Performance of MEMS Silicon Oscillator, ASFLM1, Under Wide Operating Temperature Range

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Background

Over the last few years, MEMS (Micro-Electro-Mechanical Systems) resonator-based oscillators began to be offered as commercial-off-the-shelf (COTS) parts by a few companies [1-2]. These quartz-free, miniature silicon devices could compete with the traditional crystal oscillators in providing the timing (clock function) for many digital and analog electronic circuits. They provide stable output frequency, offer great tolerance to shock and vibration, and are immune to electro-static discharge [1-2]. In addition, they are encapsulated in compact lead-free packages, cover a wide frequency range (1 MHz to 125 MHz), and are specified, depending on the grade, for extended temperature operation from -40 °C to +85 °C. The small size of the MEMS oscillators along with their reliability and thermal stability make them candidates for use in space exploration missions. Limited data, however, exist on the performance and reliability of these devices under operation in applications where extreme temperatures or thermal cycling swings, which are typical of space missions, are encountered. This report presents the results of the work obtained on the evaluation of an ABRACON Corporation MEMS silicon oscillator chip, type ASFLM1, under extreme temperatures.

Test Procedure

The device selected for evaluation comprised of ABRACON ASFLM1-1.8432-C that outputs a frequency of 1.8432 MHz and operates with a supply voltage of 3.0 volts. The low power device is based on MEMS technology by Discera Inc., and it delivers an output signal with fast rise/fall times. Table I shows some of the manufacturer's specifications for this device [1].

Table I. Manufacturer's specifications of ASFLM1 silicon MEMS oscillator [1].

Parameter	**ASFLM1**
Operating voltage (V)	3.0
Frequency (MHz)	1.8432
Operating temperature (°C)	0 to +70
Duty cycle (%)	45 to 55
Frequency tolerance (ppm)	±50
Output rise/fall time (ns)	5
Package (RoHS compliant lead-free)	Plastic QFN
Part #	ASFLM1-1.8432-C
Lot number	AB C0729

Operation stability of the silicon MEMS 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 oscillator were also investigated. The oscillator was subjected to a total of 10 cycles between -190 °C and +140 °C at a temperature rate of 10 °C/minute and a soak time of 20 minutes at the temperature extremes.

Test Results

Temperature Effects

The output frequency of the silicon MEMS oscillator as a function of temperature is shown in Figure 1. It can be seen that the oscillator exhibited good stability in its output frequency within the temperature range of -60 °C to +120 °C. At temperatures below -60 °C, the oscillator began to exhibit a gradual, slight increase in frequency as temperature was decreased further. For example, the output frequency increased from its room temperature value of 1.8432 MHz to about 1.8469 MHz at the test temperature of -190 °C; representing a 0.2% increase. At the other end of the temperature range, the oscillator frequency underwent small decrease as it dropped to 1.8425 MHz at +140 °C, as shown in Figure 1. A typical waveform of the oscillator output obtained over the wide temperature range is shown in Figure 2.

