IEC 60679-2

Edition 2.0 2026-08

INTERNATIONAL STANDARD

Piezoelectric, dielectric and electrostatic oscillators of assessed quality - Part 2: Guidelines for the use of oscillators

IEC 60679-2:2026-08(en)

ICS 31.140

ISBN 978-2-8327-1418-8

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

Piezoelectric, dielectric and electrostatic oscillators of assessed quality - Part 2: Guidelines for the use of oscillators

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of a patent, which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60679-2 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection. It is an International Standard.

This second edition cancels and replaces the first edition published in 1981. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) some new contents that reflect the latest manufacturing technologies;
b) added contents about the operating principle of crystal oscillators;
c) added contents about usage precautions for crystal oscillators.

The text of this International Standard is based on the following documents:

Draft	Report on voting
49/1540/FDIS	49/1544/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts of the IEC 60679 series, published under the general title *Piezoelectric, dielectric and electrostatic oscillators of assessed quality* can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,

– withdrawn, or

– revised.

INTRODUCTION

Crystal controlled oscillators are commonly used to provide the stable frequencies required for telecommunications, navigations and data processing systems. Depending upon the frequency of operation, ambient conditions and specific oscillator design, crystal oscillators are capable of providing frequency stability varying from 1×10^{-4} to 1×10^{-10}.

This document offers a guideline that describes the general properties, performance characteristics and usage precautions for crystal oscillators.

1 Scope

This part of IEC 60679 describes the general properties, performance characteristics and usage precautions for quartz crystal oscillators. This document mainly describes crystal oscillators, but some descriptions also apply to oscillators other than crystal units (e.g. MEMS resonators).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60679-1, *Piezoelectric, dielectric, and electrostatic oscillators of assessed quality - Part 1: Generic specification*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60679-1 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
– ISO Online browsing platform: available at https://www.iso.org/obp

4 Working principle of crystal oscillators

The operating principle of crystal oscillators is easier to understand when compared with that of a pendulum. To maintain the swing of a pendulum, the position and time point of maximum amplitude of the pendulum should be detected, and the operation of pushing the pendulum back should be repeated so that the time point and position are maintained. The pendulum corresponds to a crystal unit which comprises an amplifier with a feedback circuit that provides the detection and push-back force (see Figure 1).

A typical feedback amplifier (Colpitts circuit) is shown in Figure 2, where the signals at both terminals of the crystal unit are divided at capacitors C_A, C_B, one connected to the input side and the other to the output side. It can be considered that the "detection" in the case of the pendulum is on the input side of the feedback amplifier and the "push-back force" is given on the output side. Here, R_A and R_B are bleeder resistance to provide a fixed bias to the base terminal of the oscillation transistor, R_E is negative feedback resistance connected to the emitter and R_C is load resistance connected to the collector.

Next, in the state of oscillation, as shown in Figure 3, the oscillator circuit side which is viewed from the crystal unit terminals, can be represented by a series circuit of equivalent input capacitance C_i and equivalent input resistance R_i. In this case, the crystal unit side is equivalently an inductive effective inductance L_e and an effective resistance R_e and the crystal oscillation conditions are as follows:

Frequency condition:

$$\omega L_e - \frac{1}{\omega C_i} = 0 \qquad (1)$$

where

ωL_e is the inductive effective inductance, and

ωC_i is the equivalent input capacitance.

Amplitude condition:

$$R_e \le |R_i| \tag{2}$$

where

R_e is the effective resistance;

R_i is the equivalent input resistance.

The frequency condition determines the oscillation frequency. For the amplitude condition, equivalent input resistance on the circuit side shall be negative value in the vicinity of the oscillation frequency and at the small signal on the start-up, then this is called negative resistance. This negative resistance can be obtained with active circuits such as transistors and operational amplifiers. $|R_i|$ shall be designed to be larger than R_e in order to ensure oscillation at the start-up of the oscillator, meaning that $R_e = |R_i|$ in the steady-state following the end of the start-up and the oscillation becomes the steady-state amplitude.

