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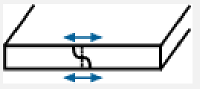
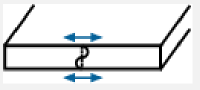
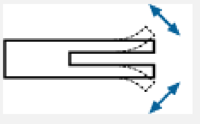
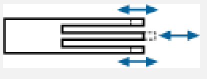
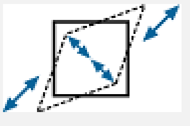
Technical Guide

CITIZEN FINEDEVICE CO., LTD.

Types of crystal cut

Relation among crystal cut, mode of vibration and frequency range

Crystal Cut	Mode of vibration		Frequency range (kHz)	Capacitance ratio (C0/C1)
AT	Thickness shear Fundamental		800~5,000 2,000~80,000	450~300 220
	3rd overtone		20,000~90,000	n2 x 250 n: Overtone order
	5rd overtone		40,000~150,000	
	7rd overtone		70,000~210,000	
BT	Thickness shear Fundamental		3,000~30,000	650
XY	Flexural (Tuning fork)		16~150	425~800
	Extensional		600~3,000	400
DT	Face shear		100~500	400
CT			150~850	350
SL			180~700	400

Crystal unit equivalent circuit

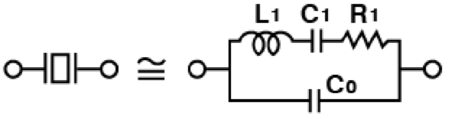
A crystal unit in the main resonance frequency may be expressed as an electrical equivalent circuit: a circuit ordinarily composed of a series circuit consisting of an inductance, capacitance and resistance, and a capacitance connected in parallel to the series circuit as shown in the drawing.

Here, C0, which is commonly known as the shunt capacitance, comprises an inter-electrode static capacitance to which the inter-terminal stray capacitance is added.

L1 and C1 are the equivalent constants of the crystal unit viewed as an electrical and mechanical oscillation system. Since both constants are determined by such factors as the type of cut, cutting angle, dimensions of the crystal blank, and construction of the electrodes, and are thus reproducible, crystal units can be manufactured with high precision.

R1, which denotes oscillation loss, is governed by conditions such as processing, storage, and dimensions of the crystal unit.

L1 is referred to as motional inductance, C1 is referred as motional capacitance, and R1 is referred as motional (series) resistance.



L1	Motional inductance
C1	Motional capacitance
R1	Motional(series)resistance
C0	Shunt capacitance

The electrical equivalent circuit, composed of L1, C1, R1 and C0, all of which are correlated, may be expressed by the following equation.

$$f_r = \frac{1}{2\pi\sqrt{L_1C_1}}$$

Shown below are some equations by which the performances of crystal units are expressed

