BS EN 60679-6:2011

BSI Standards Publication

Quartz crystal controlled oscillators of assessed quality

Part 6: Phase jitter measurement method for quartz crystal oscillators and SAW oscillators — Application guidelines

National foreword

This British Standard is the UK implementation of EN 60679-6:2011. It is identical to IEC 60679-6:2011. It supersedes DD IEC/PAS 60679-6:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/49, Piezoelectric devices for frequency control and selection.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Quartz crystal controlled oscillators of assessed quality - Part 6: Phase jitter measurement method for quartz crystal oscillators and SAW oscillators - Application guidelines
(IEC 60679-6:2011)

Oscillateurs pilotés par quartz sous assurance de la qualité - Partie 6: Méthode de mesure de la gigue de phase pour les oscillateurs à quartz et les oscillateurs SAW - Lignes directrices pour l'application (CEI 60679-6:2011)

Quarzoszillatoren mit bewerteter Qualität - Teil 6: Phasenjitter-Messverfahren für Quarzoszillatoren und OFW-Oszillatoren - Leitfaden für die Anwendung (IEC 60679-6:2011)

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Foreword

The text of document 49/935/FDIS, future edition 1 of IEC 60679-6, prepared by IEC TC 49, Piezoelectric, Dielectric and Electrostatic Devices and Associated Materials for FrequencyControl, Selection and Detection, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60679-6 on 2011-04-18.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-01-18
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2014-04-18

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60679-6:2011 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application 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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60679-1	2007	Quartz crystal controlled oscillators of assessed quality - Part 1: Generic specification	EN 60679-1	2007

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INTRODUCTION

The study of phase jitter measurement methods was conducted in accordance with the agreement during the IEC TC 49 Berlin international meeting in 2001. At this meeting, the decision was made that Japan should assume the responsibilities of this study. Then, the technical committee of the Quartz Crystal Industry Association of Japan (QIAJ) proceeded with this study. This study was substantially conducted during the years 2002 to 2005 and can be referred to as the first stage of the study. The second stage is being continued at present.

Phase jitter has become one of the essential measurement items by digitization of electronic devices. However, theoretically, some ambiguity is still left in the phase jitter. Since no standard measurement method is proposed, suppliers and customers may be mutually exposed to a risk which could cause enormous economic losses.

To avoid this risk, this document provides a standard, based on the study results during the first stage, for each company of QIAJ members to avoid anxiety as to the measurement of the phase jitter and for the purpose of giving guidance without any mistakes.

In this standard, a recommendation to make r.m.s. jitter a measurement object is presented. The reason why this recommendation is submitted is because the oscillators resulting in ultra-low amount of jitter are targeted as the object to be measured.

Oscillators are analogue-type electronic devices. Their sine wave output signals are more favourable than the signals obtained by electronic systems. Moreover, the output is utilized as the reference clock of the measurement equipment, leading to a situation in which the amount of phase jitter is shown to be smaller than the amount of phase jitter of the measurement equipment. Accordingly, this may give the impression that the measured amount of phase jitter is not from the oscillators but rather the amount of phase jitter generated by the measurement equipment, or the measurement system. Therefore, when adopting the amount of other phase jitters as the measurement items, a recommendation is presented to select measurement equipment and a measurement system capable of being verified and confirmed sufficiently, contractually determined between suppliers and customers. Moreover, when the phase noise method is used, the random jitter values need to be discussed after defining the jitter frequency bands from start to end of integrating the phase noise.

In case of doubts related to the measurement values, refer to the application of Allan Variance [1][1] .

Frequency stability was compiled into a single work by IEEE in 1966 [2]. Then, the definition was applied to atomic oscillators, crystal oscillators, as well as electronic systems for telecommunication, information, audio-visual, and the like.

Conventional crystal oscillators and electronic systems have analogue systems and their signal waveforms are sine waves. Therefore, the short-term frequency stability as one field of the frequency stability is measured as the phase noise or Allan Variance. Recently, digitization of electronic systems is progressing. Under such circumstance, the short-term frequency stability has been measured as the phase jitter.

On the other hand, the oscillators are analogue-type electronic devices. For the oscillators, the signals having square waves or waveforms similar thereto are demanded by users to be easily fit into the electronic systems. Naturally, for the short-term frequency stability, the measurement as the phase jitter is frequently demanded by users.

