

# Oscillation Circuit & Examination Method

## 1. Oscillation circuit

The crystal resonator is a passive component, and is therefore affected by the power voltage, ambient temperature, circuit configuration, circuit constant and substrate wiring pattern, etc. There can be classified roughly into 2 types of operation, normal and abnormal. In the design of the oscillation circuit, therefore, to ensure oscillation of crystal resonator and keeping it stable should be considered first. After those points are confirmed, accuracy of frequency, frequency pullability, modulation level, start-up time and others should be considered as the next step.

## 2. Roles of components & reference values

In the design of the oscillation circuit, it is necessary to understand the role of individual components. Referencing to C-MOS IC (Toshiba: 74HCU04AP) based oscillation circuit (Fig.1), the roles are described in Table 1.

When the feedback resistor ( $R_f$ ) is not mounted in the oscillation circuit, as shown in Table 1, the resonator does not start oscillation even if power is applied to the oscillation circuit. Unless a resistor of appropriate value is connected, oscillation may not start in the desired mode of the crystal resonator but undesired overtone or fundamental oscillation may start instead.

In the case of the fundamental resonator (MHz band) feedback resistance is usually  $1\text{ M}\Omega$ . In the case of the overtone resonator (MHz band), depending on IC and frequency characteristics, it is in the range of several  $\text{k}\Omega$ - tens of  $\text{k}\Omega$ . In the case of tuning fork type resonators (kHz band), it is necessary to connect a resistor of  $10\text{ M}\Omega$  or more.

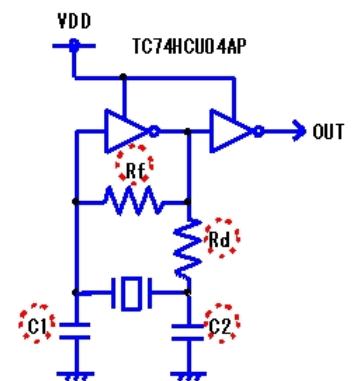


Fig.-1

Table-1

Parts No.	Parts name	Roles
$R_f$	Feedback resistance	Feedback current and signal from output to input of inverter in the oscillation circuit. Its value changes depending order of oscillation.
$R_d$	Dumping resistance	Limits the current that flows into resonator, adjusts the negative resistance and drive level, prevents abnormal oscillation of resonator and suppresses frequency fluctuations.
$C_1, C_2$	External capacitors	Adjusts the negative resistance, drive level and oscillating frequency. Also sets any given load capacity.

Appropriate values of dumping resistor ( $R_d$ ) depend on the type of resonator, frequency band and the value of the external capacitor ( $C_1, C_2$ ). The most optimized values are determined after measuring the characteristics of the oscillation circuit (including negative resistance, drive level and so on). Reference values for the AT cut resonator (MHz band) are in the range of several hundred  $\Omega$ -several  $\text{k}\Omega$ . For tuning fork type resonators (kHz band) the reference values are in the range of  $100\text{ k}\Omega$  - several hundred  $\text{k}\Omega$ .

Appropriate values of external capacitors are in the range of  $3\text{ pF}$  -  $33\text{ pF}$  depending on the type of resonator, frequency band, value of dumping resistors and the order of oscillation.

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## 3. Methods of examining oscillation circuit

### Measurement of oscillating frequency

It is essential to measure correct values, as far as possible, of the oscillating frequency of the resonator mounted on the circuit, using correct methods. In the measurement of oscillating frequency, probes and frequency counters are usually used and the most important point is to minimize influence of measuring tools for measurement.

There are three methods of measuring frequencies, as shown in the following figures (Fig. 2, 3 and 4). The most accurate method of measurement is to use a spectrum analyzer having capability to measure without contacting the oscillation circuit.

In Fig. 2, probes do not affect frequency because the frequency output from the buffer inverter is measured.

In Fig. 3, probes do not affect frequency because the buffer output frequency (1/1, 1/2, etc.) in IC is measured.