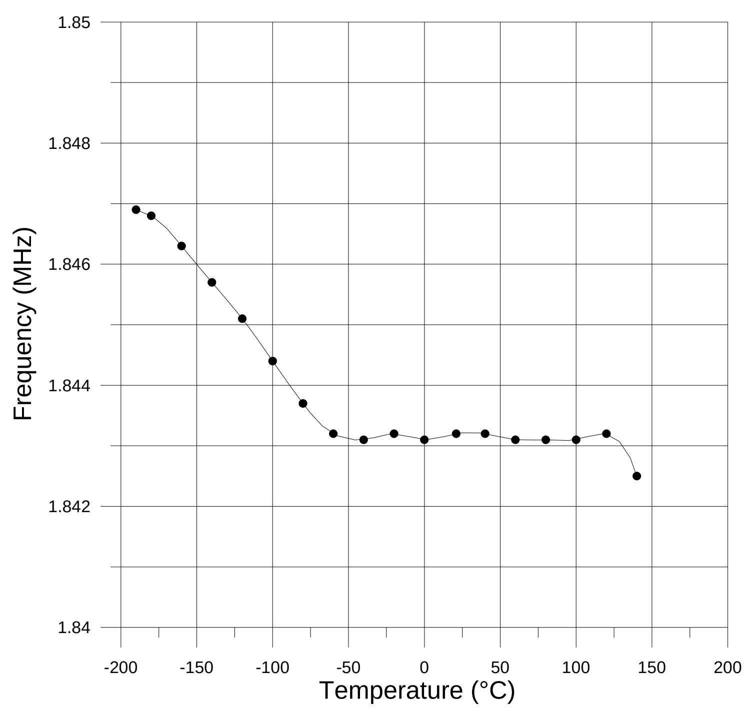

Figure 1. Variation in oscillator output frequency with temperature.

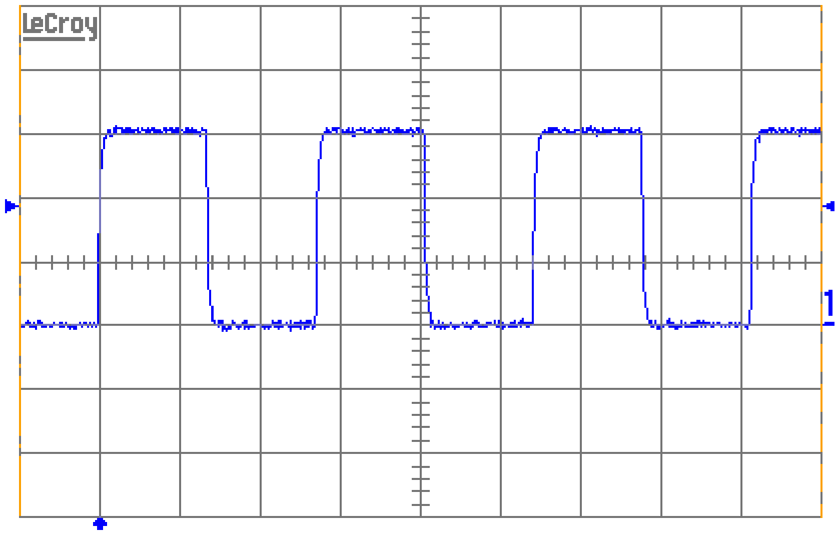

Figure 2. Output waveform of the ASFLM1 silicon MEMS oscillator.
(Scale: Horizontal 0.2 μs/div, Vertical 1 V/div)

The duty cycle of the MEMS oscillator output signal did not display any significant change over the test temperature range as it retained a value around 49.94 % throughout the whole test temperature range between -190 °C and +140 °C, as depicted in Figure 3.

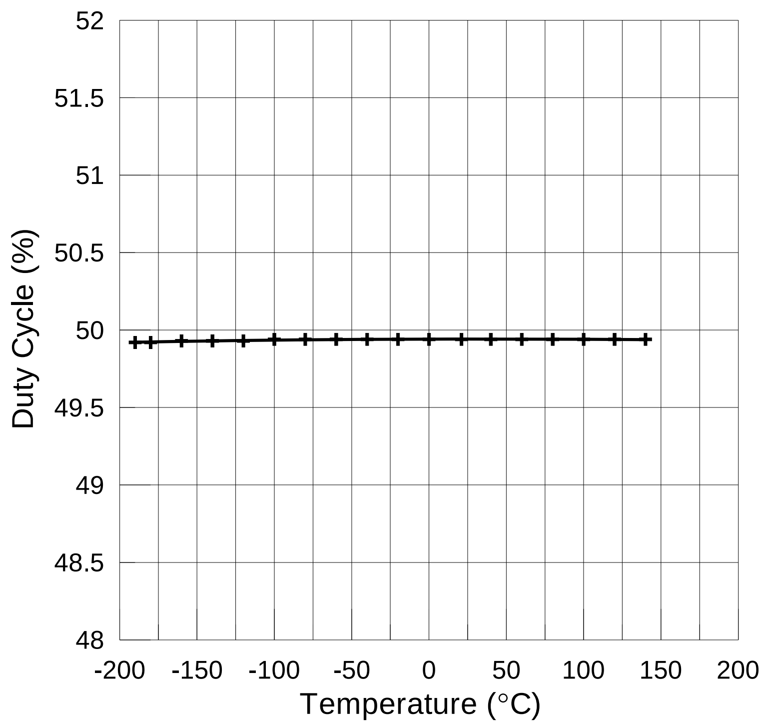

Figure 3. Duty cycle of oscillator output versus temperature.

