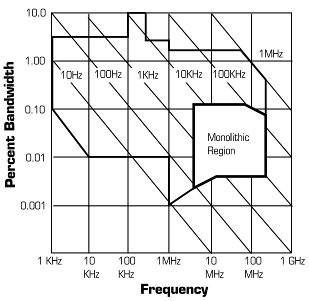
CRYSTAL FILTERS & CRYSTAL UNITS

The following section contains information about OFC Crystal Filters & Crystal Units

CRYSTAL FILTERS
Reference Tables

OPERATING REGIONS



Best Operating Regions

This chart gives the regions where crystal filters can be built. The “Discrete Filter” region shows where filters can be built using individual crystals, capacitors, coils, transformers and resistors. The “Monolithic” region defines where filters that employ two or more resonators per individual crystal unit (plus some other discrete components) can be manufactured.

The difficulty increases as the edge of the chart is approached and some filter types cannot be realized at or near the edge of the chart. Filters which fall in the two shaded regions will be the most producible and all approximation types can be realized within these regions.

Bandpass

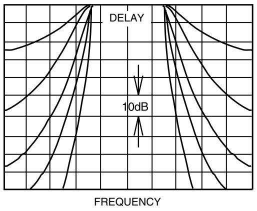
Bandpass filters will pass a band of frequencies and attenuate other bands of frequencies both above and below the passband. Single sideband filters are bandpass designs but they form such an important sub-set that they are often given their own classification.

Band Reject

Band reject filters attenuate a specified band of frequencies while passing a broad range of frequencies adjacent to the rejected band. Discriminators are similar to filters except that they produce an output DC voltage which is proportional to the input frequency.

Theoretical Shape Factors (60/3 dB) for Monotonic Responses

Number of Poles	2	3	4	5	6	8	10
Filter Type							
Butterworth	32	10.	5.6	4.0	3.2	2.4	2.2
Chebyshev 0.1 dB	29	8.5	4.4	3.0	2.3	1.7	1.4
Chebyshev 0.5 dB	27	7.7	4.0	2.7	2.2	1.6	1.4



Practical Shape Factors (60/3 dB) for Monotonic Responses

Number of Poles	2	3	4	5	6	8	10
Filter Type							
Butterworth	32	10.0	5.8	4.2	3.3	2.5	2.2
Chebyshev 0.1 dB	30	9.0	4.7	3.1	2.4	1.8	1.5
Chebyshev 0.5 dB	29	8.0	4.2	2.8	2.3	1.7	1.5

Practical Limits

	Typical	Best	
Shape Factor	1.5–30	1.075	
Passband Flatness	1.0	0.10	dB
Narrowest Bandwidth	0.01	.001	%
Widest Bandwidth	2.5	10	%
Max. Attenuation	90	100	dB
Phase Linearity	± 5	± 2	°
Phase Matching	± 5 (Quad)	± 3 (All)	°
Temperature Range	–20 to +70	–45 to +105	°C
Shock	15	1500	g's
Vibration	10g Sine 10–2000Hz	45+ Gms Random	
Aging	< 10 ppM (10 years)	5 ppM (15 years)	

*** Amplitude and Delay Compensation * Phase and Amplitude Matching**
*** Hi-Rel Capability * Standard I.F. and Custom Designs Available**

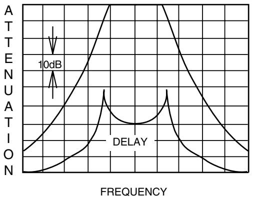
APPROXIMATION TYPES

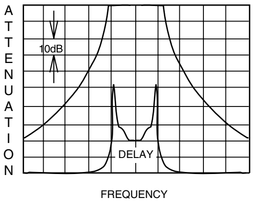
Depending upon the required specifications, an approximate type will be chosen to meet those requirements. The following are the most common types used.

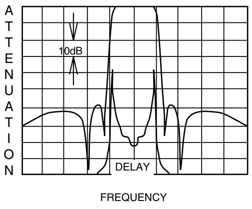
Types used for control of attenuation only:
Butterworth–Produces a very smooth, flat passband with a fair rate of roll-off. This approximation produces easily realized networks.

Chebyshev–The response is similar to the Butterworth but with a ripple within the passband and an improved roll-off rate. Networks obtained by this approximation are the most easily realized.

Cauer or Elliptic Function–The pass-band ripple is similar to the Chebyshev but with greatly improved stopband selectivity due to the addition of finite attenuation peaks. The network complexity is increased over the Butterworth or Chebyshev but it still yields practical realizations over nearly the entire operating region. All of the responses shown here are for six pole networks with identical design bandwidths.



