NASA-STD-8739.11 Tutorial Crystal, Crystal Oscillator

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Acronyms

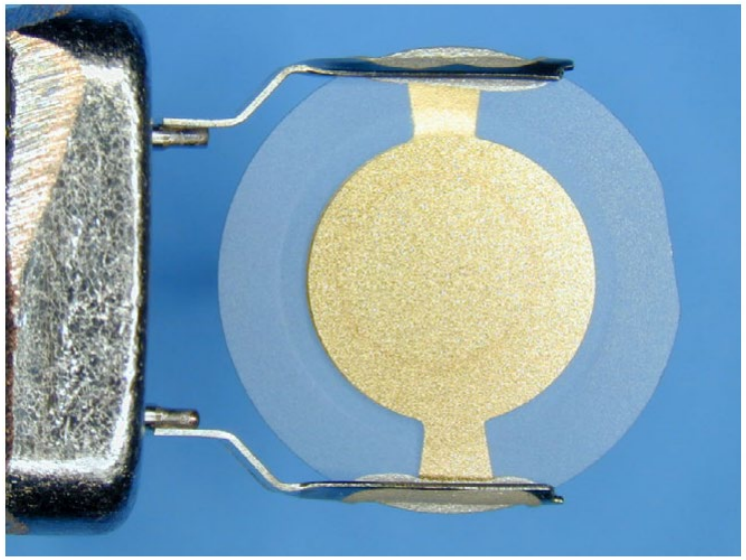
AEC	Automotive Electronics Council
COTS	Commercial-Off-The-Shelf
Cpk	Process Capability Index
DLA	Defense Logistics Agency
DoD	Department of Defense
DPA	Destructive Physical Analysis
DPPM	Defective Parts Per Million
EEEE	Electrical, Electronic, Electromechanical, Electro-Optical
EOL	End-Of-Line
ETW	Electronics Technology Workshop
FIT	Failure-In-Time
FMEA	Failure Mode and Effects Analysis
GSFC	Goddard Space Flight Center
IL	In-Line
ILPM	Industry Leading Parts Manufacturer
JEDEC	Joint Electron Device Engineering Council
LAT	Lot Acceptance Test
MEAL	Mission Environment, Application, and Lifetime
MIL-SPEC	Military Specification
NASA	National Aeronautics and Space Administration
NEPP	NASA Electronic Parts & Packaging (Program)
NESC	NASA Engineering & Safety Center
NSC	NASA Safety Center
PPAP	Production Part Approval Process
PSW	Part Submission Warrant
QML	Qualified Manufacturers List
QPL	Qualified Product List
RHA	Radiation Hardness Assurance
SMA	Safety and Mission Assurance
SMD	Standard Microcircuit Drawing
SME	Subject Matter Expert
SPC	Statistical Process Control

Crystals

- The most abundant mineral in the earth's crust is natural quartz.
- Natural quartz crystals are hard to manage. Therefore, industry uses synthetic quarts crystals.
- Synthetic quartz crystals show less frequency shift than natural quartz crystals.
- Frequency of oscillation of the quartz crystal is dependent on the thickness of the crystal







Key Considerations

- Less-pure synthetic quartz is more susceptible to radiation and temperature effects. Swept quartz is a treated quartz crystal with fewer impurities, also making it less sensitive to radiation effects.
  - Ensure the quartz has been evaluated to meet the intended radiation environment in the application
  - Obtain of certificate of conformance for the materials used in the construction of the packaged quartz units for materials source confirmation
  - Packaged quartz units should be hermetically sealed in vacuum or with a dry backfill gas—manufacturer records should document gas type, purity, moisture content, temperature, and pressure at the time of seal
  - Ensure soldering flux (when used) is completely removed from the crystal holder and package, leaving no residue on the internal cavity or external surfaces

