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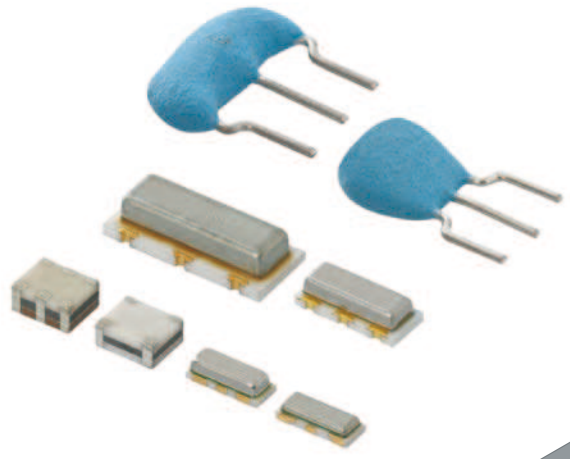
muRata
INNOVATOR IN ELECTRONICS

Ceramic Resonators (CERALOCK®)

Application Manual



Introduction

Ceramic resonators (CERALOCK®) are made of high stability piezoelectric ceramics that function as a mechanical resonator.

This device has been developed to function as a reference signal generator and the frequency is primarily adjusted by the size and thickness of the ceramic element.

With the advance of the IC technology, various equipment may be controlled by a single LSI integrated circuit, such as the one-chip microprocessor.
CERALOCK® can be used as the timing element in most microprocessor based equipment.

In the future, more and more applications will use CERALOCK® because of its high stability non-adjustment performance, miniature size and cost savings. Typical applications include TVs, VCRs, automotive electronic devices, telephones, copiers, cameras, voice synthesizers, communication equipment, remote controls and toys.

This manual describes CERALOCK® and will assist you in applying it effectively.

＊CERALOCK® is the brand name of these MURATA products.

EU RoHS Compliant

- All the products in this catalog comply with EU RoHS.
- EU RoHS is "the European Directive 2011/65/EU on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment."
- For more details, please refer to our website 'Murata's Approach for EU RoHS' (http://www.murata.com/en-eu/support/compliance/rohs).

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Product specifications are as of December 2015.

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Please check the MURATA website **(http://www.murata.com/)**
if you cannot find the part number in the catalog.

1 Characteristics and Types of CERALOCK®

RoHS

1. General Characteristics of CERALOCK®

Ceramic resonators use the mechanical resonance of piezoelectric ceramics. (Generally, lead zirconium titanate: PZT.)
The oscillation mode varies with resonant frequency.
The table on the right shows this relationship.
As a resonator device, Crystal Unit is well-known. RC oscillation circuits and LC oscillation circuits are also used to produce electrical resonance. The following are the characteristics of CERALOCK®.

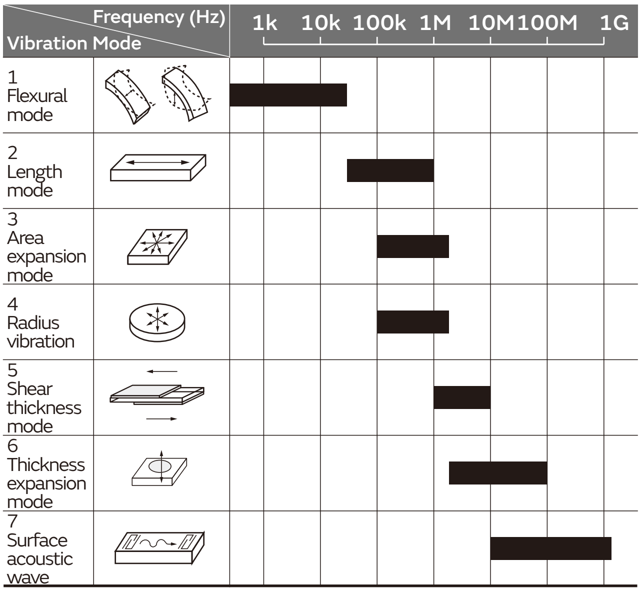
① High stability of oscillation frequency:
Oscillation frequency stability is between that of Crystal Units and LC or RC oscillation circuits.
The temperature coefficient of Crystal Units is 10–6/ °C maximum and approximately 10–3 to 10–4/°C for LC or RC oscillation circuits. For comparison these, it is 10–5/°C at –20 to +80°C for ceramic resonators.

② Small configuration and light weight:
The ceramic resonator is half the size of popular Crystal Units.

③ Low price, non-adjustment:
CERALOCK® is mass produced, resulting in low cost and high stability.
Unlike RC or LC circuits, ceramic resonators use mechanical resonance. This means it is not basically affected by external circuits or by the fluctuation of the supply voltage.
Highly stable oscillation circuits can therefore be made without the need of adjustment.

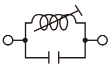
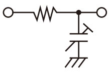
The table briefly describes the characteristics of various oscillator elements.

Vibration Mode and Frequency Range



[Note] : ←→show the direction of vibration

Characteristics of Various Oscillator Elements

Name	Symbol	Price	Size	Adjust-ment	Oscillation Frequency Initial Tolerance	Long-term Stability
LC		lower cost	Big	Required	±2.0%	Fair
CR		lower cost	Small	Required	±2.0%	Fair
Crystal Unit		Expen-sive	Big	Not required	± 0.001%	Excellent
Ceramic Resonator		Inexpen-sive	Small	Not required	±0.5%	Excellent

2. Types of CERALOCK®

MHz Band lead CERALOCK® (CSTLS Series)

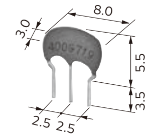
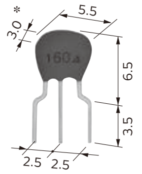
As CSTLS series does not require externally mounted capacitors, the number of components can be reduced, allowing circuits to be made more compact.
The table shows the frequency range and appearance of the three-terminal CERALOCK® with built-in load capacitance.

Part Numbering

(Ex.)	CS	T	LS	4M00	G	5	3		-A0
	❶	❷	❸	❹	❺	❻	❼	❽	❾

❶Product ID
❷Frequency/Built-in Capacitance
❸Structure/Size
LS: Round Lead Type
❹Nominal Center Frequency
❺Type
G: Thickness Shear vibration,
X: Thickness Longitudinal Vibration (3rd overtone)
❻Frequency Tolerance
1: ±0.1%, 2: ±0.2%, 3: ±0.3%, 5: ±0.5%, D: DTMF, Z: Others
❼Built-in Load capacitance
1: 5pF, 3: 15pF, 4: 22pF, 5: 30pF, 6: 47pF
❽Individual Specification
With standard products, "❽ Individual Specification" is omitted, and "❾ Package Specification Code" is carried up.
❾Packaging
–B0: Bulk,
–A0: Radial Taping H0=18mm Ammo Pack (Standard)

Part Numbers and Dimensions of lead CERALOCK® (CSTLS Series)

Part Number	Frequency	Dimensions (in mm)
CSTLS☐G	3.40–10.00MHz	
CSTLS☐X	16.00–70.00MHz	

* 16.00—32.99MHz : 3.5

MHz Band Chip CERALOCK® (CSACW/CSTCC/CSTCR/CSTCE/CSTCW Series)

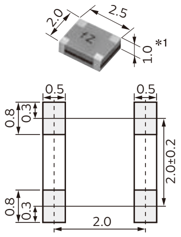
The MHz band Chip CERALOCK® has a wide frequency range and small footprint to meet further downsizing and high-density mounting requirements.
The table shows the dimensions and two-terminals standard land patterns of the CERALOCK® CSACW series.
The second table shows the dimensions and three-terminals standard land patterns of CSTCC/CSTCR/CSTCE/CSTCW series chip resonator (built-in load capacitance type.) The carrier tape dimensions of CSTCR series are shown on the next page.

