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INTERNATIONAL STANDARD

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Measurement techniques of piezoelectric, dielectric and electrostatic oscillators –
Part 1: Basic methods for the measurement

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Measurement techniques of piezoelectric, dielectric and electrostatic oscillators –
Part 1: Basic methods for the measurement

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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MEASUREMENT TECHNIQUES OF PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS –

Part 1: Basic methods for the measurement

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62884-1 has been prepared by IEC technical committee 49: Piezoelectric, dielectric and electrostatic devices and associated materials for frequency control, selection and detection.

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

CDV	Report on voting
49/1187A/CDV	49/1200/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.

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.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

MEASUREMENT TECHNIQUES OF PIEZOELECTRIC, DIELECTRIC AND ELECTROSTATIC OSCILLATORS –

Part 1: Basic methods for the measurement

1 Scope

This part of IEC 62884 specifies the measurement techniques for piezoelectric, dielectric and electrostatic oscillators, including Dielectric Resonator Oscillators (DROs) and oscillators using FBAR (hereinafter referred to as "Oscillator").

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*. Available at http://www.electropedia.org

IEC 60068-1:2013, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-7, *Basic environmental testing procedures – Part 2-7: Tests – Test Ga and guidance: Acceleration, steady state*

IEC 60068-2-10:2005, *Environmental testing – Part 2-10: Tests – Test J and guidance: Mould growth*

IEC 60068-2-13, *Basic environmental testing procedures – Part 2-13: Tests – Test M: Low air pressure*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-17:1994, *Basic environmental testing procedures – Part 2-17: Tests – Test Q: Sealing*

IEC 60068-2-20, *Environmental testing – Part 2-20: Tests – Test T: Test methods for solderability and resistance to soldering heat of devices with leads*

IEC 60068-2-21, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-45, *Basic environmental testing procedures – Part 2-45: Tests – Test XA and guidance: Immersion in cleaning solvents*

IEC 60068-2-52, *Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium, chloride solution)*

IEC 60068-2-58, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-64, *Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

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

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

Where any discrepancies occur for any reason, documents shall rank in the following order of precedence:

– detail specification;
– sectional specification;
– generic specification;
– any other international documents (for example of the IEC) to which reference is made.

The same order of precedence shall apply to equivalent national documents.

3 Terms and definitions

3.1 General

Units, graphical symbols, letter symbols and terminology shall, wherever possible, be taken from the following standards:

- IEC 60027;
- IEC 60050-561;
- IEC 60469;
- IEC 60617;
- ISO 80000-1.

3.2 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60679-1 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 shall be carried out in accordance with the relevant detail specification.

4.2 Test and measurement conditions

4.2.1 Standard conditions for testing

Unless otherwise specified, all tests shall be carried out under the standard atmospheric conditions for testing as specified in 4.3 of IEC 60068-1:2013.

– Temperature: 15 °C to 35 °C;
– Relative humidity: 25 % to 75 %;
– Air pressure: 86 kPa to 106 kPa (860 mbar to 1 060 mbar).

In case of dispute, the referee conditions are the following:

– Temperature: 25 °C ± 2 °C;
– Relative humidity: 48 % to 52 %;
– Air pressure: 86 kPa to 106 kPa (860 mbar to 1 060 mbar).

Before measurements are made, Oscillator shall be stored at the measuring temperature for a time sufficient to allow Oscillator to reach thermal equilibrium. Controlled recovery conditions and standard conditions for assisted drying are given in 4.4 and 4.5 of IEC 60068-1:2013.

The ambient temperature during the measurements shall be recorded and stated in the test report.

4.2.2 Equilibrium conditions

All electrical tests shall be conducted under equilibrium conditions, unless otherwise specified.

When test conditions cause a significant change with time of the characteristic being measured, means of compensation for such effects shall be specified, for example the period of time that Oscillator shall be maintained at specified test conditions before making a measurement.

4.2.3 Air flow conditions for temperature tests

When devices are to be measured at temperatures other than 25 °C ± 2 °C, they shall be subjected to adequate forced air circulation to ensure close temperature control.

If heat loss due to forced air circulation affects the performance of Oscillator, still air conditions shall be simulated by enclosing Oscillator in a draught shield consisting of a thermally conducting box, having internal dimensions so that a sufficient clearance is maintained from all surfaces of Oscillator. The temperature at which measurements should be taken under these conditions is the reference point temperature on the surface of the draught shield.

If a draught shield is necessary, it shall be used for both high and low temperature tests.

4.2.4 Power supplies

DC power sources used in the testing of crystal controlled oscillators shall not have a ripple content large enough to effect the desired accuracy of measurement; AC power sources shall be transient free. When the ripple and/or the transient content of the power sources are critical to the measurement being performed, their effects shall be fully defined in the detail specification.

4.2.5 Precision of measurement

The limits given in the detail specification are true values. Measurement inaccuracies shall be taken into account when evaluating the results. Precautions should be taken to reduce measurement errors to a minimum.

4.2.6 Precautions

4.2.6.1 Measurements

The measurement circuits shown for specified electrical tests are the preferred circuits. Due allowance shall be made for any loading effects in cases where the measuring apparatus modifies the characteristics being examined.

4.2.6.2 Electrostatic sensitive devices

Where the component is identified as electrostatic sensitive, precautions shall be taken to prevent damage from electrostatic charge before, during, and after test (see IEC 61000-4-2).

4.2.7 Alternative test methods

Measurements shall preferably be carried out using the methods specified. Any other method giving equivalent results may be used, except in case of dispute.

NOTE “Equivalent” means that the value of the characteristic established by such other methods falls within the specified limits when measured by the specified method.

4.3 Visual inspection

4.3.1 General

Unless otherwise specified, external visual examination shall be performed under normal factory lighting and visual conditions.

4.3.2 Visual test A

Oscillator shall be visually examined to ensure that the condition, workmanship and finish are satisfactory. The marking shall be legible.

4.3.3 Visual test B

Oscillator shall be visually examined under ×10 magnification. There shall be no cracks in the glass or damage to the terminations. Minute flaking around the further edge of a meniscus shall not be considered a crack.

4.3.4 Visual test C

Oscillator shall be visually examined. There shall be no corrosion or other deterioration likely to impair satisfactory operation. The marking shall be legible.

4.4 Dimensions and gauging procedures

4.4.1 Dimensions – Test A

The dimensions, spacing, and alignment of the terminations shall be checked and shall comply with the specified values.

4.4.2 Dimensions – Test B

The dimensions shall be measured and shall comply with the specified values.