Major Changes from EEE-INST-002

- Added discussion points in the introduction to the section (formerly covered in Table 1 Notes)
- Table 1 format has *not* changed much
  - No requirements imposed for Level 4
- Destructive Physical Analysis (DPA) added to Table 1 Requirements
- Screening flow was updated to conform with military specification flows
  - Significant reduction in screening test requirements for Levels 2 and 3. Level 3 only specifies Frequency & Resistance test (recommended) and external visual.
- Shifted to “lot acceptance test (LAT)” versus “qualification”
- No LAT required for Level 3
- Derating is limited to power only

Crystal Requirements

Table 1. CRYSTAL REQUIREMENTS 1/ 2/

Assurance Level	Specification	Use As Is	Screening	LAT	DPA
Level 1	MIL-PRF-3098		X		X
	SCD		X	X	X
Level 2	MIL-PRF-3098				X
	Automotive, Commercial, SCD		X	X	X
Level 3	MIL-PRF-3098				X
	Automotive, Commercial, SCD		X		X

Notes:

1/ The character "X" designates a requirement.

2/ Crystals shall be swept cultured quartz meeting the infrared assurance requirements of Grade A or Grade B per Electronic Components Industry Association ECIA EIA-477A for Levels 1 and 2 and is highly recommended for Levels 3 and 4.

Crystal Requirements

Table 2. CRYSTAL SCREENING 1/

Inspection/Test	Test Methods, Conditions, and Requirements	Assurance Level		
		Level 1	Level 2	Level 3
1. External Visual Inspection	MIL-PRF-3098 Paragraph 4.10.2.1 (Magnification 10X Minimum)	X	X	R
2. Thermal Frequency Repeatability	MIL-PRF-3098 Paragraph 4.10.15, 10 cycles	X		
3. Frequency & Resistance	MIL-PRF-3098 Paragraph 4.10.6	X		
	MIL-PRF-3098 Paragraph 4.10.18.1, -55 °C to +105 °C, 7 minutes, continuous measurements		X	R
4. Unwanted Modes	MIL-PRF-3098 Paragraph 4.10.9	X		
5. Capacitance Shunt	MIL-PRF-3098 Paragraph 4.10.7.1	X		
6. Quality Factor (Q)	MIL-PRF-3098 Paragraph 4.10.8	X		
7. Vibration	MIL-STD-202, Method 214, Condition 1F, $\Delta f/f \leq 1$ppm	X		
8. Thermal Shock	MIL-STD-202, Method 107, Condition B-1, $\Delta f/f \leq 1$ppm	X		
9. Aging 2/	MIL-PRF-3098 Paragraph 4.10.27.3, 30 days at 85 °C, $\Delta f/f \leq 2ppm$	X		
	MIL-PRF-3098 Paragraph 4.10.27.1, 30 days at 85 °C, $\Delta f/f \leq 5ppm$		X	
10. Maximum Percent Defective Allowable (PDA)		5%	10%	
11. Drive Sensitivity Frequency & Resistance	MIL-PRF-3098 Paragraph 4.10.11	X		
12. Insulation Resistance	MIL-PRF-3098 Paragraph 4.10.10	X		
13. Seal	MIL-STD-202, Method 112			
Fine Leak	Condition C, or G. Leakage Rate Sensitivity: 1 x 10^{-8}atm cm^3/s	X	X	
Gross Leak	Condition D, E or G	X		
14. Radiographic Inspection	MSFC-STD-355, Appendix M, View 1 in Y1 direction; View 2 90° relative to first view	X		
15. External Visual Inspection	MIL-PRF-3098 Paragraph 4.10.2.1 (Magnification 10X Minimum)	X	X	X

Notes:

1/ The character "X" designates a requirement. The character "R" designates a recommendation.