Part Numbering

(Ex.)	**CS**	**T**	**CR**	**4M00**	**G**	**5**	**3**		**-R0**
	❶	❷	❸	❹	❺	❻	❼	❽	❾

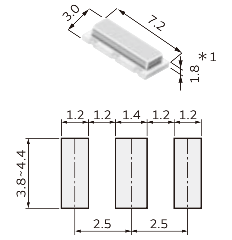
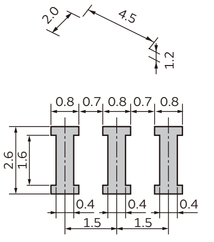
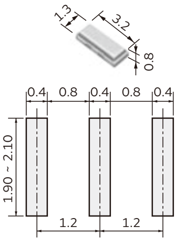
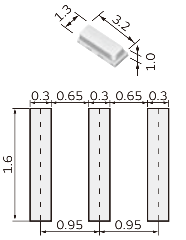
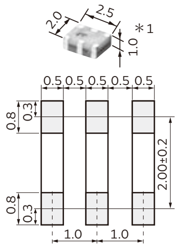
❶Product ID
❷Frequency/No capacitance built-in
A: No Capacitance Built-in, T: Built-in Capacitance
❸Structure/Size
CC/CR/CE/CN/CM: Cap Chip Type, CW: Monolithic Chip Type
❹Nominal Center Frequency
❺Type
G: Thickness Shear Vibration,
V: Thickness Longitudinal Vibration,
X: Thickness Longitudinal Vibration (3rd overtone)
❻Frequency Tolerance
1: ±0.1%, 2: ±0.2%, 3: ±0.3%, 5: ±0.5%, Z: Others
❼Load Capacitance Value
(In case of CSACW, CSACN and CSACM value is for external capacitance of standard circuit)
1: 5pF or 6pF, 2 : 10pF, 3: 15pF, 5: 33pF or 39pF,
6: 47pF
❽Individual Specification
With standard products, "❽ Individual Specification" is omitted, and "❾ Package Specification Code" is carried up.
❾Packaging
–B0: Bulk,
–R0: Plastic Taping φ180mm Reel Package

Dimensions and Standard Land Pattern of Chip CERALOCK® (CSACW Series)

Part Number	Frequency (MHz)	Dimensions Standard Land Pattern (in mm)
CSACW☐X＊2	20.01–70.00	

＊1 Thickness varies with frequency.
＊2 Conformal coating or washing of the components is not acceptable because they are not heretically sealed.

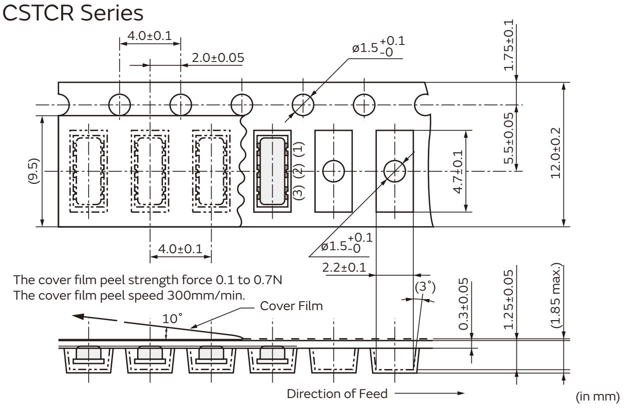
Dimensions and Standard Land Pattern of Chip CERALOCK® (CSTCC/CSTCR/CSTCE/CSTCW Series)

Part Number	Frequency (MHz)	Dimensions Standard Land Pattern (in mm)
CSTCC□G＊2	2.00–3.99	
CSTCC□G＊2	4.00–7.99	
CSTCC□G＊2	8.00–13.99	
CSTCE□V＊2	14.00–20.00	
CSTCW□X＊2	20.01–70.00	

＊1 Thickness varies with frequency.
＊2 Conformal coating or washing of the components is not acceptable because they are not hermetically sealed.

Dimensions of Carrier Tape for Chip CERALOCK®

CSTCR Series



2 Principles of CERALOCK®

RoHS

1. Equivalent Circuit Constants

Fig. 2-1 shows the symbol for a ceramic resonator. The impedance and phase characteristics measured between the terminals are shown in Fig. 2-2. This illustrates that the resonator becomes inductive in the frequency zone between the frequency Fr (resonant frequency), which provides the minimum impedance, and the frequency Fa (anti-resonant frequency), which provides the maximum impedance.

It becomes capacitive in other frequency zones. This means that the mechanical vibration of a two-terminal resonator can be replaced equivalently with a combination of series and parallel resonant circuits consisting of an inductor : L, a capacitor : C, and a resistor : R. In the vicinity of the specific frequency (Refer to Note 1 on page 8), the equivalent circuit can be expressed as shown in Fig. 2-3.

Fr and Fa frequencies are determined by the piezoelectric ceramic material and the physical parameters. The equivalent circuit constants can be determined from the following formulas. (Refer to Note 2 on page 8)

$$Fr=1/2\pi\sqrt{L_1C_1} \qquad (2\text{-}1)$$

$$Fa=1/2\pi\sqrt{L_1C_1C_0/(C_1+C_0)}=Fr\sqrt{1+C_1/C_0} \qquad (2\text{-}2)$$

$$Qm=1/2\pi FrC_1R_1 \qquad (2\text{-}3)$$

(Qm : Mechanical Q)

Considering the limited frequency range of Fr≦F≦Fa, the impedance is given as Z=Re+jωLe (Le≧0) as shown in Fig. 2-4, and CERALOCK® should work as an inductance Le (H) having the loss Re (Ω).

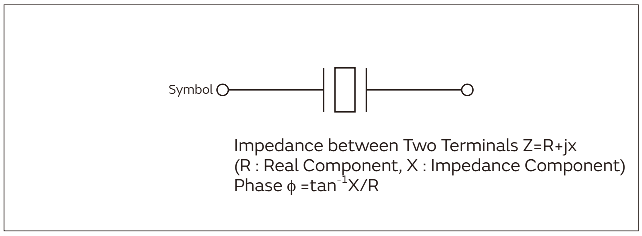


Fig. 2-1 Symbol for the Two-Terminal CERALOCK®

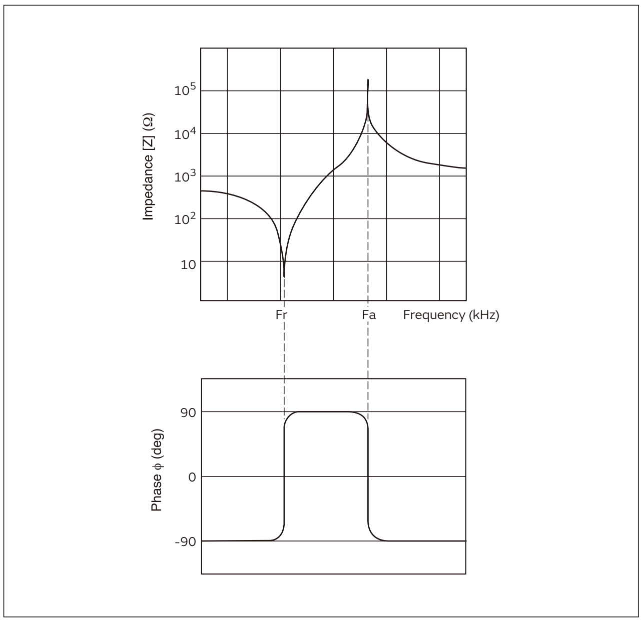
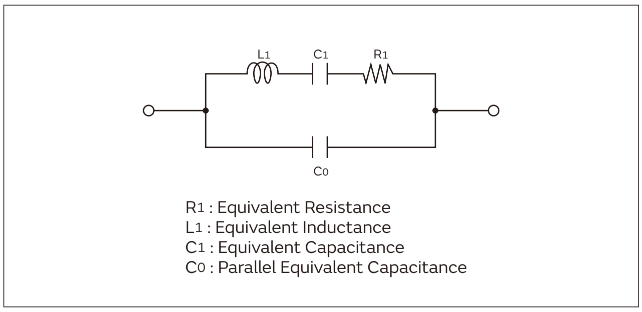
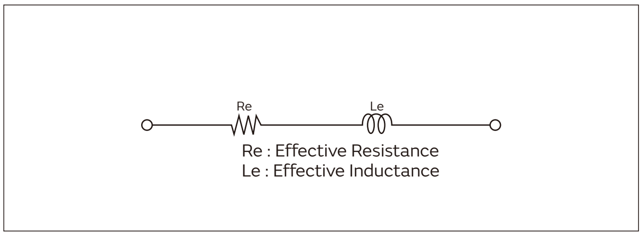


Fig. 2-2 Impedance and Phase Characteristics of CERALOCK®



R1 : Equivalent Resistance
L1 : Equivalent Inductance
C1 : Equivalent Capacitance
C0 : Parallel Equivalent Capacitance

Fig. 2-3 Electrical Equivalent Circuit of CERALOCK®



Re : Effective Resistance
Le : Effective Inductance

Fig. 2-4 Equivalent Circuit of CERALOCK® in the Frequency Band Fr≦F≦Fa

The table on this page shows a comparison of the equivalent constants between CERALOCK® and Crystal Units.
In comparison, there is a large difference in capacitance and Qm, which results in the difference of oscillating conditions, when actually operated.
The table in the appendix shows the standard values of an equivalent circuit constant for each type of CERALOCK®.
Furthermore, other higher harmonic modes exist, other than the desired oscillation mode. These other oscillation modes exist because the ceramic resonator uses mechanical resonance.
Fig. 2-5 shows those characteristics.

