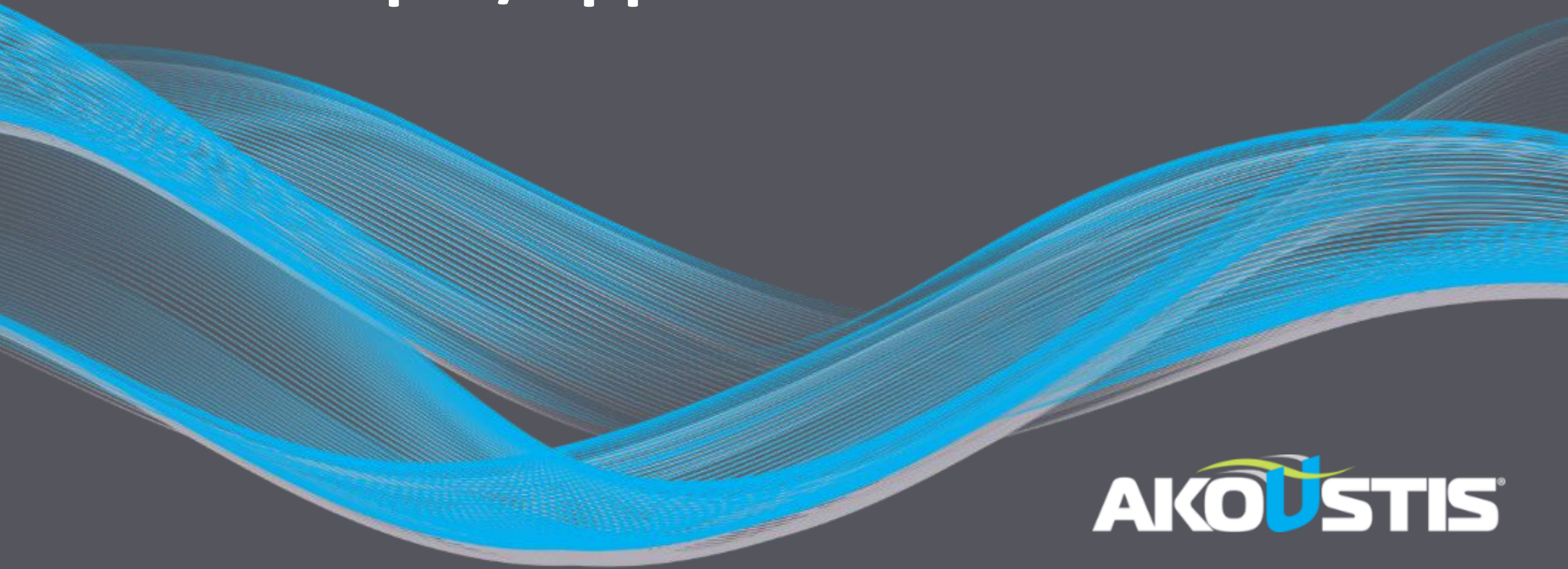
Crystal Products
White Paper/Application Notes



Topics on RFMi Xtal Products

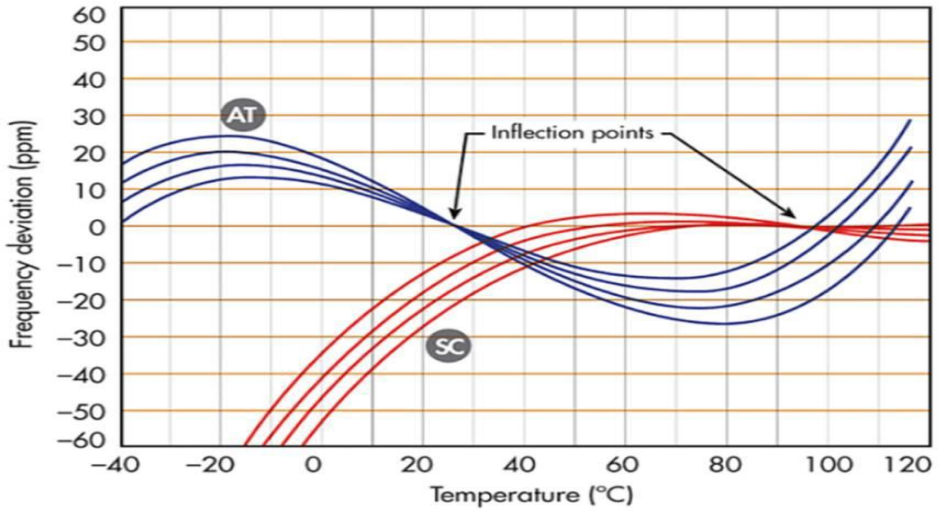
- RFMi Xtal Products
- Crystal cut angle (AT/SC)
- Graph of temp variations vs Crystal cut
- Make tolerance and over temp range
- Load capacitance effect on crystals
- Aging
- Microcontroller that tunes Xtal in VCXO, TCXO, VCTCXO, etc.
- Application circuits
- Freq. range including fundamentals and 3rd overtones we support
- Effects of drive level

