IEC 62884-2

Edition 1.0 2017-08

INTERNATIONAL STANDARD

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Measurement techniques of piezoelectric, dielectric and electrostatic oscillators –
Part 2: Phase jitter measurement method

Techniques de mesure des oscillateurs piézoélectriques, diélectriques et électrostatiques –
Partie 2: Méthode de mesure de la gigue de phase

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MEASUREMENT TECHNIQUES OF PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS –

Part 2: Phase jitter measurement method

FOREWORD

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International Standard IEC 62884-2 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection.

This bilingual version (2019-11) corresponds to the monolingual English version, published in 2017-08.

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

CDV	Report on voting
49/1212/CDV	49/1243/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

The French version of this standard has not been voted upon.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62884 series, published under the general title *Measurement techniques of piezoelectric, dielectric and electrostatic oscillators*, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

A crystal oscillator as a highly efficient and highly precise source of a frequency oscillation is widely used for fields such as the electronic equipment, communication equipment, measurement equipment and a clock. Also recently, digitalization of these equipments is advancing rapidly. In this situation, the frequency of crystal oscillator requires high precision and high stability and reduction of noise with oscillating phenomenon. A phase jitter is one of the noise characteristic in oscillation characteristic and precise measurement which is needed when shipping a component to a customer.

For advance application in electronic information and communication technology, (e.g. advanced satellite communications, control circuits for electric vehicle (EV)), necessity arises for the measurement method for common guidelines of phase jitter. In these days, measurement method of phase jitter also becomes more important from the electromagnetic influence (EMI) point of view.

This document has been restructured from IEC 60679-1:2007 (third edition) and IEC 60679-6:2011 (first edition). The test methods for oscillators have been separated from IEC 60679-6:2011 into IEC 62884 (all parts). This document covers the phase jitter measurement.

MEASUREMENT TECHNIQUES OF PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS –

Part 2: Phase jitter measurement method

1 Scope

This part of IEC 62884 specifies the methods for the measurement and evaluation of the phase jitter measurement of piezoelectric, dielectric and electrostatic oscillators, including dielectric resonator oscillators (DROs) and oscillators using a thin-film bulk acoustic resonator (FBAR) (hereinafter referred to as an "Oscillator") and gives guidance for phase jitter that allows the accurate measurement of RMS jitter.

In the measurement method, phase noise measurement equipment or a phase noise measurement system is used.

NOTE Dielectric resonator oscillators (DROs) and oscillators using FBAR are under consideration.

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*

IEC 60679-1:2017, *Piezoelectric, dielectric and electrostatic oscillators of assessed quality – Part 1: Generic specification*

IEC 60469, *Transitions, pulses and related waveforms – Terms, definitions and algorithms*

IEC 60617, *Graphical symbols for diagrams (available at http://std.iec.ch/iec60617)*

IEC 62884-1:2017, *Measurement techniques of piezoelectric, dielectric and electrostatic oscillators – Part 1: Basic methods for the measurement*

ISO 80000-1, *Quantities and units – Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60027 (all parts), IEC 60050-561, IEC 60469, IEC 60617, IEC 60679-1 and ISO 80000-1 apply.

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

- IEC Electropedia: available at http://www.electropedia.org/

- ISO Online browsing platform: available at http://www.iso.org/obp

4 Test and measurement procedures

4.1 General

The test and measurement procedures are given in Clause 4 of IEC 62884-1:2017 and shall be applied as indicated in 4.2 to Clause 8.

4.2 Test methods of phase jitter

4.2.1 General

As the measurement method, the phase noise measurement equipment (system) or the specially designed phase jitter measurement equipment shall be used.

Three basic methods are described:

a) measurement in the time domain by use of a digital real-time or sampling oscilloscope;

b) measurement in the data domain (BER test set);

c) measurement in the frequency domain using

  1) a phase noise test set, or

  2) a jitter and wander test set.

Method c) 1) using a phase noise test set is the recommended measurement method because it allows sufficient accuracy for arbitrary oscillator output frequencies.

– In the measurement of phase jitter and wander of oscillator circuits, attention should be paid to relative measurement reproducibility.

– A user and a manufacturer should deepen understanding through discussion about relative measurement reproducibility.

– Measurement equipment (including software program) should be made clear between a manufacturer and a user through a contract.