$$Q = \frac{1}{2\pi f_r C_1 R_1} = \frac{2\pi f_r L_1}{R_1}$$

$$\gamma = \frac{C_0}{C_1} \text{ (Capacitance ratio)}$$

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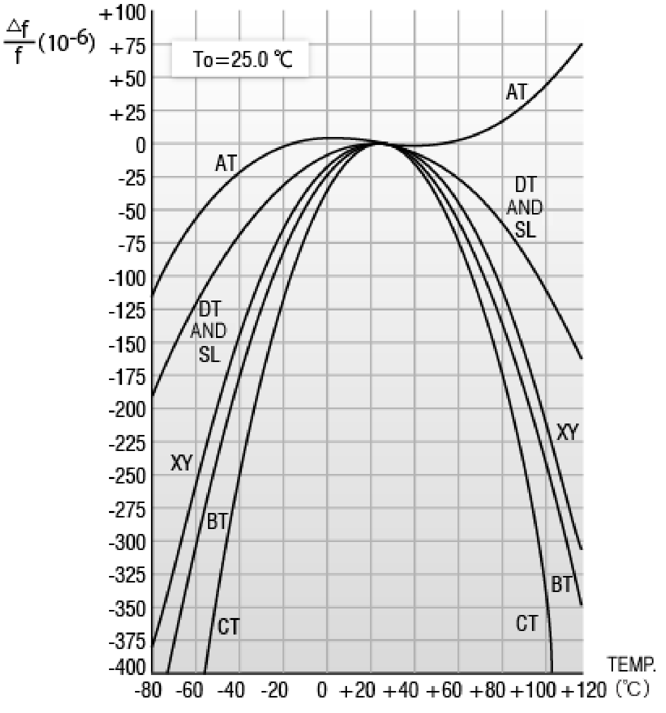
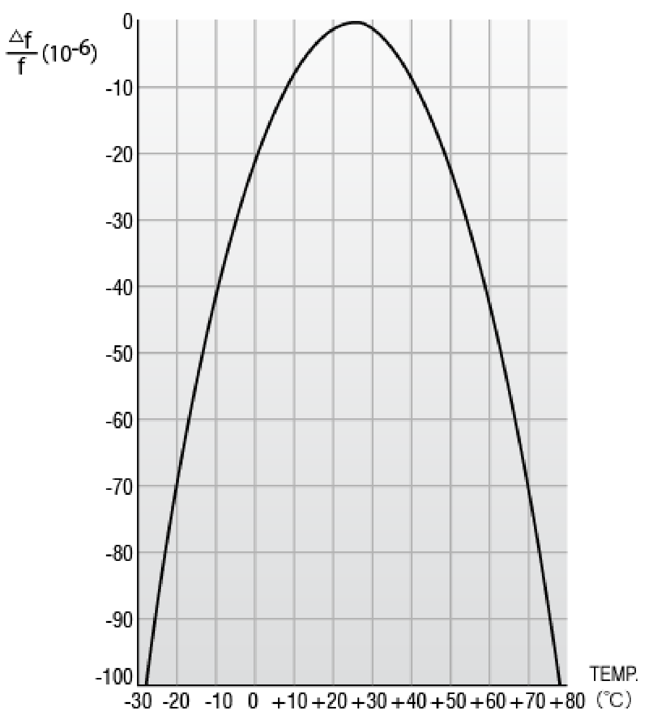
Frequency-temperature characteristics

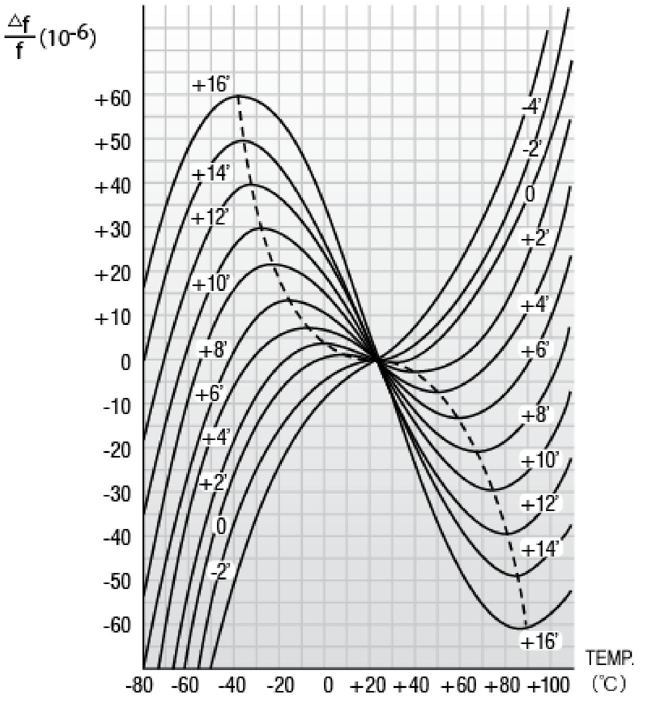
Correlation between Crystal cutting angle and Frequency-temperature characteristics