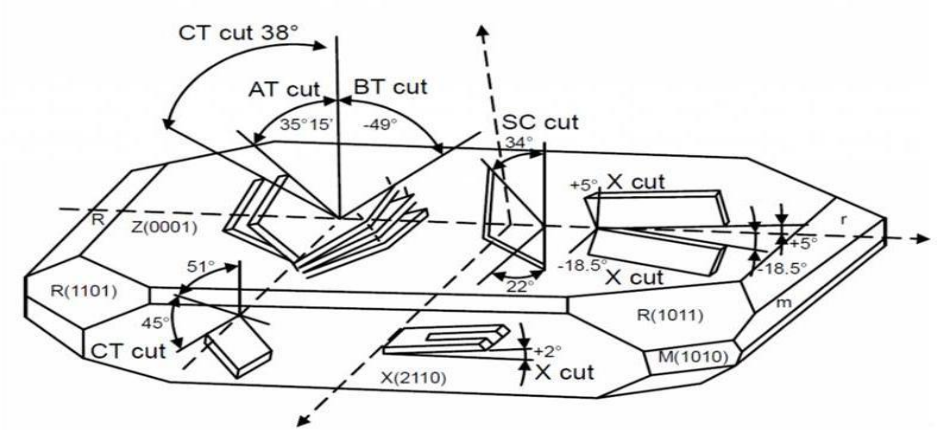
RFMi Xtal products

- XTL: Crystal Resonator
- XTC: TCXO (Temperature-Compensated Crystal Oscillator)
- XVT: VCTCXO (Voltage-Controlled Temperature-Compensated Crystal Oscillator)
- XTS: TSX (Temperature Sensing Xtal Resonator)
- XFL: Crystal Filter
- XO: Crystal Oscillator
- XVC: VCXO (Voltage-Controlled Crystal Oscillator)
- XOC: OCXO (Oven-Controlled Crystal Oscillator)

Crystal cut angle (AT/SC-cut)

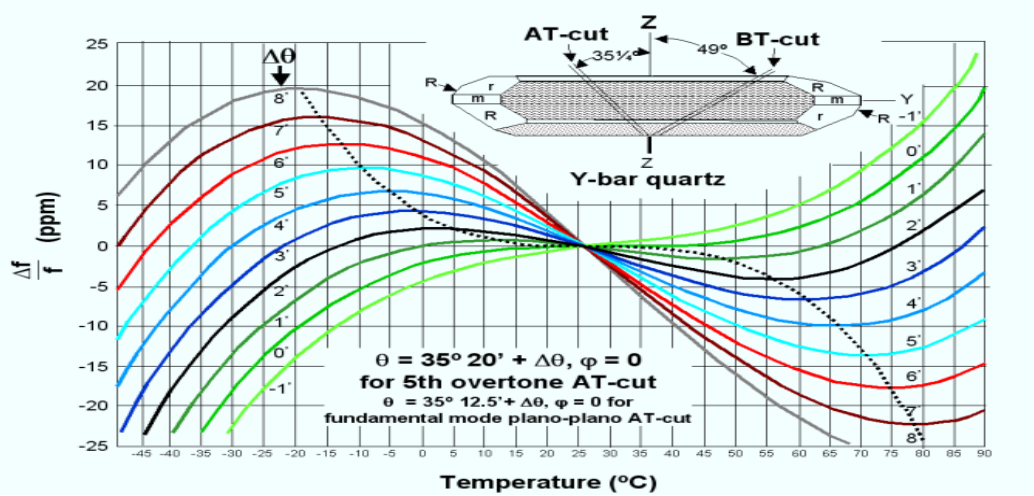
- The AT is a temperature-compensated cut, meaning the cut is oriented such that the temperature coefficients of the lattice will have minimal impact on crystal performance.
- The SC is a stress-compensated cut, but it is also temperature compensated. The SC cut is a double rotated.
- The SC-cut has better temperature stability at higher temperature ranges (up to +200C).