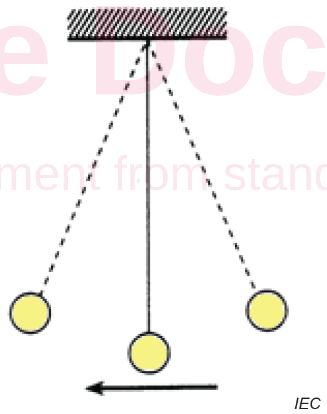


Figure 1 – Swinging pendulum motion

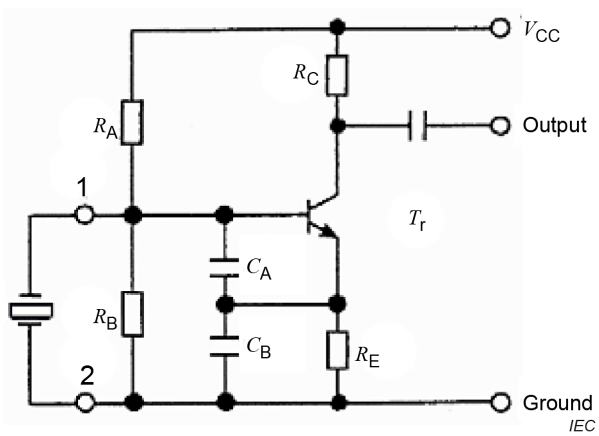


Figure 2 – Colpitts oscillator circuit

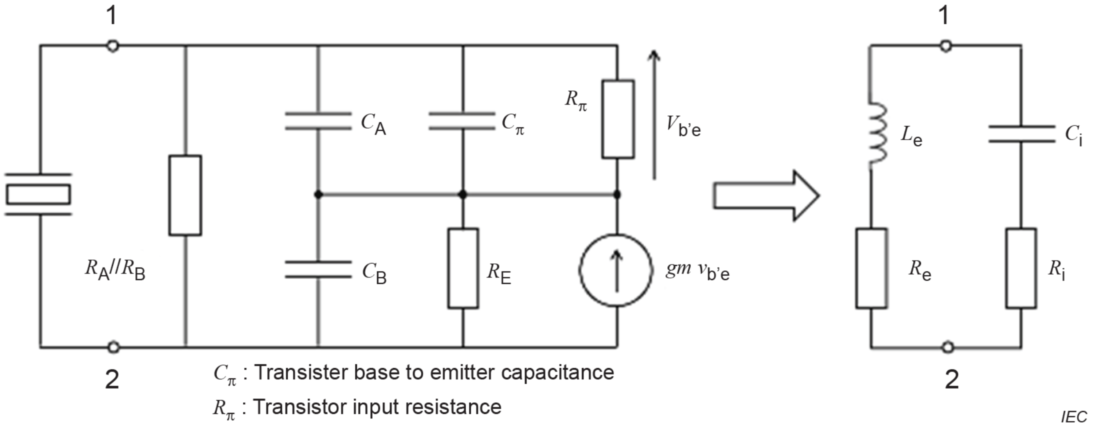


Figure 3 – Equivalent circuit of a Colpitts oscillation circuit

The circuit side capacitance C_i is called the load capacitance (C_L) with respect to the unit and is an important parameter that determines the frequency change amount from the series resonance frequency, variable sensitivity and frequency stability, etc. The relational equation is as follows:

Fractional load resonance frequency offset

$$D_L = \frac{f_L - f_r}{f_r} \approx \frac{1}{2r\left(1+\frac{C_L}{C_0}\right)} \quad (3)$$

where

f_L is the load resonance frequency;

f_r is the series resonance frequency.

Pulling sensitivity

$$S = \frac{dD_L}{dC_L} \approx \frac{-1}{2rC_0\left(1+\frac{C_L}{C_0}\right)^2} \quad (4)$$

where

C_0 is the shunt capacitance of the crystal unit;

C_1 is the motional capacitance of the crystal unit;

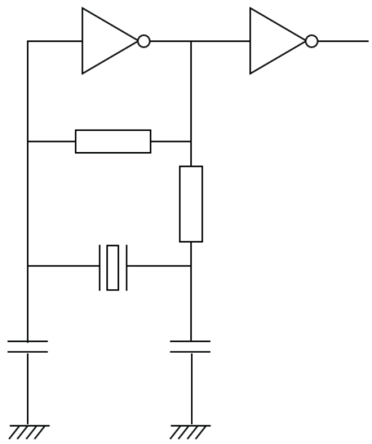
C_L is the load capacitance (C_i on the circuit side);

r is the capacitance ratio of the crystal unit (C_0/C_1).

