TQC8021

Ultra-Small, 1 to 26 MHz Oscillator

Description

The TQC8021 is the industry's smallest and the lowest power MHz oscillator. With 0.1 mW of active power consumption at 3.072 MHz output frequency, this µPower oscillator enables longer battery life for a wearable, IoT or mobile device compared to a quartz-based oscillator or resonator.

The device comes in the smallest 1.5 mm x 0.8 mm package. The unique combination of ultra-low power, ultra-small package and flexible output frequency makes it ideal for power sensitive and space constrained applications including:

- Tablets
- Fitness bands
- Health and medical monitoring
- Wearables
- Portable audio
- Input devices
- IoT devices

Features

- Ultra-low current consumption of 60 µA at 3.072 MHz
- Ultra-small 1.5 mm x 0.8 mm package
- 1 to 26 MHz with 6 decimal places of accuracy
- Operating temperature from -40°C to 85°C. Contact TQC for -40°C to 105°C option
- Frequency stability as low as ±100 ppm. Contact TQCime for ±25 ppm or ±50 ppm options
- Programmable output drive strength for best EMI or driving multiple loads
- Ultra-light weight of 1.28 mg
- RoHS and REACH compliant, Pb-free, Halogen-free and Antimony-free

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TempFlat MEMS™

Electrical Specifications

Table 1. Electrical Characteristics

All Min and Max limits are specified over temperature and rated operating voltage with 15 pF output load unless otherwise stated. Typical values are at 25°C and nominal supply voltage.

Parameters	Symbol	Min.	Typ.	Max.	Unit	Condition
Frequency Range						
Output Frequency Range	f	1.000000		26.000000	MHz	
Frequency Stability and Aging						
Initial Tolerance	f_tol	-15	–	+15	ppm	Frequency offset at 25°C post reflow
Frequency Stability	f_stab	-100	–	+100	ppm	Inclusive of initial tolerance, and variations over operating temperature, rated power supply voltage and output load. Contact TQC for ±25 or ±50 ppm options.
First Year Aging	f_1year	-3		+3	ppm	at 25°C
Operating Temperature Range						
Operating Temperature Range	T_use	-20	–	+70	°C	Extended Commercial
		-40	–	+85	°C	Industrial. Contact TQC for -40°C to 105°C option.
Supply Voltage and Current Consumption						
Supply Voltage	VDD	1.62	1.8	1.98	V	Contact TQCime for 3.3V option
Current Consumption[1]	IDD	–	60	–	µA	f = 3.072 MHz, no load
		–	110	130	µA	f = 6.144 MHz, no load
		–	230	270	µA	f = 6.144 MHz, 10 pF load
		–	160	–	µA	f = 12 MHz, no load
Standby Current	I_std	–	0.7	1.3	µA	ST pin = HIGH, output is weakly pulled down
LVCMOS Output Characteristics						
Duty Cycle	DC	45	–	55	%	
Rise/Fall Time	T_r, T_f	–	4	8	ns	20% - 80%. Contact TQC for other programmable rise/fall options
Output High Voltage	VOH	90%	–	–	VDD	IOH = -0.5 mA
Output Low Voltage	VOL	–	–	10%	VDD	IOL = 0.5 mA
Input Characteristics						
Input High Voltage	VIH	80%	–	–	VDD	
Input Low Voltage	VIL	–	–	20%	VDD	
Input Slew Rate	In-slew	10	–	–	V/µs	
Input Pull-down Impedance	Z_in	300	–	–	kΩ	Active mode (ST pin = LOW)
		2.5	4	–	MΩ	Standby mode (ST pin = HIGH)

Electrical Specifications

Table 1. Electrical Characteristics

All Min and Max limits are specified over temperature and rated operating voltage with 15 pF output load unless otherwise stated. Typical values are at 25°C and nominal supply voltage.

Parameters	Symbol	Min.	Typ.	Max.	Unit	Condition
Startup, Standby and Resume Timing						
Startup Time	T_start	–	75	150	ms	Measured from the time VDD reaches 90% of its final value
Standby Time	T_stdby	–	–	20	µs	Measured from the time ST pin crosses 50% threshold
Resume Time	T_resume	–	2	3	ms	Measured from the time ST pin crosses 50% threshold
Jitter						
RMS Period Jitter	T_jitt	–	75	110	ps	f = 6.144 MHz
RMS Phase Jitter	T_phj	–	0.8	2.5	ns	f = 6.144 MHz, Integration bandwidth = 100 Hz to 40 kHz
						Note 2

Notes:

1. Current consumption with load is a function of the output frequency and output load. For any given output frequency, the capacitive loading will increase current consumption equal to C_load*VDD*f(MHz).
2. Max spec inclusive of 25 mV peak-to-peak sinusoidal noise on VDD. Noise frequency 100 Hz to 20 MHz.