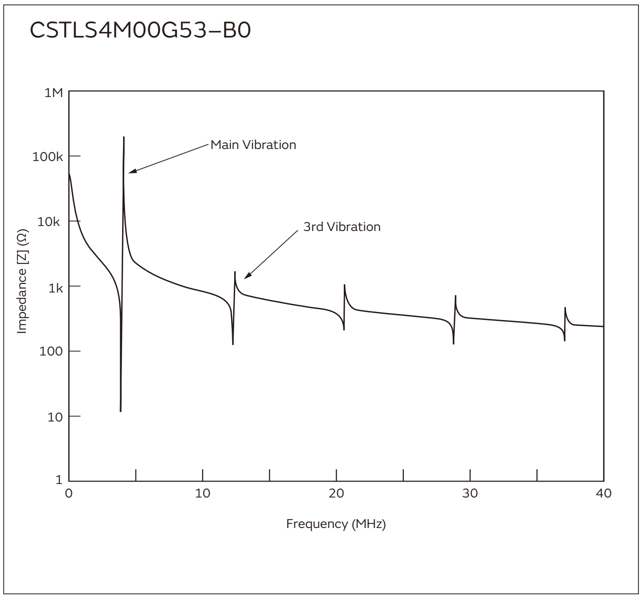


Fig. 2-5 Spurious Characteristics of CERALOCK®

Comparison of Equivalent Circuits of CERALOCK® and Crystal Unit (Reference)

Resonator	Oscillation Frequency	L_1 (μH)	C_1 (pF)	C_0 (pF)	R_1 (Ω)	Qm	dF (kHz)
CERALOCK®	2.00MHz	1.71×10^3	4	20.8	43.9	475	177.2
	4.00MHz	0.46×10^3	3.8	19.8	9	1220	350.9
	8.00MHz	0.13×10^3	3.5	19.9	8	775	641.6
Crystal Unit	2.457MHz	7.20×10^5	0.005	2.39	37	298869	3
	4.00MHz	2.10×10^5	0.007	2.39	22.1	240986	6
	8.00MHz	1.80×10^5	0.002	4.48	154.7	59600	2

Notes

(Note 1)

The relationship between the size of the resonator and the resonant frequency is described as follows. For example, the frequency doubles if the thickness doubles, when thickness vibration is used.

The following relationship is obtained when the length of the resonators is ℓ, the resonance frequency is Fr, the speed of sound waves travelling through piezoelectric ceramics, and the wavelength is λ.

$$\begin{cases} Fr \cdot \ell = \text{Const.} \\ \text{(frequency constant, } Fr \cdot t \text{ for the thickness)} \\ \lambda = 2\ell \\ C = Fr \cdot \lambda = 2Fr \cdot \ell \end{cases}$$

As seen in the above formula, the frequency constant determines the size of the resonator.

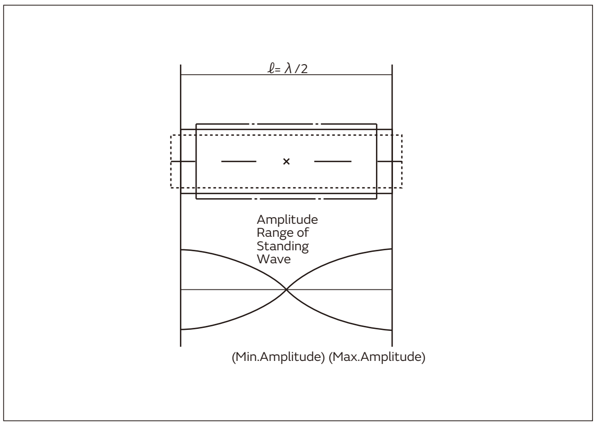


Fig. Ⅰ

(Note 2)

In Fig. 2-3, when resistance R1 is omitted for simplification, the impedance Z (ω) between two terminals is expressed by the following formula.

$$Z(\omega) = \frac{\frac{1}{j\omega C_0}\left(j\omega L_1 + \frac{1}{j\omega C_1}\right)}{\frac{1}{j\omega C_0} + \left(j\omega L_1 + \frac{1}{j\omega C_1}\right)}$$

$$= \frac{j\left(\omega L_1 - \frac{1}{\omega C_1}\right)}{1 + \frac{C_0}{C_1} - \omega^2 C_0 L_1}$$

When $\omega = \frac{1}{\sqrt{L_1 C_1}} = \omega r$, $Z(\omega r) = 0$

When $\omega = \frac{1}{\sqrt{C_0 C_1 L_1/(C_0 + C_1)}} = \omega a$, $Z(\omega a) = \infty$

Therefore from $\omega = 2\pi F$,

$$Fr = \omega r/2\pi = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

$$Fa = \omega a/2\pi = \frac{1}{2\pi\sqrt{C_0 C_1 L_1/(C_0 + C_1)}} = Fr\sqrt{1 + \frac{C_1}{C_0}}$$

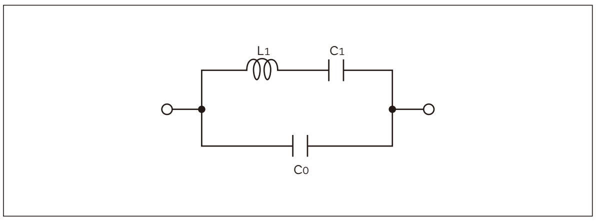


Fig. Ⅱ

2. Basic Oscillation Circuits

Generally, basic oscillation circuits can be grouped into the following 3 categories.

① Use of positive feedback
② Use of negative resistance element
③ Use of delay in transfer time or phase

In the case of ceramic resonators, Crystal Units, and LC oscillators, positive feedback is the circuit of choice.
Among the positive feedback oscillation circuit using an LC, the tuning type anti-coupling oscillation circuit, Colpitts and Hartley circuits are typically used.
See Fig. 2-6.

In Fig. 2-6, a transistor, which is the most basic amplifier, is used.
The oscillation frequencies are approximately the same as the resonance frequency of the circuit consisting of L, C_{L1} and C_{L2} in the Colpitts circuit or consisting of L_1, L_2 and C in the Hartley circuit. These frequencies can be represented by the following formulas. (Refer to Note 3 on page 11.)

(Colpitts Circuit)

$$f_{osc.} \fallingdotseq \frac{1}{2\pi\sqrt{L \cdot \frac{C_{L1} \cdot C_{L2}}{C_{L1} + C_{L2}}}} \quad \text{——————(2-4)}$$

(Hartley Circuit)

$$f_{osc.} \fallingdotseq \frac{1}{2\pi\sqrt{C(L_1 + L_2)}} \quad \text{——————(2-5)}$$

In an LC network, the inductor is replaced by a ceramic resonator, taking advantage of the fact that the resonator becomes inductive between resonant and anti-resonant frequencies.
This is most commonly used in the Colpitts circuit.
The operating principle of these oscillation circuits can be seen in Fig. 2-7. Oscillation occurs when the following conditions are satisfied.

$$\left\{\begin{array}{l} \text{Loop Gain } G = \alpha \cdot \beta \geqq 1 \\ \text{Phase Amount} \\ \qquad \theta = \theta_1 + \theta_2 = 360^\circ \times n \ (n = 1, 2, \cdots) \end{array}\right. \qquad (2\text{-}6)$$

In Colpitts circuit, an inverter of $\theta 1$ = 180° is used, and it is inverted more than θ_2 = 180° with L and C in the feedback circuit. The operation with a ceramic resonator can be considered the same.

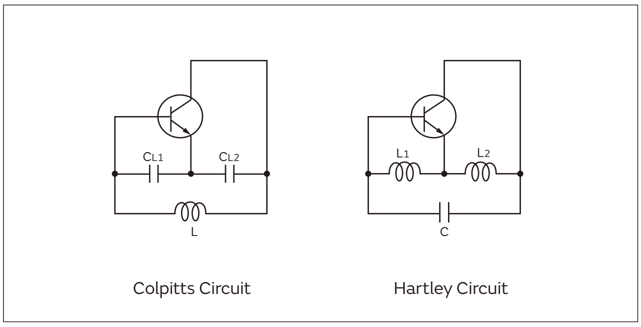


Fig. 2-6 Basic Configuration of LC Oscillation Circuit

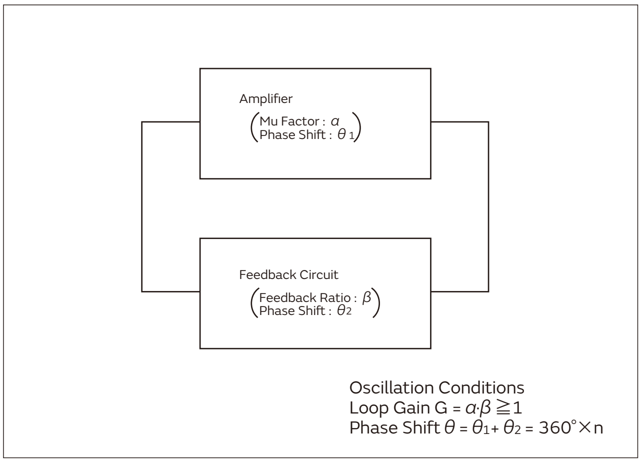


Fig. 2-7 Principle of Oscillation

It is common and simple to utilize an inverter for the Colpitts circuit with CERALOCK®.
Fig. 2-8 shows the basic oscillation circuit with inverter.
In an open loop circuit by cutting at point Ⓐ, it is possible to measure loop gain G and phase shift θ.
Fig. 2-9 shows the actual measuring circuit, and an example of the measuring result is shown in Fig. 2-10.