Frequency-temperature characteristics of Tuning Fork Crystal Unit

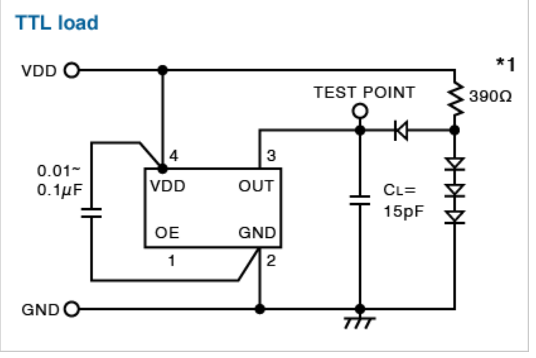


Correlation between Crystal cutting angle and Frequency-temperature characteristics of AT-cut Crystal Unit



Test Circuit

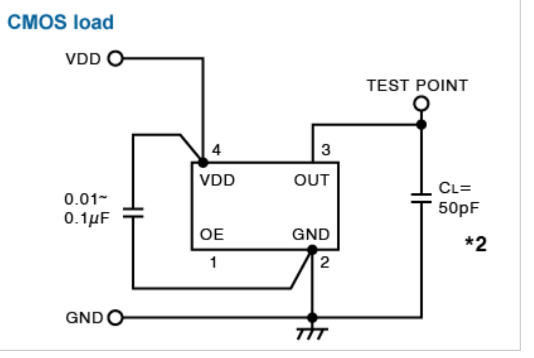
CSX-750F/SSX-750P SERIES



*1

390Ω	CSX-750(FC)
820Ω	SSX-750(PT, PK)

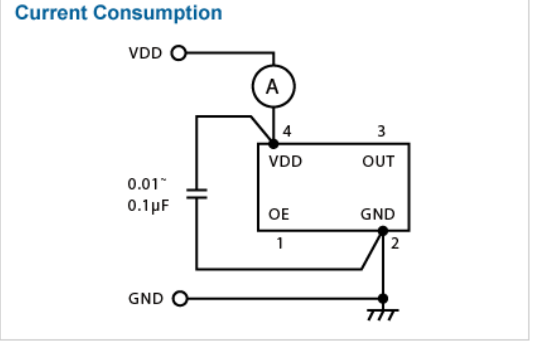
CMOS load



*2

50pF	CSX-750(FC)
30pF	CSX-750(FB, FJ)
25pF	SSX-750(PC, PD)
15pF	SSX-750(PB, PJ), CSX-252F

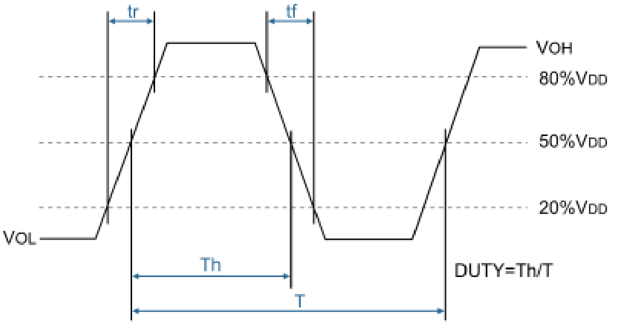
Current Consumption



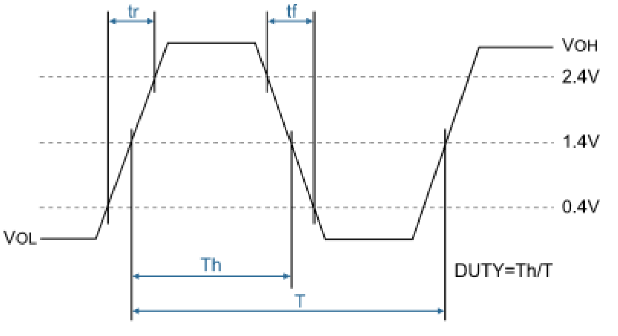
Output wave-form

Oscillators output wave-form

CMOS load



TTL load



Measurement conditions

1. Oscilloscope
   - Input impedance: No less than 1 MΩ
   - Input capacitance: No more than 15 pF
   - Band width: No less than 500 MHz
   - Make the grounding lead of the probe as short as possible
2. The CL includes the probe capacitance.
3. Grounding should be single-point grounding.
4. Supply voltage impedance should be as low as possible. Rise time from 0V to 0.9Vdd is to be more than 150 µs.
5. Use an ammeter with small internal impedance.

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