4.5 Electrical test procedures

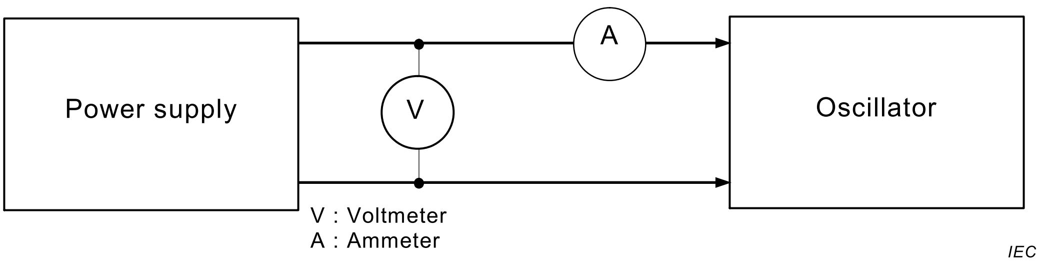
4.5.1 Insulation resistance

A maximum voltage of 20 V, unless otherwise stated in the detail specification, shall be applied to the specified test points using the test circuit shown in Figure 1a. The resulting current shall be measured. It shall be less than the specified maximum value.

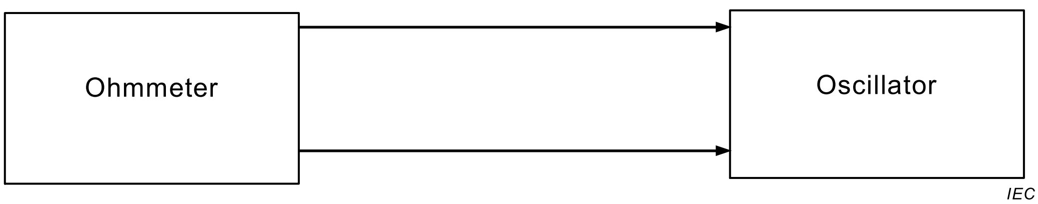
Alternatively, the resistance shall be directly measured with an ohmmeter (see Figure 1b). It shall be greater than the minimum specified.

Precautions shall be taken to ensure that measurements are made across the specified points with an applied voltage of the correct polarity and not exceeding the specified value. Failure to observe any of these conditions can result in damage to the device under test.

After the test, measurements shall be made to ensure that Oscillator is still functional.



a) – Voltage-current method



b) – Ohmmeter method

Figure 1 – Test circuits for insulation resistance measurements

4.5.2 Voltage proof

The specified voltage shall be applied only across the designated terminals, using the test circuit shown in Figure 2, after any specified preconditioning procedures have been applied. The source resistance and maximum permissible current flow shall be stated in the detail specification.

There shall be no arcing or other evidence of electrical breakdown.

After the test, measurements shall be made to ensure that Oscillator is still functional.

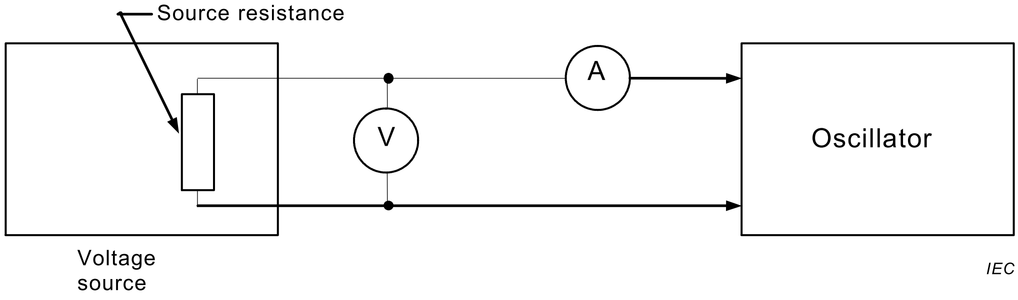


Figure 2 – Test circuit for voltage proof test

4.5.3 Input power

4.5.3.1 Oscillator input power

Oscillator shall be connected to the power supply and specified load as shown in Figure 3. The specified voltage shall be applied and allowed to stabilize for the specified time. Measurements of the voltage and current shall be made at the reference temperature, unless otherwise stated in the detail specification. The input power shall be calculated using these measurements.

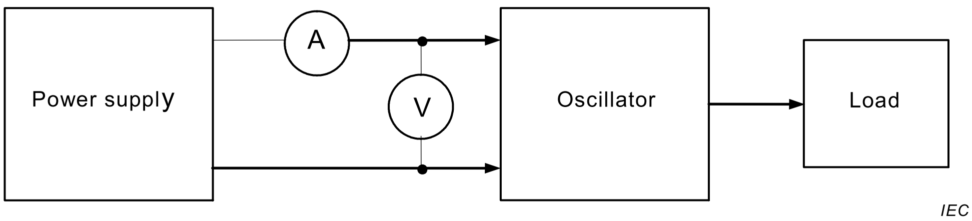


Figure 3 – Test circuit for oscillator input power measurement

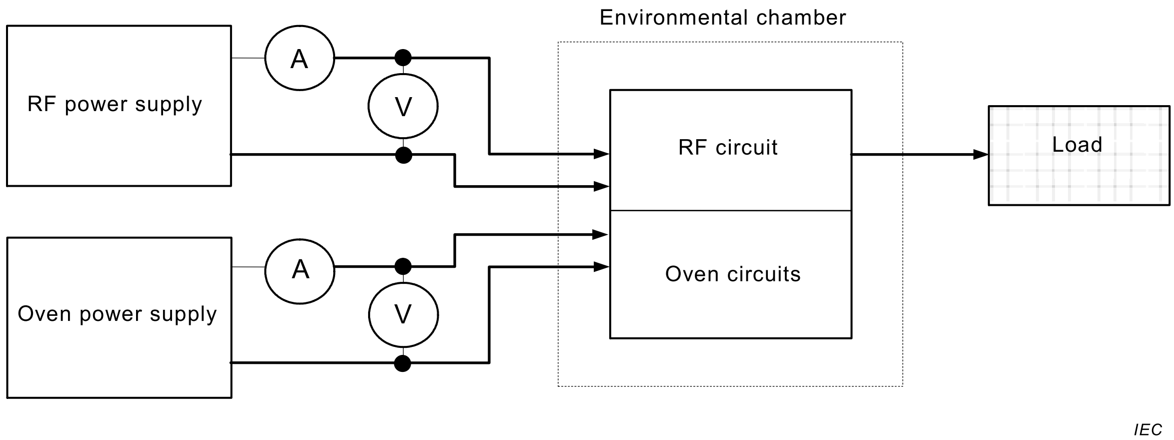
4.5.3.2 Oven and oscillator input power

Oscillator shall be connected to the test circuit (see note to Figure 4) and placed in the environmental chamber as shown in Figure 4. The load and supply voltage(s) shall be as specified in the detail specification. Where the input power to Oscillator will be affected by forced air circulation, still air conditions shall be simulated by enclosing Oscillator in a draught shield, as described in 4.2.3. Readings of voltage and current shall be taken at the specified temperatures as stated in the detail specification (usually at the minimum and maximum of the operating temperature range, as well as at the reference temperature).

The temperature will normally be taken as the reference point temperature on the surface of the draught shield, when used. If peak power is specified, the transient values of voltage and current shall be measured when the environmental chamber is adjusted to each of the specified temperatures. In this case, it can be necessary to attach a recording meter to the ammeter and/or voltmeter, so as to measure adequately the transient values.

Oscillator and oven shall be allowed to reach thermal equilibrium at the operating temperature, while unenergized, prior to any measurement of peak power. Should peak power be required, the environmental chamber shall have a thermal time constant significantly less than that of the oven-oscillator combination being measured.

