Crystals

This document addresses application and reliability characteristics for quartz crystal devices and Surface Acoustic Wave (SAW) devices. Information pertaining to military-grade quartz crystal units may be found in MIL-PRF-3098, “General Specification for Quartz Crystal Units” and MIL-PRF-55310, “General Specification for Crystal Controlled Oscillators”. Complete listings of the military specifications are available from DSCC (Defense Supply Center Columbus) 3990 E. Broad St., Columbus, Ohio, 43216-5000.

Quartz crystals have a number of applications and are employed in a variety of electronic circuits and systems. Quartz is the piezoelectric material used in most applications. Typical applications for piezoelectric crystals include frequency control (oscillators), delay lines, timing, and transducers.

Surface Acoustic Wave (SAW) devices are advanced electronic components used primarily in high frequency signal processing applications. Typical uses for SAW devices include band pass filters and delay lines.

Packaging

Crystals come in the many different packages, depending upon the application of the device. Surface mount technology is employed for both ceramic and plastic packages, and through-hole mounted devices are also available. Oscillator devices are also available in ceramic and plastic J-leaded configurations and in ceramic leadless chip form. Oscillators are also available in through-hole configurations in 14, 8, and 6 pin dual in-line packages. Recommend that oscillators are sealed in glass, metal, or ceramic packages, and hermetic packages are utilized where appropriate. Recommend that no adhesive or polymeric materials are used for package lid attachment or seal, and flux is not used in the final sealing process. Also, recommend that sufficient distance be maintained between the lid seal and any glass-to-metal seal to preclude damage or seal degradation when a welding process is used for final lid seal.

The packaging requirements outlined in MIL-PRF-3098 are recommended for general crystal units and the packaging requirements in MIL-PRF-55310 are recommended for crystal oscillator units. SAW devices can also be purchased in a variety of package styles. Metal can, dual in-line package, and flat pack styles are typical outlines that are used.

Failure Mechanisms and Anomalies

It is estimated that about 90% of quartz crystal failures are open circuits. The remaining 10% of failures occur when electrical contact remains but there is a

lack of oscillation due to the loss of the piezoelectric phenomena characteristic with the crystal structure.

Electrical parameters of piezoelectric crystals are deteriorated by excessive driving current or from high voltages that cause mechanical stress and movement to be generated in the crystal plate. When the voltage is excessive, mechanical forces cause motion in excess of the elastic limit of the crystal. This results in crystal fracture, such as a lifted platelet. Such fractures, when occurring in sufficient number, will cause enough change to the operating electrical characteristics for the crystal to go out of specification or to cease operation entirely.

For crystal units employed in systems for the intended purpose of frequency control, a crystal may experience a change in its frequency over of time. This phenomenon is known as aging, or drift. One of the primary causes for this is mass transfer to or from the resonator surfaces due to absorption and release of contamination. Another factor is the stress relief within the mounting structure or at the interface between the quartz and the electrodes. The aging rate for crystals tends to be greatest when the unit is new, as stabilization tends to occur as time passes. Temperature changes experienced by crystals can initiate the beginning of a new aging cycle. The aging temperature evaluation techniques outlined in MIL-PRF-3098 may be used as a guideline in addressing aging considerations for crystal units.

Reliability

MIL-HDBK-217 provides reliability prediction models for quartz crystal and SAW devices. For quartz crystals, the part failure rate is based upon the base failure rate, the quality factor of the part, and the environmental factor (the environment in which the device is used). The base failure rate is a function of the frequency (in MHz) of the crystal unit. For SAW devices, the part failure rate is a function of the part quality factor and the environmental factor.

Table 1. Derating Requirements for Surface Acoustic Wave (SAW) Devices

Parameter	Derating
Input Power from Max Limit (F > 500 MHz)	13 dBm
Input Power from Max Limit (F < 500 MHz)	18 dBm
Operating Temperature	125^{o}C

Derating

Standard crystal units do not require any special derating. The specified maximum and minimum parameters given in the specification should be used as limiting factors. Surface Acoustic Wave (SAW) devices should be derated in accordance with Table 1. The degree of derating is dependent on the frequency at which the device operates. At frequencies of about 500 MHz, the derating requirements are relaxed.