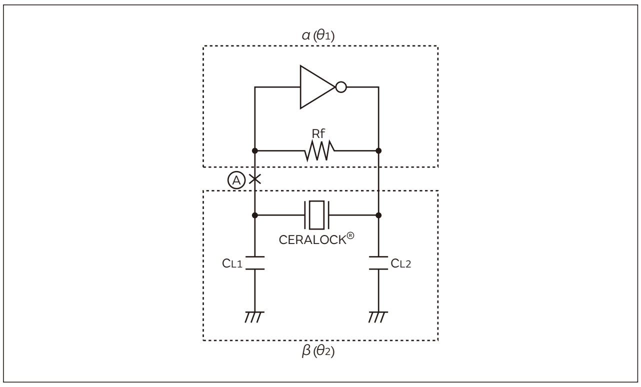


Fig. 2-8 Basic Oscillation Circuit with Inverters

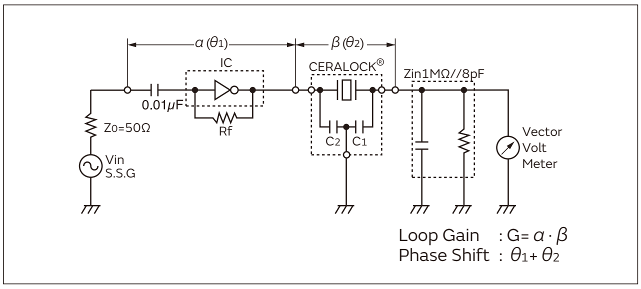


Fig. 2-9 Measuring Circuit Network of Loop Gain and Phase Shift

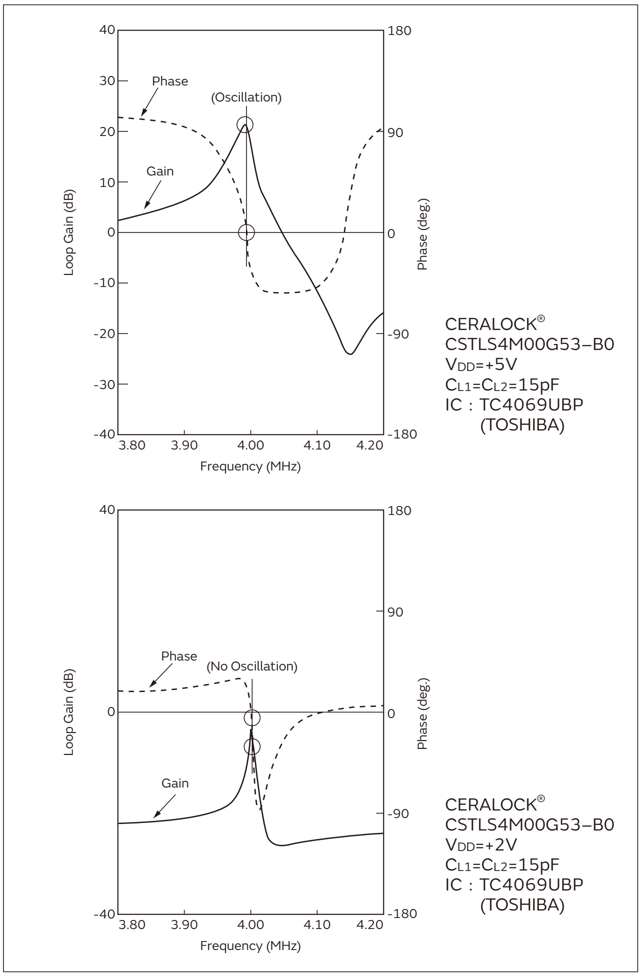


Fig. 2-10 Measured Results of Loop Gain and Phase Shift

Notes

(Note 3)

Fig.Ⅲ shows the equivalent circuit of an emitter grounding type transistor circuit. In the figure, R*i* stands for input impedance, R0 stands for output impedance and ß stands for current amplification rate.

When the oscillation circuit in Fig.2-6 is expressed by using the equivalent circuit in Fig.Ⅲ, it becomes like Fig.Ⅳ. Z1, Z2 and Z are as shown in the table for each Hartley type and Colpitts type circuit.

The following 3 formulas are obtained based on Fig.Ⅳ.

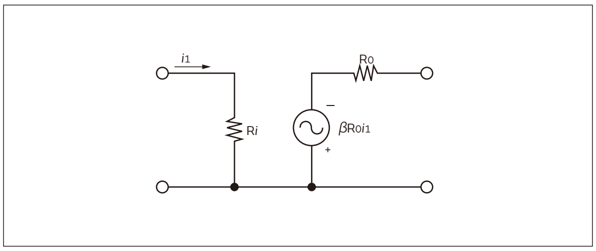
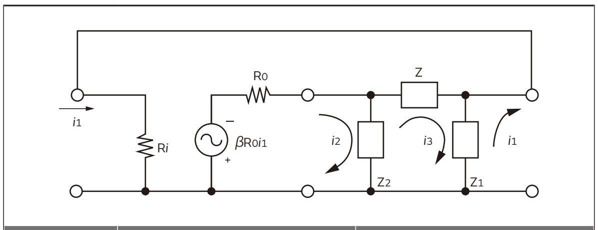


Fig.Ⅲ



	Hartley Type	Colpitts Type
Z₁	jωL₁	1／jωC$_{L1}$
Z₂	jωL₂	1／jωC$_{L2}$
Z	1／jωC	jωL

Fig.Ⅳ Hartley/Colpitts Type LC Oscillation Circuits

$$\begin{cases} \beta R_0 i_1+(R_0+Z_2)\, i_2-Z_2 i_3=0 \cdots\cdots\cdots\cdots & (1) \\ Z_1 i_1+Z_2 i_2-(Z_2+Z+Z_1)\, i_3=0 \cdots\cdots\cdots\cdots & (2) \\ (Z_1+Ri)\, i_1-Z_1 i_3=0 \cdots\cdots\cdots\cdots & (3) \end{cases}$$

As $i1 \neq 0$, $i2 \neq 0$, $i3 \neq 0$ are required for continuous oscillation, the following conditional formula can be performed by solving the formulas of (1), (2) and (3) on the current.

$$\begin{cases} \beta R_0 Z_1 Z_2=(Z_1+Ri)Z_2^2-\{Z_1(Z_2+Z)+ \\ \qquad (Z_2+Z+Z_1)Ri\}(Z_2+R_0) \cdots\cdots\cdots\cdots \quad (4) \end{cases}$$

Then, as Z1, Z2 and Z are all imaginary numbers, the following conditional formula is obtained by dividing the formula (4) into the real number part and the imaginary number part.

$$\begin{cases} \text{(Imaginary number part)} \\ \quad Z_1 Z_2 Z+(Z_1+Z_2+Z)RiR_0=0 \cdots\cdots\cdots\cdots & (5) \\ \text{(Real number part)} \\ \quad \beta R_0 Z_1 Z_2+Z_1(Z+Z_2)R_0+ \\ \quad Z_2(Z+Z_1)Ri=0 \cdots\cdots\cdots\cdots & (6) \end{cases}$$

Formula (5) represents the phase condition and formula (6) represents the power condition.

Oscillation frequency can be obtained by applying the elements shown in the aforementioned table to Z₁, Z₂ and Z solving it for angular frequency ω.

(Hartley Type)

$$\omega^2 osc=(2\pi fosc.)^2=\frac{1}{(L_1L_2)\,C\{1+\dfrac{L_1\cdot L_2}{(L_1+L_2)\,CRiR_0}\}} \cdots\cdots\cdots\cdots \quad (7)$$

(Colpitts Type)

$$\omega^2 osc=(2\pi\, fosc.)^2=\frac{1}{L\,\dfrac{C_{L1}\cdot C_{L2}}{C_{L1}+C_{L2}}}\cdot\{1+\frac{L}{(C_{L1}+C_{L2})\,RiR_0}\} \cdots\cdots\cdots\cdots \quad (8)$$

In either circuit, the term in brackets will be 1 as long as R*i* and R0 is large enough. Therefore oscillation frequency can be obtained by the following formula.

(Hartley Type) $fosc. \fallingdotseq \dfrac{1}{2\pi\sqrt{(L_1+L_2)C}}$ …… (9)

(Colpitts Type) $fosc. \fallingdotseq \dfrac{1}{2\pi\sqrt{L\cdot\dfrac{C_{L1}\cdot C_{L2}}{C_{L1}+C_{L2}}}}$ ……(10)

3 Specifications of CERALOCK®

RoHS

1. Electrical Specifications

The frequency stability of CERALOCK® is between that of Crystal Units and LC or RC oscillators. Temperature stability is ±0.3 to ±0.5% against initial values within -20 to +80 °C. The initial frequency precision is ±0.5% for standard products. The frequency of the standard CERALOCK® is adjusted by the standard measuring circuit, but the oscillation frequency may shift when used in the actual IC circuit. Usually, if the frequency precision needed for clock signal of a 1 chip microcomputer is approximately ±2 to 3% under working conditions, CERALOCK® standard type can be used in most cases. If exact oscillation frequency is required for a special purpose, Murata can manufacture the ceramic resonator for the desired frequency.