The input power is calculated using the measured values of voltage and current.



NOTE The power to Oscillator can be supplied from the same power supply.

Figure 4 – Test circuit for oven and oscillator input power measurement

4.5.3.3 Oven input power

To measure the oven input power only, the test procedure described in 4.5.3.2 shall be used, except that the power supply to Oscillator shall be disconnected.

4.5.4 Output frequency

4.5.4.1 General

Output frequency measurements shall be made using either method 1 or method 2 described below, according to the accuracy specified for Oscillator.

The following precautions shall be observed:

– the accuracy and resolution of the system shall always be an order better than that of the frequency to be determined;
– Oscillator shall be correctly loaded;
– the stability and accuracy of the system shall be verified by periodic checks of the frequency standard against an internationally recognized standard;
– for accurate measurements, it is essential that great care be taken to ensure that environmental conditions do not influence the results.

4.5.4.2 Method 1 – Measurement for accuracies less than or equal to 1×10^{-8}

Oscillator shall be connected, as shown in Figure 5, to the specified supply voltage and load. It shall be allowed to stabilize for the specified time under normal operating conditions.

The frequency shall then be measured on the frequency counter. The frequency may be determined either by direct frequency measurement or by period averaging. The time period of measurement will normally lie in the range of 0,1 s to 10 s. Period averaging will generally be used for the measurement of frequencies less than 5 MHz.

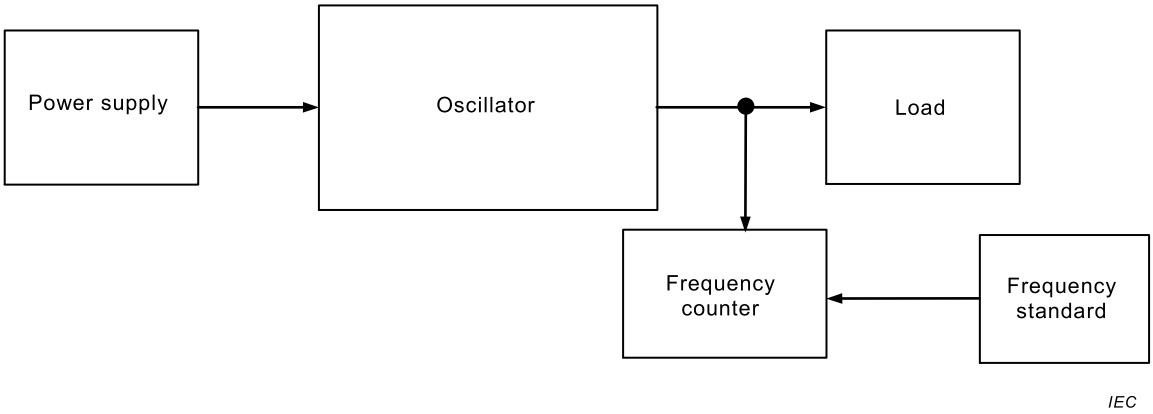


Figure 5 – Test circuit for measurement of output frequency, method1

4.5.4.3 Method 2 – Measurement for accuracies greater than 1 × 10^{-8}

Oscillator shall be connected, as shown in Figure 6, to the specified supply voltage and load. It shall be allowed to stabilize for the specified time under normal operating conditions.

The frequency shall be measured on the frequency counter after multiplication to a frequency commensurate with the required accuracy. The time period will normally be in the range of 0,1 s to 10 s. For example a 2,5 MHz signal would need to be multiplied to 25 MHz to enable a measurement of frequency to be obtained to an accuracy better than 1 × 10^{-8} within 10 s.

Alternative methods include the use of a high speed counter in place of the frequency multiplier. It is also possible to use a system of phase comparison against a frequency synthesizer which is driven from a frequency standard, for accuracies of 1 × 10^{-10} or better.

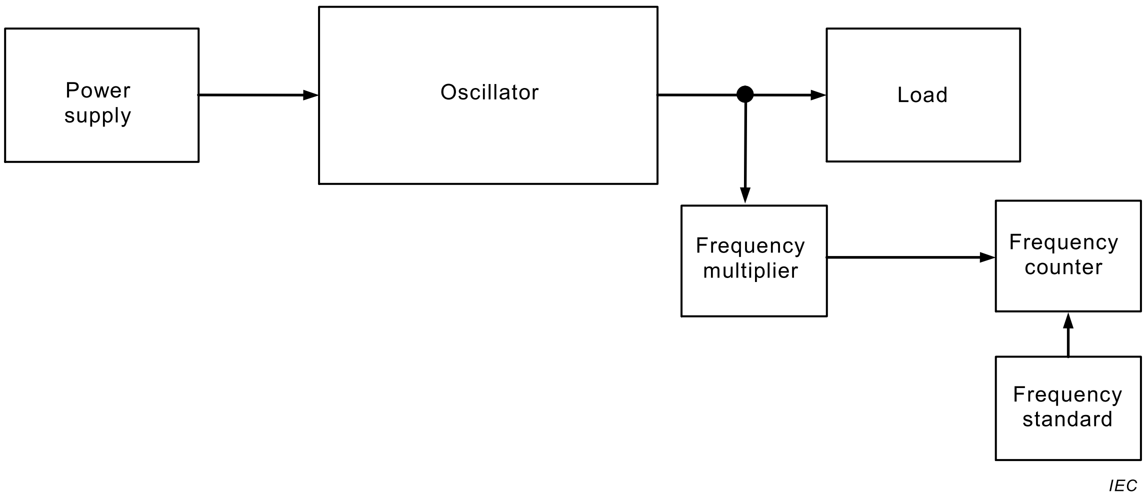


Figure 6 – Test circuit for measurement of output frequency, method 2

4.5.5 Frequency/temperature characteristics

4.5.5.1 Frequency at specified temperature

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load using the test circuit shown in Figure 7. The specified supply voltage shall then be applied to Oscillator.

Where the input power to Oscillator will be affected by forced air circulation, still air conditions shall be simulated by enclosing Oscillator in a draught shield as described in 4.2.3.

The chamber shall be allowed to stabilize at the specified temperature and, when Oscillator has reached equilibrium (see 4.2.2), measurements of the frequency shall be made using the appropriate measurement method given in 4.5.4.2 or 4.5.4.3.