Table 2. Pin Description

Pin	Symbol	Functionality	
1	ST	Input	L: Specified frequency output H: Output is low (weak pull down). Device goes to the standby mode. Supply current reduces to I_std.
2	OUT	Output	LVCMOS clock output
3	VDD	Power	Supply voltage. Bypass with a 0.01µF X7R capacitor.
4	GND	Power	Connect to ground

Top View

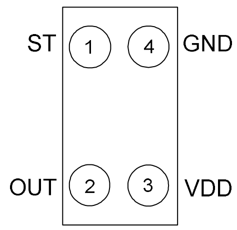


Figure 1. Pin Assignments

Table 3. Absolute Maximum Limits

Attempted operation outside the absolute maximum ratings may cause permanent damage to the part. Actual performance of the IC is only guaranteed within the operational specifications, not at absolute maximum ratings.

Parameter	Test Condition	Value	Unit
Continuous Power Supply Voltage Range (VDD)		-0.5 to 3.63	V
Short Duration Maximum Power Supply Voltage (VDD)	<30 seconds	4.0	V
Continuous Maximum Operating Temperature		105	°C
Short Duration Maximum Operating Temperature	≤30 seconds	125	°C
Human Body Model (HBM) ESD Protection	JESD22-A115	2000	V
Charge-Device Model (CDM) ESD Protection	JESD22-C101	750	V
Machine Model (MM) ESD Protection	T_A = 25°C	200	V
Latch-up Tolerance	JESD78 Compliant		
Mechanical Shock Resistance	MIl 883, Method 2002	10,000	*g*
Mechanical Vibration Resistance	MIl 883, Method 2007	70	*g*
1508 CSP Junction Temperature		150	°C
Storage Temperature		-65 to 150	°C
Soldering Temperature (follow standard Pb free soldering guidelines)	–	260	°C

Block Diagram

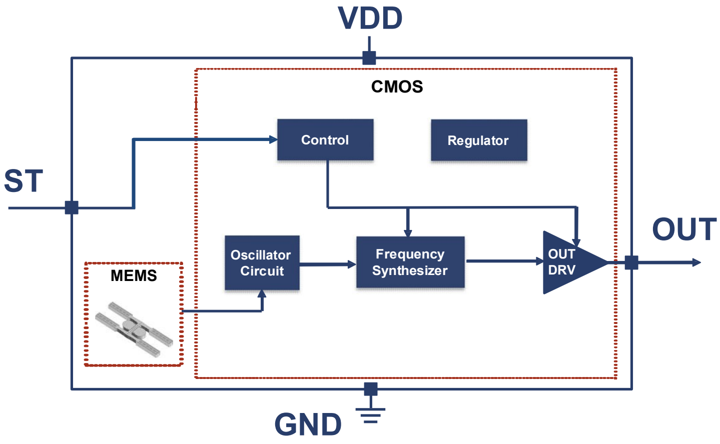


Figure 2. TQC8021 Block Diagram

Device Operating Modes and Outputs

The TQC8021 supports a ≤0.7 μA standby mode for battery-powered and other power sensitive applications. The switching between the active and standby modes is controlled by the logic level on the ST pin as shown in the table below.

Table 4. Operating Modes and Output States

ST Pin	MODE	OUTPUT	IDD Example
LOW	Active	Specified frequency	60 μA @ 3.072 MHz
FLOAT	Active with 200 kΩ internal pull-down	Specified frequency	60 μA @ 3.072 MHz
HIGH	Standby	Hi-Z, pulled-down with 1 MΩ impedence	1.3 μA

Active Mode

The TQC8021 operates in the active mode when the ST pin is at logic LOW or FLOAT. In the active mode, the device uses the on-chip frequency synthesizer to generate an output from the internal MEMS resonator reference. The frequency of the output is factory programmed based on the device ordering code.