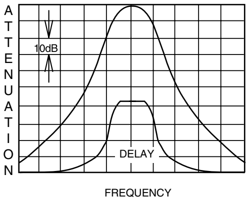


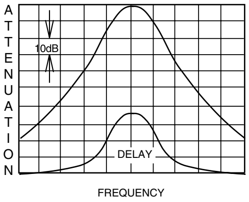


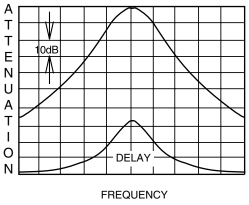
Types used for phase and delay control:
Bessel or Linear Phase
This approximation is the Butterworth of delay control, producing filters with a flat delay around center frequency. The more poles used the wider the flat region extends. The roll-off rate is poor. There are some realization restrictions - designs cannot be obtained over the entire operating region.

Gaussian–Very similar to the Bessel except that the delay has a slight bump at center frequency and the roll-off rate is slower. Because of the delay response ringing characteristics are better than Bessel. Realization restrictions also apply to these filters.

Synchronously Tuned–These filters have the same advantages and disadvantages as the Bessel and Gaussian except that the ringing response is the best of all design types, and the roll-off is even slower than the Gaussian. As with the other two types some realization restrictions apply. Responses shown are for 6 pole networks with identical 3 dB design bandwidths.



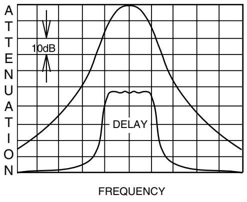


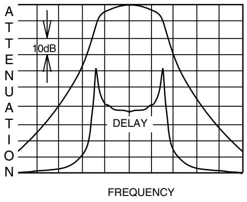


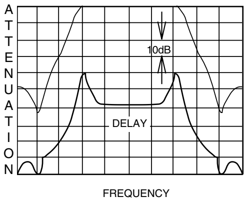
Compromise types:
Chebyshev Phase Error
Here the Chebyshev approximating technique is applied to the phase (delay) over the passband region producing a bell shaped amplitude similar to a Gaussian or Bessel design and an equiripple phase and delay response. Selectivity is better than the Bessel or Gaussian.

Gaussian to 6 (or 12) dB
These filters have passband response that follows the Gaussian shape–at either the 6 or 12dB point response changes and follows the Butterworth characteristic. The phase/delay response is somewhat improved over a strict Butterworth and attenuation is better than true Gaussian–it is a true compromise type of approximation. As with all filters when attempting to control phase response, realization becomes more difficult and the operating region is slightly restricted.

Custom Ringing Response–When good ringing response and good attenuation are required, a custom ringing response filter can be synthesized. Due to need to control phase and attenuation, these filters require more components and are somewhat larger and more costly than other types.







ORDERING CODES FOR CRYSTAL UNITS

MODE		HOLDER				CALIBRATION TOLERANCE AT REFERENCE TEMPERATURE		TEMPERATURE STABILITY OR TOTAL TOLERANCE		OPERATING TEMPERATURE RANGE		CIRCUIT CONDITION	
CODE	DESC	CODE	DESCRIPTION	CODE	DESCRIPTION	CODE	DESCRIPTION	CODE	DESCRIPTION	CODE	DESCRIPTION	CODE	DESCRIPTION
A	Fund	06	HC–6 standard	0	Standard			X	± 2 ppm stability	X	+15 to +35		
B	3rd.	17	HC–17 standard	1	Undercut pins			Y	± 3 ppm stability	Y	+10 to +40		
C*	ot.	18	HC–18 standard	2	Modified can			Z	± 4 ppm stability	Z	+5 to +45		
D*	5th ot.	25	HC–25 standard		height					A	0 to +50	00	Series resonance
E*	7th ot.	32	HC–32 standard	3	Slimline	B	± 5 ppm	B	± 5 ppm stability	B	-5 to +55		
F*	9th ot.	33	HC–33 (HC–6 wires)	4	3rd wire	C	± 7 ppm	C	± 7 ppm stability				
	11th	35	HC–35 (TO–5 type)	5	Modified can	D	± 10 ppm	D	± 10 ppm stability	D	-10 to +60		
	ot.	37	HC–37 (TO–8 type)		height	E	± 15 ppm	E	± 15 ppm stability	E	-15 to +65		Parallel
		80	HC–45 (micro–min.)	6	Modified can	F	± 20 ppm	F	± 20 ppm stability	F	-20 to +70	01	resonance load
		40	HC–40 (EO 7)		height	G	± 25 ppm	G	± 25 ppm stability	G	-25 to +75		capacity 100pf or
				7	Coldweld****	H	± 30 ppm	H	± 30 ppm stability	H	-30 to +80		more. Advise
						J	± 40 ppm	J	± 40 ppm stability	J	-40 to +90		actual value.
				9	Resistance	M	± 50 ppm	M	± 50 ppm stability	M	-55 to +105		
					weld	K	± 100 ppm	L	± 75 ppm stability	L	+55/+65 Oven		Parallel
								K	± 100 ppm stability	T	+60/+70 Oven	10–90	resonance load
								N	± 150 ppm stability	N	+65/+75 Oven		capacity in pf.
								S	Specific curve	P	+70/+80 Oven		
								T	± 20 ppm‡ (B)†	R	+75/+85 Oven		
								U	± 25 ppm‡ (C)†	S	+80/+90 Oven		
								V	± 30 ppm‡ (D)†	U	+50/+60 Oven		
								W	± 50 ppm‡ (F)†				
								P	± 100 ppm‡ (H)†		Reference or		Calibration at
								R	± 20 ppm‡ (M)†		Calibration	99	reference
								O	Not specified		Temperature is		temperature in
											the mid-point of		customer's
									† We use these		the above ranges		oscillator
									calibration codes		not specified.		
									w/corresponding				
									total tolerances.				