For advance application in electronic information and communication technology: (e.g.: advanced satellite communications, control circuits for electric vehicle (EV) and etc.), necessity arises for the measurement method for common guidelines of phase jitter. In these

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1 Numbers in square brackets refer to the Bibliography.

days, measurement method of phase jitter also becomes more important from the electromagnetic influence (EMI) point of view.

In that sense, international standardization as IEC 60679-6 of phase jitter measurement method is significant and timely. The measurement method of phase jitter described in this document is the newest method by which quantitative measurement was made possible from the breakthrough of the measurement system technology, in the hope to get attention from not only a device engineer but also a system engineer and expected to be widely used.

QUARTZ CRYSTAL CONTROLLED OSCILLATORS OF ASSESSED QUALITY –

Part 6: Phase jitter measurement method for quartz crystal oscillators and SAW oscillators – Application guidelines

1 Scope

This part of the IEC 60679 series applies to the phase jitter measurement of quartz crystal oscillators and SAW oscillators used for electronic devices and gives guidance for phase jitter that allows the accurate measurement of r.m.s. jitter.

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

The measuring frequency range is from 10 MHz to1 000 MHz.

This standard applies to quartz crystal oscillators and SAW oscillators used in electronic devices and modules that have the multiplication or division functions based on these oscillators. The type of phase jitter applied to these oscillators is the r.m.s. jitter. In the following text, these oscillators and modules will be referred to as “oscillator(s)” for simplicity.

2 Normative references

The following referenced documents are indispensable for the application 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 60679-1:2007, *Quartz crystal controlled oscillators of assessed quality – Part 1: Generic specification*

3 Terms, definitions and general concepts

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60679-1:2007 apply.

Units, drawings, codes, and characters are also based on IEC 60679-1.

3.2 General concepts

3.2.1 Phase jitter

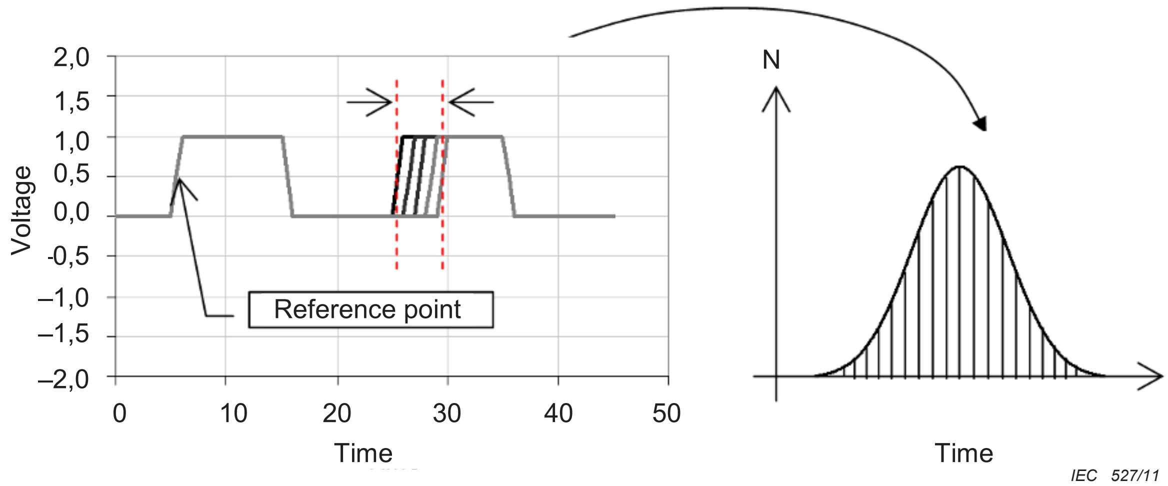
The phase jitter of oscillators means an electronic noise of signal waveforms in terms of time. On the other hand, the phase jitter is described as a jitter in which the frequency of signal deflection exceeds 10 Hz and as a wander in which the frequency is 10 Hz or less.

It is difficult to observe the wander of oscillators. The wander is a phenomenon which is confirmed in electronic parts such as optical cables susceptible to expansion and contraction even by a small amount of temperature changes. Therefore, the wander is generally not discussed in the oscillators. In this document also, phase jitter is targeted only to the jitter.