Standby Mode

The TQC8021 operates in the standby mode when the ST pin is at logic HIGH. In the standby mode, all internal circuits with the exception of the MEMS oscillator circuit and the ST pin detection logic are turned off to reduce power consumption. While in standby mode, the input impedance of the ST pin is increased to further reduce system-level power consumption.

The output driver of the device in the standby mode is pulled-down with 1 MΩ impedance.

Output During Startup and Resume

The TQC8021 starts up with the output disabled. The output is enabled once all internal circuit blocks are active, and logic LOW or FLOAT is detected on the ST pin.

As shown in Table 4, logic HIGH at the ST pin forces the TQC8021 into the "standby" state, causing the output to disable. Upon pulling the ST pin LOW, the device enters the "resume" state, keeping the output disabled. Once the "resume" state ends, the device output enables.

The first clock pulse after startup or resume is accurate to the rated stability.

Low Power Design Guidelines

For high EM noise environments, we recommend the following design guidelines:

- Place oscillator as far away from EM noise sources as possible (e.g., high-voltage switching regulators, motor drive control).
- Route noisy PCB traces, such as digital data lines or high di/dt power supply lines, away from the TQC oscillator.
- Place a solid GND plane underneath the TQC oscillator to shield the oscillator from noisy traces on the other board layers.

Manufacturing Guidelines

- No Ultrasonic or Megasonic Cleaning: Do not subject the TQC8021 to an ultrasonic or megasonic cleaning environment. Permanent damage or long-term reliability issues to the device may occur in such an event.
- Applying board-level underfill (BLUF) to the device is acceptable, but will cause a slight shift of few PPM in the initial frequency tolerance. Tested with UF3810, UF3808, and FP4530 underfill.
- Reflow profile, per JESD22-A113D.
- For additional manufacturing guidelines and marking/tape-reel instructions, click on the following link:

Test Circuits

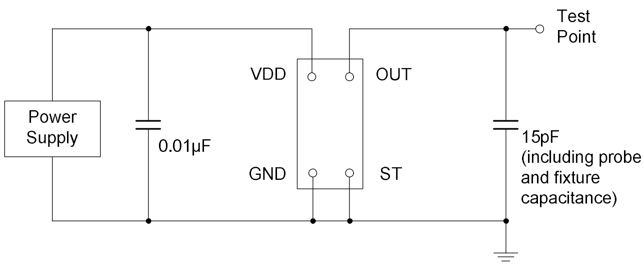


Figure 3. Test Circuit

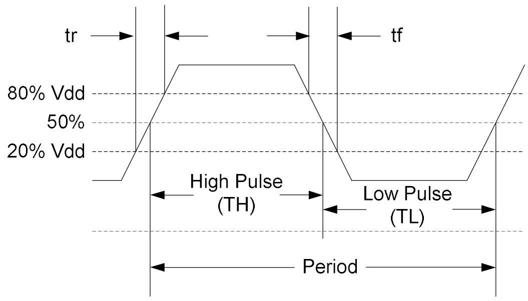


Figure 4. Waveform[3]

Note:

3. Duty Cycle is computed as Duty Cycle =TH/Period.

Timing Diagram

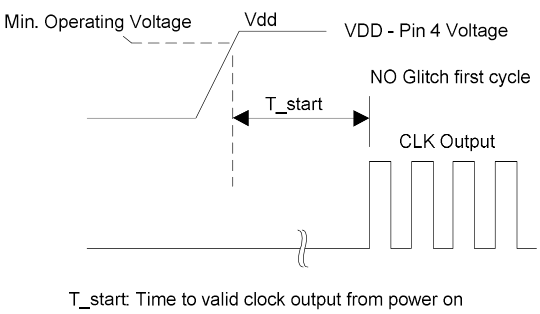


Figure 5. Startup Timing[4, 5]

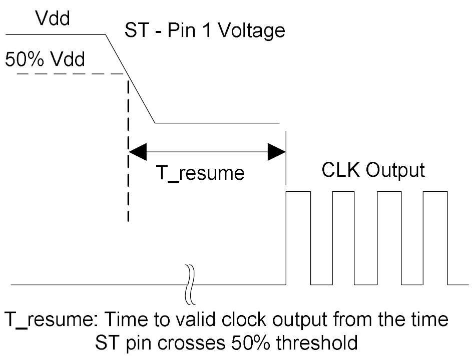


Figure 6. Resume Timing[4, 5]