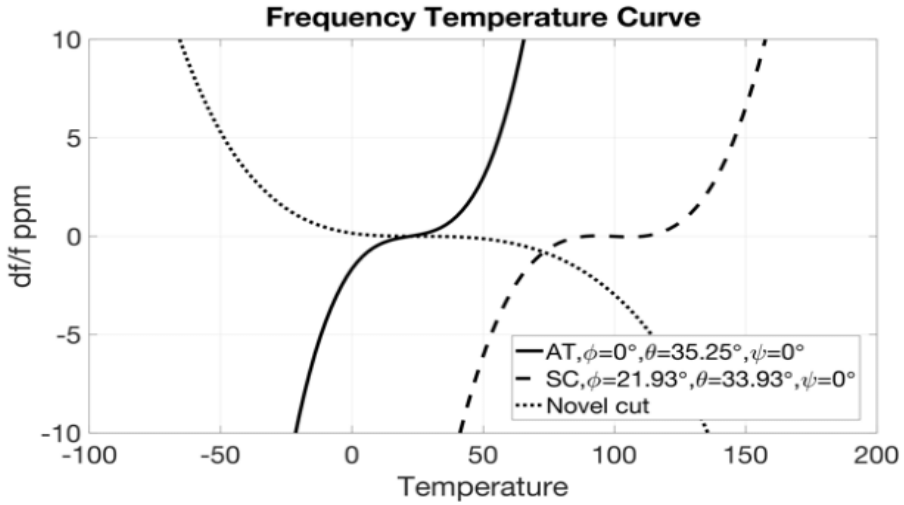


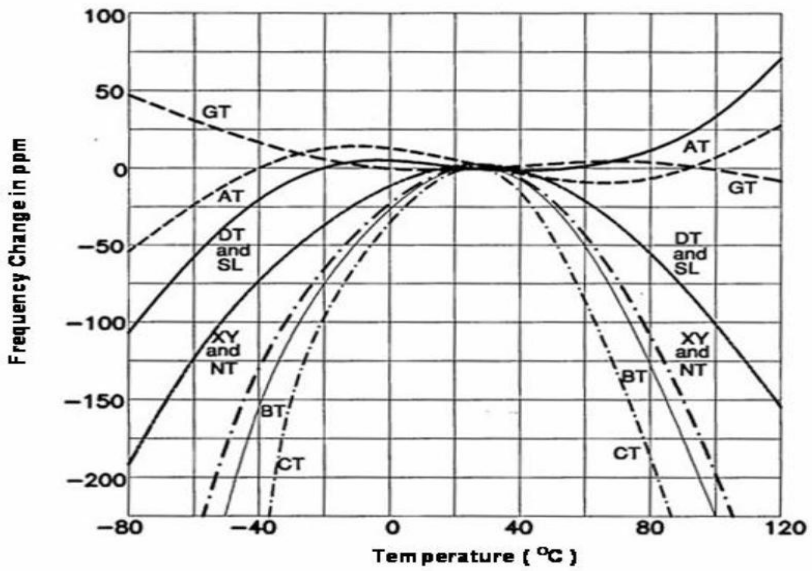


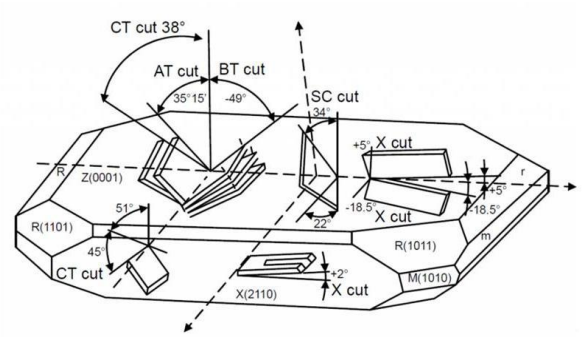
AT Cut - Inflect around 25C , frequency stable in a wide temperature range
SC Cut - Inflect around 95C , Frequency stable at High-Temperatures

Temperature variations vs Crystal cut



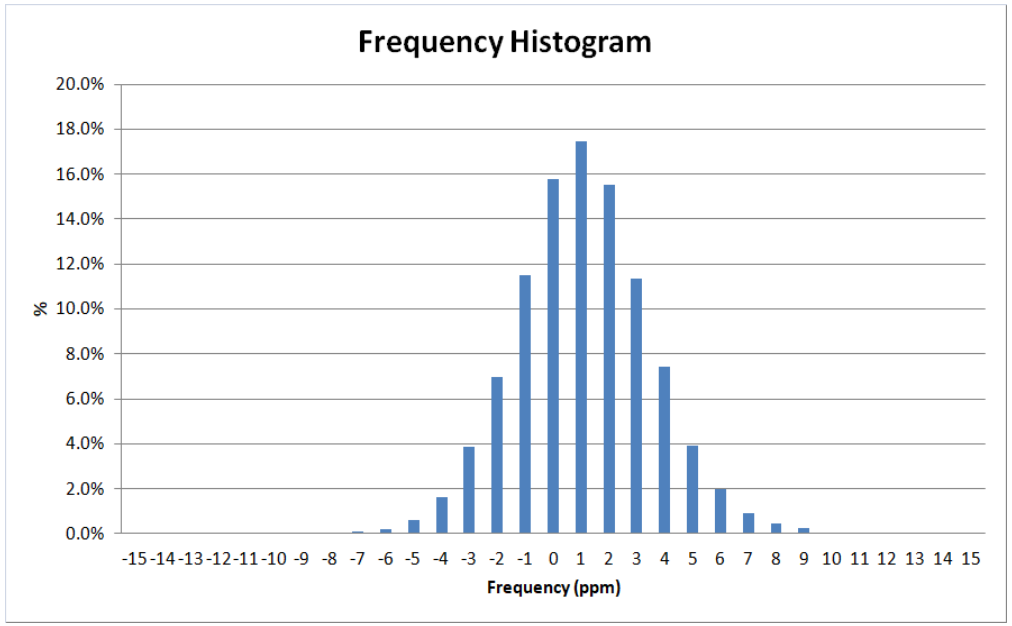






Crystal Cut type: AT Cut, GT Cut, DT Cut, BT Cut, CT Cut …etc.

