Is the size alone decisive?

When space is limited for embedded computers, the obvious solution is to use a quartz crystal with a very small design. However, many application boards are still released with very large crystals. Therefore, you can still find the electrical specifications of the larger crystals in the application notes of these microcontrollers. These are often crystals in metal packages like HC-49/KX-3H or HC-49/SMD. If a much smaller crystal is used, such specifications can no longer be met. This can unsettle some users when they are faced with the decision to tackle a re-design of their application. This paper will attempt to highlight the differences between large and small quartz crystals and provide practical advice on how to determine the optimum quartz size.

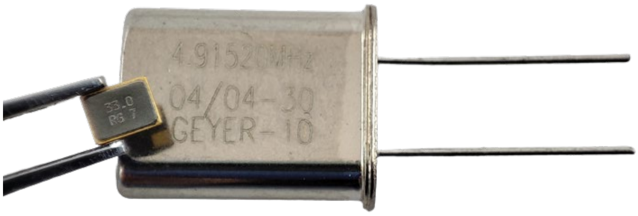

Fig 1: A modern SMD crystal over a quartz of the older design "HC-49" (3.2 x 2.5 mm or 13 x 10 mm). The volume for the accommodation of the quartz disk is much smaller. This has consequences for the electrical properties, which must be taken into account. (GEYER Electronic)

Low ESR – a challenge for smaller designs

Figure 1 shows a quartz of the older "HC-49" design behind a modern SMD quartz in a ceramic package. The consequences for the electrical behavior are obvious due to the highly reduced volume. Despite improved production methods, the low resonant resistances of the HC-49 cannot be achieved in every smaller package. The smaller the inner quartz disk, the higher the resonant resistance (ESR). At the same time, the power handling capacity of the crystal is lower. Both are at the expense of the oscillation reserve. Therefore, the oscillator circuit should be optimally matched to the crystal used. For dimensioning and testing of the oscillating safety please read our document "Oscillating crystal or quartz oscillator - how to use?"

Very small crystals only starting at 8 MHz

Small quartz crystal are only available above 8 MHz and this minimum frequency increases as the package gets smaller. This is due to the natural interference at the edges of each crystal and undesirable oscillation modes. Without suitable suppression of these interferences, spurious resonances will occur. At low frequencies, the thickness-to-diameter ratio of the quartz disk is greater and suppression of the edge effects becomes more difficult.

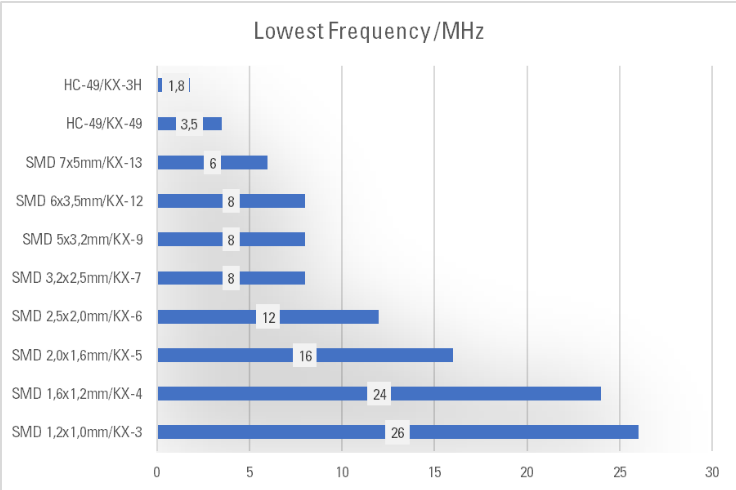

Figure 2: Available frequencies for different sizes. (GEYER Electronic)

Tight tolerances for applications like Bluetooth

No special requirements are placed on the oscillating crystals for the usual clock applications. The situation is different, however, when the transmitter and receiver have to be tuned to each other, as is the case with Bluetooth, for example. Bluetooth requires a particularly narrow tolerance (+/-20 ppm) for a circuit using crystals. The technical limit for oscillating crystals is just about this specification (i.e. +/-10 ppm at 25°C plus +/-10 ppm over the temperature range). Even though the technology is continuously developing, the required tolerances can still be achieved to a limited extent for small sizes, as Table 1 shows.

SMD package	7 x 5 mm	6 x 3,5 mm	3 x 2,5 mm
Temperature range /°C	-40 ...+85	-25 ...+85	-20 ...+70

Table 1: Temperature range of various crystals that can be used for Bluetooth (i.e. +/-10 ppm at 25°C and +/-10 ppm in temperature range). The frequency is 13 MHz. (GEYER Electronic)

More pulling sensitivity with larger crystals

Quartz crystals and oscillators are characterized by a pulling tolerance, which is:

1. proportional to the dynamic capacitance C1. The larger the case, the larger the crystal and the possible C1.

2. inversely proportional to the square of (C0 + CL). Thus, smaller CL results in higher draw sensitivity. However, too small a nominal load capacitance makes adjustment to the required nominal frequency difficult or reduces frequency stability for the user.

Table 2 shows typical draw sensitivities for common oscillating crystals. As can be seen, the realizable pull sensitivity increases with larger packages. The last two columns also show the improved draw sensitivity with smaller load capacitance.

In addition, it is generally clear that the draw sensitivity increases with frequency - a larger C1 can be realized at higher frequencies.

Frequency	Pulling sensitivity in ppm/pF			
SMD package	HC-49U	7 x 5 mm	5 x 3,2 mm	5 x 3,2 mm
Load capacitance	16 pF	16 pF	16 pF	12 pF
8 MHz	11	9	5	8
16 MHz	16	13	8	12

Table 2: Pulling sensitivity of different sized oscillating crystals. The load capacitances correspond to typical values in this design. (GEYER Electronic)

Conclusions

Re-designs or new designs with small sizes and ever lower power consumption are now commonplace. However, physics still plays a major role in the manufacturing of crystals and therefore the influence of ESR, CL and pull sensitivity must be taken into account in a good, future-oriented design.

Please contact us with your request - we will support you with the design.

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