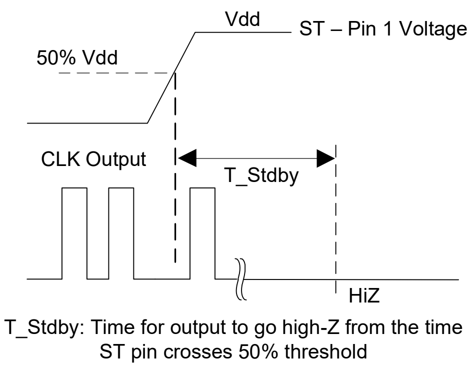


Figure 7. Standby Timing[4]

Notes:

4. TQC8021 supports "no runt" pulses and "no glitch" output during startup or resume.
5. TQC8021 supports gated output which is accurate within rated frequency stability from the first cycle.

TQC8021

Ultra-Small, 1 to 26 MHz Oscillator

Performance Plots[6]

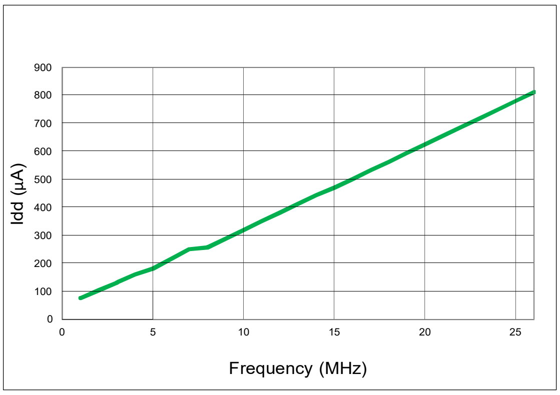


Figure 8. Idd vs Frequency[7]