The following are the general electrical specifications of CERALOCK®. (As for the standard measuring circuit of oscillation frequency, please refer to the next chapter “Application to Typical Oscillation Circuits”.)

Electrical Specifications of MHz Band Lead CERALOCK® (CSTLS Series)

Electrical specifications of CSTLS series are shown in the tables. Please note that oscillation frequency measuring circuit constants of the CSTLS □G56 series (with H-CMOS IC) depends on frequency.

Resonant Impedance Specifications of CSTLS/ Series

Type	Frequency Range (MHz)	Resonant Impedance (Ω max.)
CSTLS□G	3.40 — 3.99	50
	4.00 — 7.99	30
	8.00 — 10.00	25
CSTLS□X	16.00 — 32.99	50
	33.00 — 50.00	40

MHz band three-terminal CERALOCK® (CSTLS Series) is built-in load capacitance.

Fig. 3-1 shows the electrical equivalent circuit.

The table shows the general specifications of the CSTLS series. Input and output terminals of the three-terminal CERALOCK® are shown in the table titled Dimensions of CERALOCK® CSTLS series in Chapter 1 on page 6.

But connecting reverse, the oscillating characteristics are not affected except that the frequency has a slight lag.

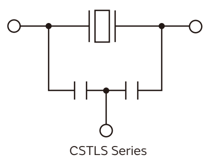
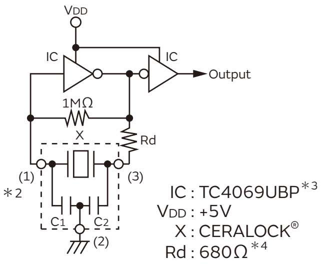


Fig. 3-1 Symbol for the Three-Terminal CERALOCK®

General Specifications CSTLS Series

Item / Part Number	Frequency Range (MHz)	Initial Tolerance of Oscillation Frequency	Temperature Stability of Oscillation Frequency (-20 to +80°C)	Oscillating Frequency Aging	Standard Circuit for Oscillation Frequency
CSTLS□G53/56	3.40—10.00	±0.5%	±0.2%[*1]	±0.2%	 IC : TC4069UBP[*3] V_{DD} : +5V X : CERALOCK® Rd : 680Ω[*4]
CSTLS□X	16.00—50.00	±0.5%	±0.2%	±0.2%	

＊1 This value varies for built-in Capacitance
＊2 If connected conversely, a slight frequency lag may occur.
＊3 G56/X series : TC74HCU04(TOSHIBA)
＊4 This resistance value applies to the CSTLS□G56 series.

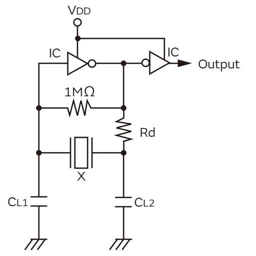
Electrical Specifications of MHz Band Chip CERALOCK® (CSACW Series) (CSTCC/CSTCR/CSTCE/CSTCW Series)

General specifications of chip CERALOCK® (CSACW series)and (CSTCC/CSTCR/CSTCE/CSTCW series) are shown in the tables respectively.

Resonant Impedance of CSTCC/CSTCR/CSTCE/CSTCW/CSACW Series

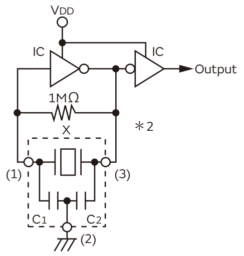
Type	Frequency Range (MHz)	Resonant Impedance (Ω max.)
CSTCC□G	2.00～2.99	80
	3.00～3.99	50
CSTCR□G	4.00～5.99	60
	6.00～7.99	50
CSTCE□G	8.00～10.00	40
	10.01～13.990	30
CSTCE□V	14.00～20.000	40
CSACW□X/CSTCW□X	20.01～24.990	80
	25.00～29.990	60
	30.00～60.000	50
	60.01～70.000	60

General Specifications of CSACW Series

Item / Part Number	Frequency Range (MHz)	Initial Tolerance of Oscillation Frequency	Temperature Stability of Oscillation Frequency (-20 to +80°C)	Oscillating Frequency Aging	Standard Circuit for Oscillation Frequency
CSACW□X53	20.01～24.99	±0.5%	±0.2%	±0.1%	 IC : TC74HCU04＊(TOSHIBA)(＊1) V_{DD} : +5V X : Chip CERALOCK® C_{L1}, C_{L2} : This value varies for frequency.
CSACW□X51	25.00～70.00	±0.5%	±0.2%	±0.1%	

＊1 X51 Series (60.01—70.00MHz); SN74AHCU04

General Specifications of CSTCC/CSTCR/CSTCE/CSTCW Series

Item / Part Number	Frequency Range (MHz)	Initial Tolerance of Oscillation Frequency	Temperature Stability of Oscillation Frequency (-20 to +80°C)	Oscillating Frequency Aging	Standard Circuit for Oscillation Frequency
CSTCC□G	2.00—3.99	±0.5%	±0.3%＊3	±0.3%	 IC : TC4069UBP＊1(TOSHIBA) V_{DD} : +5V X : Chip CERALOCK®
CSTCR□G	4.00—7.99	±0.5%	±0.2%	±0.1%	
CSTCE□G	8.00—13.99	±0.5%	±0.2%	±0.1%	
CSTCE□V	14.00—20.00	±0.5%	±0.3%	±0.3%	
CSTCW□X	20.01—70.00	±0.5%	±0.2%	±0.1%	

＊1 V, X Series; TC74HCU04(TOSHIBA), X Series (50.00—70.00MHz); SN74AHCU04(TI)
＊2 If connected in the wrong direction, the above specification may not be guaranteed.
＊3 This value varies for built-in Capacitance and Frequency.

2. Mechanical and Environmental Specifications of CERALOCK®

The tables show the standard test conditions of mechanical strength and environmental specifications of CERALOCK®. Fig. 3-2 shows the changes of oscillation frequency in each test, the table on the next page shows the criteria after the tests, and Fig. 3-3 shows the reflow soldering profile.

Test Conditions for Standard Reliability of CERALOCK®

Item	Conditions
1. Shock Resistance	Measure after dropping from a height of $\boxed{a}$ cm to $\boxed{b}$ floor surface 3 times.
2. Soldering Heat Resistance	Lead terminals are immersed up to 2.0 mm from the resonator's body in solder bath of $\boxed{c}$, and then the resonator shall be measured after being placed in natural condition for 1 hour.[*1] Reflow profile show in Fig. 3-3 of heat stress is applied to the resonator, then the resonator shall be measured after being placed in natural condition for 1 hour.[*2]
3. Vibration Resistance	Measure after applying vibration of 10 to 55Hz amplitude of 2 mm to each of 3 directions, X, Y, Z.
4. Humidity Resistance	Keep in a chamber with a temperature of $\boxed{d}$ and humidity of 90 to 95% for $\boxed{e}$ hours. Leave for 1 hour before measurement.
5. Storage at High Temperature	Keep in a chamber at 85±2℃ for $\boxed{e}$ hours. Leave for 1 hour before measurement.
6. Storage at Low Temperature	Keep in a chamber at $\boxed{f}$ ℃ for $\boxed{e}$ hours. Leave for 1 hour before measurement.
7. Temperature Cycling	Keep in a chamber at -55℃ for 30 minutes. After leaving at room temperature for 15 minutes, keep in a chamber at +85℃ for 30 minutes, and then room temperature for 15 minutes. After 10 cycles of the above, measure at room temperature.
8. Terminal Strength	Apply 1 kg of static load vertically to each terminal and measure.[*1]

[*1] Applies to CERALOCK® Lead Type
[*2] Applies to MHz Band Chip CERALOCK®

1. CSTLS Series

Type	fosc.	a	b	c	d	e	f
G	3.40—10.00MHz	100	concrete	350±10℃	60±2℃	1000	−55±2℃
X	16.00—50.00MHz	100	concrete	350±10℃	60±2℃	1000	−55±2℃

2. CSACW Series

Type	fosc.	a	b	c	d	e	f
X	20.01—50.00MHz	100	wooden plate	—	60±2℃	1000	−55±2℃

3. CSTCC/CSTCR/CSTCE/CSTCW Series

Type	fosc.	a	b	c	d	e	f
G	2.00—13.99MHz	100	wooden plate	—	60±2℃	1000	−55±2℃
V	14.00—20.00MHz	100	wooden plate	—	60±2℃	1000	−55±2℃
X	20.01—70.00MHz	100	wooden plate	—	60±2℃	1000	−55±2℃