Make tolerance (Frequency variations at room temp) and how this impacts cost/yield



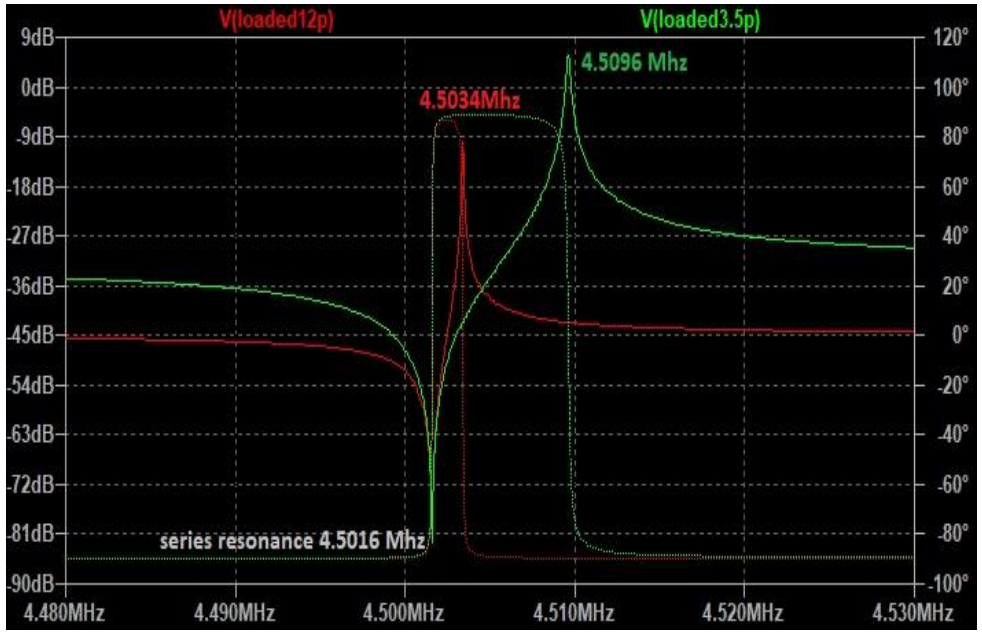
SPEC for normal distribution
+/-10ppm = cost
+/-7ppm = cost x ~1.02
+/-5ppm = cost x ~1.09
+/-3ppm = cost x ~1.33

Frequency variations over temperature range

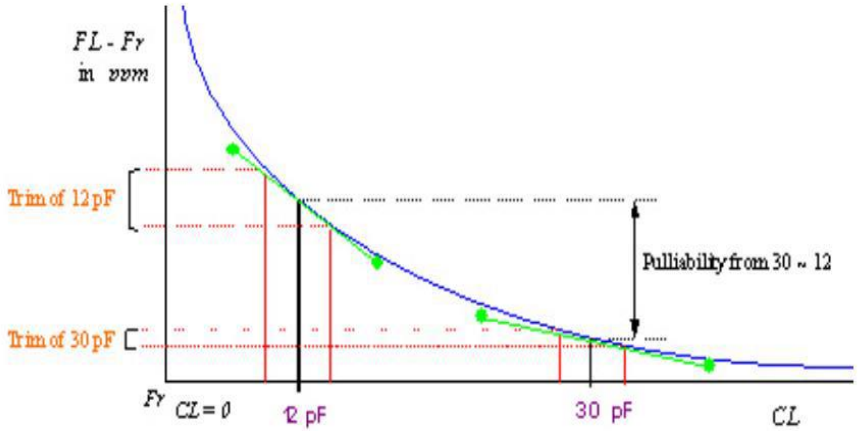
Frequency of quartz crystal (Xtal) varies with temperature changes, e.g., +/-15ppm over -40C to +85C. If a more accurate frequency is desired, a temperature compensated crystal oscillator, know as a TCXO, would be required with only a few ppm of frequency change even over a wide temperature range. The cost of TCXO is higher than a Xtal as the additional IC is programed to tune the frequency over the temperature range.

Load capacitance effect on crystals

Load capacitance is the effective capacitance between the crystal terminals. To achieve the correct frequency, the MFG will specify the correct Load capacitance (CL). A different load capacitance will produce a different frequency. The below graph shows a 4.5016MHz crystal with CL of 12pF in RED and the same crystal with a CL of 3.5pF (MFG recommended).



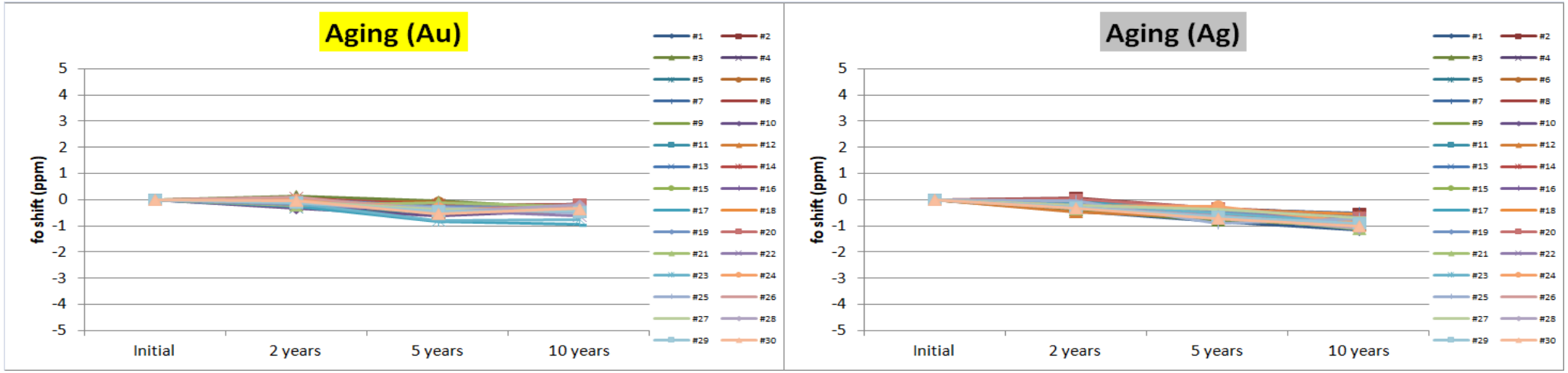
FL = FR * (1 + C1 / 2 * (C0 + CL))



