

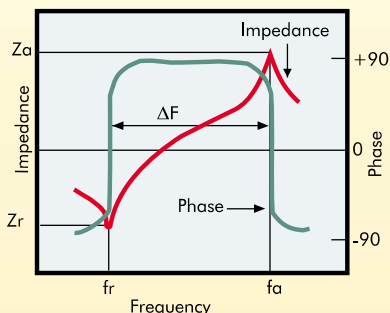
# Technical Notes



## How to design an oscillator circuit with CERALOCK®

The following article describes how to design a clock oscillator circuit by using CERALOCK® (resonators), how to get the optimum circuit constant of each component, and also discusses the differences between CERALOCK® and a quartz crystal resonator.

**Figure 1 - Frequency characteristics of impedance and phase of CERALOCK®**



### 1. Differences between a CERALOCK® and a quartz crystal resonator

Figure 1 shows the typical frequency characteristics of phase and impedance for CERALOCK®.

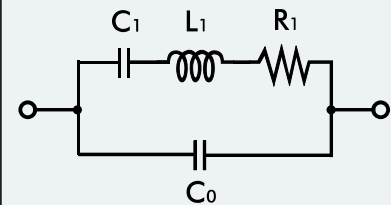
CERALOCK® is inductive in the frequency range between the resonant frequency ( $f_r$ ) of the minimum impedance value and the anti-resonant frequency ( $f_a$ ) of the maximum impedance value. Outside these ranges it is capacitive.

When using CERALOCK® to construct an oscillator circuit, the inductive characteristics between  $f_r$  and  $f_a$  are

utilized instead of L in the LC oscillator circuit.

Figure 2 shows the equivalent circuit of either CERALOCK® or quartz crystal resonators. The circuit is a series-parallel resonator circuit that comprises the equivalent resistance  $R_1$ , the equivalent inductance  $L_1$ , the equivalent capacitance  $C_1$  and the capacitance between the electrodes

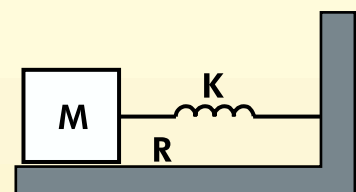
**Figure 2 - Equivalent circuit of CERALOCK®**



$C_0$ . Table 1 shows typical values for each circuit element of both CERALOCK® and quartz crystal resonators.

Figure 3 shows the analogy between the electrical equation of motion and the mechanical equation of motion.

**Figure 3 - Mechanical and electrical equation of motion**



- R : Friction (Equivalent to  $R_1$ )
- K : Spring constant (Equivalent to  $\frac{1}{C_1}$ )
- M : Mass (Equivalent to  $L_1$ )

