ISOTEMP RESEARCH, INC.

Crystal Oscillator Aging

This technical note is to help customers specify aging of crystal oscillators. Long term frequency drift is an important characteristic of crystal oscillators and is specified by an aging requirement. If the nature of aging is not understood, aging requirements may be improperly specified. The modeling presented here has been used by ISOTEMP RESEARCH, INC. for many years and concurs with MIL-0-55310B.

An appropriate method for modeling oscillator aging is to plot a semi-logarithmic graph with time on the logarithmic axis and frequency on the linear axis. Figure 1 is an example of actual crystal data. The plotted data indicates that a straight line is the best representation for long term aging. This method is based on data from a large number of crystals from several manufacturers. Regression is used to obtain the straight line model

$$f(t) = K \ln (t/t_1) + f_1 \qquad (1)$$

where f(t) is frequency, t is time, and t_1 and f_1 are corresponding values on the line. Aging slope K is determined by using two frequency points on the line corresponding to t_1 and t_2 so that

$$K = [\ f(t_2) - f(t_1)\ ] / [\ \ln(t_2) - \ln(t_1)\ ]$$
$$= [\ f(t_2) - f(t_1)\ ] / \ln(t_2 / t_1) \qquad (2)$$

By making appropriate substitutions, the model given in equation (1) is identical to

$$f(t) = A \ln(Bt + 1) + f_o$$

which is presented in military specification MIL-0-55310B.

For evaluation, age oscillators until a straight line is established. Note, oscillators may not exhibit a consistent aging pattern the first few days. Figure 1 illustrates early aging inconsistency and straight line modeling. Curvature to point (A) represents the early inconsistency, and the straight line shows the expected long term aging. Aging tests performed by the customer will always exhibit curvature due to previous aging by the manufacturer. It can be shown mathematically that the aging curve asymptotically approaches a straight line.

The frequency change during an interval of time t_a after a pre-aging period t_1 is the commonly used method for specifying aging. Typically, t_a is an operating period such as 1 year, and t_1 is a period such as 30 days. The equation to calculate long term frequency change is derived from equation (1). Write equation (1) for t_1 and $t_1 + t_a$, and subtract one equation from the other to obtain the frequency change

$$df = f(t_1 + t_a) - f(t_1) = K \ln[(t_a / t_1) + 1] \qquad (3)$$

The daily aging rate may be obtained by differentiating equation (1) to obtain

$$df(t)/dt = K/t \tag{4}$$

This relationship allows calculation of a required daily aging rate any time based on an aging slope K.

To apply these equations, refer to figure 1. Using data from the straight line at points (A) and (B) equation (2) yields

$$K = [(-47E-8) - (-17E-8)] / [\ln(100 / 20)]$$
$$= -18.6E-8$$

To calculate the aging during the first year after day 15 use equation (3) to obtain

$$df / f = (-18.6E-8) \ln(365 / 15 + 1)$$
$$= -60.2E-8$$

or for 10 years of aging

$$df / f = (-18.6E-8) \ln(3650/15 + 1)$$
$$= -102E-8$$

The daily aging rate at day 15 from equation (4) is

$$df(t) / dt = (-18.6E-8) / 15$$
$$= (-1.24E-8) / Day$$

The required daily aging rate at the end of a given preaging period to meet an aging specification is shown in the following calculations. Suppose a total aging of 3 PPM is specified for 10 years after 30 days preaging. From equation (3)

$$K = 3 / [\ln (3650 / 30 + 1)]$$
$$= 0.624 PPM$$

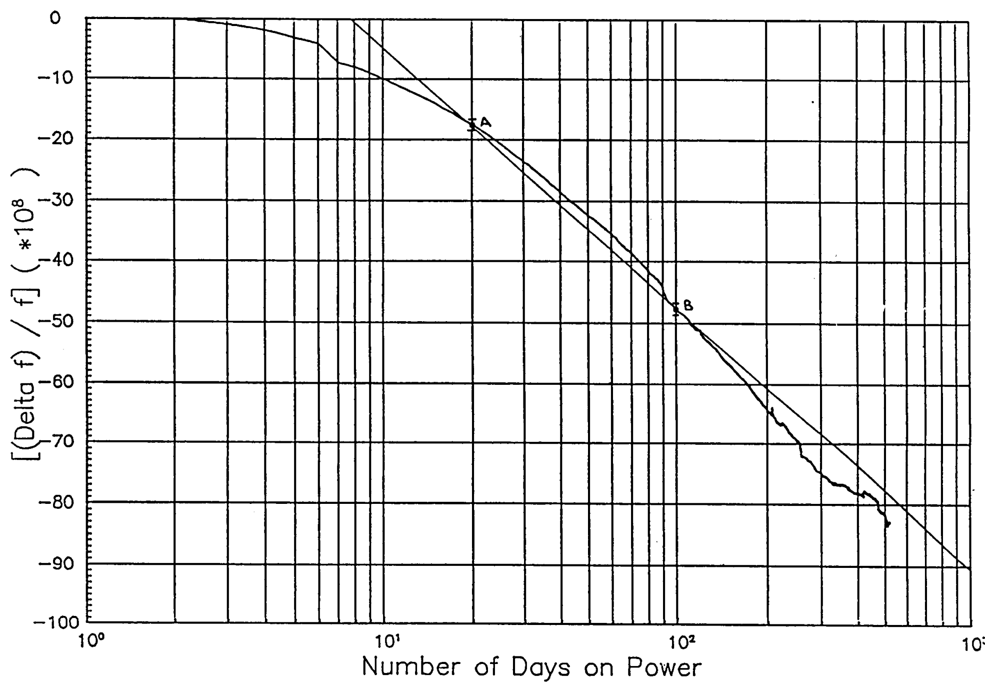
And from equation (4)

$$df(t) / dt = 0.624 / 30$$
$$= 0.0208 PPM / Day$$

on day 30.

The first example demonstrates that a major portion of aging occurs early in the oscillator's life. Also, a good aging oscillator can have a relatively large daily aging rate early in its operation. ISOTEMP RESEARCH, INC. has many years of experience in making aging evaluations and would be pleased to help you in specifying crystal oscillator aging.

Figure 1 Oscillator Aging



REFERENCES: MIL-O-55310B Military specification for crystal oscillators. U.S. government.

For further information on the specification and application of Ovenized Crystal Oscillators, please contact the sales or engineering staff at Isotemp Research, Inc. For reprints of this article, ask for document number 146-000.

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Isotemp Research Inc. is an American company building performance ovens and oscillators since 1968