– When phase jitter and wander is calculated from phase noise, the range of frequency deviation should be made clear between a user and a manufacturer through a contract.

4.2.2 Measurement in the time domain

Digital real-time or sampling oscilloscopes with wide bandwidth, fast sampling rates, and large data memories are commercially available (see Figure 1), in some cases with special jitter evaluation software.

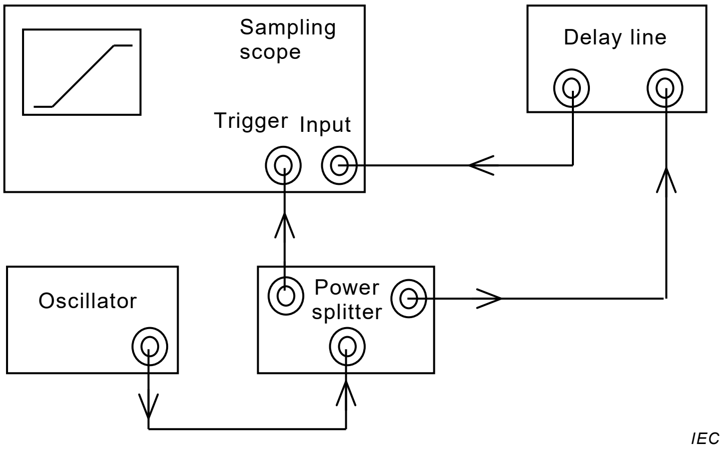

Figure 1 – Phase jitter measurement with sampling oscilloscope

The time variation of the edges of the clock signal relative to the trigger edge is displayed and stored over a large number (typically thousands) of cycles. Instrument software allows the determination of the peak-to-peak jitter value and a statistical evaluation of its distribution. The sampling oscilloscope method does not allow an accurate evaluation of the spectral content of the jitter. Also, jitter larger than one unit interval (UI) cannot be distinguished.

The measured jitter value is worse than the jitter of the device under test due to the internal jitter of the instrument's clock.

$$J_{\mathrm{DUT}} = \sqrt{(J_{\mathrm{meas}})^2 - (J_{\mathrm{int}})^2}$$

where

J_{DUT} is the measured jitter;

J_{meas} is the jitter of the device under test;

J_{int} is the internal jitter of the instrument's clock.

High stability/low noise Oscillator exhibits a significantly lower jitter than the instrument's clock jitter and trigger stability. Therefore, this technology is currently not suitable for accurate jitter measurement of such Oscillator.

4.2.3 Measurement in the data domain

Bit-error rate (BER) test sets are used for measuring bit-error rate to characterise the overall system performance of a communication subsystem. It is difficult to deduct the contribution of the Oscillator jitter to the system BER. This method also does not yield quantitative jitter performance values for the Oscillator.

4.2.4 Measurement in the frequency domain

4.2.4.1 Methods of phase noise test set

Phase jitter can be tested in the frequency domain using the well-established phase noise test method with a phase locked loop as described in 4.5.25 of IEC 62884-1:2017.

The range of detuned frequency shall be determined by contracts between customers and suppliers after discussion between them. The formula for calculating the RMS jitter from a phase noise is based on the calculation method for the amount of phase jitter shown in Annex A.

For given SDH/SONET applications, the Fourier frequency range (f_{min} … f_{max}) may be selected as described in 3.2.53 of IEC 60679-1:2017. If not specified in the relevant data sheet, the recommended Fourier frequency range is as given by f_3 to f_4 in Table 1.

Table 1 – Fourier frequency range for phase noise test

Oscillator output frequency	$f_0 = f_{min}$	f_3	$f_4 = f_{max}$
1 MHz to < 10 MHz	10 Hz	10 kHz	100 kHz
10 MHz to < 50 MHz	20 Hz	20 kHz	500 kHz
50 MHz to < 200 MHz	100 Hz	50 kHz	1,5 MHz
200 MHz to < 1 000 MHz	1,0 kHz	200 kHz	5,0 MHz
1 000 MHz to < 5 000 MHz	5,0 kHz	500 kHz	15 MHz
≥ 5 000 MHz	20 kHz	2 MHz	80 MHz

From Table 1, it can be seen that the most stringent requirement applies over the range f_3 to f_4.

Jitter performance over a frequency-band other than f_3 to f_4 may also be defined.

