more than you expect

WÜRTH ELEKTRONIK

DESIGN KIT

WE-XTAL 32.768 kHz Watch Crystals

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- Time Keeping with Quartz Crystals
- Quartz Crystal Handling Precautions

Version 1.0

Order Code 830 001

Introduction

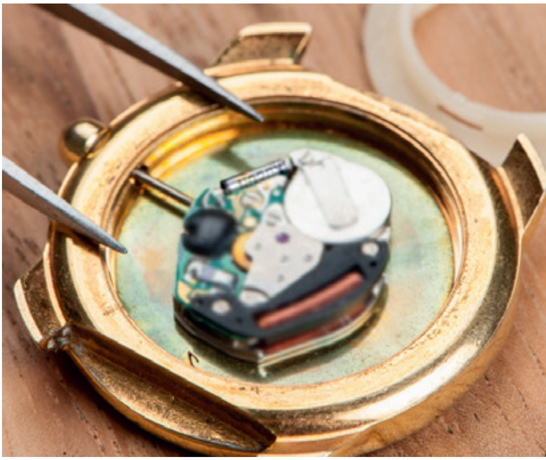
In the majority of electronic designs a Real Time Clock is required to enable the application to run a clock or maybe time stamp activities, etc. The RTC will either be a standalone component or more commonly embedded in the microprocessor or chipset. In all cases the RTC requires a precise clocking frequency to enable it to keep the correct time. The frequency used is 32.768 kHz as this can be divided down using a 15 stage binary counter to 1 Hz (1 second).

In 1969 the first watch was manufactured using a 32.768 kHz quartz crystal and these low cost crystals became known as watch crystals. The actual quartz used is an X-cut type with two prongs and known as a tuning fork. This cut of quartz has a low temperature coefficient, low impedance and low C0/C1 ratio which makes these crystals ideal as the standard timekeeping reference for the electronics industry.

Specification requirements

Break down of specification required to be able to quote the correct part:

1. Package size: (mm)
2. Frequency of oscillation: 32.768 kHz
3. Tolerance: (±ppm). The maximum acceptable deviation from the frequency of oscillation, when at 25 °C
4. Load Capacitance (pF). The combined capacitance presented to the crystal by the PCB.



Timekeeping with Quartz Crystals

Since its introduction the 32.768 kHz miniature watch crystal has become the most popular time keeping reference ever. This application note is intended to give some guidance as to the use of quartz crystals in time keeping applications.

In almost all circumstances designers will want to use simple logic gate oscillators for this application for the sake of convenience and cost. The criteria normally applied to this type of design are that it should be accurate, low in cost and low in power consumption. Using a watch crystal and CMOS logic all these criteria can be met.

In a CMOS oscillator circuit, power consumption rises with frequency and so it makes sense to reduce the operation frequency to a minimum; this is the reason for choosing 32.768 kHz. The second way of reducing power consumption in a CMOS circuit is to reduce the size of any loads being driven. It is partly for this reason that watch crystals are designed to operate with typically CL of 12.5 pF or 6 pF load, instead of the more usual 20 or 30 pF used for MHz crystals. It also has to do with: (a) to keep the crystal drive level low while maintaining adequate inverter input voltage, and (b) to allow the use of a very tiny trimmer capacitor while still providing the necessary trimming range.

The basic requirements of a CMOS inverter oscillator can be met with a single gate and a handful of other components to provide bias and feedback. Figure 1 shows a typical circuit of this type. The load capacitance seen by the quartz crystal is the series combination of Cout and Cin together with any circuit strays including the logic gate input and output pin capacitances. The component values used in figure 1 work well and give good correlation with measured test results obtained from a Saunders 250B crystal impedance meter. The apparent load capacitance presented to the crystal is:

$$\frac{C_{out} \, x \, C_{in}}{C_{out} + C_{in}}$$

C_{out} = Gate output capacitor
C_{in} = Gate input capacitor

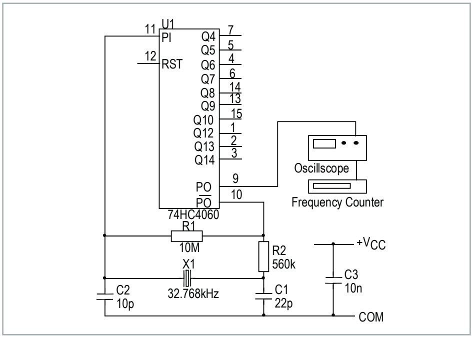


Figure 1

Timekeeping with Quartz Crystals

This gives a figure of 6.9 pF load. This is well below the required figure of 12.5 pF, however both the input and output pins of the logic gate present an appreciable load. These additional values need to be added to the 6.9 pF. These loads will typically be in the order of 3 pF to 4 pF per pin but can be up to 10 pF and will also depend on the logic family used. These extra loads together with any stray capacitances in circuit should add up to 12.5 pF.

If a trimmable oscillator is needed, the 22 pF output capacitor can be replaced by a fixed 10 pF capacitor in parallel with a 2 pF to 22 pF trimmer. For best results NPO, COG or similar low-temperature-coefficient dielectric capacitors should be used for best stability.