In Fig. 4, in the case of no buffer output from the IC, to minimize influence of probes, a capacitor smaller than 3pF is inserted between the output pin of IC (XTAL OUT) and the probe. However, using this method, the output waveform may be smaller and may not be measured with frequency counter due to sensitivity of frequency counter even though it can be measured with oscilloscope. In that case, use an amplifier for measurement.

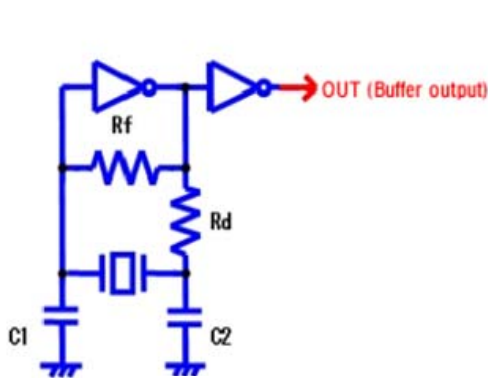


Fig.-2

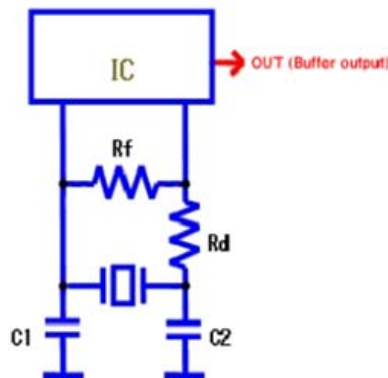


Fig.-3

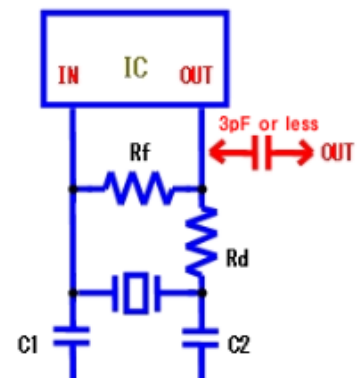


Fig.-4

In addition, oscillating frequency is different by the measurement points.

1. Measuring the buffer output
2. Measuring the oscillating stage output
3. Measuring the oscillating stage output via a capacitor

Fig. 5 shows above 1-3 measurement points and the measured oscillating frequencies except the buffer output are lower by the influence of the probe.

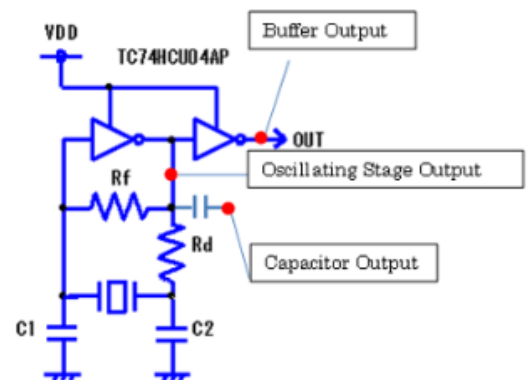


Fig.-5

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## 4. Measurement of negative resistance

This is the measurement to determine the margin of oscillation, and is used to predict the stability of oscillation from obtained values.

As shown in **Fig. 6**, insert a resistor ( $R$ ) in series to the resonator and replace it to one step greater value of resistor until stop oscillation. This resistance value just before the resonator stops oscillation is negative resistance.