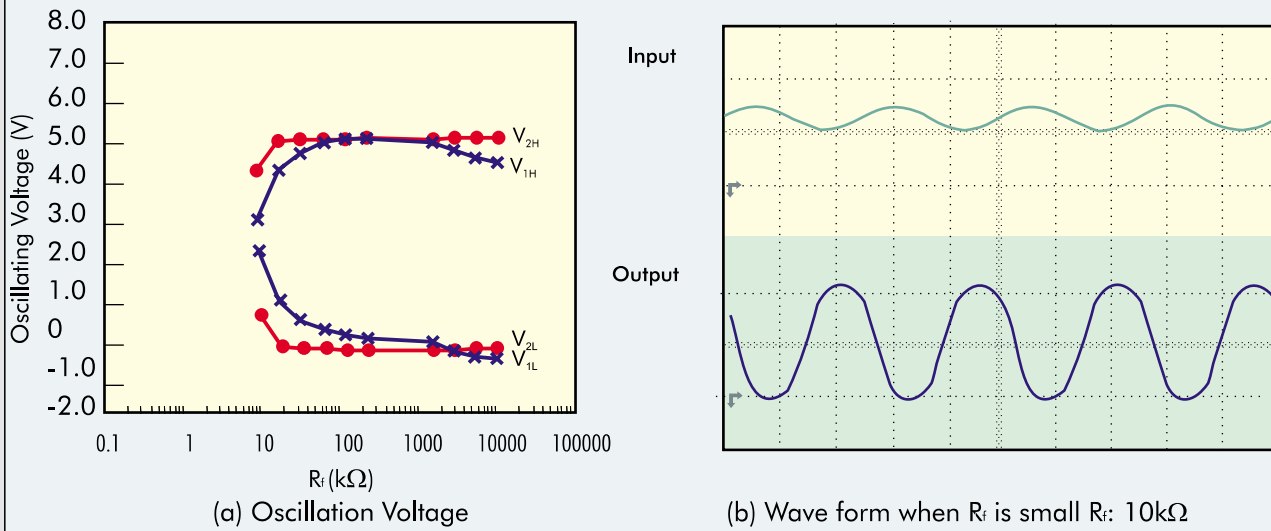
Mechanical equation of motion

$$M \frac{dv}{dt} + Rv + k \int v dt = F$$

Electrical equation of motion

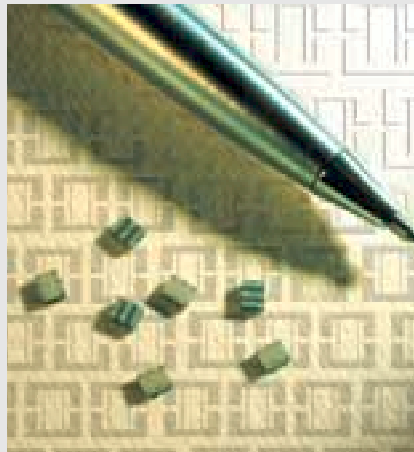
$$L_1 \frac{di}{dt} + R_1 i + \frac{1}{C_1} \int i dt = V$$

Figure 5 - Oscillation characteristics when feedback resistance  $R_f$  is changed



**(2) Load capacitance:  $C_L$  ( $C_{L1} = C_{L2}$ )**

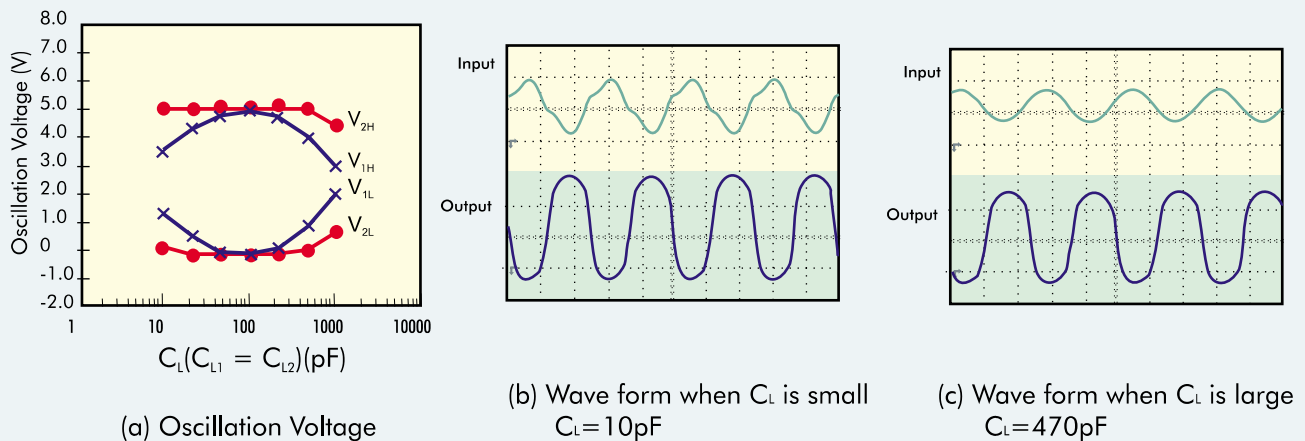
Figure 6a shows the change of oscillation voltage when load capacitance  $C_L$  is varied.  $C_L$  is an important parameter that affects the stability and frequency of oscillation. Load capacitance must be carefully selected to match the IC as, when  $C_L$  gets too small, the wave form becomes distorted (Figure 6b) and oscillation becomes unstable. When  $C_L$  gets too large, the oscillation voltage decreases (Figure 6c) and the oscillation may well stop altogether.



**(3) Damping resistance:  $R_d$**

Figure 7(a) shows the change of the oscillation voltage when damping resistance  $R_d$  is varied. There are many cases where an overshoot or undershoot of oscillation voltage is generated when the  $R_d$  is zero (Figure 7b). This can be avoided by adding  $R_d$  (Figure 7c). Also,  $R_d$  forms a low pass filter with load capacitance  $C_{L2}$ , and makes the loop gain smaller at higher frequency and suppresses unwanted oscillation in the high frequency

Figure 6 - Oscillation characteristics when load capacitance  $C_L$  ( $C_{L1} = C_{L2}$ ) is changed



**Table 1 - Typical electrical characteristics of CERALOCK® and a quartz crystal resonator**

	CERALOCK®	Quartz crystal resonator
Frequency	4.00MHz	4.00MHz
L1 (μH)	887	$3.08 \times 10^5$
C1 (pF)	1.88	$5.13 \times 10^{-3}$
C0 (pF)	15.7	$1.83 \times 10^3$
R1 (Ω)	8.04	8.48

As shown in Table 1, CERALOCK® has a smaller value of  $L_1$  which is equivalent to mass  $M$  of the mechanical equation of motion, and a larger value of  $C_1$  which is equivalent to the reciprocal of the spring constant  $k$ . This means that the CERALOCK® has faster rise time than the quartz crystal resonator.

