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PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

Quartz crystal controlled oscillators of assessed quality –

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

IEC/PAS 60679-6:2008(E)

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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 guide

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IEC-PAS 60679-6 was submitted by the Japanese Institute of Electronics, Information and Communication Engineers and has been processed by IEC technical committee 49: Piezoelectric and dielectric devices for frequency control and selection.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
49/784/NP	49/793A/RVN

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of three years starting from the publication date. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

INTRODUCTION

With the advance of information and telecommunication technologies, such information and telecommunication devices as measuring instruments and computers have played important roles in society. Recently, these devices have been digitized and proliferated on a worldwide basis. For these devices, crystal oscillators with low phase noise are necessary. This standard deals with the phase jitter measurement method.

International standardization of industrial standards regarding electronic devices is conducted by many technical committees in the International Electrotechnical Commission (IEC), located in Geneva. TC 49 works on standardization of international trade regarding piezoelectric and dielectric devices for frequency control and selection. There are 10 working groups (WG) in TC49, and WG6 formulates and deliberates international standards regarding measurement methods.

The special committee for piezoelectric and dielectric devices for frequency control and selection in the standard investigatory panel of the electronic information communication society has been working as a domestic deliberative body of IEC/TC49. The activities of the domestic committee for TC49/WG6 are conducted in the measurement method committee of the technical committee in the Quartz Industry Association of Japan (QIAJ) which consists of crystal device manufacturers.

This PAS was formulated as QIAJ technical standard QIAJ-B-011. Phase jitter is a kind of electronic noise. Other major electronic noise is phase noise. Therefore, the IEC document should cover both phase jitter and phase noise. However, the phase noise measurement method has not yet been organized completely. Taking into account the fact that the phase jitter measurement method is increasingly important due to the advance in digitization, we considered that we should proceed with the standardization without waiting for the completion of the study of the phase noise measurement method so that the phase jitter measurement method can be used in as wide a range as possible. In this context, we requested the technical committee of the QIAJ to formulate a standard. As a result, the guideline for phase jitter measurement method of crystal oscillators and SAW oscillators was prepared and this will be issued as a standard of the Standard Investigatory Panel of the Electronic Information Communication Society.

This standard is the result of collected wisdom in the field of advanced technology in Japan, and it is open to the public as a standard of the Institute of Electronics, Information and Communication Engineers. It is expected that this standard will contribute to the development of technology in this fast-growing field.

QUARTZ CRYSTAL CONTROLLED OSCILLATORS OF ASSESSED QUALITY –

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

1 Scope

This PAS 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 to 700 MHz.

This PAS 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, *Quartz crystal controlled oscillators of assessed quality – Part 1: Generic specification*

3 Terms, definitions, glossary and general terms

In the event of contradictory/inconsistent descriptions in the specification that arise due to certain reasons, the following priority applies.

– Specific standard
– IEC 60679-1
– General rule by product type
– General rule by item
– Other quoted international standard criteria (for example, IEC)

The same prioritization also applies to the equivalent domestic standard.

Annex A gives a description of the terms with regard to phase jitter.

Unit, drawing, codes, and characters are based on IEC 60679-1.

4 Measurement method

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

4.1 Frequency range and the measurement method

The measurement range shall be 10 MHz to 700 MHz. As the measurement method, the phase noise measurement equipment (system) or the specially designed phase jitter measurement equipment shall be used.

4.2 Method of using the phase noise measurement value

The recommended method of measuring phase jitter using phase noise measurements is as given in 4.2.1 to 4.2.4.

4.2.1 Measurement equipment/system

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

4.2.2 Measurement item

RMS jitter

NOTE Only random jitter. No period jitter.

4.2.3 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 the phase noise is described in Annex A.

4.2.4 Phase noise measurement method

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

As the phase noise measurement method, an orthogonal phase detection method (referred to also as an orthogonal comparison method or a PLL method) shall be used, 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.

4.3 Measurement method for the use of the specially designed measurement equipment

The specification of the method using the specially designed measurement equipment is based on the following.

4.3.1 Measurement equipment and system

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

4.3.2 Measurement items

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

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.

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.

4.4 Block diagram of the measurement

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

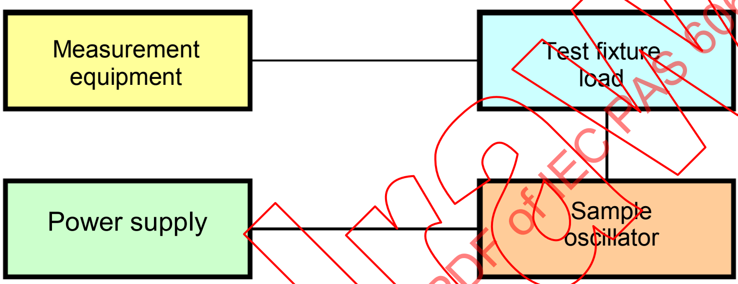

Figure 1 – Equivalent block diagram

4.5 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 oscillation output voltage changes depend 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 by contract.