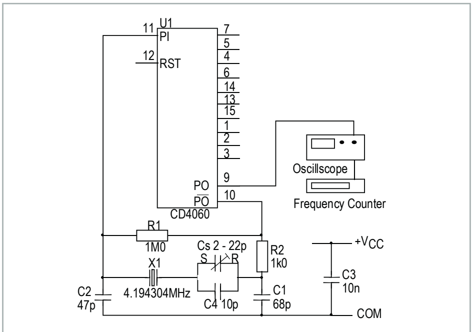


Figure 2

A frequently expressed requirement for oscillators such as this is close tolerance, often indeed in layouts in which no provision will be made for a trimmer. Apart from the effect of capacitor tolerances, it must be appreciated that because their values are low, the somewhat variable impedances attributable to the IC will result in a somewhat uncertain phase shift, hence oscillation frequency. A trimmer is recommended strongly, therefore, if precision better than, say, ±50 ppm is needed, regardless of the actual crystal tolerance.

The other important effect is that due to temperature variation. Watch crystals and other similar types below 1 MHz have a parabolic frequency-temperature characteristic with a design turnover temperature of 25 °C (see Figure 3). The tolerance of the turnover temperature and the parabolic curvature constant, typically ±3 °C and 0.038 ppm/°C2 respectively, mean that close tolerances can be maintained over only a limited temperature range. This is of little consequence in a watch, of course, since in use it is kept close to the crystal's turnover temperature, but it could render the choice of this type of crystal less cost effective than an AT-cut unit if an operating temperature range wider than 0 to 50 °C is desired.

A similar circuit for 4.194304 MHz (32.768 kHz x 27) AT-cut crystals is illustrated in Figure 2 C3 and C4 are intended to facilitate precise frequency trimming of crystals calibrated at the standard clock crystal load of 12 pF. If trimming is not required, either replace those capacitors with a 18 pF or 22 pF fixed unit (choose the value which results in oscillation closest to nominal frequency), or omit them altogether and specify the crystals for calibration at 30 pF load.

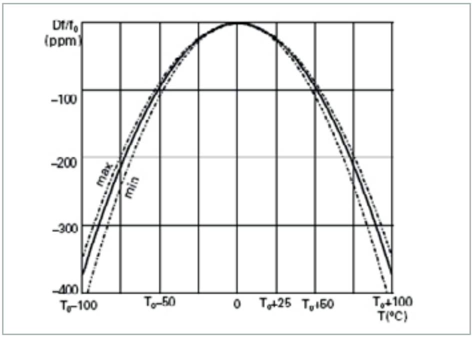


Figure 3

Crystal Handling Precautions

Crystal Unit Structure

A quartz crystal unit includes a small strip or disk of quartz that is processed to an exact size and thickness dependent on the customer specified resonating frequency. The quartz is plated with conducting electrodes and mounted in a hermetically sealed protective enclosure (see Figure 1).

The electrodes connect to leads that pass through the base assembly via glass-to-metal seals or, in the case of a SMD ceramic package (see Figure 1); the electrodes connect to the pads via layered plated ceramic.

Crystal units are often encapsulated together with other circuitry to realize a fully functional module, e.g. an oscillator or a complex filter. Figure 3 illustrates simple crystal oscillators. Because of the nature of the crystal unit, correct handling is very important.

Mechanical shock

Crystal components are manufactured to withstand a certain level of mechanical shock. These levels are outlined within the environmental specifications for each individual component type throughout out the specification sheets.

Excessive levels of shock can cause a change to the electrical characteristics, which will most likely manifest itself as a change of frequency. Severe mistreatment, such as dropping onto a hard surface, may well result in actual breakage of the quartz blank. In the case of ceramic packaged components it is also possible that the ceramic may crack, resulting in a loss of hermeticity.

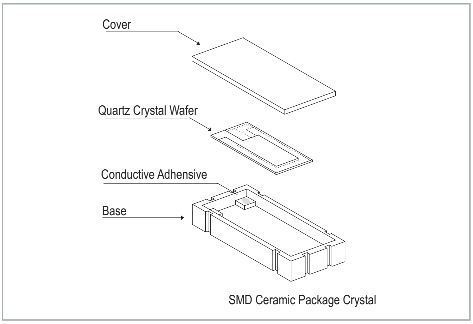


Figure 1

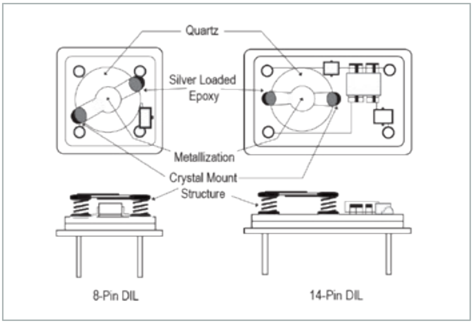


Figure 2

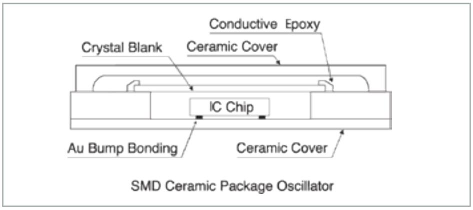


Figure 3

Crystal Handling Precautions

Handling leads

Excessive bending of leads can cause damage to the glass to metal seal, which can result in loss of hermeticity of the enclosure. Enclosures are filled with a dry inert gas and loss of hermeticity will result in a rapid deterioration of the product due to atmospheric contamination. Care should therefore be taken when handling a crystal not to pull or bend the leads. If the component needs to be moved in a way that involves bending, the lead should be bent slightly away from the glass seal to avoid cracking it. The recommended minimum radius of curvature is product dependent, e.g. 2 mm for HC49 crystals and 1mm for UM1s.