To compute the phase jitter, the phase noise data $L(f)$ have to be integrated in the considered frequency ranges and evaluated as follows.

Compute the spectral density of phase fluctuations $S_\varphi(f)$ from the single-sideband phase noise plot 10 $\log_{10} L(f)$:

$$S_\varphi(f) = 2L(f)$$

Integrate $S_\varphi(f)$ over the specified Fourier frequency range f_{min} to f_{max} to get the mean squared phase jitter in that bandwidth:

$$\left\langle \Delta\varphi^2(f) \right\rangle = \int_{f_{min}}^{f_{max}} S_\varphi(f)\,df$$

The mean square phase jitter can be approximated by stepwise integration over the specified Fourier frequency range f_{min} to f_{max} segmented by n, for example:

$$\left\langle \Delta\varphi^2(f) \right\rangle \approx \sum S_\varphi(f_i)\Delta f_i$$

where

$$\Delta f_i = f_{i+1} - f_i \ (i = 1 \ldots n - 1)$$

with

$$f_1 = f_{min} \text{ and } f_n = f_{max}$$

The square root $\Delta\varphi(f)$ of the integral is the effective or RMS phase jitter in radians. It can be converted into degrees, fractions of unit interval (UI), or time (in seconds) by multiplication with the following factor k:

	Degree °	Unit interval UI	Time s
k =	$360/2\pi$	$1/(2\pi)$	$1/(2\pi f_c)$

For random jitter, the peak-to-peak value is assumed to be 7 times the value computed above (see 3.2.53 of IEC 60679-1:2017).

Accuracy:

A 1 dB error of the phase noise data 10 $\log_{10} L(f)$ over the full Fourier frequency range causes a jitter inaccuracy of approximately 10 %.

4.2.4.2 Methods of communication analyser

Commercially available communication analyser may be used to measure jitter and wander of clock sources with the method described in ITU-T Recommendation O.172 (see Figure 2). The working principle is similar to the phase noise measurement technique using the quadrature method. Softwares supplied with the test sets deliver directly all characteristic values for jitter and wander in numeric and graphical presentation.

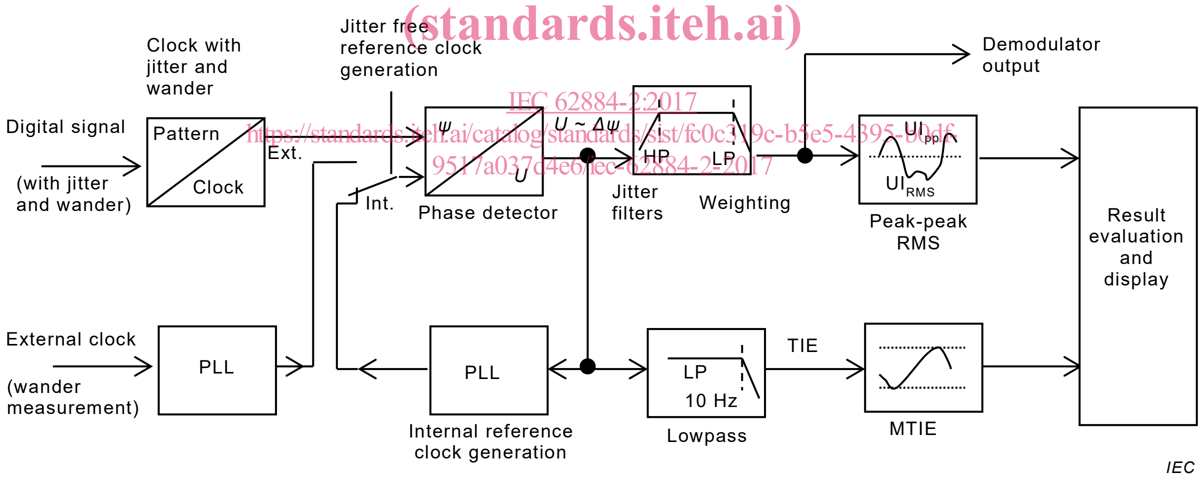

Figure 2 – Block diagram of a jitter and wander analyser according to ITU-T O.172

The advantage of these systems over the phase noise test is that a measurement of both RMS and peak-to-peak jitter is possible. The disadvantage is that these systems require an input signal (Oscillator frequency) according to the standard data bit rates for optical communication systems (SONET, SDH) – see Table 2.