4.6 Measurement equipment

The specification required for the measurement equipment is described in the following subclauses without any necessity of adhering to this specification. The adoption of measurement equipment which satisfies sufficiently the requirements of oscillators is important.

4.6.1 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.

4.6.2 Frequency range

The frequency range shall be 10 MHz to 700 MHz. Several items of measurement equipment may be used according to each frequency band.

4.6.3 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 PAS.

4.6.4 Output voltage

The output voltage shall be 500 mV or more.

4.7 Test fixture

The specification demanded for measurement implements is 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 the load impedance may not be built in, a recommendation is presented to use measurement implements having the load impedance built therein in order to reduce influences on the phase jitter of the oscillators to be measured from a thermal noise or the like from the load impedance.

4.8 Cable, tools and instruments, etc.

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

5 Measurement and the measurement environment

5.1 Set-up before taking measurements

Attention should be paid to the following matters.

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.

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 by contract.

6.5 Measurement in accelerated ageing

Only the oscillator to be measured shall be set to the temperature and time based on the specification in the temperature bath as appropriately selected, and then caused to immobilize, and thus the accelerated ageing shall be measured.

7 Other points to be noted

Consideration shall be taken so as to obtain the measurement results understandable to suppliers and customers by eliminating any possibility that an electronic noise may be involved in the measurement system from the supply source line through paying attention also 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 by contract.

Annex A
(normative)

Calculation method for the amount of phase jitter

A.0 Introduction

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

A.1 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 the of 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.2 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 the formula (1), wherein K_φ is a constant, and the unit is K_φ (V/rad).

$$\Delta V_{out} = K_\varphi \cdot \Delta\varphi \qquad (A.1)$$

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

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

wherein, if $S_{\text{vrms}}(f)$ 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 the formula (3).

$$\begin{aligned} S_{\varphi}(f) &= \frac{(\Delta\varphi_{\text{rms}}(f))^2}{B} \\ &= \frac{(\Delta V_{\text{rms}}(f))^2}{\text{K}\varphi^2 \cdot B} \\ &= \frac{S_{\text{vrms}}(f)}{\text{K}\varphi^2} \; \frac{\text{rad}^2}{\text{Hz}} \end{aligned} \tag{A.3}$$

When the results are converted into the SSB phase noise as shown below, the SSB phase noise can be expressed by the formula (4),

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

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

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

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

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

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

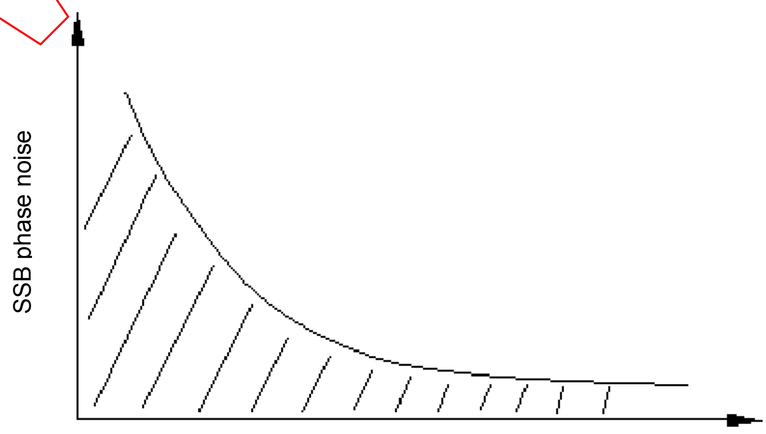

Figure A.1 – Concept diagram of SSB phase noise

A.3 Commentary

A.3.1 History of establishment and points to note

The study of phase jitter measurement methods was conducted in accordance with the agreement during the IEC TC49 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 QIAJ proceeded with this study. This study was substantially conducted during the years 2002 to 2005 and can be referred to, without exaggeration, as the first stage. The second stage of the study 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 PAS 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 a part of this PAS, unsolved issues still remain. However, since this part will be solved during the second stage, if any doubts are created, a sincere request is addressed for suppliers and customers to mutually consult so as to solve the issues.

Next, in this PAS, a recommendation is presented to make r.m.s. jitter a measurement object. This recommendation is submitted because, as the object to be measured, the oscillators resulting in the ultra-low amount of jitter are targeted.

The oscillators are analogue-type electronic devices. As for the signals, sine wave output more favourable than electronic systems can be obtained. Moreover, the output is utilized as the reference clock of the measurement equipment. Therefore, such a case is frequently experienced as showing the amount of phase jitter to be smaller than the amount of phase jitter of the measurement equipment. Accordingly, such a case may be experienced that the measured amount of phase jitter is not from the oscillators, and shows the amount of phase jitter on the side of the measurement equipment, or of the measurement system. Therefore, when adopting the amount of other phase jitters as the measurement items, a recommendation is presented to select the measurement equipment and the measurement system sufficiently capable of being verified and confirmed, and determined by contracts 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.

If any doubts are created as to the measurement values, it is requested that the application of Allan Variance [1][1] can be studied.

A.3.2 Theoretical positioning of phase jitter

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

The conventional crystal oscillators and electronic systems have analogue systems with exception of a part, and the 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 the circumstance, the short-term frequency stability has been measured as the phase jitter.

