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 and so this production process must be well controlled. Ideally the manufacturing method is as clean as possible to negate any effects and give good ageing results.

Stress

This can occur within various components of the crystal from 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 causes 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 example ageing test results of crystals, it can be seen that the change in frequency is generally greatest in the 1st year and decays away with time. It must be noted however that for example if a device is specified at ±5ppm max per year; it does not follow that the ageing after 5 yrs 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 reduces 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 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.

The production process must be consistent from part to part, from the manufacture of the quartz blank, the electrode size and its placement, to the epoxy used to mount the quartz and its curing thermal profile, all have a slight affect on frequency. Devices can age negatively or positively depending upon 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 by soaking devices at elevated temperatures and measuring frequency movement at relevant intervals. It is normal to test crystals using a passive test (i.e. non-powered). The general rule used is that soaking a crystal at +85°C for 30 days is equivalent to 1 year of ageing at normal room temperature. If this test is extended for enough time then the recorded data can be plotted graphically to enable via extrapolation, the prediction 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 over temperature to any great degree as this parameter is dictated by the 'cut-angle' of the quartz used. If 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 decreases then the more important ageing becomes. For example using a TCXO at ±1ppm stability over temperature will require ageing to be kept to 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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