While the quartz crystal oscillator takes a few milliseconds to start up, CERALOCK® oscillators take only a few tens of microseconds. Because of shorter start up time, CERALOCK® is suitable for use in such equipment

that requires frequent start-up or power-on from a sleep state. This is particularly the case for microcomputers that use energy saving standby modes, because a quick rise times result in faster computing.

## 2. Design notes for selecting each circuit constant of an oscillator circuit

Usually, a C-MOS inverter is used for an oscillator circuit that uses either CERALOCK® or quartz crystal resonators. However, as Table 1 shows, the equivalent circuit constant values differ very much from each other and attention must be paid to design a stable oscillator.

Also, the optimum circuit constant for each component differs depending on the combinations of IC and CERALOCK®. Generally, the optimum value for each component is assumed to be the circuit constant when oscillation voltage at the IC's input and output terminals becomes the maximum value within the IC's drive voltage rating.

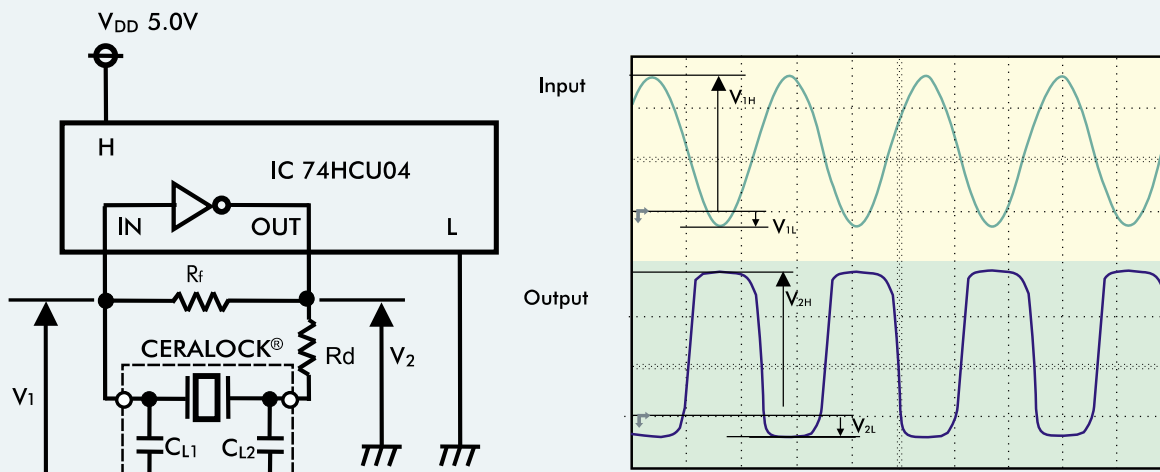
Following is an explanation of the key points to bear in mind when selecting

the optimum circuit constants for each component. This is demonstrated by showing the oscillation voltage and wave form (Figure 4b) of the reference circuit (Figure 4a). Figure 4 to Figure 6 show the peak and bottom of the oscillation wave form, where  $V_{1H}$ ,  $V_{1L}$  are the measured voltages at the IC's input terminals and  $V_{2H}$ ,  $V_{2L}$  the measured voltages at the output terminals.

### (1) Feedback resistance: $R_f$

The feedback resistance  $R_f$  serves as a bias resistance to operate the C-MOS inverter as an inverting amplifier. Figure 5a shows the changes of the oscillation voltage when the feedback resistance  $R_f$  is varied. When  $R_f$  gets too small, the gain of the amplifier decreases and consequently the oscillation voltage decreases (Figure 5b). When  $R_f$  gets too large, and the insulation resistance at the IC's input decreases, the oscillation may become unstable or stop altogether. Normally about one Mohm is the recommended value for  $R_f$  when using CERALOCK®, if the IC has five Mohm or more of  $R_f$  built in.

**Figure 4 - Example of oscillator circuit and wave form**

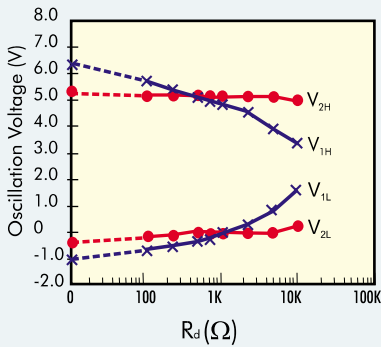


(a) Example of oscillator circuit with resonator

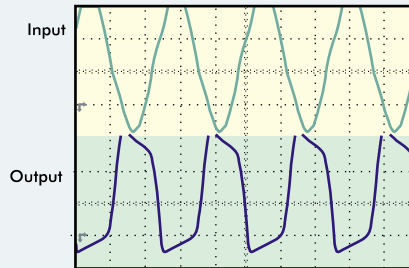
Setting values  
 CERALOCK®: CSTCR4M00G55-RO  
 $R_f$ :  $1M\Omega$   
 $CL1, CL2$ :  $39pF$   
 $R_d$ :  $680\Omega$   
 $R_s$ :  $0\Omega$