*	Available at series resonance only
**	Standard types for all codes as per MIL–H–10056
***	Not all holders available with modifications
‡	Total tolerance (measured from nominal frequency)
****	Some holders are only coldweld, such as HC–35/U, in which case "7" is not necessary and if used indicates 4 point mount.

To order: Telephone, FAX or E-mail OFC specifying the following information:

	Mode of Operation	Holder	Holder	Calibration Tolerance	Temperature Stability or Total Tolerance	Temperature Range	Circuit Condition	Frequency
Example	C	18	9	F	W	M	00	90.000MHz
Order								

Oak Frequency Control Group manufactures quartz resonators from 1.5 Hz to 360MHz, fundamental to 11th overtone, in a complete range of holder styles using solder seal, resistance weld or cold weld sealing methods. OFC leads the industry in the design and manufacture of low phase noise and microphonics, low aging rate, doubly rotated crystals and high frequency fundamentals. Our facilities are designed to cover your prototype or emergency needs, along with a proficiency in economical high volume production.

DOUBLY ROTATED AT CUT CRYSTAL UNITS

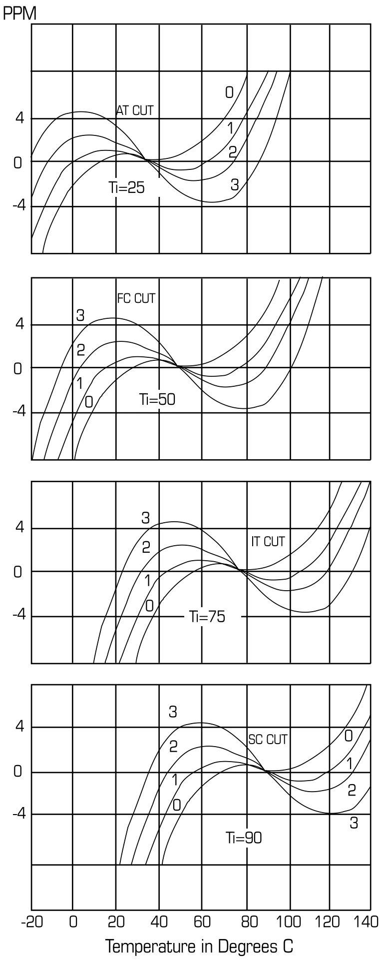
DRAT resonators are the right choice for oven controlled crystal oscillators (OCXO). Development of DRAT resonators has significantly improved achievable OCXO characteristics. Presence of the very strong B mode (8 to 10% above the main mode frequency) somewhat complicates oscillator design. More complex processes, lower yields and lower motional capacitance, causing tighter tolerance requirements, all contribute to higher costs of DRAT cuts. Oak Frequency Control Group has established a design and manufacture capability for a range of doubly rotated resonators such as FC, IT and SC resonators.

Frequency–temperature curves of DRAT resonators are very similar to those of AT–cut. The most significant difference is that where AT has an inflection temperature (Ti) in the area of 25°C to 30°C depending on design and frequency, the inflection temperature will be in the area of 45°C to 55°C for FC, 70°C to 80°C for IT and 85°C to 95°C for SC. Curves of DRAT resonators are flatter than corresponding AT cuts.