2/ If after 15 days the measured aging rate is equal to or less than one-half of the specified aging rate, the aging test may cease

Table 3. CRYSTAL LOT ACCEPTANCE TEST 1/

Inspection/Test	Test Methods, Conditions, and Requirements	Quantity (Accept Number)	
		Level 1	Level 2
Subgroup 1		15(0)	10(0)
Frequency and Resistance	MIL-PRF-3098 Paragraph 4.10.6	X	
	MIL-PRF-3098 Paragraph 4.10.18.1, -55 °C to +105 °C, 7 minutes, continuous measurements		X
Shock	MIL-STD-202, Method 213, Condition E or F	X	
	MIL-STD-202, Method 213, Condition C (100G)		X
Frequency and Resistance	MIL-PRF-3098 Paragraph 4.10.6	X	
	MIL-PRF-3098 Paragraph 4.10.18.1, -55 °C to +105 °C, 7 minutes, continuous measurements		X
Vibration (Frequency and Resistance Offset)	MIL-STD-202, Method 214, Condition 1K ($\Delta f/f \leq 1$ *ppm*)	X	X
	MIL-STD-202, Method 204, Condition A (10g), 3 hours per axis		
Thermal Frequency Repeatability	MIL-PRF-3098 Paragraph 4.10.15, 2 times	X	
Subgroup 2		15(0)	10(0)
Frequency and Resistance	MIL-PRF-3098 Paragraph 4.10.6	X	
	MIL-PRF-3098 Paragraph 4.10.18.1, -55 °C to +105 °C, 7 minutes, continuous measurements		X
Thermal Shock	MIL-STD-202, Method 107, Condition B-2 (50 cycles)	X	
	MIL-STD-202, Method 107, Condition B (exception 15 cycles)		X
Frequency and Resistance	MIL-PRF-3098 Paragraph 4.10.6	X	
	MIL-PRF-3098 Paragraph 4.10.18.1, -55 °C to +105 °C, 7 minutes, continuous measurements		X
Subgroup 3		15(0)	10(0)
Aging	MIL-PRF-3098 Paragraph 4.10.27.3, 40 days at 85 °C, $\Delta f/f \leq 2ppm$	X	
	MIL-PRF-3098 Paragraph 4.10.27.1, 30 days at 85 °C, $\Delta f/f \leq 5ppm$		X

Crystal Oscillators

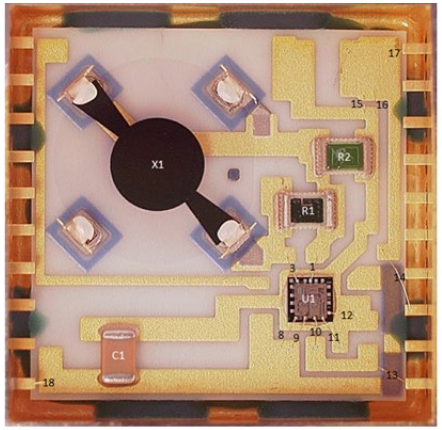
- Crystal oscillators are a hybrid technology comprised of microelectronic circuits with active and passive discrete devices and a piezoelectric crystal. There are 3 classes of crystal oscillators:
  - Class 1: Uses exclusively discrete type electronic parts (including surface mount devices), assembled and interconnected on a printed circuit board or insulating substrate
  - Class 2: Uses microelectronic circuit elements electrically and mechanically interconnected on an insulating substrate with deposited resistors, capacitors, or conductors. Used in a package backfilled with inert gas.
  - Class 3: Uses mixed technology (combination of discrete technology and microelectronic technology)

Crystal Oscillators

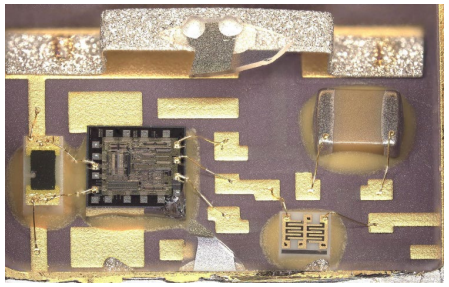
- All crystal oscillator classes are designed for a variety of frequencies and environmental conditions
- Multiple oscillator types are described in MIL-PRF-55310 for various applications, such as voltage, temperature, oven-controlled, etc.
- Automotive/commercial grade oscillators have similar designs, using commercial grade internal device elements in their construction