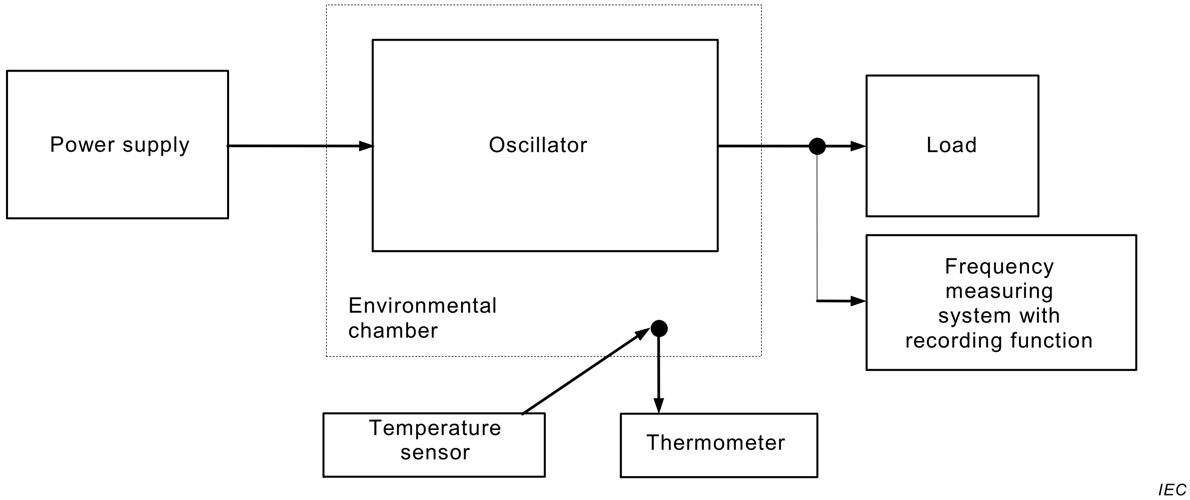


Figure 7 – Test circuit for measurement of frequency/temperature characteristics

4.5.5.2 Total frequency excursion

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load using the test circuit shown in Figure 7. The specified supply voltage shall then be applied to Oscillator.

Where the input power to Oscillator will be affected by forced air circulation, still air conditions shall be simulated by enclosing Oscillator in a draught shield as described in 4.2.3.

The chamber shall be allowed to stabilize at a temperature extreme and, when Oscillator has reached equilibrium (see 4.2.2), the frequency and temperature shall be recorded using the appropriate frequency measurement method given in 4.5.4.2 or 4.5.4.3.

The test chamber temperature shall be changed in incremental steps of 1,5 °C, ensuring that equilibrium is reached after each temperature step, or changed at a rate of 0,5 °C/min to the other extreme of temperature, unless otherwise specified in the detail specification.

Recordings of the frequency and temperature shall be made during the test.

If it is required by the detail specification to determine the reproducibility of the frequency/temperature characteristics, the frequencies shall be recorded with temperature changes in both directions.

NOTE In some applications, it can be required to determine the reproducibility of the frequency/temperature characteristics as the temperature is first increased from minimum to maximum, then decreased from maximum to minimum. Differences in the characteristics obtained during increasing and decreasing temperatures are called retrace errors, or hysteresis, and are of particular importance when testing TCXO devices.

4.5.6 Frequency/load coefficient

Using a frequency measuring system as described in 4.5.4, measurements of Oscillator output frequency shall be made for the specified nominal load, minimum load and maximum load, all other operating parameters being maintained constant at their specified values. The load values shall then be calculated taking into account the effect of the measuring equipment connected to the output of Oscillator, which shall be included in the total load value.

4.5.7 Frequency/voltage coefficient

Using a frequency measuring system as described in 4.5.4, and maintaining all other operating parameters at their specified values, measurement of Oscillator frequency shall be made when the power supply voltage is adjusted to its specified nominal value, to its minimum value and to its maximum value. In all cases, the specified stabilization time shall be allowed between adjustment of supply voltage and measurement of frequency.

A transient frequency excursion can occur immediately after adjustment of the power supply voltage, particularly if the device under test is either an OCXO or TCXO type. When the magnitude of this transient excursion is of importance, recording type meters shall be used to record the frequency excursion. The maximum permissible deviations during the transient interval shall be separately specified.

When required, an environmental chamber shall be used to maintain the ambient temperature at its specified value during the performance of this test.

4.5.8 Frequency stability with thermal transient

4.5.8.1 The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load, using the test circuit shown in Figure 7. The specified voltage shall then be applied to Oscillator. The chamber shall be allowed to stabilize and Oscillator to reach equilibrium (see 4.2.2) at the specified initial temperature T_1. Oscillator output frequency shall be recorded.

The environmental chamber temperature shall then be changed at the specified rate to the final temperature T_2.

Oscillator output frequency and the environmental chamber temperature (as measured at the reference point) should be continuously recorded during and after this operation, resulting in a plot of both frequency change and temperature change similar to that in Figure 8, from which the thermal response time and the overshoot can be determined.

The overshoot of the transient excursion shall be specified in fractional parts of the nominal frequency (e.g. overshoot shall not exceed 2×10^{-7}):

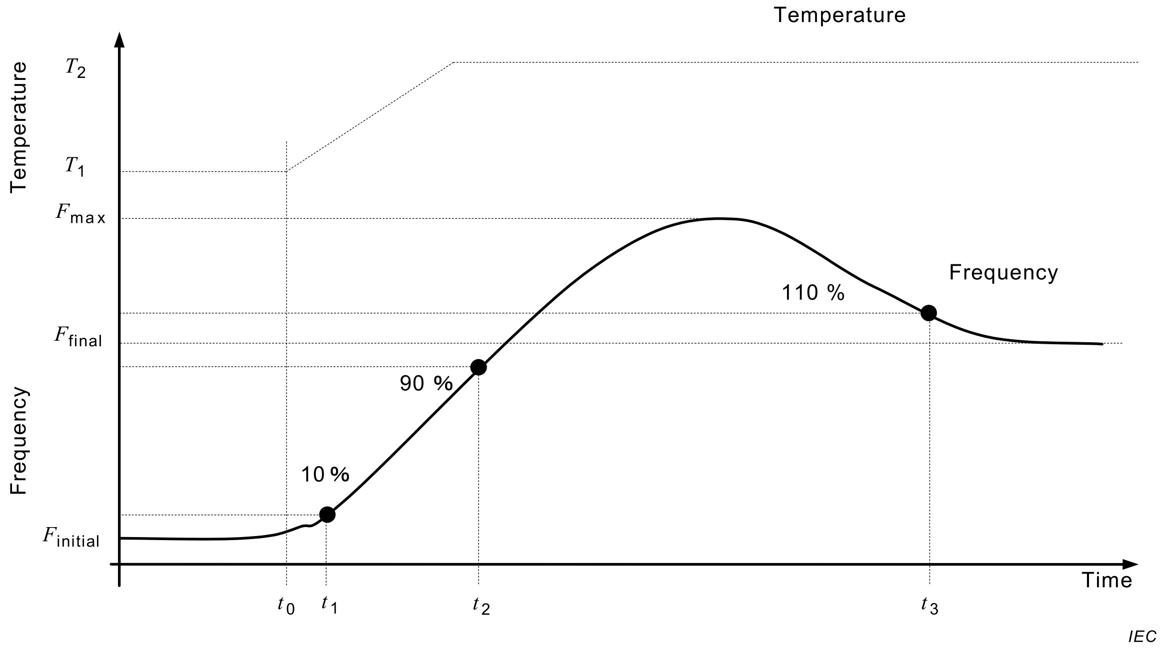
$$\Delta F_{OS} = \frac{F_{\text{max}} - F_{\text{final}}}{F_{\text{nominal}}}$$

4.5.8.2 Unless otherwise specified, the thermal response time is the time interval between the instant the frequency has changed 10 % of the overall change and the instant the frequency has attained a value within 10 % (of the change) of its final frequency.