As for signals, an ideal cycle (t) is inversely proportional to a frequency (f). More specifically, the relation is expressed by Equation (1).

$$t = \frac{1}{f} \qquad (1)$$

Actually, the cycle is varied by receiving various influences. This phenomenon is the phase jitter and can be confirmed by thickening of edges of waveforms when using oscilloscopes or the like. Regarding the method for measuring and evaluating such phase jitter, statistical measurement techniques are utilized as shown is shown in Figure 1. The numerical values in Figure 1 are treated as a symbol. The position of 0,5 of signal waveform is defined as a reference point in the vertical axis, and the edges of the reference point are defined to be not varied. When attention is paid to the edges after one cycle, every time when the signals repeatedly move on the screen of CRT in the lateral direction, the edges after one cycle are not reproduced. Then, plurality edges have become to exist. This phenomenon is induced when repeatedly measuring the signals, and referred to as the phase jitter.



a) Output waveform **b) Histogram of the all jitters**

Figure 1 – Voltage versus time

This phase jitter is treated as a normal distribution. Then, when analysed, the phase jitter can be divided into several types of properties. More specifically, the phase jitter is classified in several types. In this document, the phase jitter is classified in the seven types as described below. In the following, these properties and the cause systems are made clear.

3.2.2 r.m.s jitter

The r.m.s. jitter is the phase jitter which comes to have the normal distribution shown in Figure 2. The r.m.s. jitter is a standard deviation obtained on the basis of statistical treatments and defined as a 1 σ portion

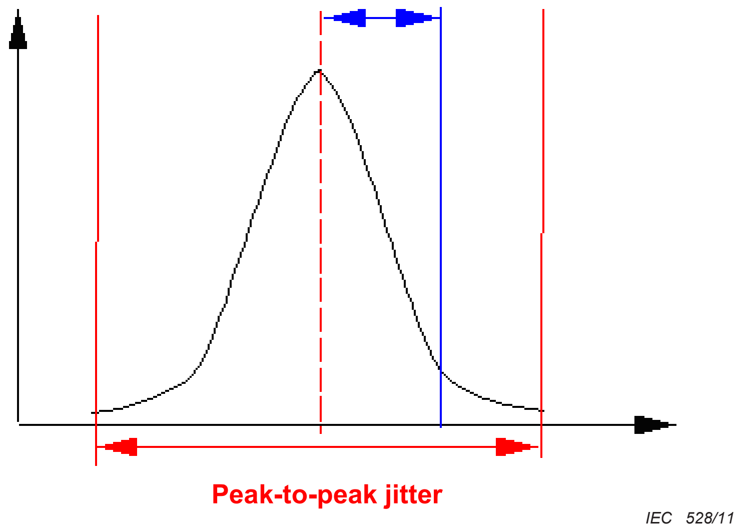


Figure 2 – Explanatory diagram of the amount of jitter applied to r.m.s. jitter

From statistics, any measurement data is meant to exist in 1 σ at a probability of 68,26 %. Therefore, when the measurement times are 10 000, approximately 6 826 pieces of the measurement data are considered to be contained. On the contrary, 31,74 % (3 174 pieces) of the measurement data is indicated to be outside the plus and minus sides of 1 σ. If the data outside the definition is considered to be errors, 31,74 % can be considered to be the error rate.

3.2.3 Peak-to-peak jitter

The peak-to-peak jitter is the phase jitter which comes to have the normal distribution shown in Figure 2. The amount of phase jitter of one cycle is totalized and statistically treated on the base point of the reference point of phase jitter shown in Figure 1. In this case, the amount of phase jitter is assumed to provide the normal distribution.

The difference between the maximum value and the minimum value (namely, change width) is referred to as the peak-to-peak jitter. Since the jitter values become larger as the measurement times are increased, the jitter also becomes the total jitter as described later. This term comes on when negotiating specifications between customers and oscillator makers.

NOTE Since the peak-to-peak jitter or the r.m.s. jitter indicates the amount of phase jitter to the measurement times thereof, the jitter indicates operating conditions of measurement samples in a short period of time. Moreover, the jitter has values effective only to an ideal normal distribution (Gaussian distributions), and the effectiveness can be maintained to be low in cases of non-Gaussian distributions having distorted distributions such as binomial distributions and chi-square distributions. Accordingly, when applying the peak-to-peak jitter or the r.m.s. jitter, the measurement times are required to be clearly defined contractually between customers and supplier sides.