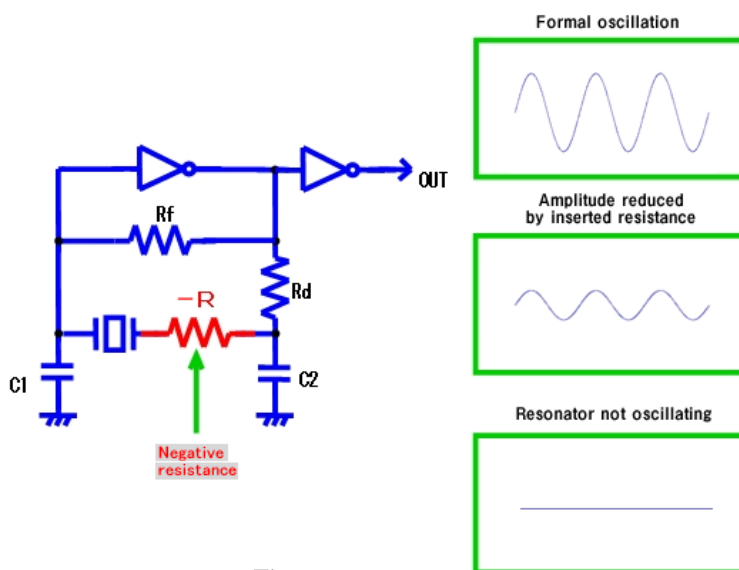


Fig.-6

Cautions:

- Check oscillation waveform with an oscilloscope at the measurement point.
- Check the minimum value of negative resistance in the operating voltage range.
- Check negative resistance by changing temperature.

(Use dryers, quenching agents, temperature controlled ovens, etc. according to the operating temperature range.)

- Negative resistance 10 times greater than maximum crystal impedance is recommended for automotive application and safety devices to human life. For other applications, 5 times greater than maximum crystal impedance is recommended.

**\*These recommended values are subjected to change without prior notice.**

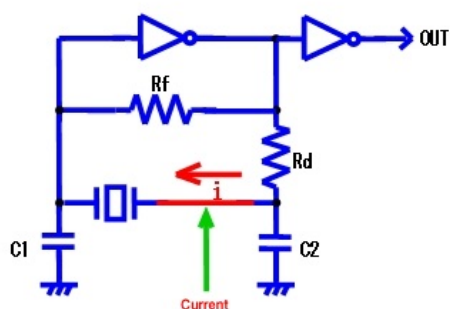
# Oscillation Circuit & Examination Method

## 5. Measurement of drive levels

In the oscillation circuit used, measure the power consumed by an operating resonator.

As shown in **Fig. 7**, measure the current ( $i$ ) that flows into the resonator by using a current probe. (We use P6022/Tektronix)

Other measurements may be available. In the method using a probe contacting the oscillation circuit, however, correct value cannot be obtained because current flows into the GND from the probe.



**Fig.-7**

Calculation formula

$$DL(\text{drive level:W})=i^2 \times R1$$

- $i(\text{A})$ :Current (effective value)
- $R1(\Omega)$ :Serial resistance of resonator

Caution:

Allowable Max. drive level of resonator depends on the size of resonator and oscillation mode. Please contact us for details.

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## 6. Check of abnormal oscillation

In the oscillation circuit, check for the possibility of resonator oscillation with undesired oscillation mode.

-- Simple method of checking --

When the oscillation mode of the resonator is fundamental, as shown in **Fig. 9**, abnormal oscillation can be tested by grabbing two leads of the resonator with slightly wet fingers and detaching fingers while turning the power from OFF to ON. If the 3rd overtone oscillation is not observed in oscilloscope, there is no possibility of abnormal oscillation. On the other hand, if the 3rd overtone oscillation is observed in oscilloscope when the fingers are detached, there is a possibility of abnormal oscillation.

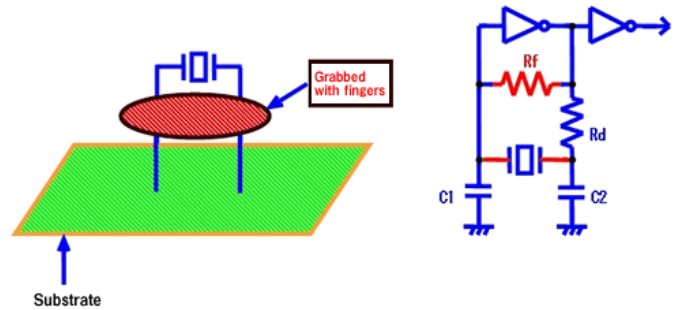
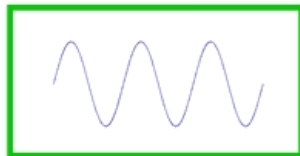


Fig.-8

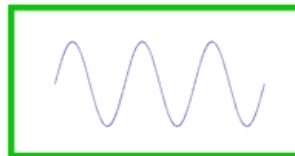
Checking by wet fingers is to form a small resistance between resonator terminals and reduce  $R_f$  as shown in the circuit diagram in **Fig. 8** to allow oscillation with high frequency band.