There are two possible cases, as shown by the sample recordings in Figure 8:

– when the overshoot is less than 10 %, the thermal response time is equal to $t_2 - t_1$ min;

– when the overshoot is equal or greater than 10 %, the thermal response time is equal to $t_3 - t_1$ min.



t_0 is start time of measurement;

t_1 is time for frequency to change 10 % of the steady-state increment;

t_2 is time for frequency to change 90 % of the steady-state increment;

t_3 is time for frequency to reach 110 % of the steady-state increment on the recovery form overshoot (in the case where overshoot is greater than 10 %).

Figure 8 – Thermal transient behaviour of typical oscillator

4.5.9 Oscillation start-up

4.5.9.1 General

The purpose is to determine the reliable start-up of the oscillation amplitude and to measure the start-up time.

Figure 9 depicts the generalized oscillator circuit.

The start-up characteristics of a real crystal oscillator depend on the following major factors.

Oscillator stage:

– noise factor of the active device;
– open loop gain (or excess negative resistance) of the oscillation sustaining stage;
– amplitude limiting of the active circuit;
– loaded Q (or effective bandwidth of the resonator);
– drive level dependency of the crystal resonance resistance.

Output stage:

– analog sinusoidal output;
– logic output.

Internal power lines:

– blocking capacitors;
– voltage regulators.

Supply voltage:

– rise time, soak time, off time;
– output impedance.

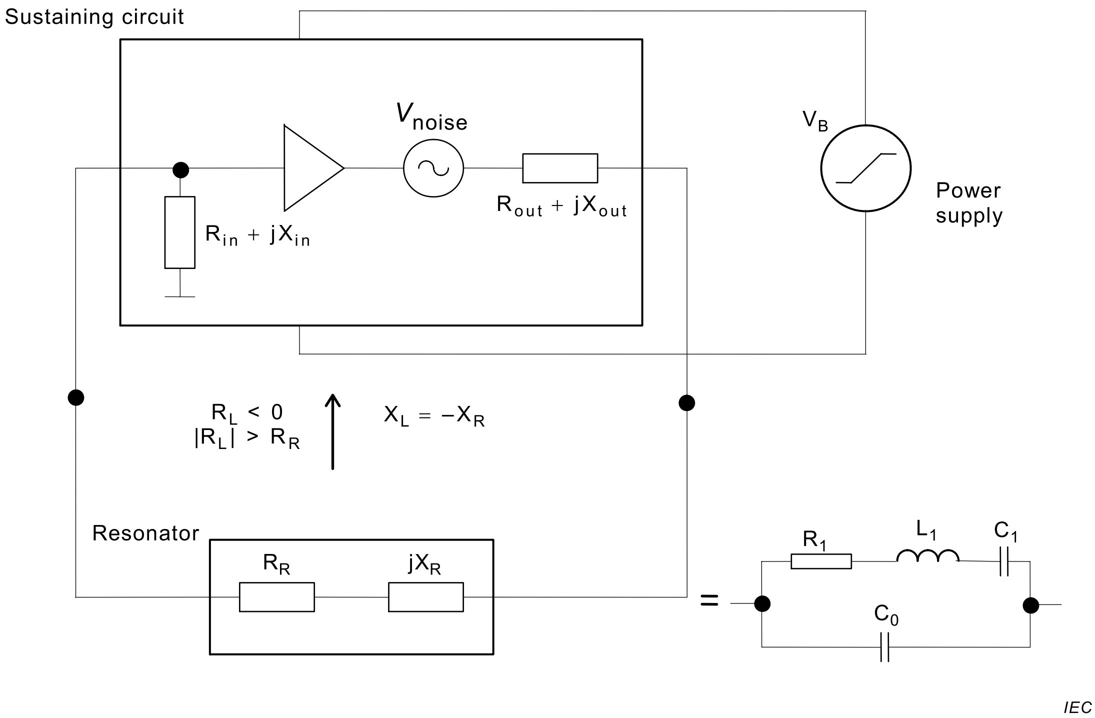


Figure 9 – Generalized oscillator circuit

4.5.9.2 Start-up behaviour

In order to determine whether the oscillation starts up reliably, Oscillator shall be connected to the test circuit for start-up behaviour shown in Figure 10.

Oscillator shall be connected to a programmable power supply. The r.f. output signal and the supply voltage are registered by an oscilloscope, the time scale of which is suitably set to display the whole start-up interval.

The supply voltage ramps linearly from zero to the nominal operating voltage. The ramp time t_{ramp} is chosen to be at least 100 to 1 000 times the specified or expected start-up time of Oscillator.

Oscillator shall show a regular and repeatable start-up behaviour within the time interval of the supply voltage ramp, as shown in Figure 11.

The following test conditions shall be stated in the detail specification:

– power supply voltage;
– load details;
– start-up time;
– in case of VCXO, DC control voltage.

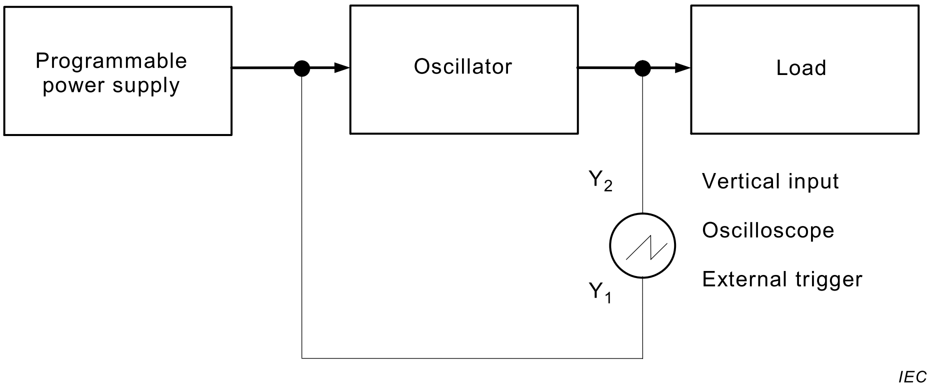


Figure 10 – Test circuit for start-up behaviour and start-up time measurement

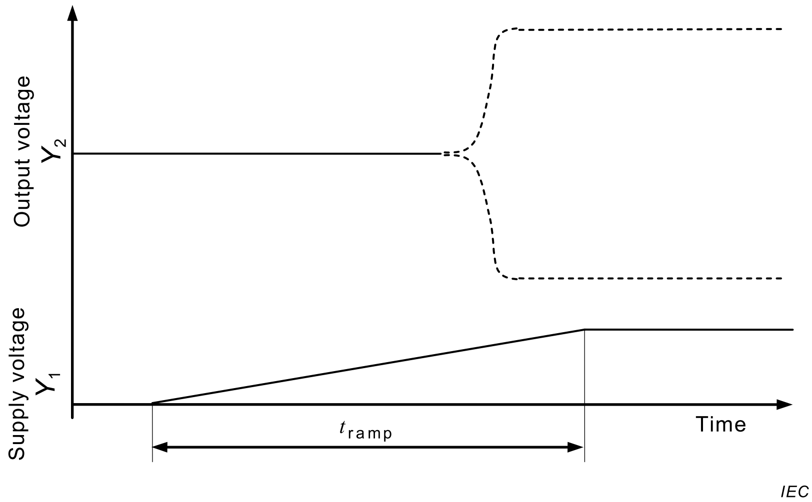


Figure 11 – Typical start-up behaviour with slow supply voltage ramp

4.5.9.3 Start-up time

In order to measure the start-up time of oscillation t_{SU} under specified conditions, Oscillator shall be connected to a programmable power supply (see Figure 10).