CL (pF)	Frequency (ppm)	TS(Pulling Sensitivity) ppm/pF
↑	↓	↓
↓	↑	↑

Aging

Aging refers to the change in frequency over time. Aging of quartz crystals affects their long-term stability/accuracy. Many factors contribute to Aging such as the material used, environment, mechanical stress, power cycle, thermal stresses, etc.. Typical aging ranges from +/-**1**ppm in the first year to around +/-**5**ppm over 10 years depending on the type of crystal product.



Aging from material
Au ~+/-1ppm
Ag ~+/-2ppm

Microcontroller that tunes Xtal in VCXO, TCXO, VCTCXO or OCXO

VCXO (Voltage Controlled Crystal Oscillator)
Base frequency is defined by the Crystal unit, use Control Voltage to tune the Frequency , tuning range is +/-10~100ppm or more.

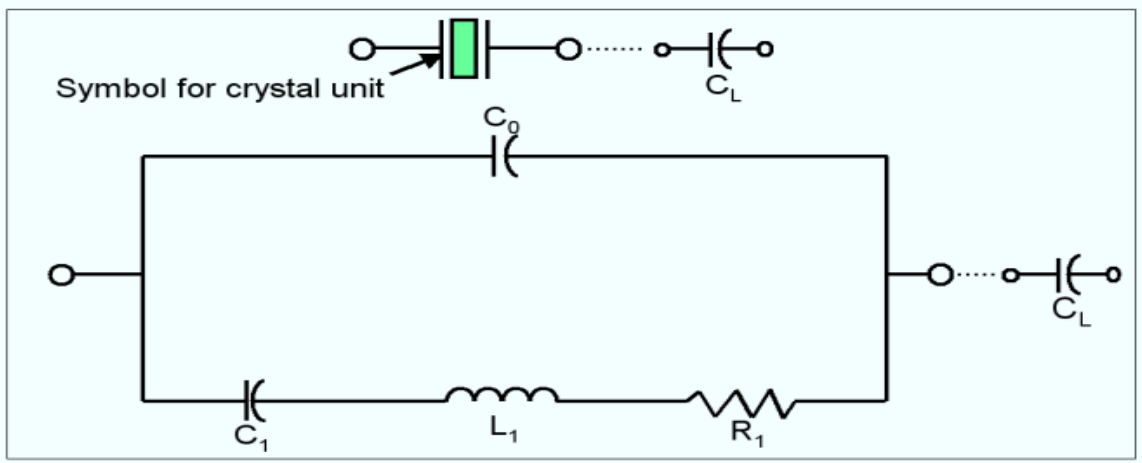
TCXO (Temperature Compensate Crystal Oscillator)
Base frequency is defined by the Crystal unit, use temperature compensation circuit of the IC programmed for Frequency stability at +/-0.5~2.0ppm for the operation temperature range.

VCTCXO (Voltage Controlled Temperature Compensate Crystal Oscillator)
Base frequency is defined by the Crystal unit, use Control Voltage to tune the Frequency, use temperature compensation circuit of the IC programmed for Frequency stability at +/-0.5~2.0ppm for the operation temperature range.

OCXO (Oven Controlled Crystal Oscillator)
It uses Oven to control environment temperature of the Crystal blank, the frequency stability < 50~100ppb.

Application/test circuits

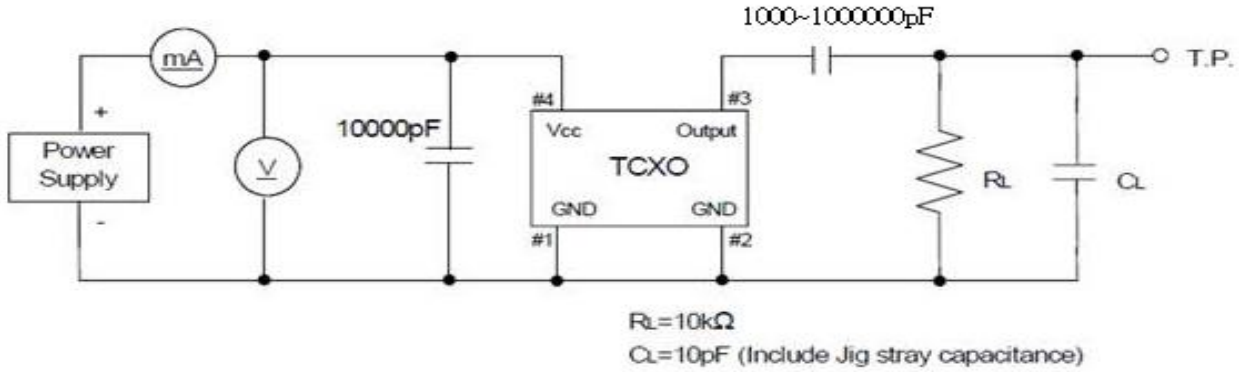
a) XTL: Crystal Resonator Equivalent Circuit