5 Classification of crystal oscillators

5.1 General

In very general terms, a crystal oscillator can be described as consisting of an amplifier or gain circuit, together with a positive feedback network. A typical oscillation circuit is shown in Figure 4.



IEC

Figure 4 – Basic diagram of a crystal oscillator

Self-oscillation of such a circuit will occur provided the loop gain exceeds unity at some frequency for which the total loop phase is 2 nπ (n = 0, 1, 2...). The level of the oscillation signal will depend on circuit gain characteristics, while the oscillation frequency will be determined by phase considerations. The output signal spectrum will depend upon the level of oscillation, electrical noise from circuit elements and the bandwidths of the circuits. Generally, the spectral width is extremely small and, for a majority of applications, only the centre or average frequency behaviour should be considered. Disregarding for the moment the degradation of a signal purity by electrical noise, the average frequency of oscillation will always be determined by the loop phase requirement. Frequency deviations will result whenever any perturbation of loop phase occurs. These perturbations can be generally considered to be of two types, namely:

a) deviations in electrical circuit parameters;

b) deviations in the crystal unit.

Type a) deviations include such factors as the temperature coefficients of capacitors, inductors, resistors and transistors; the ageing of these devices; their voltage and current characteristics and their susceptibility to mechanical disturbance. Whatever the cause, a phase perturbation ($\sphericalangle\varphi_N$) in the circuit transfer phase will cause a change in the average oscillation frequency:

$$\Delta f = f_0 \frac{\Delta\varphi_N}{2Q_X} \tag{5}$$

where

f_0 is the nominal oscillation frequency and

Q_X is the effective Q of the narrowband crystal network.

Type b) deviations include changes in crystal unit characteristics caused by temperature, temperature gradient, drive level, "frequency ageing" and mechanical environment (shock, acceleration and vibration). The crystal oscillation circuit is generally designed to use a gain circuit having a band as broad as practicable, in order to reduce the network phase sensitivity as much as possible. The crystal feedback network, on the other hand, is usually designed to have a transmission band as narrow as can be obtained so as to make the oscillation frequency depend essentially only upon the crystal unit characteristics. When frequency adjustment is required, it is preferably accomplished by introducing a variable reactance which changes the frequency of the crystal network without widening the transmission band. When these general practices are followed, the oscillator frequency stability will depend primarily upon the characteristics of the crystal unit, which should be chosen so as to:

c) have a high Q-factor;

d) exhibit a small change of frequency over the intended operating temperature range;

e) have a low drive level dependence (DLD) of frequency and resonance resistance;

f) provide low sensitivity to mechanical shock, acceleration, and vibration;

g) exhibit a small frequency drift due to ageing.

5.2 SPXO (clock oscillator)

Most electronic equipment is required to operate over a range of ambient temperatures, i.e. −10 °C to +60 °C, or −40 °C to +85 °C. Consequently, the frequency/temperature characteristic of the crystal unit is usually the most important factor in determining the frequency stability of simple packaged crystal oscillators (SPXO). For low-frequency crystal units vibrating in flexural or extensional modes, deviations as great as $\pm 1 \times 10^{-4}$ might be expected, while the thickness shear types (frequencies above about 1 MHz) can be expected to deviate by about $\pm 2 \times 10^{-5}$ over a temperature range of −40 °C to +90 °C. When better frequency stability is required, it is necessary to provide temperature compensation circuitry, or to provide a temperature-stabilized environment for the crystal unit by means of a temperature control device. Special characteristics of oscillators of these types are considered in 5.3. The temperature behaviour of frequency of crystal units is dependent upon the dimensions of the quartz plate, the mode of vibration, the material and thickness of electrodes, the mounting methods employed and, mainly, the orientation of the plate with respect to the crystallographic axes. Figure 5 shows the characteristics which can be obtained for various orientations of an AT-cut crystal unit.