Tape-and-reel product

Before using crystal components on automated placement machines, tests should be undertaken to assess the level of shock that the crystal devices will be subjected to during the placement process. If necessary the shock level should be reduced.

Cracked HC49

Temperature

If crystals are subjected to extreme temperatures outside storage temperature limits, the electrical performance can be affected, resulting in eventual failure. During soldering it will be necessary to subject the components to high temperatures for limited periods of time, please refer to the RoHS Status of IQD Products document for maximum limiting values.

Broken Watch Crystal

Electrostatic discharge (ESD)

Only at extreme voltages can static electricity be seen, heard or even felt, but even the lowest voltages can damage electronic circuits. The damage caused to oscillators as a result of ESD may not immediately be evident but can be delayed, causing the oscillator circuitry to degrade, which in turn can cause failure of the oscillator in the field. Although quartz is not necessarily susceptible to ESD damage, the associated electronic circuitry contained within an oscillator is, and should be considered as an Electro Static Discharge Sensitive (ESDS) device. ESDS devices should only be handled in an ESD Protected Area (EPA), where proper precautions against ESD damage are taken.

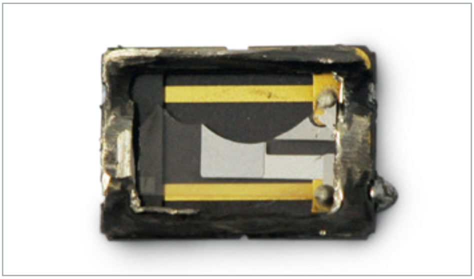
Crystal Handling Precautions

Any transportation should be undertaken using the appropriate protective packaging. All packaging should be marked with a warning notice, and protective measures and packaging should conform to BS EN 61340-5-1. For a more detailed breakdown of the precautions that should be taken, please contact our Customer Support Department.

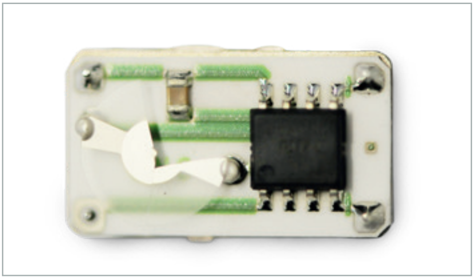
Moisture Sensitivity Level protection

A small number of oscillators sold by IQD Frequency Products are sensitive to moisture ingress. This means that they can absorb moisture from the atmosphere, then during reflow soldering the moisture expands into steam and can crack the package thus resulting in permanent damage.

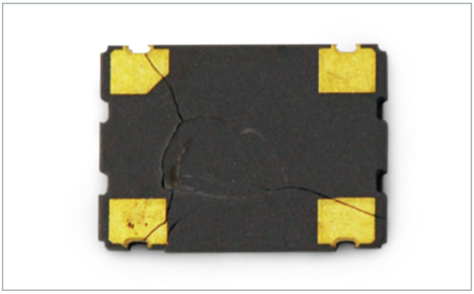
Levels of sensitivity to this type of damage are quantified with reference to JDEC-STD-020 and the relevant MSL level will be given on the device data sheet. On occasions when product is sensitive to this type of damage the product will arrive with you packaged and marked in accordance with JDEC-STD-033. Storage and handling of these products should continue to be performed in accordance with JDEC-STD-033 to avoid damage to the product during reflow.



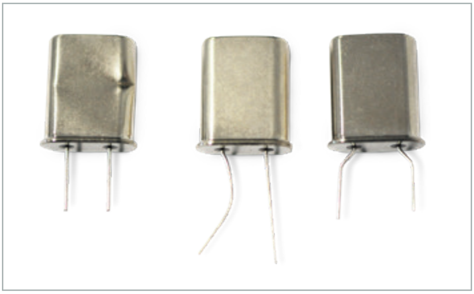
Cracked Strip Resonator



Cracked 14-pin DIL



Cracked Ceramic Package



Bent Leads

more than you expect

Würth Elektronik eiSos differs from all other component manufacturers in several aspects:

- We guarantee all catalogue products are manufactured to stock
- Samples free of charge
- Orders below MOQ
- Design kits with lifelong free refill
- Design Guide Trilogy of Magnetics, Trilogy of Connectors, Abc of Capacitors, Abc of Power Modules & Application Handbook The LTspice IV Simulator
- Design Seminars and Webinars free of charge
- Reference designs of leading IC manufacturers
- Worldwide technical sales force and field application engineers on site

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