3.2.4 Random jitter

The random jitter is shown in Figure 3. The random jitter represents unpredictable phase jitter components.

The random jitter naturally and inductively occurs as influenced by the characteristics, thermal noise, etc., originally involved in the measurement equipment per se or oscillators. Furthermore, random jitter has the characteristics that the distribution width of measurement values becomes larger (namely, boundless characteristics) as the observation period of time becomes longer. Therefore, the distribution chart can be considered as an ideal normal distribution. Moreover, the random jitter is determined as a standard deviation based on the distribution chart obtained by the measurement of phase jitter. Accordingly, in the case of oscillators, the random jitter may become the amount of jitter equivalent to the r.m.s. jitter. Moreover, since the random jitter becomes the amount of jitter of the measurement equipment per second, the random jitter is one of the measures for judging applicability to measuring the phase jitter of oscillators.

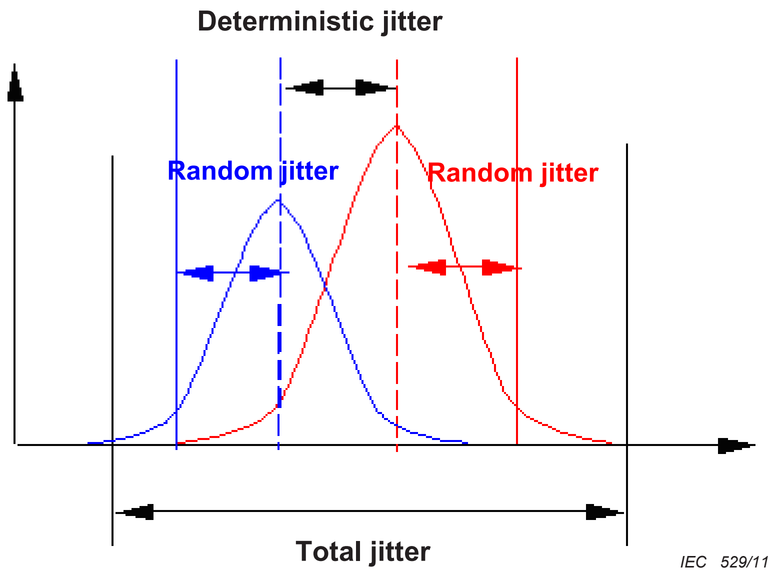


Figure 3 – Explanatory diagram of random jitter, deterministic jitter, and total jitter

3.2.5 Deterministic jitter

The deterministic jitter occurs by various factors of regularity (circuit designs, electromagnetic induction, or induced from external environment), and has characteristics inasmuch as the change width of distribution has a boundary and thus can be expressed by the parts sandwiched between right and left random jitters. On the other hand, the components forming the deterministic jitter include the period jitter or periodic jitter and the data-dependent jitter.

3.2.6 Period (periodic) jitter

The period jitter or periodic jitter shows variations of timings of multiple cycles consecutively provided such as two cycles and three cycles. The period jitter or periodic jitter can be determined by grasping the relationship with the r.m.s. jitter between the multiple cycles and each cycle, and thus grasping whether or not periodic irregularities appear. As for the periodic components of this jitter, such components are considered as an electronic noise caused by the power supply and cross-talk from electronic parts around oscillators to be measured, and further from cores in the vicinity in the case of IC.

If the Fast Fourier Transform (FFT) can be executed, the frequency as the cause clearly appears as a spectrum. Although this jitter is naturally required to be considered for the oscillators, it is difficult to detect the jitter by using measurement equipment in general.

3.2.7 Data-dependent jitter

The data-dependent jitter is considered to be the jitter components due to duty cycle distortion and inter symbol interference, and is negligible for oscillators.

3.2.8 Total jitter

The total jitter is defined as the jitter obtained by totalizing all of the jitters.

3.3 Points to be considered for measurement

3.3.1 Measurement equipment

For the oscillators, requests of infinite variety are provided by customers. The output waveforms are not limited to square waves. The demands for output voltage as small as not applicable to the measurement equipment may also be provided.