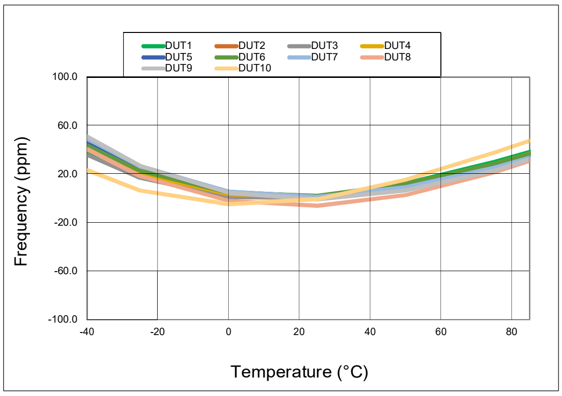


Figure 9. Frequency vs Temperature

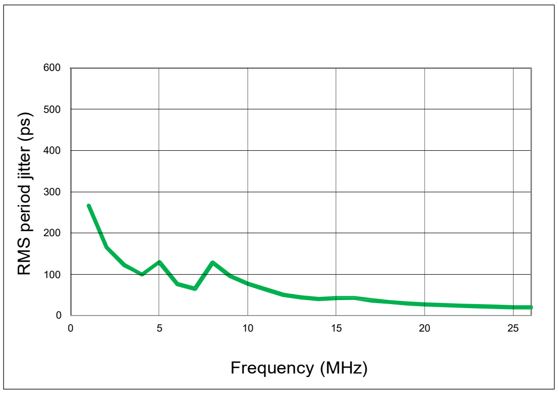


Figure 10. RMS Period Jitter vs Frequency

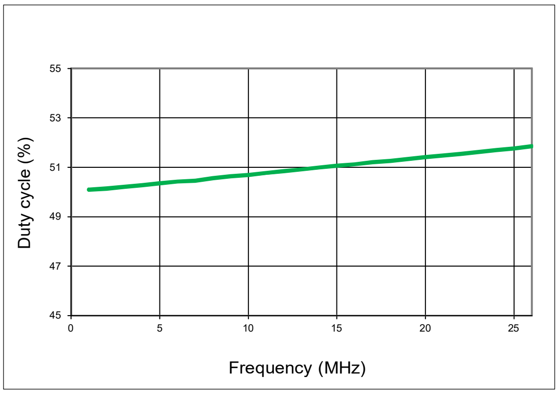


Figure 11. Duty Cycle vs Frequency

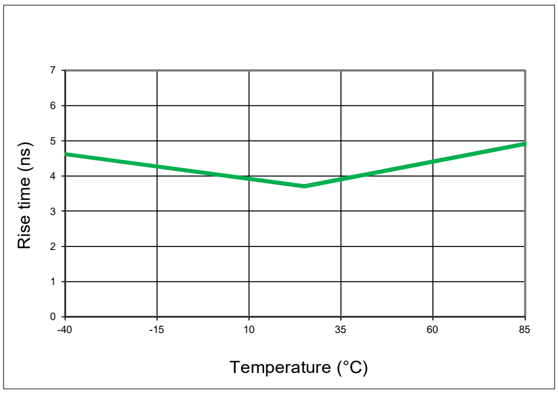


Figure 12. Rise Time vs Temperature[7]

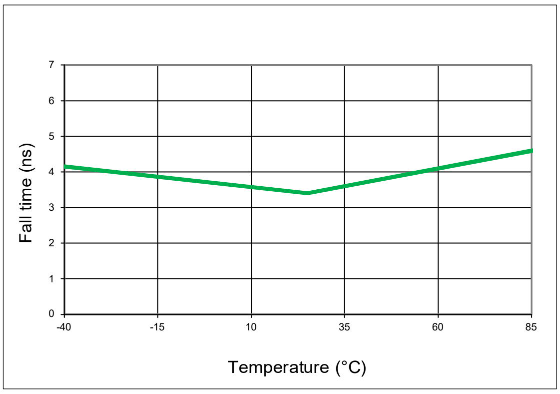


Figure 13. Fall Time vs Temperature[7]

Performance Plots[6]

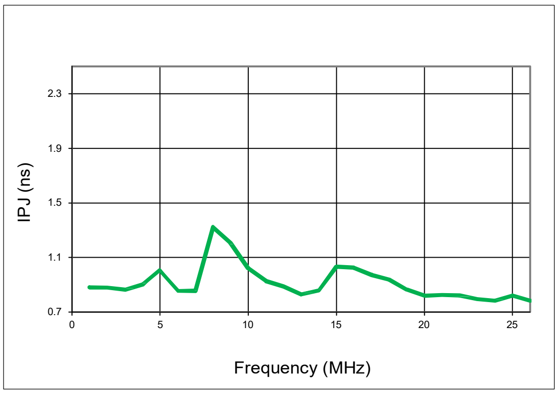


Figure 14. RMS Phase Jitter Random vs Frequency[8]

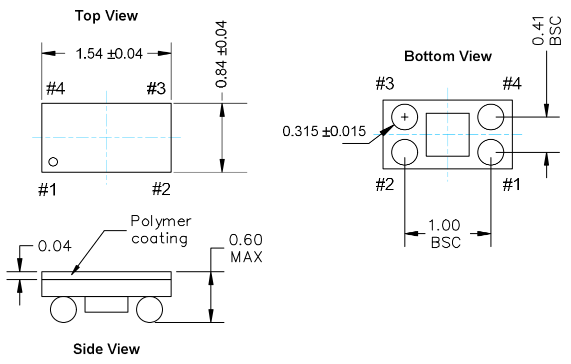
Notes:

6. All data is measured at room temperature, unless otherwise stated.
7. For Figure 8, data is measured with 10 pF load. For Figures 12 and 13, data is measured with 15 pF load.
8. Integration range is from 100 Hz to 40 kHz.

Dimensions and Patterns

<table>
<tr><th>Package Size – Dimensions (Unit: mm)</th><th>Recommended Land Pattern (Unit: mm)</th></tr>
<tr><td>

1.55 x 0.85 mm CSP



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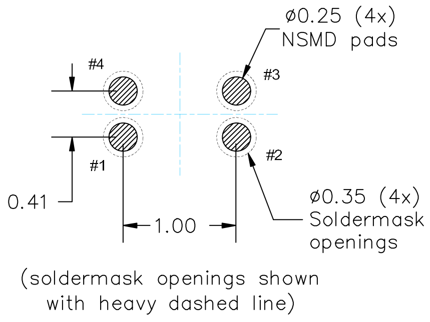