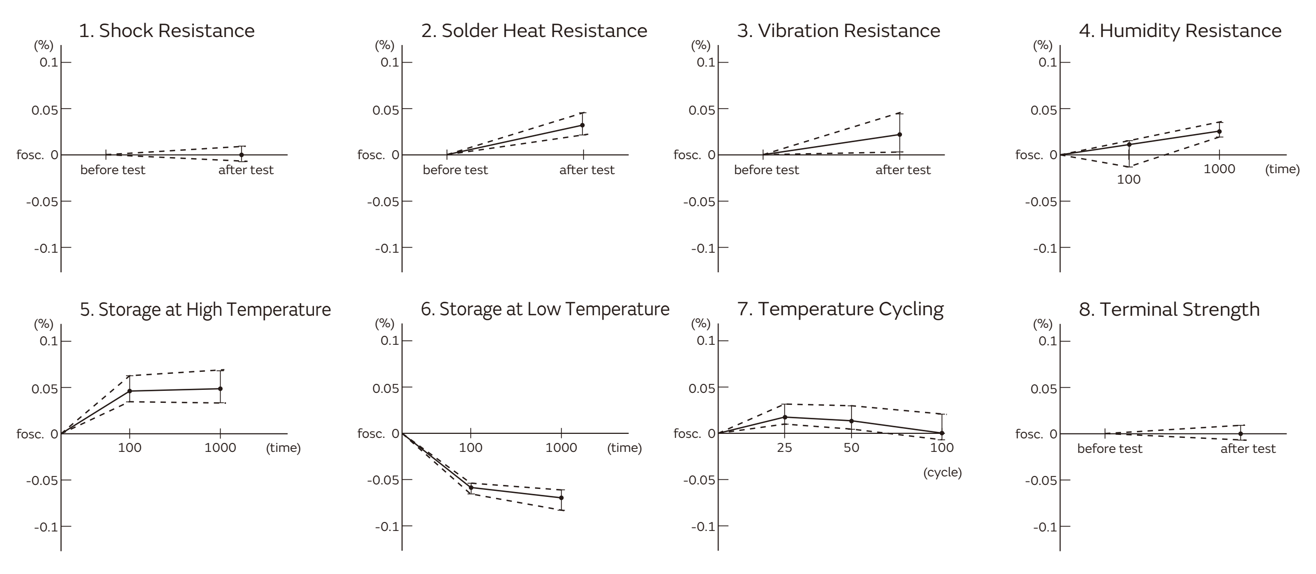


Fig. 3-2 General Changes of Oscillation Frequency in Each Reliability Test (CSTLS4M00G53–B0)

Deviation after Reliability Test

Item Type	Oscillation Frequency	Other
Every Series	within±0.2%* (from initial value)	Meets the individual specification of each product.

∗ CSTCC Series : within±0.3%

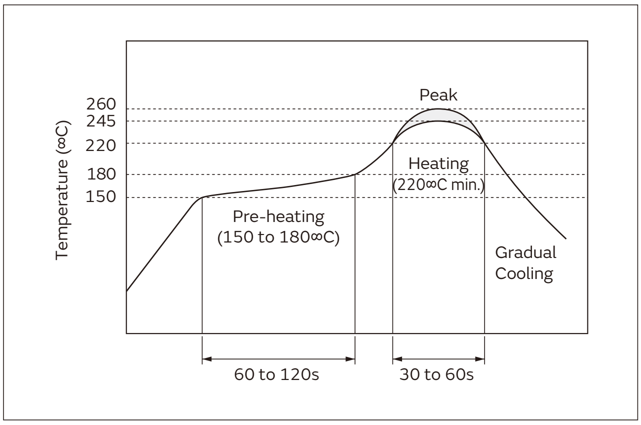


Fig. 3-3 Reflow Soldering Profile for MHz Band Chip CERALOCK®

4 Applications of Typical Oscillation Circuits

RoHS

As described in Chapter 2, the most common oscillation circuit with CERALOCK® is to replace L of a Colpitts circuit with CERALOCK®. The design of the circuit varies with the application and the IC being used, etc. Although the basic configuration of the circuit is the same as that of Crystal Units, the difference in mechanical Q results in the difference of the circuit constant.
This chapter briefly describes the characteristics of the oscillation circuit and gives some typical examples.

1. Cautions for Designing Oscillation Circuits

It is becoming more common to configure the oscillation circuit with a digital IC, and the simplest way is to use an inverter gate.
Fig. 4-1 shows the configuration of a basic oscillation circuit with a C-MOS inverter.
INV. 1 works as an inverter amplifier of the oscillation circuit.
INV. 2 acts to shape the waveform and also acts as a buffer for the connection of a frequency counter.
The feedback resistance Rf provides negative feedback around the inverter in order to put it in the linear region, so the oscillation will start, when power is applied.
If the value of Rf is too large, and if the insulation resistance of the input inverter is accidentally decreased, oscillation will stop due to the loss of loop gain. Also, if Rf is too great, noise from other circuits can be introduced into the oscillation circuit.
Obviously, if Rf is too small, loop gain will be low. An Rf of 1MΩ is generally used with a ceramic resonator.
Damping resistor Rd provides loose coupling between the inverter and the feedback circuit and decreases the loading on the inverter, thus saving energy.
In addition, the damping resistor stabilizes the phase of the feedback circuit and provides a means of reducing the gain in the high frequency area, thus preventing the possibility of spurious oscillation.
Load capacitance C_{L1} and C_{L2} provide the phase lag of 180°.
The proper selected value depends on the application, the IC used, and the frequency.

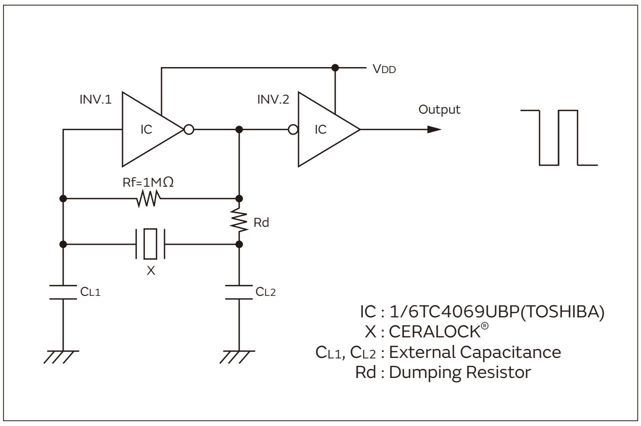


Fig. 4-1 Basic Oscillation Circuit with C-MOS Inverter

Oscillation frequency fosc. in this circuit is expressed approximately by the following equation.

$$\text{fosc.}=\text{Fr}\sqrt{1+\frac{C_1}{C_0+C_L}} \qquad (4\text{-}1)$$

Where, Fr=Resonance frequency of CERALOCK®

C_1 : Equivalent series capacitance of CERALOCK®

C_0 : Equivalent parallel capacitance of CERALOCK®

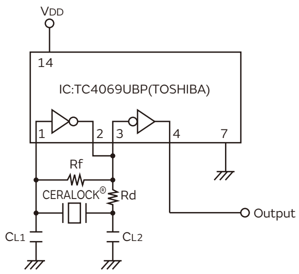
$$C_L=\frac{C_{L1}\cdot C_{L2}}{C_{L1}+C_{L2}}$$

This clearly shows that the oscillation frequency is influenced by the loading capacitance. Further caution should be paid in defining its value when a tight tolerance of oscillation frequency is required.

2. Application to Various Oscillation Circuits

Application to C-MOS Inverter

For the C-MOS inverting amplifier, the one-stage 4069 C-MOS group is best suited.
The C-MOS 4049 type is not used, because the three-stage buffer type has excessive gain, which causes RC oscillation and ringing.
Murata employs the TOSHIBA TC4069UBP as a C-MOS standard circuit. This circuit is shown in
Fig. 4-2. The oscillation frequency of the standard CERALOCK® (C-MOS specifications) is adjusted by the circuit in Fig. 4-2.

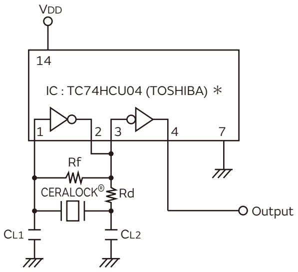


Item / Part Number	Frequency Rage	VDD	Circuit Constant			
			C_{L1}	C_{L2}	Rf	Rd
CSTLS□G53	3.40—10.00MHz	+5V	(15pF)	(15pF)	1MΩ	0

Fig. 4-2 C-MOS Standard Circuit

Application to H-CMOS Inverter

Recently, high-speed C-MOS (H-CMOS) have been used more frequently for oscillation circuits allowing high speed and energy saving control for the microprocessor.
There are two types of H-CMOS inverters: the un- buffered 74HCU series and the 74HC series with buffers.
The 74HCU system is optimum for the CERALOCK® oscillation circuit.
Fig. 4-3 shows our standard H-CMOS circuit.
Since H-CMOS has high gain, especially in the high frequency area, greater loading capacitor (CL) and damping resistor (Rd) should be employed to stabilize oscillation performance. As a standard circuit, we recommend Toshiba's TC74CU04, but any 74HCU04 inverter from other manufacturers may be used.
The oscillation frequency for H-CMOS specifications is adjusted by the circuit in Fig. 4-3.



