Crystal Oscillator Testing

White Paper

Introduction

A policy concerning the testing of the reference oscillators contained within many instruments such as counters, synthesizers and spectrum analyzers has been defined and adopted in Agilent's service centers worldwide.

Quartz crystal oscillators are used extensively in measurement instruments to provide an accurate reference frequency or time base against which measured signals may be compared.

There are two characteristics of such devices which users may wish to know:

1. The absolute oscillator frequency once it has warmed up
2. The stability of the oscillator frequency over time.

Our standard policy is to test the first parameter (and to adjust where necessary) but not the second. This article is designed to help explain the rationale for this decision.

High-stability ovenized oscillators have their stability specified in terms of a drift rate per day. This means that within a 24-hour period the frequency will not change by more than the permitted tolerance over that period. This is in contrast to lower stability oscillators whose aging rate is stated over a month or a year. The frequency may well change in the short term more than the specified amount, but the long-term trend will comply with the specification — see Figure 1.

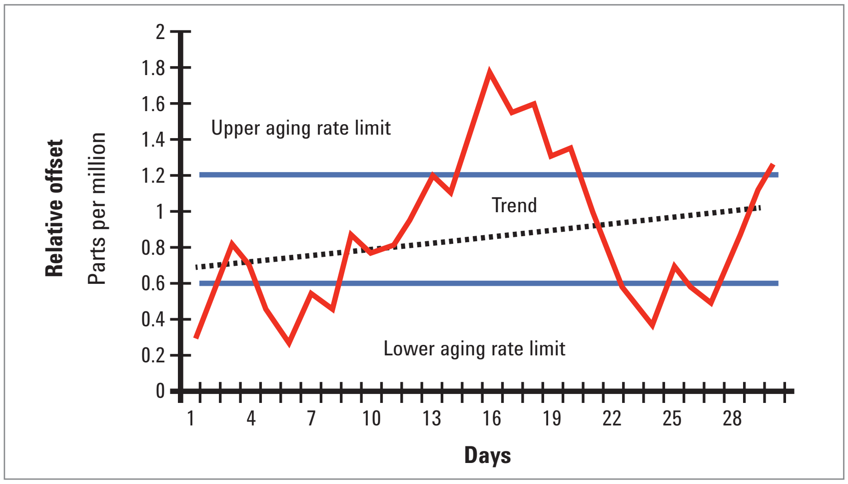

Figure 1. A representation of the frequency stability of an uncompensated or temperature compensated quartz crystal oscillator. Note how the aging rate would far exceed, or be far less than, specification if measurements were taken over a shorter period than the specified one month for this oscillator. The apparent aging rate would also vary considerably depending when the measurements were made.

Experience

Our company manufactured precision crystal oscillators for many years and during that time extensive analysis of their performance was made. In fact, hundreds of thousands of high-stability oscillators were sold giving a significant population from which to base our strategy for testing the devices.

The analysis determined that it is not generally necessary to test the drift rate of high-stability oscillators. In fact, it has been estimated that there is a 99.995% probability that an Agilent 10811-series oscillator that performs to its other specifications will also pass the aging rate specification. It is also a fact that an aging-rate check is seldom part of the recommended calibration procedure for any instruments fitted with precision crystal oscillators, whoever the manufacturer.

Test Procedure

For confidence and repeatability, the oscillator is allowed to warm up according to the following minimum times:

1. Room temperature and temperature compensated crystals: 1 hour
2. Medium performance oven: 12 hours
3. High performance oven: 48 hours

Once the instrument has warmed up, its absolute frequency is measured. This is compared to test limits that have been established for each oscillator type and, if necessary, the frequency is optimized to nominal.

Formula for calculating

Relative frequency offset

$$\frac{\text{(Measured frequency – Nominal frequency)}}{\text{Nominal frequency}}$$

For example:

Nominal or expected xtal frequency = 5 MHz
Actual measured frequency = 4.9999927 MHz

(4.9999927e6 – 5e6) / 5e6 = –1.46 x 10e–6

Drift Testing

Drift testing is only undertaken for devices with a 24-hour specification. For all other types, stability testing would require at least 30 days for a specification compliance statement to be made. Such measures would simply not be worthwhile. An illustration of the inadequacy of short-term drift testing is shown in Figure 1 where changes observed over any 24-hour period could potentially give a very misleading indication as to the oscillator's long-term performance.

Supplementary Test

To satisfy the needs of customers who want confirmation that their High Performance Oven Oscillators meet their drift specification, the aging rate measurement can be performed as a supplementary test at an additional charge. The oscillator is monitored constantly over successive 24-hour periods until compliant stability is shown. For some devices this may take up to ten days to occur (greater than ten days would be taken as a failure). The final value is then recorded as an offset from the nominal value, the drift over the 24-hours recorded and presented both numerically and graphically — see Figure 2.

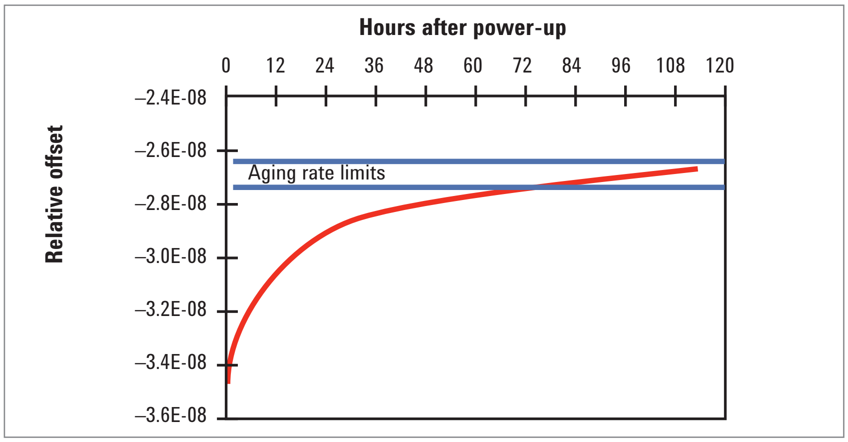

Figure 2. A representation of the warm-up characteristic of a high stability, ovenized quartz crystal oscillator. In this example the drift or aging rate specification is 1 part in 10e9 per day.

Summary

- For all instruments fitted with an internal reference oscillator we will report on the absolute reference frequency and will adjust to nominal when it is outside of predetermined limits for that particular oscillator type.
- Aging-rate (drift or long-term stability) measurement will be undertaken as a supplementary chargeable service, on request, for oscillators with a daily aging specification. This may add as much as ten days to the instrument calibration turn-around time.

Note: For instruments that are referenced to an external frequency standard such as a Caesium Beam or Rubidium Vapor device, determination of an integral oscillator's aging rate has no value to the user.

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