APPLICATION NOTE - Quartz Crystal Ageing

The 'ageing' of a quartz crystal results in a small change of frequency over time, and this effect may have to be taken into account by the customer when designing their circuit depending upon the overall specification that needs to be achieved. There are two main causes of ageing in quartz crystals, one due to mass-transfer and the other due to stress.

Mass-Transfer

Any unwanted contamination inside the device package can transfer material to or from the crystal, causing a change in the mass of the quartz blank, which will alter the frequency of the device. For example, the conductive epoxy used to mount the quartz blank can produce 'out-gassing', which can create oxidising material within the otherwise inert atmosphere inside the sealed crystal package. Therefore, the production process must be well controlled. Ideally, the manufacturing method should be as clean as possible to negate any effects and give good ageing results.

Stress

This can occur within various components of the crystal, including the processing of the quartz blank, the curing of the epoxy mounting adhesive, the crystal mounting structure and the type of metal electrode material used in the device. Heating and cooling also induce stress due to different expansion coefficients. Stress in the system usually changes over time as the system relaxes, and this can cause a change in frequency.

Ageing in practice

When looking at examples of ageing test results of crystals, it can be observed that the change in frequency is generally greatest in the 1st year and decays over with time. It must be noted, however, that if a device is specified at ±5ppm max per year; it does not follow that the ageing after 5yrs will be ±5ppm x 5yrs, i.e. ±25ppm. In practice, the example ±5ppm ageing device may be only ±1ppm to ±2ppm in the 1st year of operation and then reduce over subsequent years. It is common to use a general 'guide-rule' for crystal ageing of ±10ppm max over 10 years, although in reality it is usually much less than this.

It is impossible to fully predict the exact ageing of a device as even parts made at the same time, and from the same batch of quartz, will exhibit slightly different ageing characteristics. Although the production process must be consistent from part to part, various factors ranging from the manufacturing of the quartz blank, the size and placement of electrode, to the epoxy used for mounting the quartz and its curing thermal profile, all have a slight effect on frequency. Devices can age negatively or positively, depending on the internal causes, although parts from one batch tend to follow similar results. Generally, the ageing effect is negative in over 90% of parts manufactured.

Accelerated ageing

It is common industry practice to use an accelerated ageing process to predict long-term frequency movement. This is achieved by soaking devices at elevated temperatures and measuring frequency changes at relevant time intervals. It is customary to test crystals using a passive method (i.e. non-powered). The general rule employed is that soaking a crystal at +85°C for 30 days is considered equivalent to 1 year of ageing at normal room temperature. If this test is extended for sufficient duration, the recorded data can be graphically plotted to enable extrapolation, thereby predicting the aspect of future long-term ageing.

Frequency adjustment

Note that the ageing of quartz effectively changes the frequency tolerance of the crystal and does not directly influence the stability of the quartz crystal to any great degree, as this parameter is dictated by the 'cut-angle' of the quartz used.

When using quartz oscillators that have a voltage-control function, such as VCXOs, TCXOs or OCXOs, the output frequency can be adjusted back to its nominally specified value.

Design

The engineer designing a circuit, using either a crystal or oscillator will generally know what overall stability figure their equipment must meet over a particular time period.

As the tolerance and/or stability of a device decrease, the important of ageing becomes more significant. For example, using a TCXO at ±1ppm stability will require ageing to be kept at relatively small values. However, if the total frequency movement allowance of a design is, for example ±200ppm, and a device with a rating of ±100ppm is used, then a small amount of ageing can effectively be ignored.

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