Recommend 4-mil (0.1mm) stencil thickness

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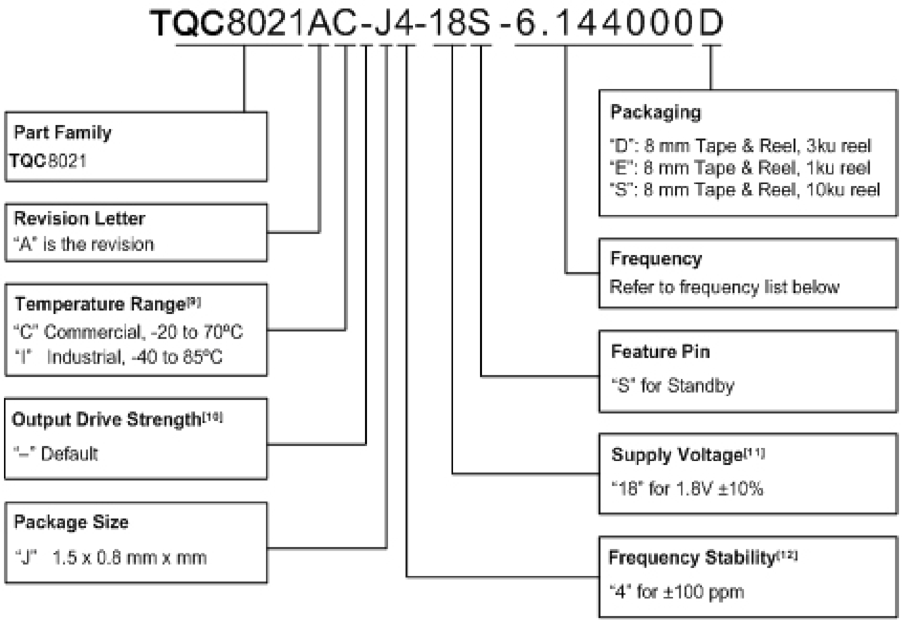
</table>

Ordering Information



Notes:

9. Contact TQC for -40 to 105ºC option.
10. Contact TQC for other drive strength options that result in different rise/fall time for any given output load.
11. Contact TQC for 3.3V option.
12. Contact TQC for ±25 or ±50 ppm options.

Table 5. List of Standard Frequencies [13]

2.048 MHz	4 MHz	6.144 MHz	12 MHz	12.288 MHz	16 MHz	19.2 MHz
24 MHz	26 MHz					

Notes:

13. All frequencies from 1 to 26 MHz are in production. Contact your TQC distributors or TQC sales offices from minimum order quantity requirement.

Revision History

Table 5. Datasheet Version and Change Log

Version	Release Date	Change Summary
0.1	12/15/14	Advance Information
0.2	1/27/15	• Updated CSP dimension tolerance • Removed 2.0 mm x 1.6 mm package • Changed to 6.144 MHz as the reference frequency for jitter, IDD and other relevant parameters • Changed resume time (max) to 5 ms • Changed the parameter PSNR to Power Supply Noise Sensitivity and specified in RMS
0.3	3/31/15	• Changed VIL and VIH values in the EC table • Reduced standby time in the EC table • Revised phase jitter condition to include power supply noise sensitivity • Removed power supply noise spec
0.9	5/22/15	• Added typical values for active and standby current • Added current consumption for additional frequencies • Changed ±50 ppm option to Contact TQC • Added manufacturing guideline • Other miscellaneous format and footnote changes
1.0	11/18/15	• Revised initial tolerance, current consumption, standby current, input high/low voltage, input pull-down impedance, startup/resume time and RMS period/phase jitter in Table.1 • Added performance plots
1.1	2/19/16	• Added 10 Standard frequencies to the ordering information

Silicon MEMS Outperforms Quartz

Best Reliability

Silicon is inherently more reliable than quartz. Figure 1 shows a comparison with quartz technology.

Why is EpiSeal™ MEMS Best in Class:

- EpiSeal MEMS resonators are hermetically vacuum-sealed during wafer processing, which eliminates foreign particles and improves long term aging and reliability
- MEMS resonator is paired with advanced analog IC

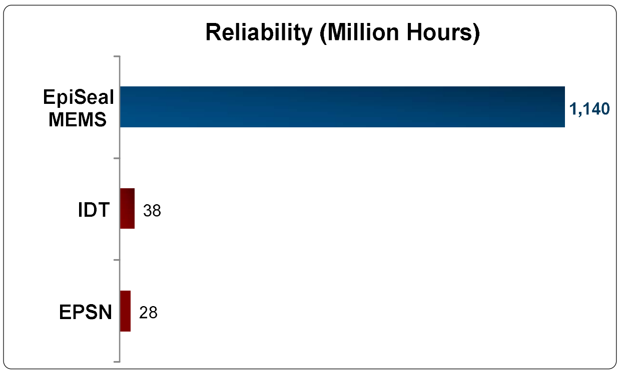


Figure 1. Reliability Comparison[1]

Best Electro Magnetic Susceptibility (EMS)

EpiSeal MEMS oscillators in plastic packages are up to 54 times more immune to external electromagnetic fields than quartz oscillators as shown in Figure 3.