∗ 60.01—70.00MHz : SN74AHCU04(TI)

Item Part Number	Frequency Rage	VDD	Circuit Constant			
			C_{L1}	C_{L2}	Rf	Rd
CSTLS □ G56	3.40～10.00MHz	+5V	(47pF)	(47pF)	1MΩ	680Ω
CSTLS □ X	16.00～19.99MHz	+3V	(5pF)	(5pF)	1MΩ	470Ω
		+5V	(15pF)	(15pF)	1MΩ	220Ω
		+5V	(22pF)	(22pF)	1MΩ	0
		+5V	(33pF)	(33pF)	1MΩ	0
	20.00～25.99MHz	+3V	(5pF)	(5pF)	1MΩ	0
		+5V	(15pF)	(15pF)	1MΩ	0
		+5V	(22pF)	(22pF)	15KΩ	0
		+5V	(33pF)	(33pF)	4.7KΩ	0
	26.00～32.99MHz	+5V	(5pF)	(5pF)	1MΩ	0
		+5V	(15pF)	(15pF)	15KΩ	0
		+5V	(22pF)	(22pF)	4.7KΩ	0
		+5V	(33pF)	(33pF)	3.3KΩ	0
	33.00～50.00MHz	+5V	(5pF)	(5pF)	1MΩ	0
		+5V	(15pF)	(15pF)	15KΩ	0

Fig. 4-3 H-CMOS Standard Circuit

5 Characteristics of CERALOCK® Oscillation Circuits

RoHS

This chapter describes the general characteristics of the basic oscillation of Fig. 4-1 (page17). Contact Murata for detailed characteristics of oscillation with specific kinds of ICs and LSIs.

1. Stability of Oscillation Frequency

Fig. 5-1 shows examples of actual measurements for stability of the oscillation frequency.
The stability versus temperature change is ±0.1 to 0.5% within a range of -20 to +80°C, although it varies slightly depending on the ceramic material.
Influence of load capacitance (C_{L1}, C_{L2}) on the oscillation frequency is relatively high, as seen in formula (4-1) (Page18).
It varies approximately ±0.05% for a capacitance deviation of ±10%. The stability versus supply voltage is normally within ±0.05% in the working voltage range, although it varies with the characteristics of the IC.

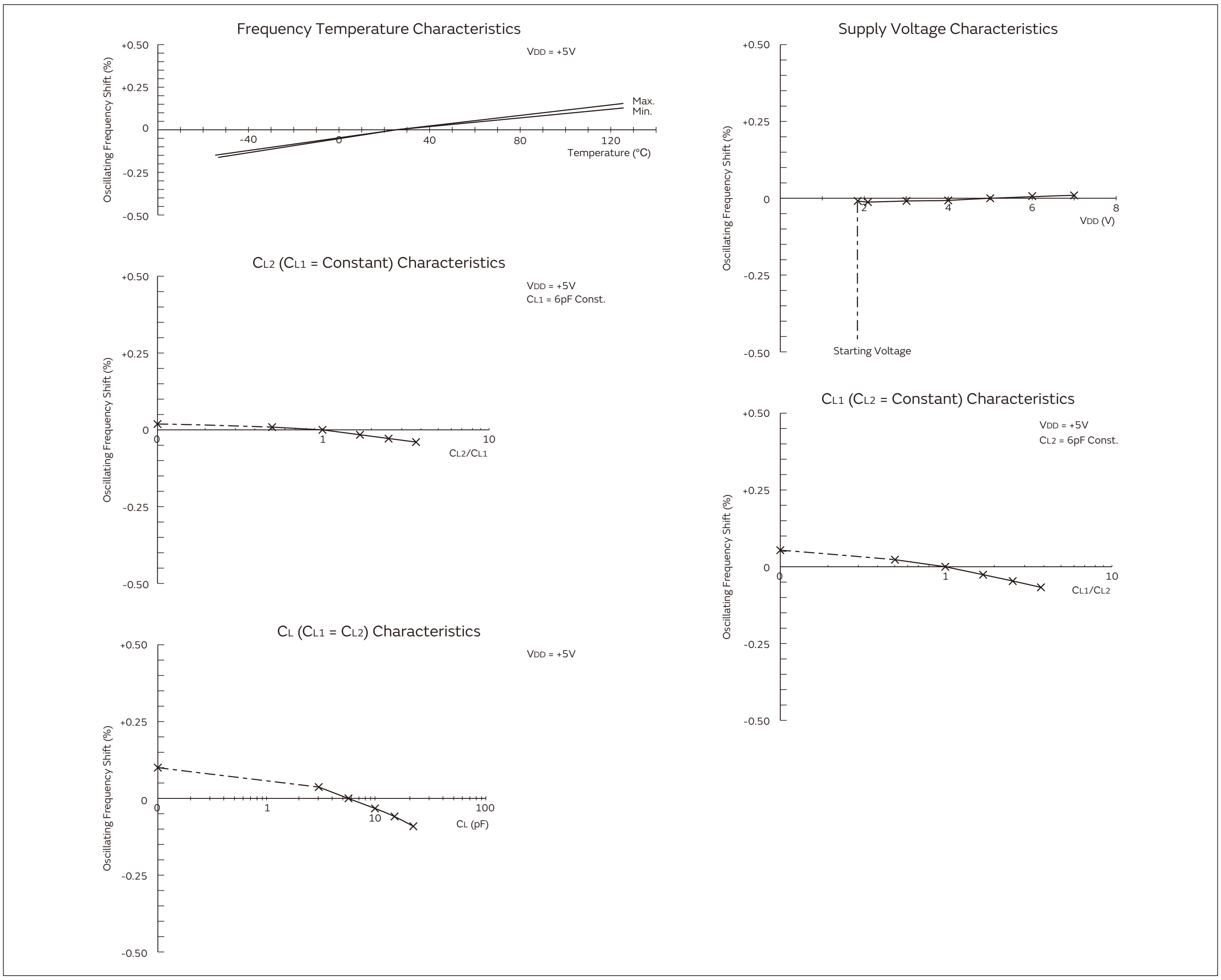
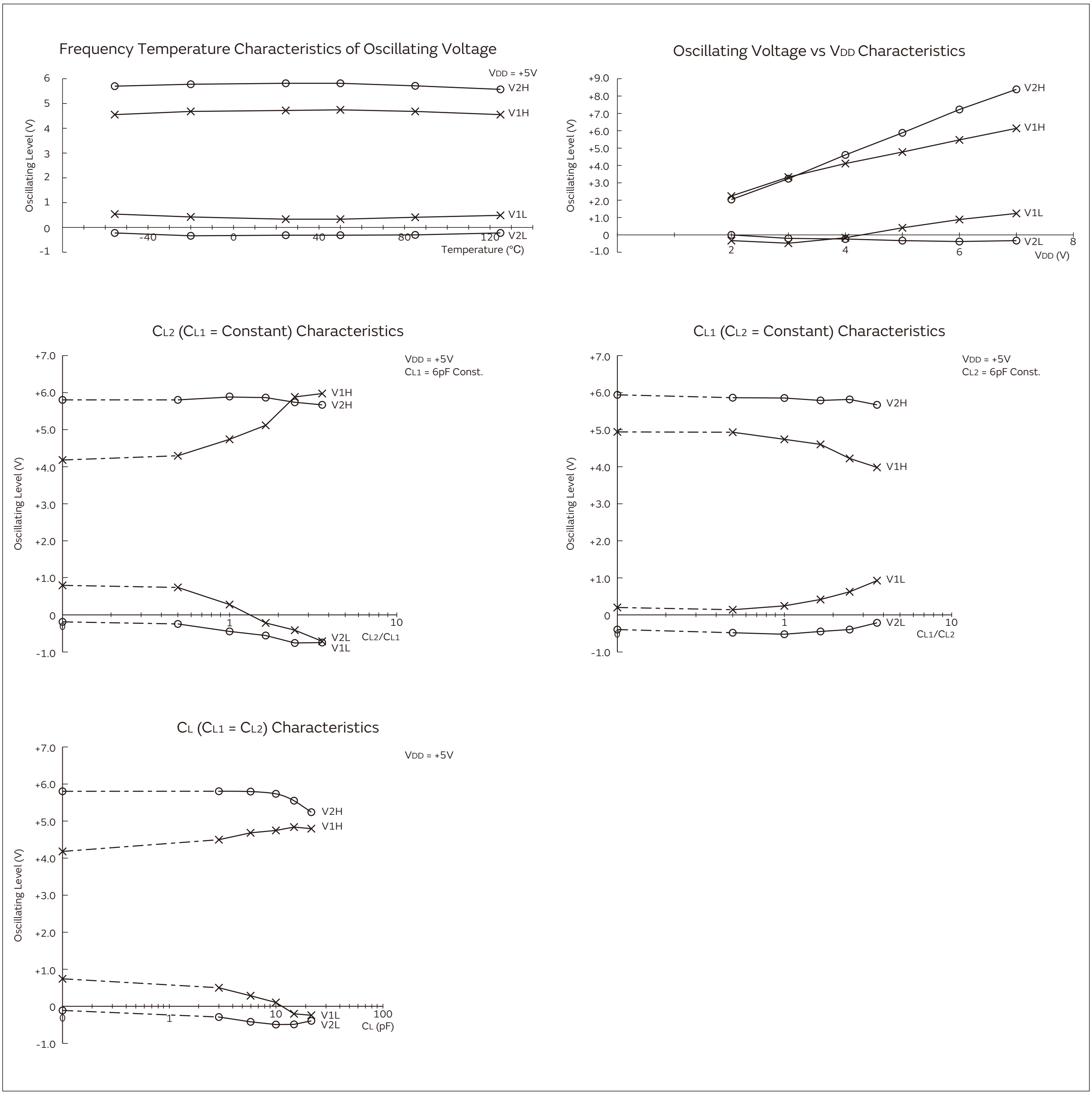