The rise and fall times of the output signal displayed similar dependence on temperature. Both of these characteristics were found to exhibit 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. These changes in the rise and fall time of the oscillator's output signal are shown in Figures 4 and 5, respectively.

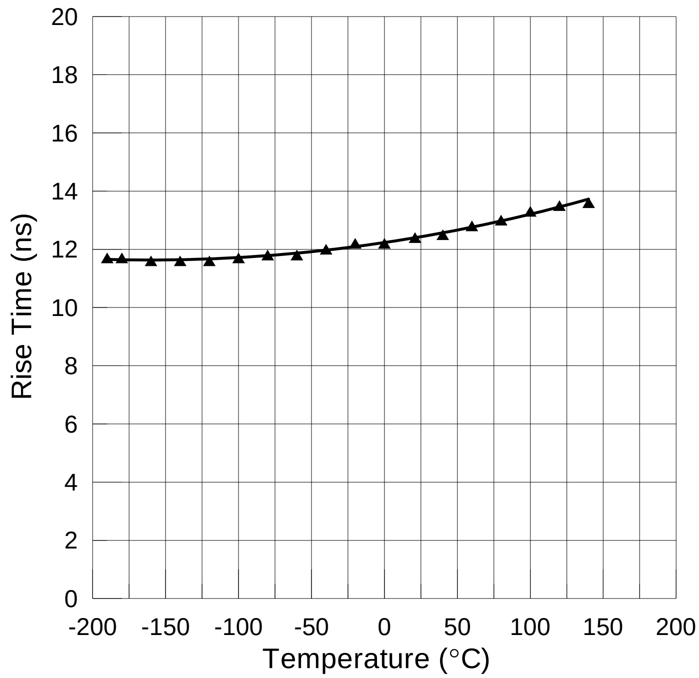

Figure 4. Rise time of output signal versus temperature.

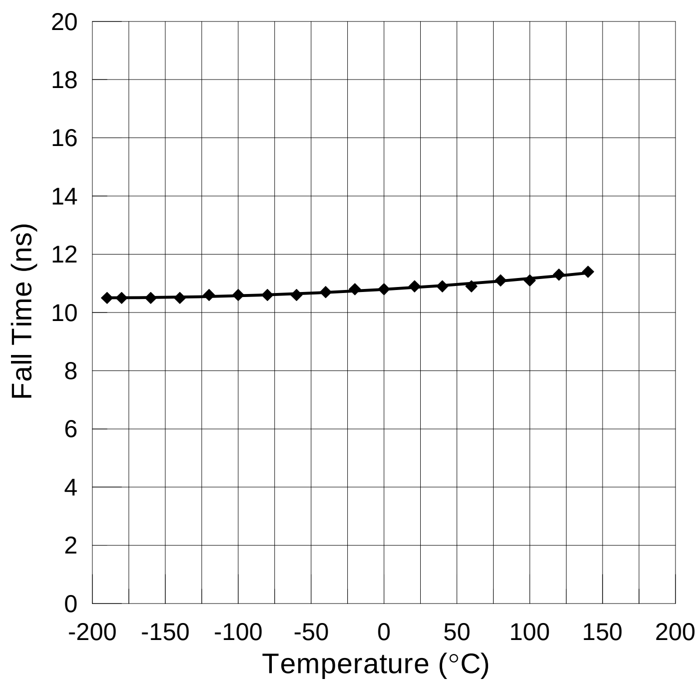

Figure 5. Fall time of output signal versus temperature.

