Activity Dips in Crystal Oscillators

APPLICATION NOTE QTAN-102

ACTIVITY DIPS IN QUARTZ OSCILLATORS

In quartz crystals there are a great many technical terms, specifications and complex physical characteristics that can be overwhelming to people who do not work directly at the engineering level in the Quartz Crystal Industry.

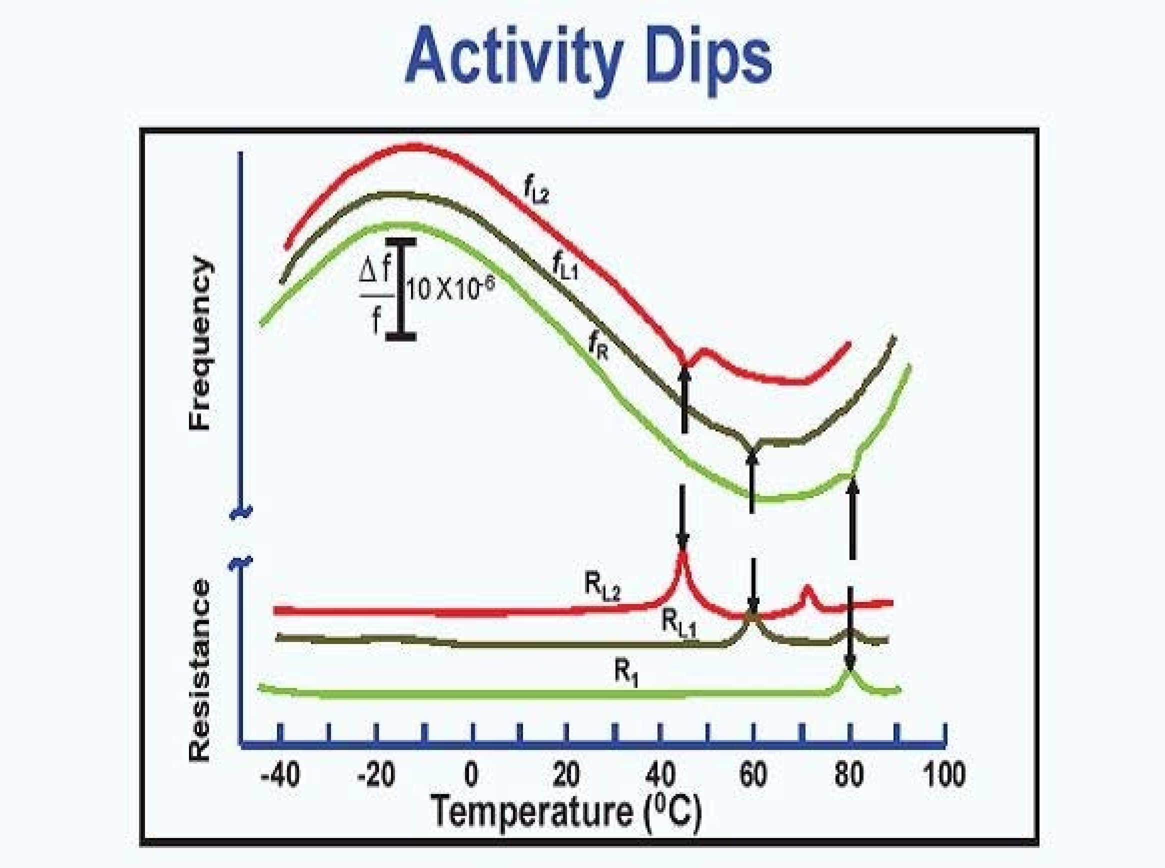
It’s related to an abnormal failure mode of crystal clock oscillators that can be tested for and almost completely eradicated through care of an efficient and active process.

An activity dip is a relatively sudden increase in the crystals resistance, (a perturbation) in the quartz crystals series resistance (Rs) over temperature. Generally activity dips are caused by an interfering mode of vibration (coupled mode) in the quartz crystal. These modes bleed energy from the main mode. Therefore, a coupled mode sharply increases the resistance of the main mode as soon as the frequency of the coupled mode coincides with the frequency of the main mode. These interfering modes are actually high overtones (up to the 50th overtone) of low frequency flexure modes. They have a very steep temperature coefficient of about -20 ppm/°C. So they only coincide with the main mode frequency for a fairly narrow temperature range. An interfering mode can be designed out. If not designed out, the coupled mode will cause an activity dip.   See Figure 1.