The r.f. output signal and the supply voltage shall be registered by an oscilloscope, the time scale of which is suitably set to display the whole start-up interval.

The supply voltage ramps up linearly from zero to the nominal operating voltage. The ramp time t_{ramp} is chosen to be less than one tenth of the specified or expected start-up time of Oscillator.

The start-up time t_{SU} is measured as the difference between the starting point of the DC ramp and the time when the r.f. output signal fulfils certain conditions which are given below:

a) quasi-sinusoidal waveforms

   the signal envelope is 90 % of the steady-state peak-to-peak amplitude, unless otherwise specified;

b) pulse waveforms

   the output pulse sequence is periodical near the steady-state frequency while its low level V_{LO} remains below V_{OL} and its high level V_{HI} exceeds V_{OH} permanently, where V_{OH} and V_{OL} are defined by the applicable logic family.

Precaution:

Logic output may show spurious oscillations prior to the appearance of the steady-state signal.

Make sure that the internal blocking capacitors of Oscillator are discharged before the start of the measurement.

An example is given in Figure 12.

The described procedure can be applied either as a single shot or as a periodical measurement. In the latter case, the following conditions shall be fulfilled (see Figure 13):

t_{ramp} as above;

t_{hold} $\geq 100\ t_{SU}$;

t_{off} minimum length shall be chosen so that a further prolongation does not change the result for t_{SU}, for example $t_{off} \geq 100\ t_{SU}$.

During t_{off} the supply voltage terminal of Oscillator shall be short-circuited to ground in order to discharge internal blocking capacitors properly.

The factor 100 in formulae for t_{hold} and t_{off} can be reduced to smaller volumes, however, it should be verified that the measured start-up time is not changed, particularly for high Q resonators.

Precaution:

The power supply shall be able to deliver sufficient current to realize the specified voltage ramp at Oscillator supply voltage terminal. It shall be able to drain the discharge current of Oscillator during the t_{off} period.

Specified conditions

The following test conditions shall be stated in the detail specification:

– power supply voltage;
– load details;
– start-up time;
– in the case of VCXO: DC control voltage.

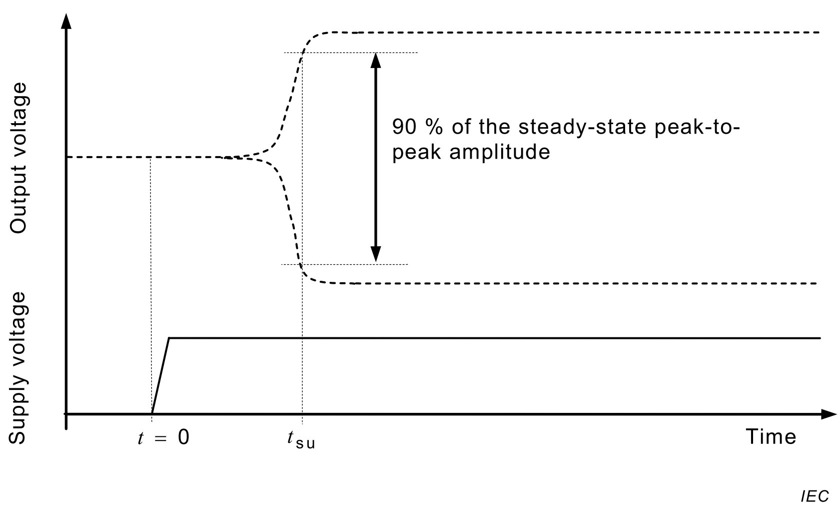


Figure 12 – Definition of start-up time

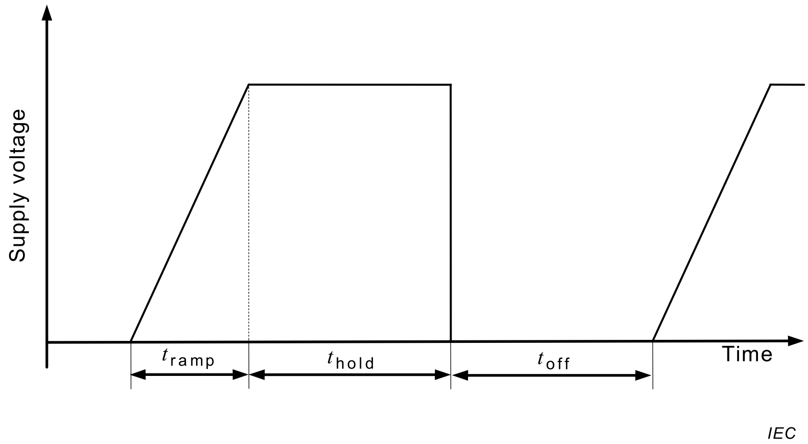


Figure 13 – Supply voltage waveform for periodical t_{SU} measurement

4.5.10 Stabilization time

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load using the test circuit shown in Figure 7. The frequency measurement used shall be as described in 4.5.4. The temperature of the chamber shall be adjusted to that specified in the detail specification. Oscillator shall then be energized and the output frequency registered on the recording meter as a function of time. The stabilization time t_s shall be the time taken for Oscillator output frequency to remain within a specified tolerance of its long-term value determined after a specified elapsed time (see Figure 14).

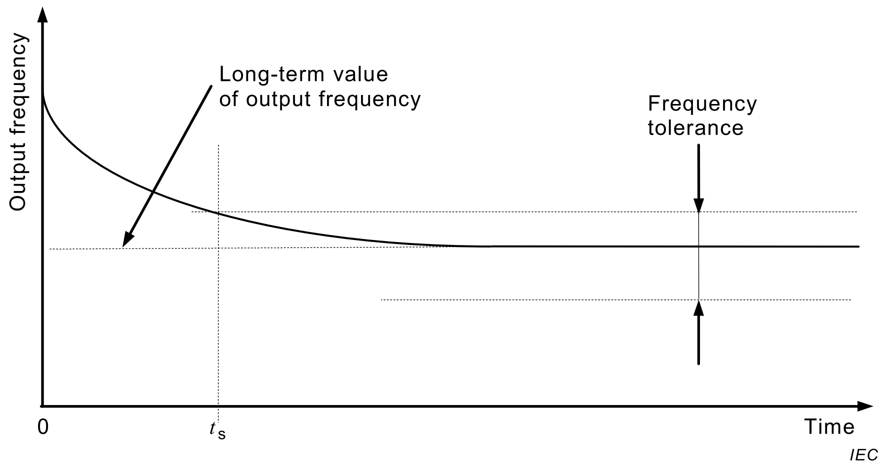


Figure 14 – Typical oscillator stabilization characteristic

4.5.11 Frequency adjustment range

Oscillator shall be connected as shown in 4.5.4 and, where necessary, to an appropriate control voltage. Oscillator shall be energized and allowed to stabilize for the specified time under normal operating conditions. The means by which Oscillator output frequency adjustment is made shall be adjusted to its maximum and minimum and the output frequency measured, unless otherwise stated in the detail specification.