Why is EpiSeal MEMS Best in Class:

- Internal differential architecture for best common mode noise rejection
- Electrostatically driven MEMS resonator is more immune to EMS

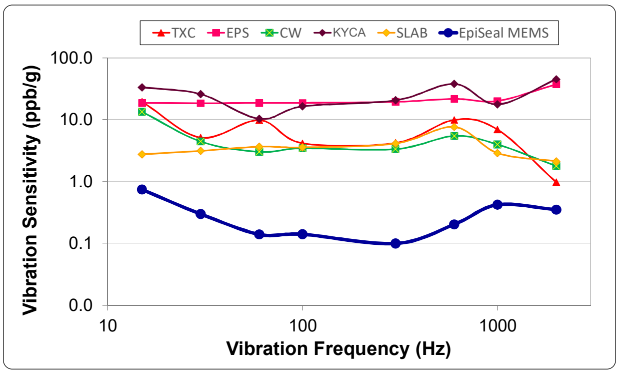


Figure 3. Electro Magnetic Susceptibility (EMS)[3]

Best Aging

Unlike quartz, EpiSeal MEMS oscillators have excellent long-term aging performance which is why every new EpiSeal MEMS product specifies 10-year aging.

Why is EpiSeal MEMS Best in Class:

- EpiSeal MEMS resonators are hermetically vacuum-sealed during wafer processing, which eliminates foreign particles and improves long term aging and reliability
- Inherently better immunity of electrostatically driven MEMS resonator

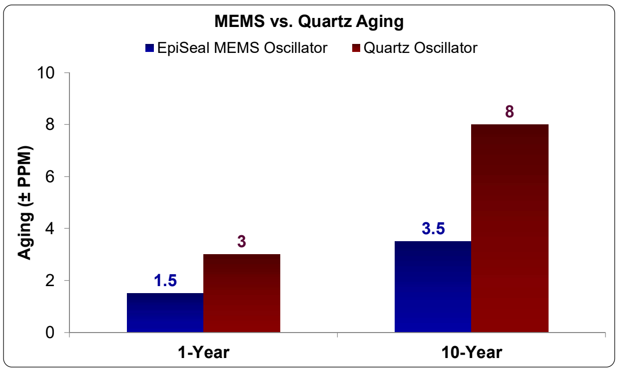


Figure 2. Aging Comparison[2]

Best Power Supply Noise Rejection

EpiSeal MEMS oscillators are more resilient against noise on the power supply. A comparison is shown in Figure 4.

Why is EpiSeal MEMS Best in Class:

- On-chip regulators and internal differential architecture for common mode noise rejection
- MEMS resonator is paired with advanced analog CMOS IC

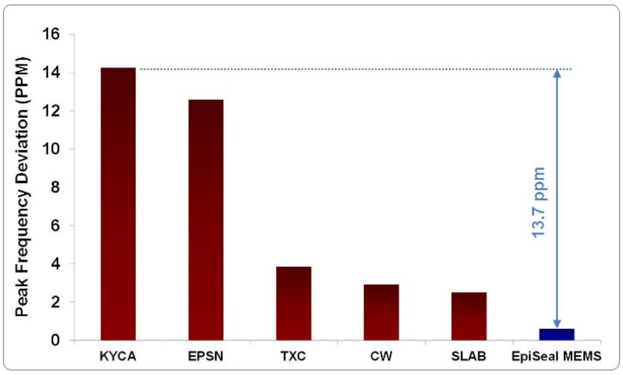


Figure 4. Power Supply Noise Rejection[4]

Best Vibration Robustness

High-vibration environments are all around us. All electronics, from handheld devices to enterprise servers and storage systems are subject to vibration. Figure 5 shows a comparison of vibration robustness.