These are usually fairly narrow in temperature roughly 5 to 30°C wide. For a given design, activity dips will tend to be about the same temperature range. Because a coupled mode is quartz based, it causes any activity dip is very repeatable over time and temperature. See the example below.

The magnitude of the effect of a coupled mode can range from minor to catastrophic to intermittent. This depends on the strength of the interfering mode and how sensitive the application is to changes in oscillator output level, frequency shifts of about 2 to 20 ppm etc. An activity dip can cause a system to lose phase lock or other types of problems.

Another cause of activity dip is a particle stuck on or near to the active area of the crystal. This type of activity dip can change with time and temperature and time. These would be affected by the particle becoming either detached from the crystals surface or moving to another position. This position change could therefore cause the dip to get better, worse of disappear at least temporarily. Also to go from not detected to suddenly occurring or changing the magnitude at the temperature the dip occurs.



Activity dips in the f vs. T and R vs. T when operated with and without load capacitors. Dip temperatures are a function of C_L, which indicates that the dip is caused by a mode (probably flexure) with a large negative temperature coefficient.

Figure 1

At Q-Tech, we have the capabilities to design around potential activity dips and / or screen them out in our temperature test procedures. That is just one of the many reasons we are the #1 manufacturer of high reliability oscillators in the world.

Some considerations for designing an AT-cut activity dips free quartz oscillator:

1) Quartz processing and manufacturing:
    a. Physical geometry of the crystal unit design
    b. Electrode parameters and design (R1, C1, C0, L1)
    c. Load capacitance
    d. Drive level and Drive level dependency (DLD)
    e. Particles introduced during base or final plating
    f. Contaminants such as oil from vacuum pumps
    g. Scratch(es) on the crystal blank
    h. Crystal cut and operating mode
    i. Method of mounting
    j. Operating temperature window

2) Circuit design:
    a. Amplifier margin and gain
    b. Load capacitance
    c. Match amplifier gain with crystal drive level
    d. Operating mode (Fundamental mode versus 3^{rd} or 5^{th} Overtone mode)
    e. Operating temperature
    f. Method of attaching crystal

3) Method of test:
    a. Test on finished crystal level prior to mounting
    b. Test at finished oscillator level (See Figure 2)
    c. Screening test
    d. Slew rate
    e. Slow Ramp test (1.25°C/minute) or frequency measurement at every degree or every five degrees characterization for activity dips. See figure 3 and 4.