The temperature stability advantage is valid only for higher temperatures where DRAT resonators can show up to 10 times improvement in stability compared to AT resonators. For wide temperature ranges which include temperatures below 0°C, better stability can be obtained with AT–cut resonators.

The main advantages of these resonators, in particular the SC (Stress Compensated) type, include:

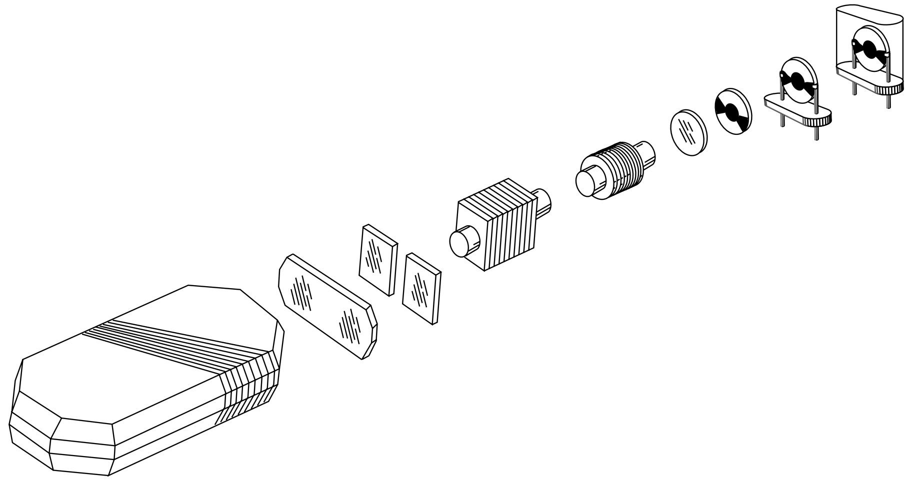
Generalized Frequency-Temperature Characteristic



- Improved frequency–temperature stability for ovenized applications with operating temperatures in the 60°C to 80°C range.
- Reduced amplitude frequency effect which allows higher drive levels and improved signal to noise ratio.
- Superior thermal transient characteristics resulting in improved short term stability and faster warm-up times in oven operation.
- Improved aging characteristics.
- Improved vibration sensitivity.
- Higher C0/C1 ratio resulting in reduced sensitivity to circuit component changes.
- Higher Q Factor – 10 to 15% higher than AT–cut.

For your specific requirements, please contact our engineering staff.

PROCESSING THE QUARTZ CRYSTAL



STEP 1 The first step in manufacturing a crystal is to cut the cultured quartz bar into thin wafers. The wafers are rectangular because the quartz bar is twice as wide as it is high. Cutting is done using a slurry saw and setting the blades at a very precise angle with reference to the crystalographic axis in the quartz bar.

STEP 2 The rectangular wafers are stacked together and cut in half, resulting in square wafers.

STEP 3 The square wafers, or blanks, are x-rayed to confirm the angle of cut from the main bar. This is critical, as the accuracy of the initial cut will determine the temperature coefficient of the finished unit.

STEP 4 The wafers are stacked together, turned round on a special lathe and sorted into tight frequency groups by measuring them on a special frequency counter.

STEP 5 The crystals start at a base frequency lower than the final required frequency. The thicker the crystal blank, the lower the frequency. Conversely, the thinner the blank, the higher the frequency. In order to move the crystal blank toward its final frequency, it is rotated between two metal grinding, or lapping, plates. A special abrasive suspended in a liquid is poured between the rotating plates, and the blanks are ground thinner until they reach a frequency slightly higher than the final, required frequency.

STEP 6 The crystal blanks are placed in a special mask, exposing only a specific area. This area is paddle shaped and identical on either side of the blank, except that it runs in opposing directions from the center of the blank. The mask is placed in a special vacuum chamber and metal is vaporized onto the mask, covering the exposed areas. This very precise operation – depositing electrodes and, at the same time, adding thickness to the blank – lowers the crystal frequency to a point approaching its final frequency.

STEP 7 The plated blank is mounted on a metal base. This is done by slipping the blank into clips on the base, allowing the plated electrodes to come in contact with a special, conductive epoxy.

STEP 8 The mounted blank is fine tuned onto final frequency by vaporizing metal, usually gold, onto the center of the plated electrodes.

STEP 9 The crystal is placed in a vacuum chamber and encapsulated. The cover is sealed to the base by either resistance welding or cold welding.

STEP 10 The final step, prior to packaging and shipping, is to conduct all necessary electrical and physical tests to ensure that the unit meets all customer requirements and specifications.

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