Since the oscillators have an ultra-low noise, such a case may be experienced that the amount of jitter of the measurement equipment *per se* is detected. Therefore, for the amount of jitter of the measurement equipment *per se*, the measurement equipment shall have the jitter floor smaller by one digit as compared with the amount of jitter of assumed oscillators. Moreover, the frequency range and the output waveforms are requested to be applicable not only to square waves but also to sine waves.

Since measurement equipment in general, are provided with the specification of a degree applicable to digital electronic systems, a sufficient study is required for adapting the measurement equipment for oscillator purposes.

a) In case of digital oscilloscopes, no appropriate measurement equipment for such oscillator purpose is found.
b) When applying digital oscilloscopes to the phase jitter measurement, it is recommended to select the measurement equipment and the measurement system capable of being sufficiently verified and confirmed, and to be determined by contract between suppliers and customers.
c) When applying time interval based analysers to the phase jitter measurements, the following shortcomings are observed; compared to oscillators, the random jitter of jitter floor is equivalent, or larger; the application of sine waves is difficult; the low frequency cannot be applied to the range of such oscillators, and the output voltage is low so that an amplifier is required. Therefore, selecting the time interval based analysers requires careful consideration.
d) The phase jitter may be calculated from phase noise measurement values by using the phase noise measurement equipment or measurement system. In this case, the detuned frequency shall be determined by contract between suppliers and customers. When the detuned frequency does not remain in the range of the phase noise measurement equipment or the measurement system, in particular, when the upper limit of the detuned frequency becomes a floor level, care shall be taken not to create misunderstanding between customers and suppliers, by defining that the voltage of floor level is exactly according to the contract established between them.

Within the range investigated during the first stage of the study, no devices satisfying the requirements were found among sampling oscilloscopes and specially designed measurement equipment. However, since information is obtained that a part of specially designed measurement equipment satisfying the requirements has been put on the market, the specially designed measurement equipment falls within the scope of this standard.

3.3.2 Factors of measurement errors

With regard to oscillators, the factors contributing to phase jitter measurement errors are the following:

a) Power supply

   The power supply is required for driving the oscillators. If unstable power supply is used, the unstable power supply is observed as converted into jitter. Therefore the use of power supply having a sufficiently low noise is desirable. Since losses occur on the wiring cable between power supply terminals and oscillators or amplifiers, and since contact resistance is produced, the amount of phase jitter may be increased from this part.
b) Test fixer and load

The load is formed of resistors and fixed capacitors. Since the resistors exist, generation of electronic noise cannot be avoided. The possibility of playing a role in collecting the electronic noise as an antenna may be exemplified.

c) Amplifier (when an amplifier at the time of measurement is used)

The amplifier is formed of electronic parts including active elements and resistors. Therefore, generation of electronic noise cannot be avoided.

d) Cable

The cable including losses therein and therefore is a source of / generating electronic noise. Since the reflectance changes as the impedance changes in function of the length caused by temperature characteristics, the change may be misread as the wander. An electronic noise due to contact change of connectors may occur. The possibility of playing the role of collecting the electronic noise as an antenna may be exemplified.

e) Input-output impedance of measurement system

The load impedance of oscillators widely ranges from 5 Ω to 100 MΩ. The parts used for the load impedance include the following three types:

1) capacitor only;
2) resistance element only;
3) combined use of a capacitor and a resistance element.

In 1) only the capacitor phase jitter measurement values can be neglected. In 2) and in 3) attention is needed because the phase jitter measurement values cannot be neglected by the thermal noise from the resistance element.

f) Measurement of phase jitter for frequencies exceeding 1 GHz

In general, the waveforms of signals (including demodulated signals) exceeding 1 GHz are modified sine waves. Therefore, attention is needed because the amount of phase jitter, which suppliers and customers intended, may be difficult to obtain by sampling oscilloscopes or specially designed measurement equipment.

4 Measurement method

4.1 General

The measurement method applied to oscillators is based on the following.

4.2 Frequency range and the measurement method

The measurement range shall be 10 MHz to 1 000 MHz. The phase noise measurement equipment (system) or the specially designed phase jitter measurement equipment shall be used as measurement method.

4.3 Method using the phase noise measurement value

4.3.1 Overview

The recommended method for measuring phase jitter using phase noise measurements is as given in 4.3.2 to 4.3.4 below.

4.3.2 Measurement equipment and system

The measurement equipment and system shall be the phase noise measurement equipment or the phase noise measurement system.