Crystal Oscillators

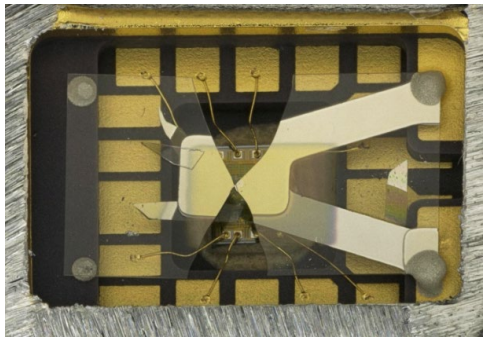


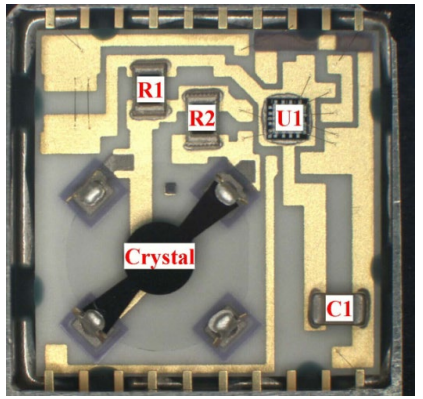












CRYSTAL OSCILLATOR TYPES PER MIL-PRF-55310

Description	Abbreviation	Oscillator Type No.
Crystal Oscillators	XO	1
Voltage-Controller Crystal Oscillators	VCXO	2
Temperature-Compensated Crystal Oscillators	TCXO	3
Oven-Controlled Crystal Oscillators	OCXO	4
Temperature-Compensated/Voltage-Controlled Crystal Oscillators	TCVCXO	5
Oven-Controlled Voltage-Controlled Crystal Oscillators	OCVCXO	6
Microcomputer-Compensated Crystal Oscillators	MCXO	7
Rubidium—Crystal Oscillators	RbXO	8
Surface Acoustic Wave Oscillators	SAWO	9

Major Changes from EEE-INST-002

- Added discussion points in the introduction to the section (formerly covered in Table 1 Notes)
- Requirements table (Table 1A) format has *not* changed much
  - No requirements imposed for Level 4
- Destructive Physical Analysis (DPA) added to Table 1A Requirements
- Added surface acoustic wave oscillators to Table 1B Crystal Oscillator Types
- Screening flow was updated to conform with military specification flows
  - Significant reduction in screening test requirements for Levels 2 and 3. Level 3 only specifies electrical test (recommended) and external visual.
- Shifted to “lot acceptance test (LAT)” versus “qualification”
- No LAT required for Level 3
- Table 4 derating factor applies to digital microcircuits only. Because oscillators are similar to hybrid microcircuits in construction, added Black Box derating method.

Crystal Oscillator Requirements

Table 1A. CRYSTAL OSCILLATOR REQUIREMENTS 1/

Assurance Level	Crystal Oscillator Class	Specification	Use As-Is	Element Eval /4	Screening	LAT	DPA
Level 1	QPL Class 1, 2 or 3 (Product Level S) **2/**	MIL-PRF-55310					X
	SCD	VICD, SCD		X	X 3/	X	X
Level 2	QPL Class 1, 2 or 3 (Product Level S, B)	MIL-PRF-55310					X
	Commercial, Automotive, SCD	VICD, SCD, AEC-Q200			X	X	X
Level 3	QPL Class 1, 2 or 3 (Product Level S, B, C)	MIL-PRF-55310	X				
	Commercial, Automotive, SCD	VICD, SCD, AEC-Q200			X		X

Notes:

1/ The character "X" designates a requirement.

2/ QPL Crystal Oscillator Class 1, Class 2 and Class 3 with temperature range C, D and E are not acceptable for Level 1 projects.

3/ PIND required unless already performed by manufacturer.

4/ Depending on Crystal Oscillator Class, Element Evaluation per MIL-PRF-55310, Appendix B.

DRAFT

Send email to address below for questions

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