4.5.12 Retrace characteristics

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load, using the test circuit shown in Figure 7. The chamber shall be maintained at a temperature in the range 20 °C to 30 °C, controlled within ±0,5 °C, unless otherwise stated in the detail specification. Oscillator shall be energized and all operating parameters adjusted to specified values, after which the frequency shall be measured as a function of time.

Following a specific period of operation (t_1, Figure 15, which shall exceed the stabilization time), the output frequency shall be recorded. Oscillator is then turned off, and allowed to assume the specified storage temperature for the specified time period t_2. At the end of the storage period, power is again applied, and frequency recorded as a function of time. The retrace time t_r is the time period following application of power required for the output frequency to return to within the specified tolerance of the value recorded before turn-off.

If Oscillator is stored (during period t_2) elsewhere than in the environmental chamber, adequate time shall be allowed for Oscillator to settle to the temperature specified for frequency measurement before any measurement of frequency takes place; this stabilization time (in an unenergized condition) should be taken as a part of the storage period t_2.

NOTE Provision is made for a separate specification of measurement temperature as, although the temperatures can be the same, the tolerance of the storage temperature can be considerably greater than that of the measurement temperature.

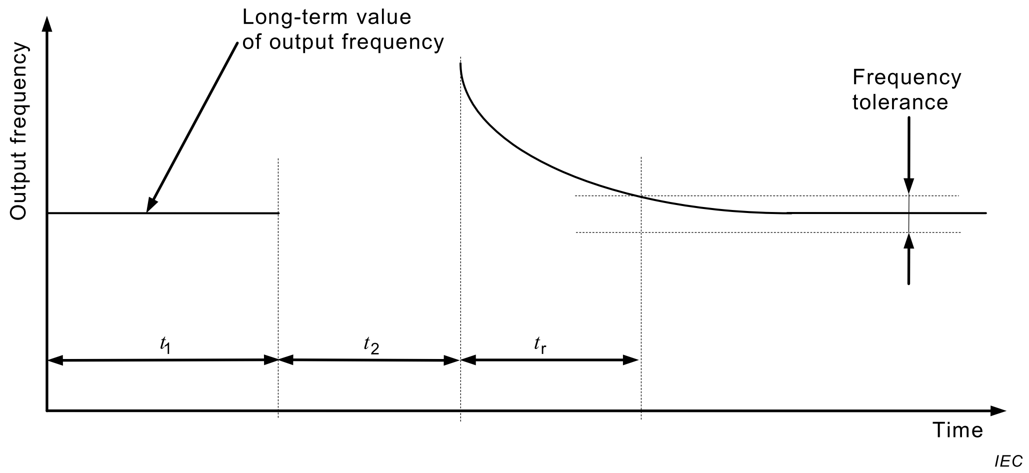


Figure 15 – Example of retrace characteristic

4.5.13 Oscillator output voltage (sinusoidal)

Oscillator shall be connected, as shown in Figure 16, to the specified supply voltage and load. It shall be allowed to stabilize for the specified period of time. The output voltage shall be measured across the load, and shall remain within the specified limits over the range of any frequency adjustment specified. Measurements shall be performed at the reference temperature, but may be carried out over the operating temperature range if required by the detail specification. Measurement shall be made with an r.f. voltmeter for r.m.s. voltages and an oscilloscope for peak-to-peak voltages.

In the case of quasi-sinusoidal waveforms, the measurement of output power shall always be performed by a direct-reading power meter or by means of a true r.m.s. reading voltmeter.

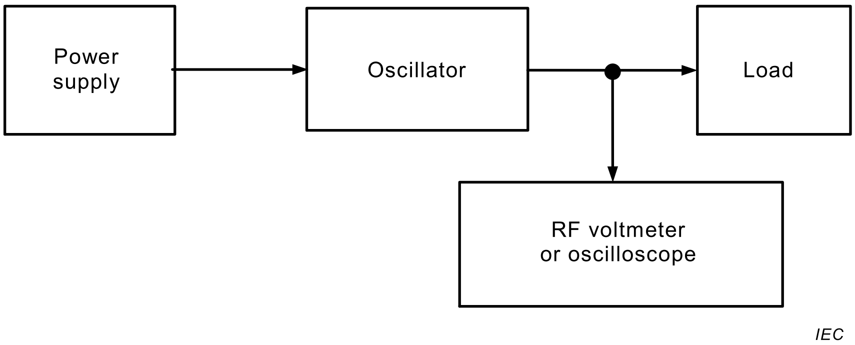


Figure 16 – Test circuit for the measurement of output voltage

4.5.14 Oscillator output voltage (pulse waveform)

Oscillator shall be connected, as shown in Figure 17, with the specified load (see Annex A of IEC 60679-1:2017 for details of load circuits for logic drive).