The supply current of the oscillator as a function of temperature is shown in Figure 6. The supply current tended to exhibit an almost linear dependence on the test temperature. For instance, while the current exhibited a gradual drop in value as test temperature was decreased from room to cryogenic temperatures; it increased slightly as temperature was varied from 22 °C to 140 °C.

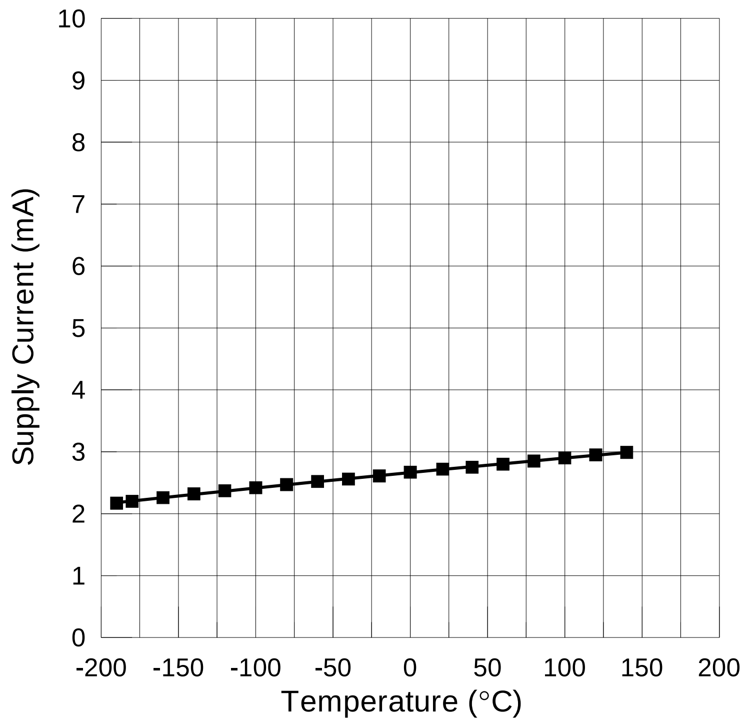

Figure 6. Supply current of oscillator as a function of temperature.

Re-Start at Extreme Temperatures

Restart capability of this silicon MEMS oscillator was investigated at the extreme test temperatures at which stable operation was maintained, i.e. -190 °C and +140 °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 -190 °C as well as at the hot temperature of +140 °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 device to a total of 10 cycles between -190 °C and +140 °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 the silicon MEMS 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 MEMS oscillator.

T(°C)	Cycling	f (MHz)	Duty cycle (%)	T_{rise} (ns)	T_{fall} (ns)	I_S (mA)
22	pre	1.8432	49.94	12.4	10.9	2.72
	post	1.8432	49.94	12.0	10.4	2.71
-190	pre	1.8469	49.92	11.7	10.5	2.17
	post	1.8467	49.93	11.4	10.1	2.19
+140	pre	1.8425	49.94	13.6	11.4	2.99
	post	1.8426	49.94	13.5	11.2	2.98

Conclusions

The performance of an ABRACON ASFLM1 silicon oscillator, which is based on MEMS technology by Discera Inc., 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 oscillator was found to maintain good operation between -190 °C and +140 °C, a range that by far exceeded its recommended specified boundaries of 0 °C to +70 °C. This silicon MEMS oscillator was also able to re-start at both -190 °C and +140 °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. This device represents a good candidate for use in space exploration missions under extreme temperature conditions, depending upon the stability requirements. More comprehensive testing, however, is required to fully establish the reliability of these devices and to determine their suitability for long-term use.

References

[1]. ABRACON Corporation, "Ultra Miniature Pure Silicon Clock Oscillator, ASFLM1" Data Sheet, Revised: 10.04.07.

[2]. SiTime Corporation, "SiT1 SiRes Fixed Frequency Oscillator, SiT1101 to SiT1273" Data Sheet, SiT1_Rev D.

Acknowledgments

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