Fig. 5-1 Examples of Actual Measurement for the Stability of Oscillation Frequency (IC: TC74HCU04 (TOSHIBA), CERALOCK®: CSACW33M8X51–B0)

2. Characteristics of the Oscillation Level

Fig. 5-2 shows examples of actual measurements of the oscillation level versus temperature, supply voltage and load capacitance (C_{L1}, C_{L2}). The oscillating amplitude is required to be stable over a wide temperature range, and temperature characteristics should be as flat as possible. The graph titled Supply Voltage Characteristics in Fig. 5-2 shows that the amplitude varies linearly with supply voltage, unless the IC has an internal power supply voltage regulator.



Frequency Temperature Characteristics of Oscillating Voltage

Oscillating Voltage vs V_{DD} Characteristics

C_{L2} (C_{L1} = Constant) Characteristics

C_{L1} (C_{L2} = Constant) Characteristics

C_L (C_{L1} = C_{L2}) Characteristics

Fig. 5-2 Examples of Actual Measurement of Oscillating Amplitude (IC: TC74HCU04(TOSHIBA), CERALOCK®: CSACW33M8X51–B0)

3. Characteristics of Oscillation Rise Time

Oscillation rise time means the time when oscillation develops from a transient area to a steady state condition, at the time the power of the IC is activated.

With a CERALOCK®, this is defined as the time to reach 90% of the oscillation level under steady state conditions as shown in Fig. 5-3.

Rise time is primarily a function of the oscillation circuit design. Generally, smaller loading capacitance, higher frequency of ceramic resonator, and lower mechanical Q of ceramic resonator cause a faster rise time. The effect of load capacitance becomes more apparent as the capacitance of the resonator decreases.

Fig. 5-4 shows how the rise time increases as the load capacitance of the resonator increases. Also, Fig. 5-4 shows how the rise time varies with supply voltage.

It is noteworthy that the rise time of CERALOCK® is one or two decades faster than a Crystal Unit.

Fig. 5-5 shows comparison of rise time between the two.

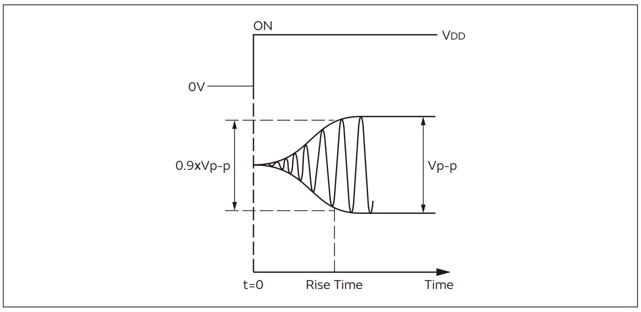


Fig. 5-3 Definition of Rise Time

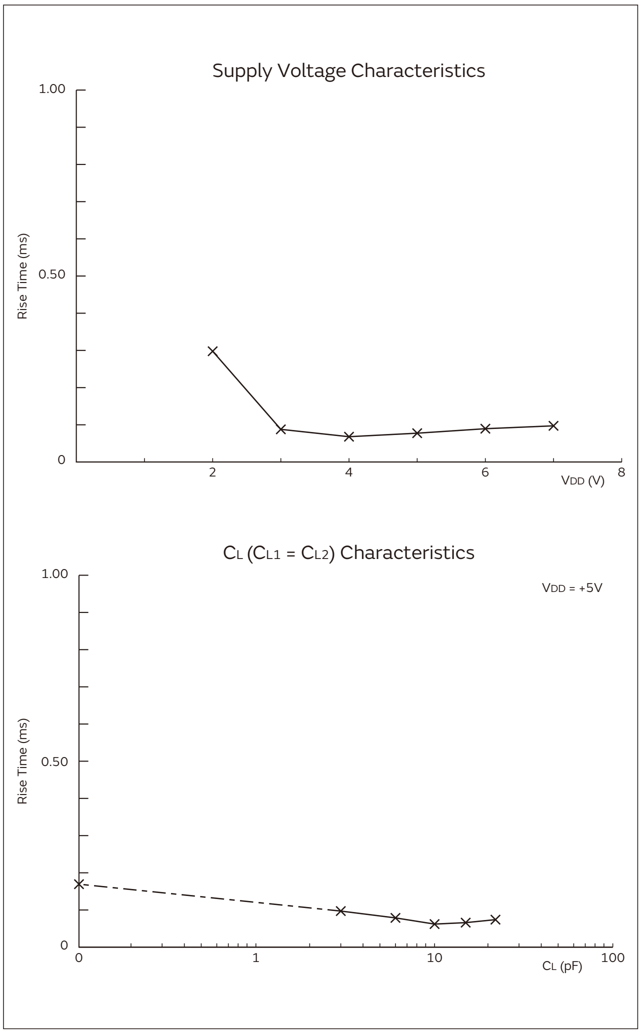
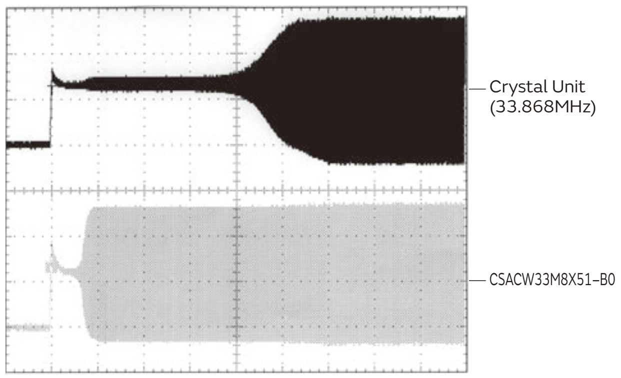


Fig. 5-4 Examples of Characteristics of Oscillation Rise Time (IC: TC74HCU04 (TOSHIBA), CERALOCK®: CSACW33M8X51–B0)



IC : TC74HCU04AP(TOSHIBA)
VDD=+5V, CL1=CL2=6pF
↑ 2.0V/div.
→0.1msec./div.

Fig. 5-5 Comparison of the Rise Time of CERALOCK® vs. a Crystal Unit

4. Starting Voltage

Starting voltage refer to the minimum supply voltage at which an oscillation circuit can operate. Starting voltage is affected by all the circuit elements, but it is determined mostly by the characteristics of the IC.
Fig. 5-6 shows an example of an actual measurement for the starting voltage characteristics against the loading capacitance.

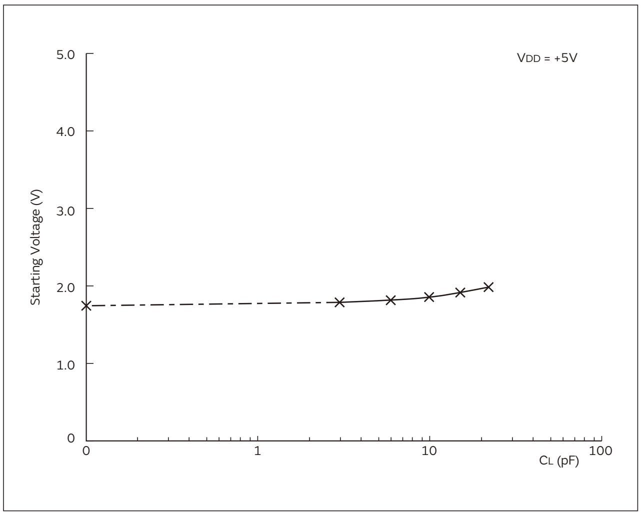


Fig. 5-6 Starting Voltage Characteristics against CL
(C_{L1}=C_{L2})
(IC: TC74HCU04 (TOSHIBA), CERALOCK®: CSACW33M8X51–B0)