4.3.3 Measurement item

The measurement item shall be the r.m.s jitter.

NOTE Only random jitter. No period jitter.

4.3.4 Range of detuning frequency

The range of detuning frequency should be determined through a prearrangement and contract between a customer and a supplier. The formula to calculate phase jitter from phase noise is described in Annex A.

4.3.5 Phase noise measurement method

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

An orthogonal phase detection method (also referred to as orthogonal comparison method or PLL method), or the measurement equipment having built-in electronic circuits for cancelling a noise in the measurement system (for example, circuits adopting a cross-correlation method) shall be used as phase noise measurement methods.

4.4 Measurement method using the specially designed measurement equipment

4.4.1 Overview

The requirements for the method using the specially designed measurement equipment are based on the following.

4.4.2 Measurement equipment and system

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

4.4.3 Measurement items

The measurement items shall be the r.m.s jitter and the period (periodic) jitter.

4.4.4 Number of measurements

The number of measurements shall be determined by contract between customers and suppliers after discussion. The target number of measurements shall be 20 000 times or more.

NOTE Attention is needed because this device may not meet the requirements of oscillators for the following reasons:

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

b) The output voltage of the oscillators 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.

4.5 Block diagram of the measurement

A representative block diagram is shown in Figure 4. A practical block diagram is utilized as modified forms of Figure 4.

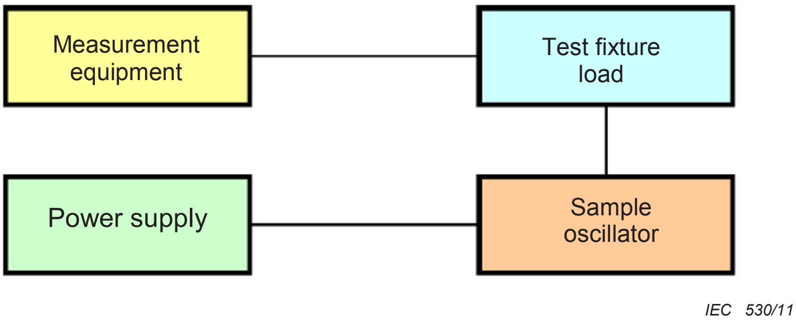


Figure 4 – Equivalent block diagram

4.6 Input and output impedance of the measurement system

The load impedance of oscillators 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 impedance of measurement systems shall be 50 Ω. For this reason, the load impedance of oscillators shall also be 50 Ω.

The changes of the oscillation output voltage depends on the load impedance of oscillators. 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 contractually.

4.7 Measurement equipment

4.7.1 General

The requirements for the measurement equipment are described in the following subclauses. There is no necessity of adhering to these requirements. However, it is important to adopt measurement equipment satisfying the requirements of oscillators.

4.7.2 Jitter floor

The jitter floor shall take values of 0,05 ps or less as the random jitter or values smaller by one digit as compared with the phase jitter demanded for the oscillators.

4.7.3 Frequency range

The frequency range shall be 10 MHz to 1 000 MHz. Several items of measurement equipment may be used according to each frequency band.

4.7.4 Output waveform

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 to a waveform per se. However, they are also used as the terms for waveforms and are, therefore, described as the type of output waveforms in this document.

4.7.5 Output voltage

The output voltage shall be 350 mV or more.

4.8 Test fixture

The requirements for measurement implements are shown below:

a) Connection between oscillators to be measured and measurement implements

   The application of sockets, connectors, screws, clips, and the like may be allowed. In addition, the oscillators to be measured and the measurement implements shall be ensured to be mechanically and electrically connectable.

b) Compatibilization of oscillators to be measured and measurement implements

   The oscillators to be measured and the measurement implements shall be capable of being earthed.

c) Although it is possible to use measurement implements without built-in load impedance, it is recommended to use measurement implements with built-in load impedance in order to reduce influences, on the phase jitter of the oscillators to be measured, from a thermal noise or the like coming from the load impedance.

4.9 Cable, tools and instruments

- Cable: the double-shield type of a 50 Ω system shall be used. The cable shall be as short as possible.
- Connectors: the 50 Ω system shall be used. It is recommended that SMA or N-type connectors be used.