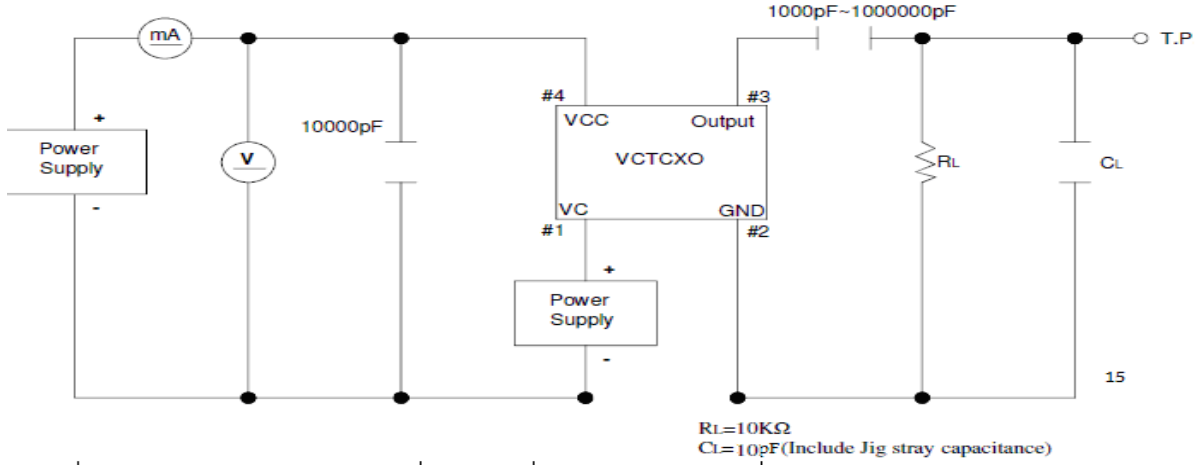
CL = Load capacitance
Co = Static capacitance (includes package parasitic)
C1 = motional capacitance
L1 = motional inductance
R1 = motional resistance
Fs = Series resonance frequency

Application/test circuits (Cont.)

b) XTC: TCXO (Temperature-Compensated Crystal Oscillator)



c) XVT: VCTCXO (Voltage-Controlled Temperature-Compensated Crystal Oscillator)

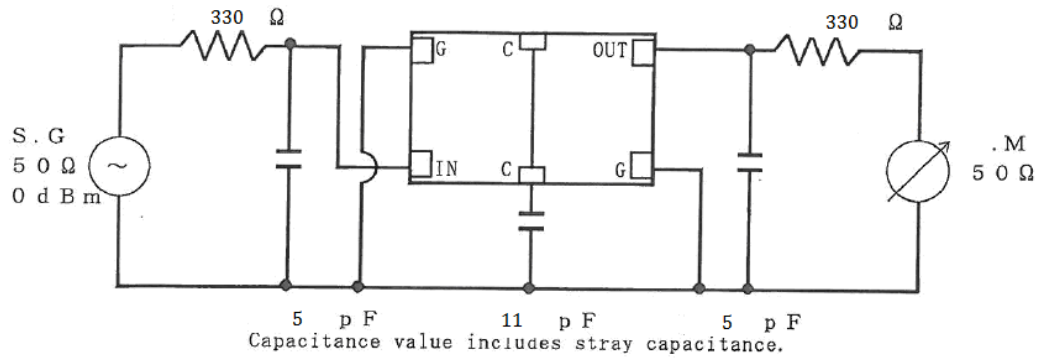


Application/test circuits (Cont.)

d) XTS: TSX (Temperature Sensing Xtal Resonator)

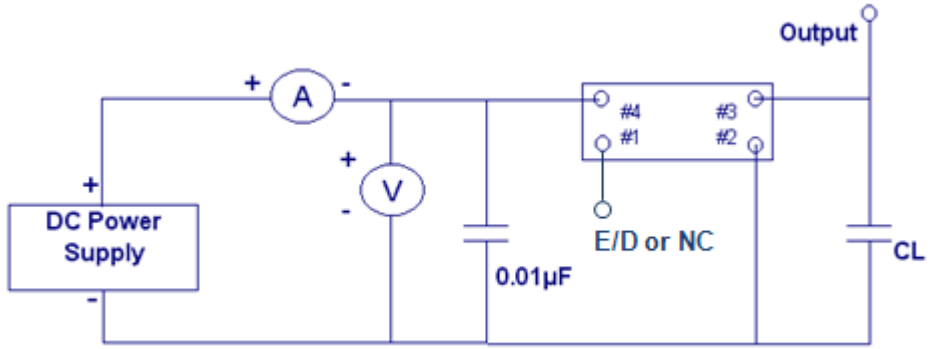
Same as XTL Crystal resonator.

e) XFL: Crystal Filter



Example circuit only. Resistor and capacitance values determined by specific filter.