Normal:

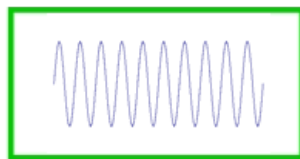
Crystal resonator is oscillating normally when lead wires are grabbed with fingers



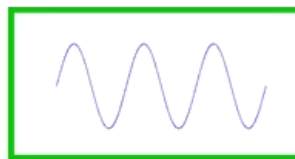
Crystal resonator is still oscillating normally even when the fingers are detached from lead wires



Overtone oscillation of crystal resonator available when lead wires are grabbed with fingers

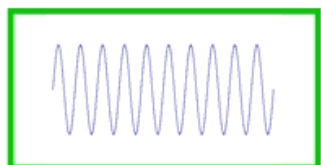


Crystal resonator is oscillating normally when the fingers are detached from lead wires



Abnormal:

Overtone oscillation of crystal resonator available when power is ON by grabbing lead wires



Overtone oscillation of crystal resonator is still available even when the fingers are detached from lead wires

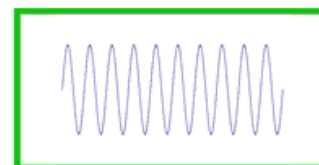


Fig.-9

# Oscillation Circuit & Examination Method

## 7. Nonconforming conditions caused by oscillation circuit & sample countermeasures

In the design of the crystal oscillation circuit, various nonconforming conditions may occur.

For example;

1. Frequency cannot be within the required range. (Although application requires precise frequency stability.)
2. Frequency cannot be adjusted. (Although frequency tunable circuit.)
3. Oscillation with 1/3 or 3 times of nominal frequency
4. Start-up time of oscillation is significantly delayed.
5. Resonator does not oscillate or Start-up time of oscillation is long.

To suppress such symptoms, it is essential at least to examine the basic items of oscillation circuit described above.

If, here, the specification of resonator need not be changed to solve nonconforming conditions, it is comparatively easy to implement countermeasures in the circuit side (See **Table 2**).

However, many characteristics of the oscillation circuit may not be met even if the conforming conditions are improved and other nonconforming conditions could occur. Therefore, the circuit should be examined by crystal supplier. Also, if you cannot solve the problem even implementing the sample countermeasures below, please contact our sales representative, we will examine the circuit to try to solve the problem.

**Table-2**

Nonconforming condition	Cause	Example countermeasure
Frequency is deviated	Load capacity of resonator is not aligned to that of oscillation circuit	Change the circuit constant (C1,C2).
		Change the load capacitance of resonator.
Frequency cannot be adjusted.	Frequency pullability by trimmer capacitor is insufficient.	Reduce the capacity value of trimmer capacitor or fixed capacitor.
Oscillation with 3 times of nominal frequency	Circuit constant is not aligned to the oscillation order of resonator	Increase the value of feedback resistance (Rf).
		Insert control resistance (Rd).
		Increase the value of outfit capacitor (C1, C2).
Oscillation with 1/3 of nominal frequency	Circuit constant is not aligned to the oscillation order of resonator	Decrease the value of feedback resistance (Rf).
		Decrease the value of control resistance (Rd).
		Decrease the value of outfit capacitor (C1, C2).
No oscillation	Circuit negative resistance is too low.	Decrease the value of control resistance (Rd).
Long start-up time		Decrease the value of outfit capacitor (C1, C2).