Table 2 – Standard bit rates for various applications

SDH	SONET	Bit rate Mbit/s	Allowed oscillator frequencies
-	OC-1	51,84	25,92 MHz, 51,84 MHz
STM-1	OC-3	155,52	77,76 MHz, 155,52 MHz
STM-4	OC-12	622,08	311,04 MHz, 622,08 MHz
STM-16	OC-48	2488,32	1 244,16 MHz, 2 488,32 MHz
STM-64	OC-192	9953,28	4 976,64 MHz, 9 953,28 MHz

An Oscillator with other output frequencies cannot be tested, which limits the area of application.

NOTE Other applications can have different requirements.

4.2.4.3 Methods of the specially designed measurement equipment

4.2.4.3.1 General

The measurement equipment and system shall be the specially designed SONET/SDH measurement equipment using a time interval analyser.

4.2.4.3.2 Measurement items

The measurement items shall be the RMS jitter and the period (periodic) jitter.

4.2.4.3.3 Number of measurements

The measurement times shall be determined by contracts between customers and suppliers after discussion between them. The target measurement times shall be 20 000 times or more.

Attention is needed because this device may not meet the requirements of the Oscillator for the following reasons.

a) The measurable range of the measurement equipment may not meet the frequency of the Oscillator to be measured.

b) The output voltage of the Oscillator is lower as compared with this device. For this reason, an amplifier is required, and the necessity of evaluating the phase jitter of the amplifier arises.

c) The realization of square waves, such as CMOS, LVDS, and LVPECL, is difficult because harmonics components decrease in the frequency bands exceeding 300 MHz. For this reason, the signal waveforms become sine waves, clipped-sine waves and the like. It is difficult to analyse them by the specially designed SONET/SDH measurement equipment, and thus a decrease in measurement accuracy is possible.

4.2.4.3.4 Block diagram of the measurement

A representative block diagram is shown in Figure 3. A practical block diagram is utilized as modified forms of Figure 1.

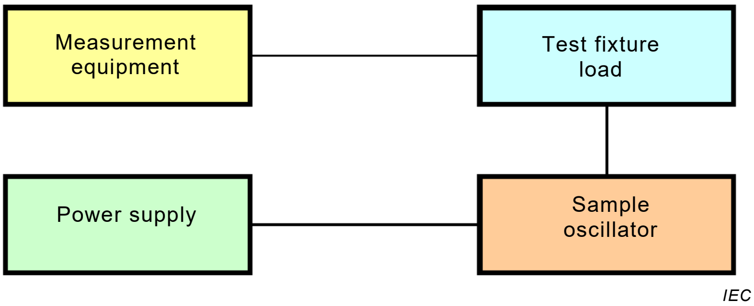

Figure 3 – Equivalent block diagram

4.3 Input and output impedances of the measurement system

The load impedance of the Oscillator widely ranges from 5 Ω to 100 MΩ. The parts to be applied are the types shown below. However, since numerous demands are made by customers, the values of this load impedance are infinite.

a) capacitor only;

b) resistor only;

c) both capacitor and resistor;

d) compliment output with bias.

Here, since the measurement system is unified into 50 Ω, the input-output impedances of measurement systems shall be 50 Ω. For this reason, the load impedance of the Oscillator shall also be 50 Ω.

The oscillation output voltage changes depend on the load impedance of the Oscillator. For this reason, the thermal noise of load circuits also changes.

As a result, since the amount of phase jitter changes, a recommendation is presented to suppliers and customers, when adopting any load impedance other than 50 Ω, to conduct a detailed study and examination and to determine the impedance by contract.

4.4 Measurement equipment

4.4.1 General

The specification required for the measurement equipment is described in 4.4.2 to 4.6 without any necessity of adhering to this document. The adoption of measurement equipment which satisfies sufficiently the requirements of the Oscillator is important.

4.4.2 Jitter floor

The jitter floor shall take values smaller by one digit as compared with the phase jitter demanded for the Oscillator.

4.4.3 Output wave form

The output waveforms shall be CMOS, LVDS, LVPECL, clipped-sine waves, sine waves, etc.

NOTE CMOS, LVDS, and LVPECL originally refer to the type of devices and not a waveform *per se*. However, they are also used as the terms showing the waveforms and are, therefore, described as the type of output waveforms in this document.