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Part 2: Guide to the use of quartz crystal oscillators

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Introduction

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For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



49/1459/CD

COMMITTEE DRAFT (CD)

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2024-08-02

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49/1441/CD, 49/1452/CC

IEC TC 49 : PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC DEVICES AND ASSOCIATED MATERIALS FOR FREQUENCY CONTROL, SELECTION AND DETECTION

SECRETARIAT:

Japan

SECRETARY:

Mr Masanobu Okazaki

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:

☐

Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

☐ ENVIRONMENT

☒ QUALITY ASSURANCE

☐ SAFETY

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Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "In Some Countries" clauses. (SEE [AC/22/2007](#) OR [NEW GUIDANCE DOC](#)).

TITLE:

Piezoelectric, dielectric and electrostatic oscillators of assessed quality - Part 2: Guide to the use of quartz crystal oscillators

NOTE FROM TC/SC OFFICERS:

The sub-par title was changed to "Part 2 Guidelines for the use of oscillators", reflecting the discussion at the Tsukuba meeting.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS OF
ASSESSED QUALITY****Part 2: Guidelines for the use of oscillators****FOREWORD**

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I 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.

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
XX/XX/FDIS	XX/XX/RVD

148
149 Full information on the voting for its approval can be found in the report on voting indicated in
150 the above table.

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

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

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

- 159 • reconfirmed,
160 • withdrawn,
161 • replaced by a revised edition, or
162 • amended.

163

164

INTRODUCTION

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

169 The specification and/or description of the performance characteristics of crystal oscillators has
170 remained a source of misunderstanding and dissatisfaction for both manufacturer and user.

171 This guide describes the general properties, performance characteristics and usage
172 precautions for crystal oscillators.

PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS OF ASSESSED QUALITY

Part 2: Guidelines for the use of oscillators

1. Scope

This part of IEC 60679 describes the general properties, performance characteristics and usage precautions for quartz crystal oscillators. This content 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 60027 (all parts). Letter symbols to be used in electrical technology.

IEC 60050-561, International electrotechnical vocabulary – Part 561 Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection. Available at www.electropedia.org

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

IEC 62884-1, Measurement technologies of piezoelectric, dielectric and electrostatic oscillators – Part 1: Basic methods for the measurement

IEC 62884-2, Measurement technologies of piezoelectric, dielectric and electrostatic oscillators – Part 2: Phase jitter measurement method

IEC 62884-3, Measurement technologies of piezoelectric, dielectric and electrostatic oscillators – Part 3: Frequency Aging test methods

IEC 62884-4, Measurement technologies of piezoelectric, dielectric and electrostatic oscillators – Part 4: Short-term frequency stability test methods

3. Terms and definitions

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

$$\text{Frequency condition} \dots \omega L_e - \frac{1}{\omega C_i} = 0$$

$$\text{Amplitude condition} \dots R_e \leq |R_i|, \quad (R_i : \text{negative resistance})$$

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. The absolute value of the negative resistance $|R_i|$ shall be designed to be sufficiently 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.

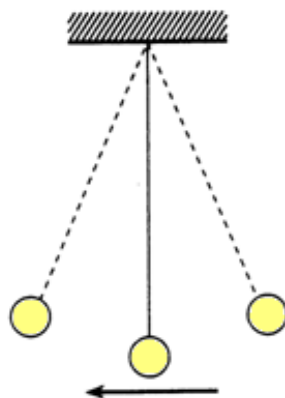


Figure 1 – Swinging pendulum motion

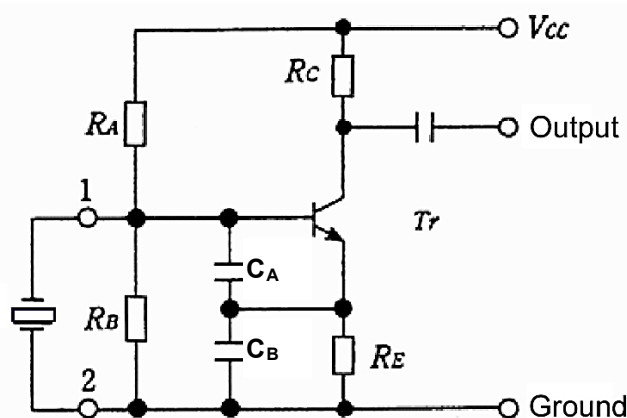


Figure 1 – Colpitts oscillator circuit

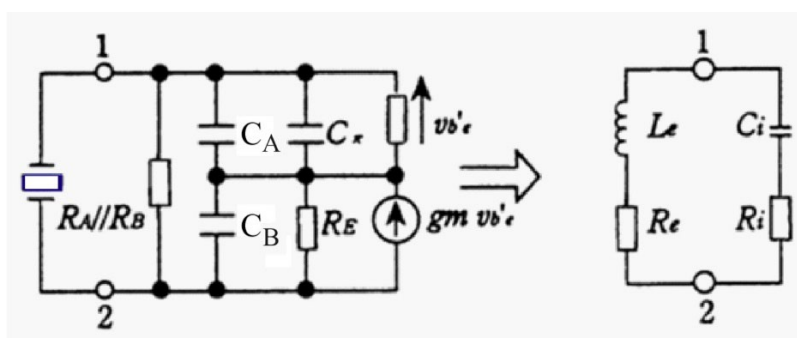


Figure 3 – Equivalent circuit of a Colpitts oscillation circuit

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:

$$\text{Fractional load resonance frequency offset (DL)} = \frac{1}{2r \left(1 + \frac{C_L}{C_0} \right)}$$

$$\text{Pulling sensitivity (S)} = \frac{-1}{2rC_0 \left(1 + \frac{C_L}{C_0} \right)^2}$$

Where

C_0 : Shunt capacitance of the crystal unit,

C_1 : Motional capacitance of the crystal unit,

C_L : Load capacitance (C_i on the circuit side),

r : 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 may 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.

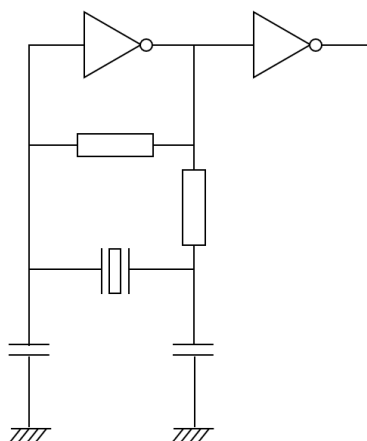


Figure 4 – Basic diagram of a crystal oscillator

Self-oscillation of such a circuit will occur provided the loop gain exceeds unity at some frequency for which the total loop phase is $2n\pi$ ($n = 0, 1, 2, \dots$). 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 center or average frequency behaviour need to 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 may be generally considered to be of two types, namely:

deviations in electrical circuit parameters.

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 ($\Delta\phi_N$) in the circuit transfer phase will cause a change in the average oscillation frequency:

$$\Delta f = f_0 \frac{\Delta\phi_N}{2Q_X}$$

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