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[1] Figures in square brackets refer to the Bibliography.

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 for facilitating to be assembled into the electronic systems. Naturally, for the short-term frequency stability, the measurement as the phase jitter is frequently demanded by users.

A.4 Description

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 PAS also, the phase jitter is targeted only to the jitter.

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

$$t = \frac{1}{f} \tag{A.1}$$

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. As the method of measuring and evaluating such phase jitter, statistical measurement techniques are utilized. This phenomenon is shown in Figure A.2. The numerical values in Figure A.2 are treated as a symbol. The position of 0,5 of signal waveforms 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.

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 PAS, the phase jitter is classified in the seven types as described below. In the following, these properties and the cause systems are made clear.

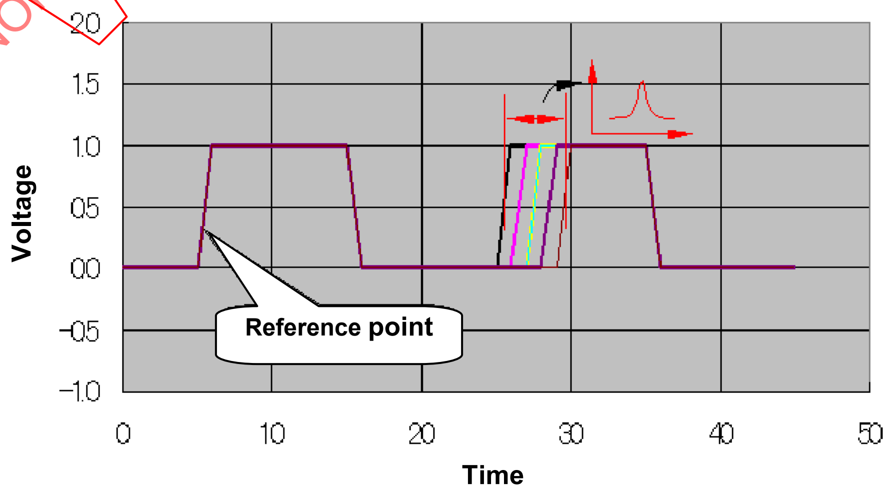

Figure A.2 – Voltage versus time

A.4.1 RMS jitter

The r.m.s. jitter is the phase jitter which comes to have the normal distribution shown in Figure A.3. The r.m.s. jitter is a standard deviation obtained on the basis of statistical treatments and defined as a 1σ portion.

From statistics, any measurement data is meant to exist in 1σ 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 1σ. If the data outside the definition is considered to be errors, 31,74 % can be considered to be the error rate.

A.4.2 Peak-to-peak jitter

The peak-to-peak jitter is the phase jitter which comes to have the normal distribution shown in Figure A.3. 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 A.2. 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 or the cycle-to-cycle 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 in 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 when considered for the 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 by contracts between customers and supplier sides.

A.4.3 Random jitter

The random jitter is shown in Figure A.4. The random jitter represents unpredictable phase jitter components.

The random jitter naturally and inductively occurs as influenced by the characteristics, thermal noise, and the like originally involved in the measurement equipment *per se* or oscillators. Furthermore, the random jitter has 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.

A.4.4 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.

A.4.5 Period (periodic) jitter

While the r.m.s. jitter represents variations in one cycle, 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.

A.4.6 Data-dependent jitter

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

A.4.7 Total jitter

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

A.5 Points to be considered for measurement

A.5.1 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 equipments in general are provided with the specification of a degree applicable to digital electronic systems, a sufficient study is required for adopting the measurement equipment for oscillator purpose.

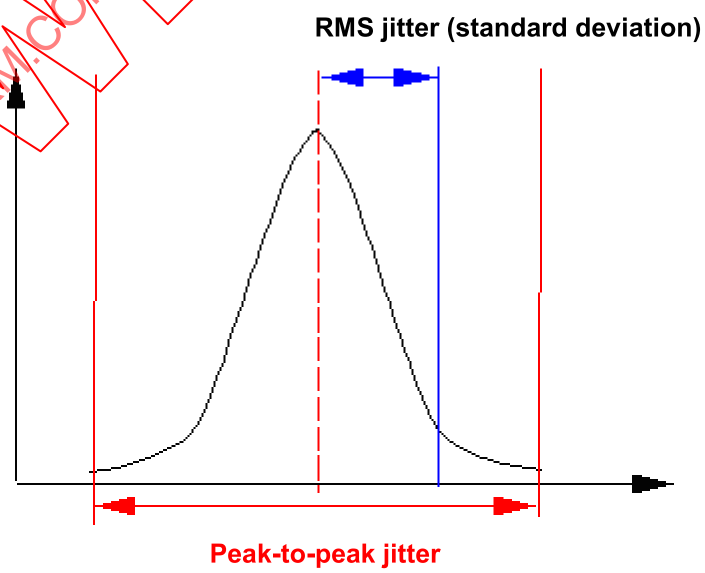

Figure A.3 – Explanatory diagram of the amount of jitter applied to r.m.s. jitter