(b) Oscillation wave form

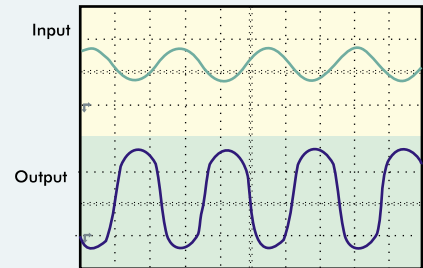
**Figure 7 - Oscillation characteristics when damping resistance  $R_d$  is changed.**



(a) Oscillation Voltage



(b) Wave form when  $R_d$  is small  
 $R_d = 0\Omega$



(c) Wave form when  $R_d$  is large  
 $R_d = 10k\Omega$

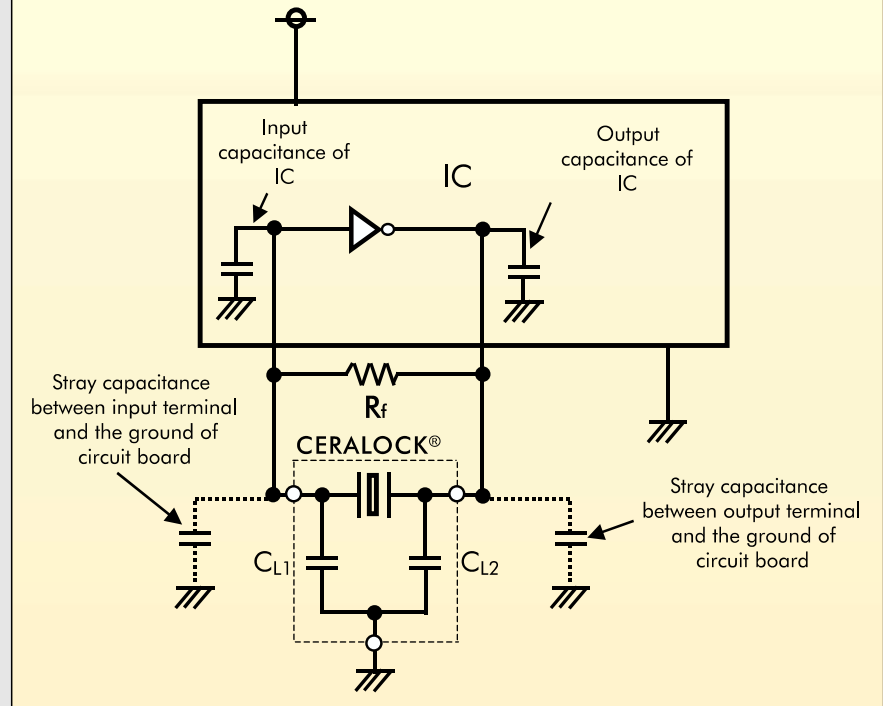
range. Another role of  $R_d$  is to reduce the current consumption and noise radiation.

### 3. Causes of the change of oscillation frequency

When using CERALOCK® for applications that requires a precise oscillation frequency, all the factors that cause frequency change must be taken into consideration and the influence of these carefully evaluated. Generally there are two major factors causing the frequency change. These are the resonant frequency change of CERALOCK® itself and the change of load capacitance  $C_{L1}$  and  $C_{L2}$ .

The causes of the resonant frequency change of CERALOCK® can be the initial deviation of resonant frequency, temperature characteristics, long-term aging characteristics and soldering heat characteristics of CERALOCK®. The change of load capacitance  $C_{L1}$  and  $C_{L2}$ , can be caused by the IC's input and output capacitance or the stray capacitance of the circuit board as shown in Figure 8. It is important to consider how much oscillation frequency is affected by these factors. The amount of frequency change caused by stray capacitance of the IC's input and output terminals can be checked by assembling circuits using a variety of

**Figure 8 - Factors that cause fluctuation of the load capacitance on the circuit**



IC samples. The stray capacitance of the circuit board varies according to the length and the width of land figure, number of layers, and material of the circuit board. The frequency change should be estimated through measurement of the stray capacitance and computer simulation. Many of the important considerations in using CERALOCK® for an oscillation circuit have been described

above. Other than the above, Murata offers evaluation reports at web site at [www.murata.com](http://www.murata.com) for various ICs and their reference circuits so that you can obtain the optimum operation. There is also a free of charge evaluation service for IC and CERALOCK®. Your local Murata office or franchised distributor will be pleased to respond to any inquiries. Ref. Tech11