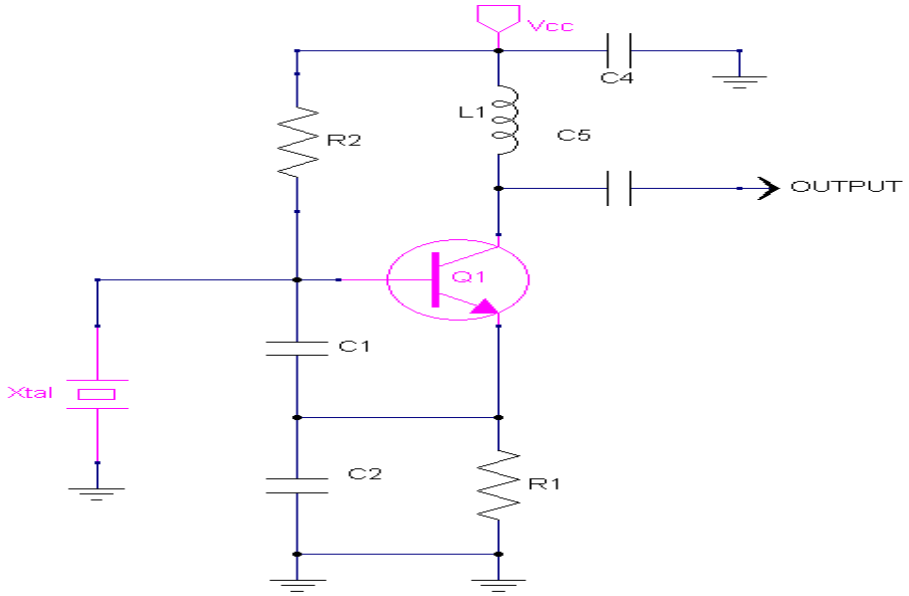
f) XO: Crystal Oscillator



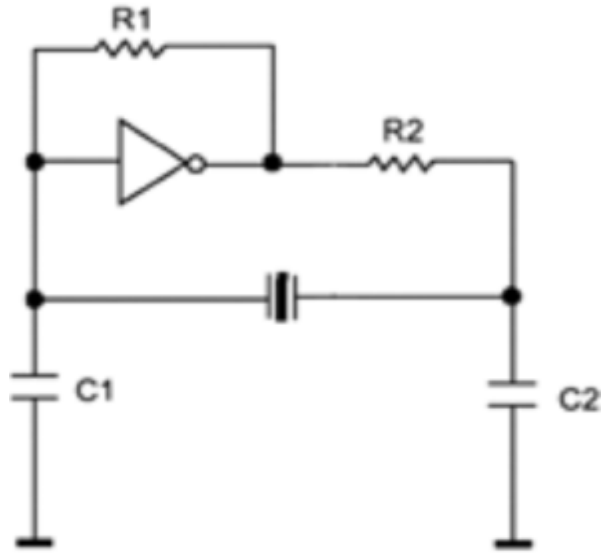
Application/test circuits (Cont.)

XO: Crystal Oscillator (Cont.)

Colpitts Oscillator circuit below example.



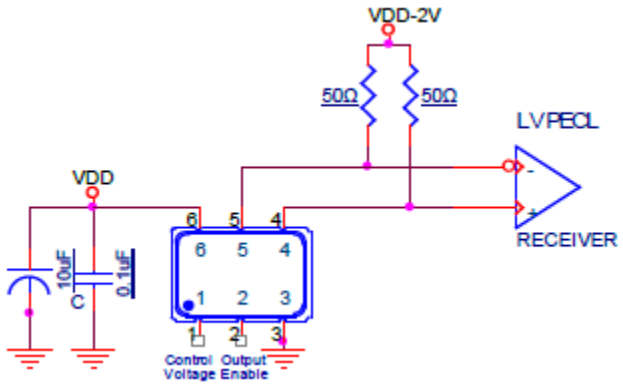
Logic gate inverter oscillator example circuit below



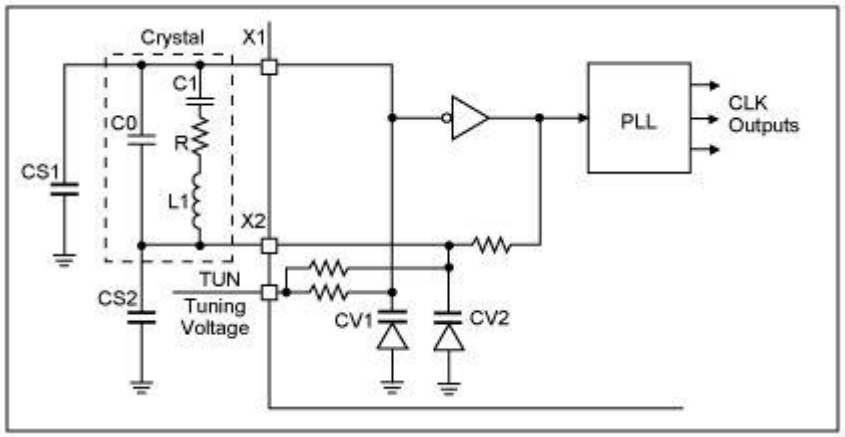
Application/test circuits (Cont.)

g) XVC: VCXO (Voltage-Controlled Crystal Oscillator) A few examples depending on applications.