Why is EpiSeal MEMS Best in Class:

- The moving mass of MEMS resonators is up to 3000 times smaller than quartz
- Center-anchored MEMS resonator is the most robust design

Best Shock Robustness

EpiSeal MEMS oscillators can withstand at least 50,000g shock. They maintain their electrical performance in operation during shock events. A comparison with quartz devices is shown in Figure 6.

Why is EpiSeal MEMS Best in Class:

- The moving mass of MEMS resonators is up to 3000 times smaller than quartz
- Center-anchored MEMS resonator is the most robust design

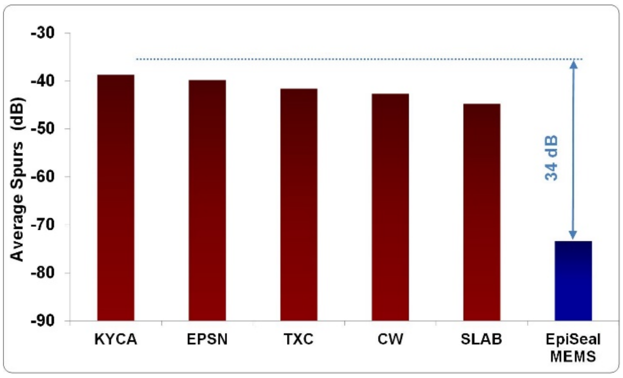


Figure 5. Vibration Robustness[5]

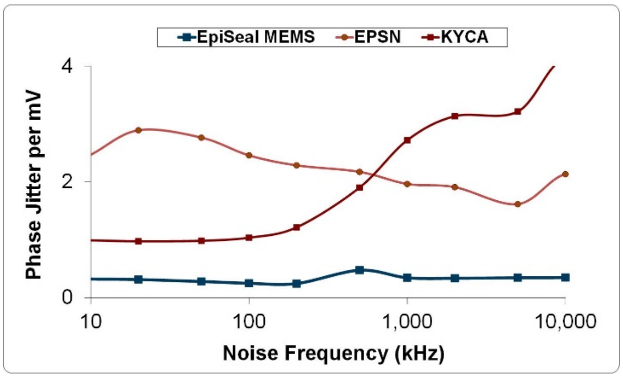


Figure 6. Shock Robustness[6]

Figure labels:

TXC = TXC
Epson = EPSN
Connor Winfield = CW
Kyocera = KYCA
SiLabs = SLAB
TQC = EpiSeal MEMS

Notes:

1. Data source: Reliability documents of named companies.
2. Data source: TQC and quartz oscillator devices datasheets.
3. Test conditions for Electro Magnetic Susceptibility (EMS):
   - According to IEC EN61000-4.3 (Electromagnetic compatibility standard)
   - Field strength: 3V/m
   - Radiated signal modulation: AM 1 kHz at 80% depth
   - Carrier frequency scan: 80 MHz – 1 GHz in 1% steps
   - Antenna polarization: Vertical
   - DUT position: Center aligned to antenna

   Devices used in this test:

Label	Manufacturer	Part Number	Technology
EpiSeal MEMS	TQC	TQC9120AC-1D2-33E156.250000	MEMS + PLL
EPSN	Epson	EG-2102CA156.2500M-PHPAL3	Quartz, SAW
TXC	TXC	BB-156.250MBE-T	Quartz, 3rd Overtone
CW	Conner Winfield	P123-156.25M	Quartz, 3rd Overtone
KYCA	AVX Kyocera	KC7050T156.250P30E00	Quartz, SAW
SLAB	SiLab	590AB-BDG	Quartz, 3rd Overtone + PLL

4. 50 mV pk-pk Sinusoidal voltage.

   Devices used in this test:

Label	Manufacturer	Part Number	Technology
EpiSeal MEMS	TQC	TQC8208AI-33-33E-25.000000	MEMS + PLL
NDK	NDK	NZ2523SB-25.6M	Quartz
KYCA	AVX Kyocera	KC2016B25M0C1GE00	Quartz
EPSN	Epson	SG-310SCF-25M0-MB3	Quartz

5. **Devices used in this test:**
   same as EMS test stated in Note 3.
6. Test conditions for shock test:
   - MIL-STD-883F Method 2002
   - Condition A: half sine wave shock pulse, 500-g, 1ms
   - Continuous frequency measurement in 100 μs gate time for 10 seconds

   Devices used in this test:
   same as EMS test stated in Note 3.
7. Additional data, including setup and detailed results, is available upon request to qualified customer.