NOTE From the viewpoint of a measuring method, this measuring system is a 50 Ω system, but the actual load impedance of an oscillator is not a 50 Ω system. When a measuring system is not a 50 Ω system, it is recommended that both, the user and the supplier agree on the use of such a system and clearly define the new measurement system contractually.

5 Measurement and the measurement environment

5.1 Set-up before taking measurements

Attention should be paid to the following:

a) The entire measurement system and the oscillators to be measured shall be installed in a measurement chamber at least 2 h previously.
b) The measurement equipment shall be set to operate for 2 h or more.
c) The frequency stability of clock signals in the measurement equipment shall be verified to be smaller than, or equivalent to, the frequency stability of the oscillators to be measured.
d) The power supply voltage of the oscillators to be measured and the measurement equipment shall be verified to be set to the a.c. voltage and the d.c. voltage as requested.
e) Restrictions shall be provided for the operation of surrounding electronic devices so as not to produce an electronic noise from the surrounding environment.

5.2 Points to be considered and noted at the time of measurement

No vibration of the measurement system shall be caused. No movement shall be caused. No shifting of the cable position shall be made.

5.3 Treatment after the measurement

It is preferable not to disassemble the measurement system after performing measurements. Periodical inspection and calibration of the measurement equipment should be ensured.

6 Measurement

6.1 Reference temperature

The reference temperature shall be +25 °C ± 5 °C.

6.2 Measurement of temperature characteristics

Only the oscillator to be measured shall be immobilized in the precisely variable temperature bath as appropriately selected, and the temperature characteristics shall be measured. No vibration shall be caused.

6.3 Measurement under vibration

Only the oscillator to be measured shall be fixed to the shaker as appropriately selected and caused to vibrate. No vibration of the measurement equipment shall be caused.

6.4 Measurement at the time of impact

Only the oscillator to be measured shall be fixed to the impact machine as appropriately selected to apply impact thereto. Moreover, no shock wave or no vibration accompanied with the impact shall be provided for the measurement equipment.

In addition, this testing is not realistic because the impact period of time is shorter than the measurement period of time. If this testing is performed, a recommendation is given to suppliers and customers to conduct a detailed study and examination and to determine the measurement contractually.

6.5 Measurement in accelerated ageing

Only the oscillator to be measured shall be set to the temperature and time, according to the appropriately selected specifications for the temperature bath, and then caused to immobilize. The accelerated ageing shall thus be measured.

7 Other points to be noted

Precaution shall be taken so as to obtain measurement results understandable by suppliers and customers. This is realisable by eliminating any possibility that an electronic noise may be involved in the measurement system from the supply source line and also by paying attention to the phase jitter of the devices applied to the measurement system, or to be applied around the system.

8 Miscellaneous

With regard to the amount of phase jitter of quartz crystal oscillators and SAW oscillators, as well as modules that have a multiplication function or a division function based on these oscillators, customers and suppliers shall conduct a detailed study and examination, and determine this contractually.

Annex A
(normative)

Calculation method for the amount of phase jitter

A.1 General

This annex gives the method of calculating the amount of phase jitter from phase noise measurement results.

A.2 Explanation

When the amount of phase jitter is calculated from the phase noise measurement results, the r.m.s. jitter can be obtained. The details are described below.

If a spectrum analyser or a phase noise measurement system is used, the phase jitter can be analysed as to the frequency components which can be used for the cause analysis of the phase jitter. According to the measurement of the phase jitter by the phase noise measurement system, the ultra-low amount of phase jitter, which cannot be measured by other jitter measurement methods, can be measured, and thus the phase noise measurement system is suitable for evaluating highly stable devices such as crystal oscillators. With regard to the signals of crystal oscillators, various types of signal waveforms such as sine waves and square waves are requested by customers. Among them, as for the sine wave signals, the application of the phase noise measurement system is theoretical and appropriate. However, as for the square wave signals, although error-increasing factors are involved, since any other method capable of firmly measuring the ultra-low amount of phase jitter has not yet been found, the phase noise measurement system is actually obliged to be applied even to the square wave signals.

In general, when the measurement results of an SSB phase noise of crystal oscillators are viewed, the offset frequency in the horizontal axis is described such as 10 Hz to 1 MHz, 1 Hz to 1 MHz, and 1 Hz to 10 MHz in many cases. In particular, for the offset frequency of 10 kHz or more as the floor level, the offset frequency is described as 1 MHz or 10 MHz. Such offset frequency is obtained because filters are provided in the measurement equipment.