PECL Output below



Other circuit example



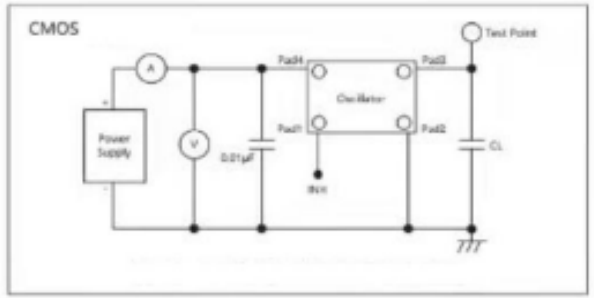
Application/test circuits (Cont.)

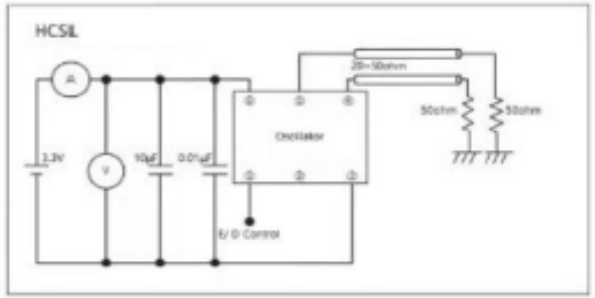
TCXO

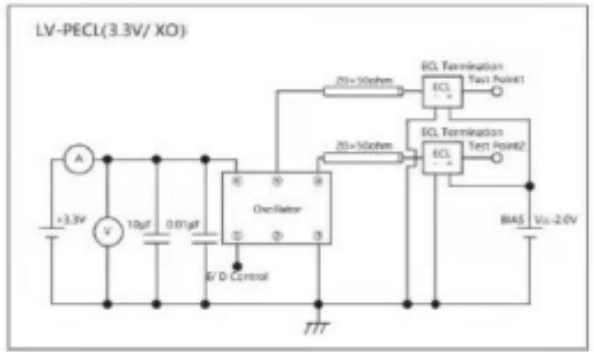
- Clipped Sine Wave
- CMOS

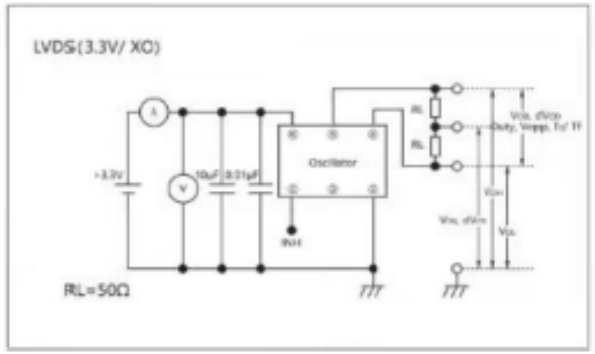
XO

- CMOS
- HCSL
- LVPECL
- LVDS









Application/test circuits (Cont.)

h) XOC: OCXO (Oven-Controlled Crystal Oscillator)

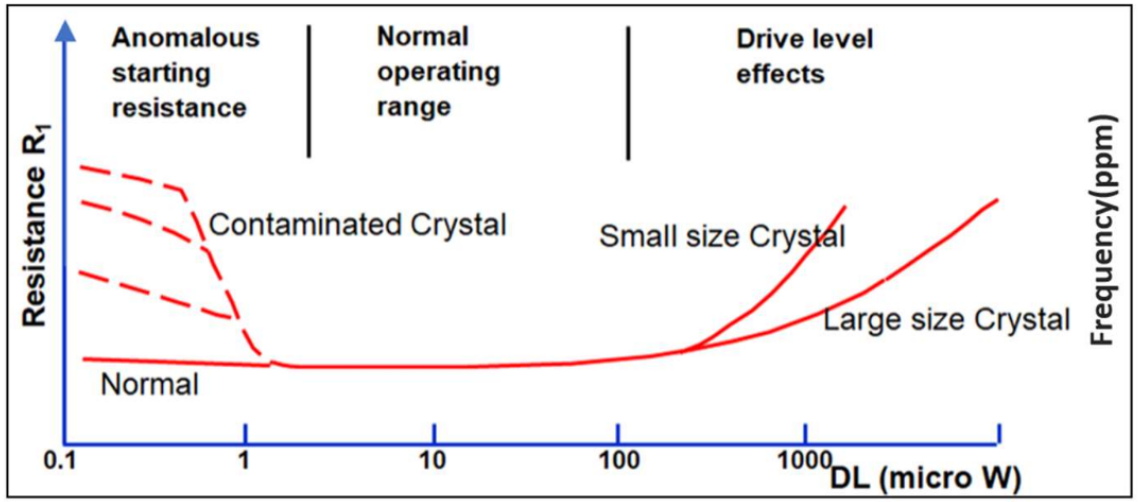
Same as other oscillators

Frequency range and including fundamentals and 3rd overtones we support

Size (Frequency Range)

Fundamental	
	5032(8~48MHz)
	3225(8~48MHz)
	2520(12~52MHz)
	2016(16~96MHz)
	1612(24~96MHz)
	1210(32~80MHz)
3rd	5032(114.285MHz)
	3225(114.285MHz)
	2520(156.25MHz)
	2016(156.25MHz)
5th	N/A

Effect of drive level



High Drive level always Frequency and Resistance will be high
Large size Crystal drive level slowly rising
Small size Crystal drive level rise rapidly at High drive level

Normal suggest Drive level < 100uW , at PCB circuit

Effect of drive level (Cont.)

Example of typical crystal resonator