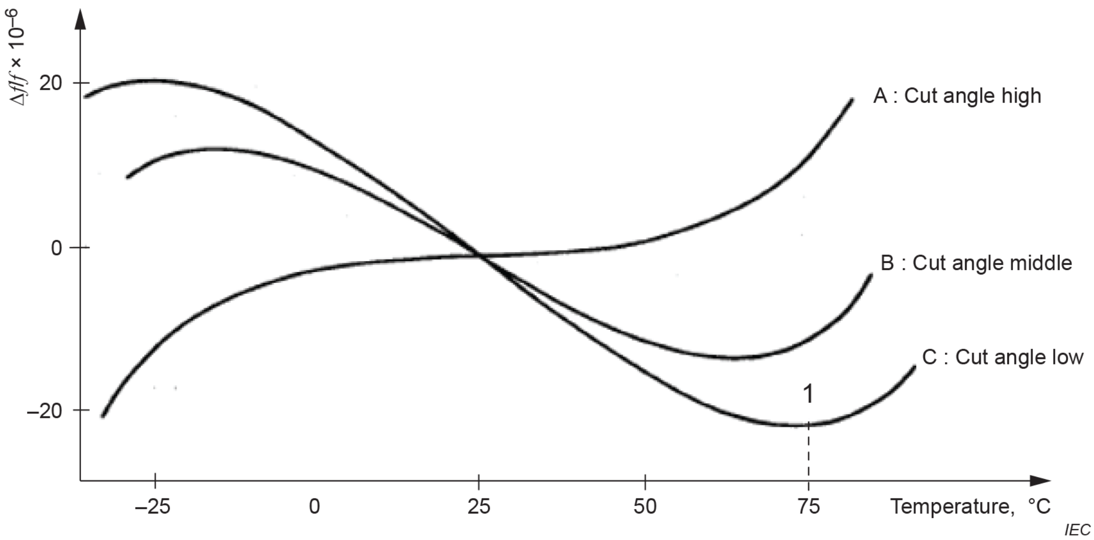


Figure 5 – Frequency-temperature characteristics of typical AT-cut crystals with different orientation angles

Figure 6 shows the characteristics which are obtained with tuning fork crystals, e.g. at the common clock frequency 32,768 kHz.

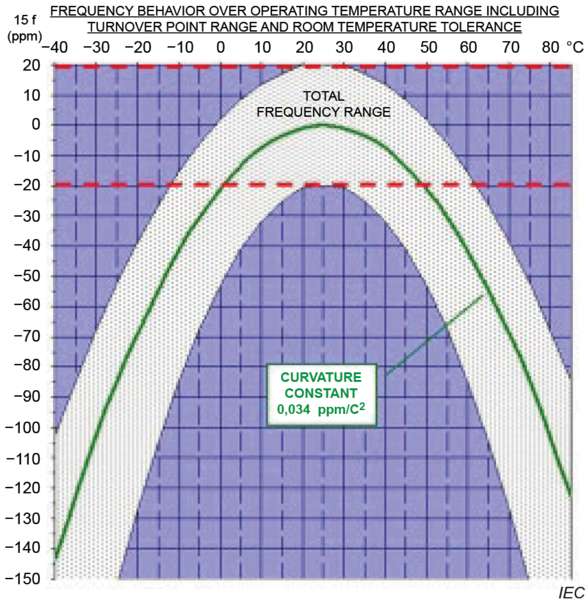
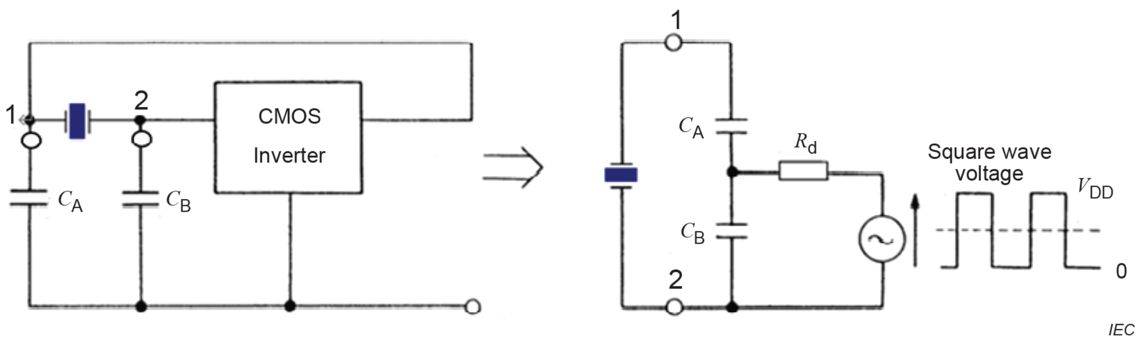


Figure 6 – Frequency-temperature characteristics of typical tuning-fork crystal

The frequency change as a function of time, usually referred to as "frequency ageing", is primarily determined by the crystal used. A typical ageing rate for 10 MHz fundamental mode crystals is 2 to 5 × 10^{-6} per year while overtone units and well-aged units exhibit values lower than this. The ageing is usually unimportant in applications using SPXO, since it is small compared with the frequency deviations caused by temperature variations. The oscillation circuit of the SPXO is a feedback amplifier for operating the crystal unit, and the CMOS oscillation circuit used in crystal oscillators for clocks, etc. is mostly an equivalent circuit as shown in Figure 7, and the circuit side can be represented by internal resistance R_d and a square wave voltage supply that varies from 0 V to V_{DD}.