Design and Material

A quartz crystal acts as a stable mechanical resonator and determines the frequency generated in an oscillator circuit. The properties of a crystal device depend significantly upon the angles at which the wafers are cut from the mother crystal. In order to cover a wide range of frequencies, different cuts are used. Table 2 summarizes the significance of these cuts of the crystal material on device performance. Recommend the specification be consulted as to the type of material used for a given application.

Table 2. Common Crystal Material Cuts

Frequency	Cut Type
F > 1MHz	AT (most common), BT, SC (high precision applications)
F < 1MHz	CT, DT

As with any device, materials should be used which enable the crystal units to meet defined performance requirements. Recommend the guidelines provided in MIL-PRF-3098 and MIL-PRF-55310 be consulted for guidance on proper material management and usage.

Facility Assessment and Quality

Crystal units should be manufactured in such a manner as to ensure that quality is uniform and free from any defects that would adversely affect life, serviceability, or appearance. The interior of the crystal unit should not contain flux, particles, residue, or other foreign or undesirable materials. In addition, fractures or cracks should be avoided. Electrode abrasion and crystal element exposure to a halogen vapor should not be present. Recommend all crystals be subjected to the qualification and group tests outlined in MIL-PRF-3098 (crystal units) and MIL-PRF-55310 (crystal oscillators) to meet the highest quality requirements. However, tests and evaluations may be tailored as needed to

assure the highest quality possible for a given crystal application (dependent upon the environment in which it is used).

Sampling

Most crystal manufacturers employ a sampling plan to control the quality of the product. Sampling plans vary among manufacturers. Crystals manufactured to MIL-PRF-3098 and MIL-PRF-55310 require a specific number of samples be evaluated and that a certain number of defects not be exceeded. Recommend that these performance specifications be consulted to determine adequate sampling inspections and recommended sample sizes.

Process Controls

Crystal units and SAW devices should be purchased from a manufacturing line employing quality controls and a monitoring system of critical processes. The Component Evaluation System outlined in Appendix B of MIL-PRF-55310 is recommended for the purchase of quartz oscillators. In particular, for crystal oscillators, a demonstrated control of the wire bonding process is considered a critical process in manufacturing control. Such a process control program should, for example, include a process machine/operator evaluation, the destructive evaluation of test samples, elimination of non-conforming process machines, a detailed corrective action program, the presence of identifiable information records (e.g., to each machine, operator, work shift, and test date), a wire bonding strength test plan, and a lot sample bond strength test plan. Appendix B of MIL-PRF-55310 provides a guideline for the implementation of such a program.

Part Assessment

Additional qualification testing or screening by the user is dependent upon the specific application for which the device is to be employed. Examples of qualification and screening plans are outlined in MIL-PRF-3098 and MIL-PRF-55310 and should be considered for the assessment of crystal units and crystal oscillators. Product specifications should be consulted for the recommended screening and qualification provisions for SAW devices.

Handling and Storage Precautions

The ESD sensitivity of crystals depends on the particular packaging style and tolerance, with tight tolerance units considered more sensitive. As a whole, crystals are not considered particularly ESD sensitive, most can be treated as Class 3 ESD sensitive. However, some Surface Acoustic Wave (SAW) devices are considered Class 2 and even Class 1 sensitive, susceptible to ESD voltages of less than 1,000 volts. ESD damage in crystals usually causes only operational

degradation, but further ESD damage to a crystal can result in catastrophic failure.

Closing Comments

The use of crystal devices and SAW units manufactured to military specifications is preferred. The use of commercially manufactured product may be acceptable only if appropriate consideration is given to factors such as packaging, quality, screening, qualification and other factors, e.g. the application and environment in which the product is used. These factors will affect the reliability of the product.