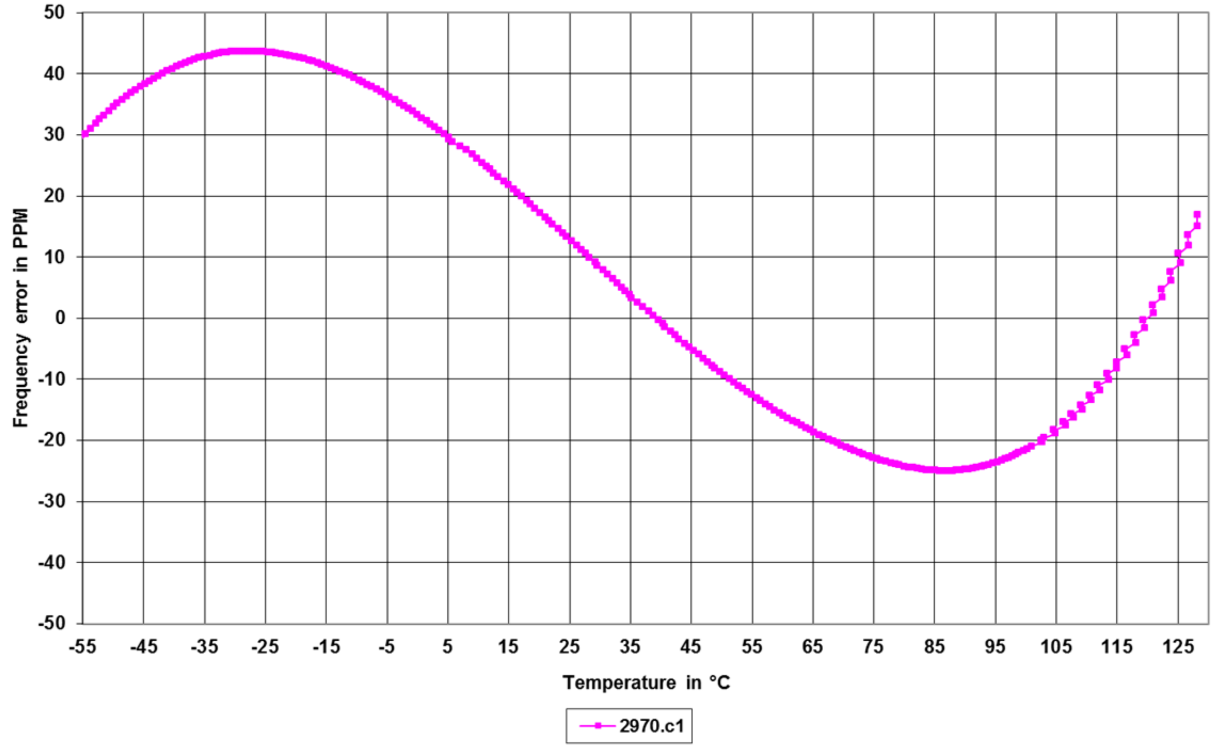


Figure 3

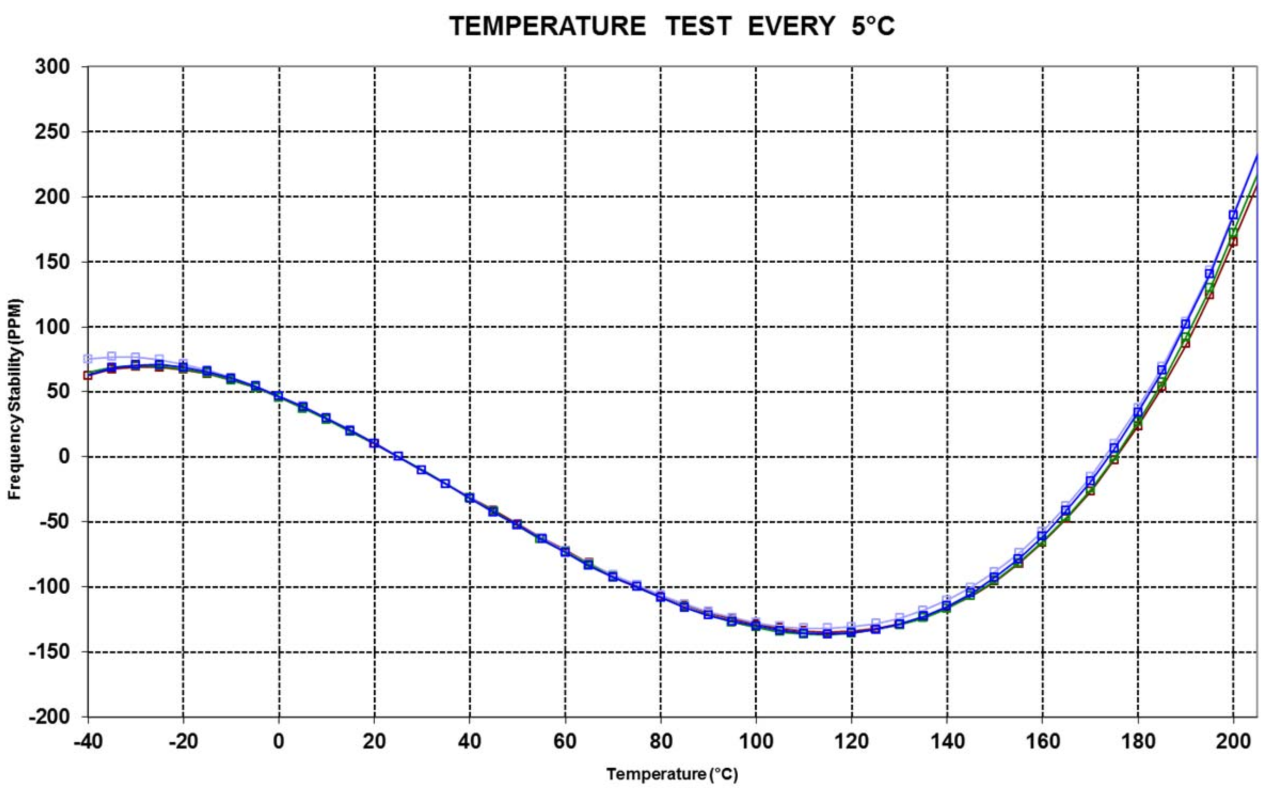


Figure 4