C_A and C_B are capacitance;

R_d is the damping resistance.

Figure 7 – CMOS oscillator circuit and equivalent circuit

For the frequency stability of the SPXO, the characteristics of the crystal unit used are almost the same as the characteristics of the oscillator. The frequency stability is said to be determined by the crystal unit's characteristics, among which, frequency/temperature characteristics and ageing are usually predominant.

5.3 TCXO

To obtain better stability than that possible with the SPXO, temperature compensated crystal oscillators (TCXO) can be used. Improved stability in TCXO will be obtained at the expense of added circuit complexity and increased cost.

TCXO are oscillators that provide temperature compensation for the frequency/temperature characteristics, which fluctuate the most in the characteristics of the frequency stability, so that the frequency fluctuations are even lower than those of theoretical frequency/temperature characteristics of crystal units. New communication systems for the transition to high frequency bands and the effective utilisation of frequencies need high frequency stability over a wide temperature range. TCXO are used in many mobile communication systems as reference oscillators suitable for this purpose. They can be broadly classified into the following three categories according to the frequency-temperature compensation method and required performance.

a) Direct analogue type [Figure 8 a)]

   As the temperature compensation circuit is connected directly to the crystal unit, resistance component of the circuit is added to the crystal resonance circuit, resulting in a decrease in effective Q and a large change in effective Q depending on temperature. The temperature compensation circuit section requires a compensation circuit design to flatten the frequency characteristics of the crystal unit. Generally, a frequency stability of about ±1,5 to $\pm 3{,}0 \times 10^{-6}$ (−40 °C to +85 °C) can be obtained.

b) Indirect analogue type [Figure 8 b)]

   This is an oscillator designed so that the reference voltage supplied from a stabilized power supply is used to create a compensation voltage by a temperature compensation circuit consisting of resistance and a temperature sensors - usually thermistors - and the compensation voltage is supplied to the voltage-controlled crystal oscillator VCXO, resulting in flat characteristics in frequency fluctuations due to changes in ambient temperature. To determine the element values of the circuit that compensate for the frequency/temperature characteristics being the cubic function of the crystal unit over a wide temperature range, it is necessary to use a computer to obtain a multi-point approximate solution with temperature as a function. The compensation accuracy is limited to $\pm 0{,}5 \times 10^{-6}$ (−20 °C to +70 °C), although it is much better than the former. In recent years, using IC circuit technology, the appearance of single-chip TCXO ICs incorporating a temperature compensation circuit which is configured to obtain a higher-order temperature compensation function by combining differential amplifiers and an oscillation circuit, has made it possible to manufacture smaller TCXO, contributing significantly to the miniaturization of mobile terminals. Generally, a frequency stability of about ±0,5 to $\pm 2{,}0 \times 10^{-6}$ (−40 °C to +85 °C) can be obtained. It should be noted that frequency hysteresis can deteriorate the frequency stability.

c) Indirect digital type [Figure 8 c)]

   This is a method that digitally performs fine compensation control for minute temperature changes in order to increase frequency stability. Typical of this method is to digitally convert the temperature information obtained by the temperature sensor and record the corresponding voltage information such the frequency deviation becomes zero in a storage medium such as ROM. Then, during operation, the VCXO is controlled by reading the voltage information corresponding to the temperature information from the storage medium. The theoretical limit of frequency stability is determined by the maximum temperature coefficient of the crystal unit with respect to the increment of ambient temperature and the voltage conversion accuracy of the D/A or A/D converter. Generally, a frequency stability of about ±0,05 to $\pm 0{,}5 \times 10^{-6}$ (−10 °C to +60 °C) can be obtained. It should be noted that frequency discontinuities can occur if the ambient temperature fluctuates between the discrete temperature steps. Furthermore, frequency hysteresis can deteriorate the frequency stability.