On the other hand, as for the phase jitter, since such filters are not required, the measurement values can be obtained regardless of the offset frequency. Therefore, no complete coincidence can be maintained to be provided for the phase noise measurement values and the phase jitter measurement values. However, in the case of oscillators having the ultra-low amount of phase jitter such as the crystal oscillators, the phase noise measurement values and the phase jitter need to be correlated, and, therefore, the phase noise and the phase jitter are used for convenience.

A.3 Relations between phase noise and phase jitter

When phase modulations are demodulated by a phase detector (converting phase fluctuations into voltage fluctuations), the relationship between phase and voltage can be expressed by Equation (A.1), wherein K_φ is a constant, and the unit is K_φ (V/rad).

$$\Delta V_{out} = K_\varphi \times \Delta\varphi \quad (A.1)$$

When the converted phase fluctuations are measured by a spectrum analyser, the relationship can be expressed by Equation (A.2).

$$\Delta V_{\mathrm{rms}}(f) = \mathrm{K}_{\varphi} \times \Delta\varphi_{\mathrm{rms}}(f) \text{ (V)} \tag{A.2}$$

wherein, if $S_{\mathrm{vrms}}(f)$ is defined as the spectral density function of the voltage fluctuations (output fluctuations of the phase detector) as measured, the spectral density function of the phase fluctuations can be expressed by Equation (A.3).

$$\begin{aligned} S_{\varphi}(f) &= \frac{(\Delta\varphi_{\mathrm{rms}}(f))^2}{B} \\ &= \frac{(\Delta V_{\mathrm{rms}}(f))^2}{\mathrm{K}\varphi^2 \times B} \\ &= \frac{S_{v\mathrm{rms}}(f)}{\mathrm{K}\varphi^2}\left(\frac{\mathrm{rad}^2}{\mathrm{Hz}}\right) \end{aligned} \tag{A.3}$$

When the results are converted into the single sideband (SSB) phase noise as shown below, the SSB phase noise can be expressed by Equation (A.4),

$$L(f) = \frac{S_{\varphi}(f)}{2} \tag{A.4}$$

wherein $S_{\varphi}(f)$ is a dB value relative to 1 rad, and also the power spectral density function of the phase fluctuations, and $L(f)$ is the SSB phase noise.

A total phase deviation in the designated band, namely, the phase jitter, can be expressed by Equations (A.5) and (A.6).

$$\Phi = \sqrt{\int_A^B S_{\varphi}(f) \times \mathrm{d}f} \text{ (rad)} \tag{A.5}$$

$$\Phi = \sqrt{\int_A^B 2 \cdot L(f) \times \mathrm{d}f} \text{ (rad)} \tag{A.6}$$

Therefore, the shaded parts (area of SSB phase noise) shown in Figure A.1 can be referred to as the phase jitter.

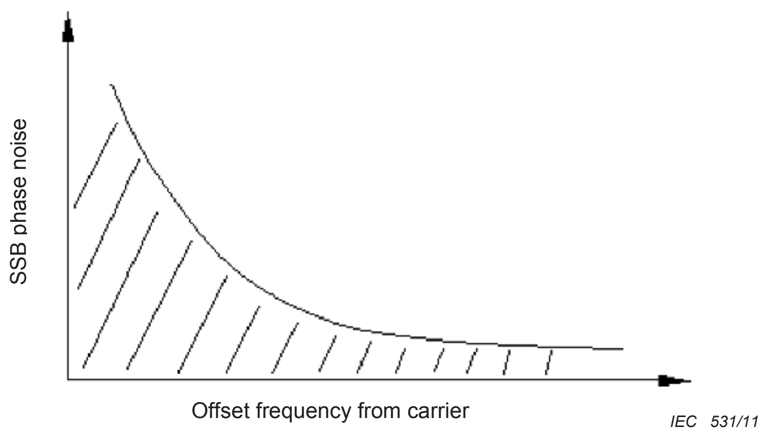


Figure A.1 – Concept diagram of SSB phase noise

This area corresponds to the r.m.s. jitter. Here, if the offset frequency range is different, the phase jitter calculation value becomes different. Since the fact is a shortcoming of this method, attention should be paid when calculating the phase jitter from the SSB phase noise.

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