °C as well as at the hot temperature of +130 °C, and the results obtained were similar to those obtained earlier at these respective temperatures.

Effects of Thermal Cycling

The effects of thermal cycling were investigated by subjecting the STCL1100 silicon oscillator chip to a total of 12 cycles between -195 °C and +130 °C at a temperature rate of 10 °C/minute. A soak time of 20 minutes was allowed at the extreme temperature prior to recording any data. 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 silicon oscillator did not undergo any significant changes in its operational characteristics due to this limited 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 silicon oscillator.

T(°C)	Cycling	f (MHz)	Duty cycle (%)	T_{rise} (ns)	T_{fall} (ns)	I_S (mA)
21	pre	10.0413	44.09	6.77	5.31	2.18
	post	10.0290	44.03	6.86	5.36	2.20
-195	pre	5.1197	48.62	12.56	9.09	1.01
	post	5.1159	48.67	12.67	9.19	1.03
+130	pre	10.0322	42.80	8.78	6.96	2.29
	post	10.0312	42.80	8.66	6.84	2.28

Conclusions

The performance of STMicroelectronics 10 MHz silicon oscillator was evaluated under exposure to extreme temperatures. The oscillator was characterized in terms of its output frequency stability, output signal rise and fall times, duty cycle, and supply current. The effects of thermal cycling and re-start capability at extreme low and high temperatures were also investigated. The silicon oscillator chip operated well with good stability in its output frequency over the temperature region of -50 °C to +130 °C, a range that by far exceeded its recommended specified boundaries of -20 °C to +85 °C. In addition, this chip, which is a low-cost oscillator designed for use in applications where great accuracy is not required, continued to function at cryogenic temperatures as low as - 195 °C but at the expense of drop in its output frequency. The STCL1100 silicon oscillator was also able to re-start at both -195 °C and +130 °C, and it exhibited no change in performance due to the thermal cycling. In addition, no physical damage was observed in the packaging material due to extreme temperature exposure and thermal cycling. Therefore, it can be concluded that this device could potentially be used in space exploration missions under extreme temperature conditions in microprocessor and other applications where tight clock accuracy is not critical. In addition to the aforementioned screening evaluation, additional testing, however, is required to fully establish the reliability of these devices and to determine their suitability for long-term use.

References

[1]. STMicroelectronics Corporation, “STCL1100/1120/1160 High Frequency Silicon Oscillator Family” Data Document, Rev 2, February 2008.

Acknowledgments

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