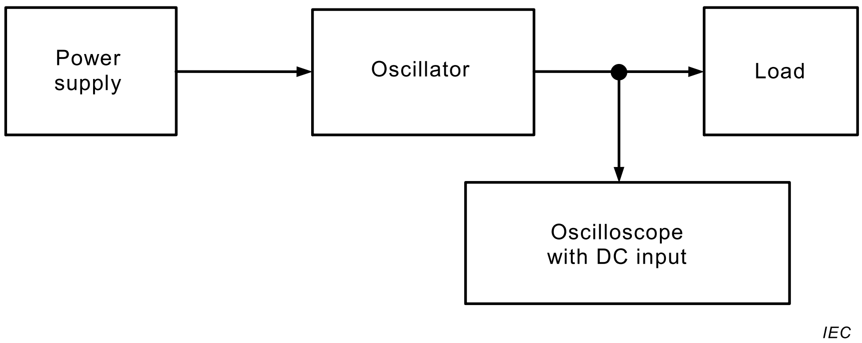


Figure 17 – Test circuit for the measurement of pulse outputs

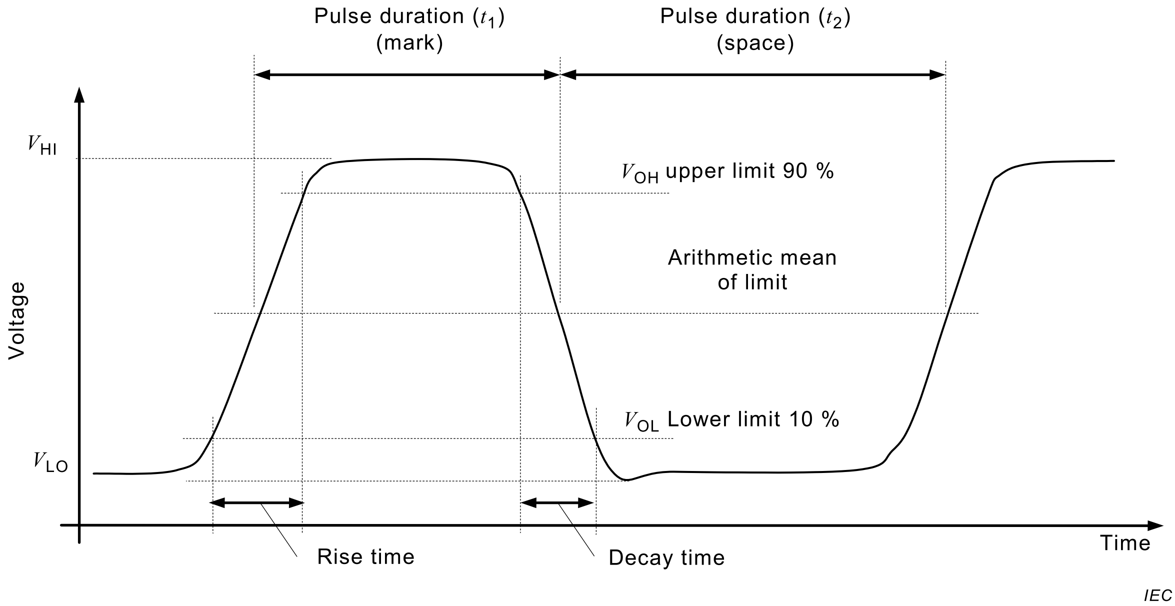


Figure 18 – Characteristics of an output waveform

The high and low level output voltages, as shown in Figure 18, shall be measured on the oscilloscope, and shall be within the limits specified in the detail specification.

4.5.15 Oscillator output waveform (sinusoidal)

Oscillator shall be connected to the specified load, as shown in Figure 19.

The spectrum analyzer shall be adjusted to display a frequency range which embraces the appropriate harmonics of Oscillator. Typical quasi-sinusoidal waveforms are shown in Figure 20, and typical frequency spectra are shown in Figure 21.

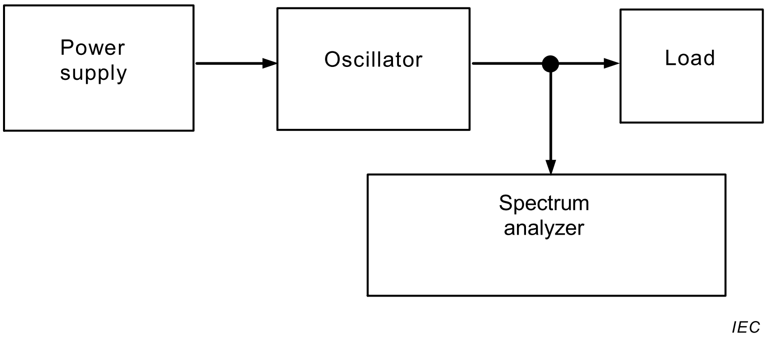
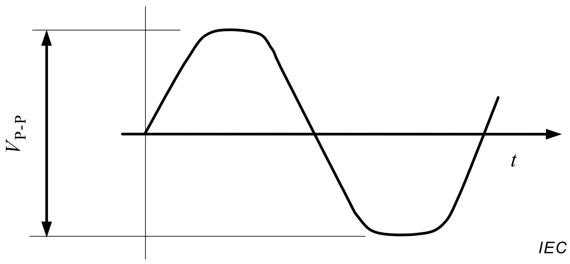
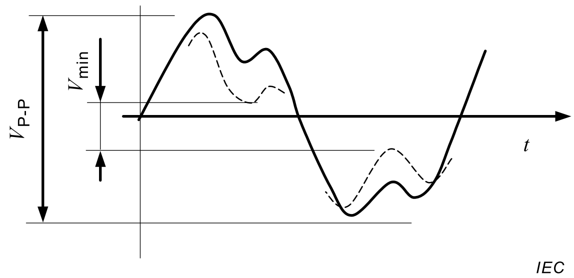


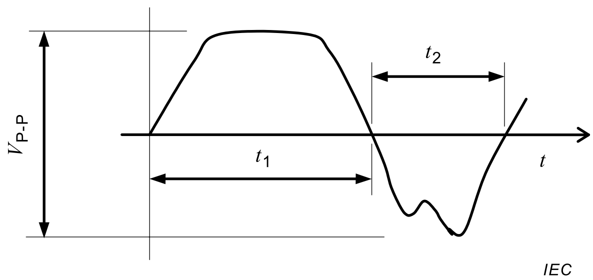
Figure 19 – Test circuit for harmonic distortion measurement



a) Symmetrical

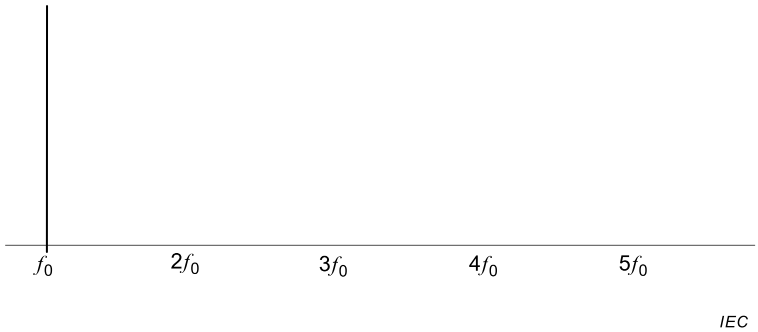


b) Large odd harmonic content

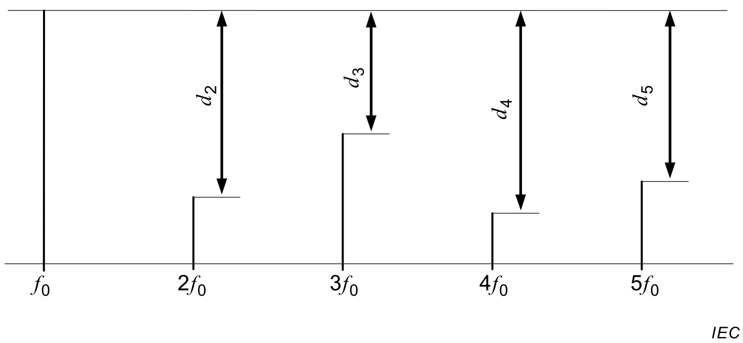


c) Large even harmonic content

Figure 20 – Quasi-sinusoidal output waveforms



a) Ideal spectrum



b) Spectrum showing severe harmonic distortion

Figure 21 – Frequency spectrum for harmonic distortion

The spectra on the spectrum analyzer shall be measured, usually directly in decibels, as a power ratio with respect to the carrier power, expressed in decibels or, alternatively, the percentage distortion of the harmonic shall be calculated as follows:

$$D_x = \frac{100}{10^{d_x/20}}$$

where

D_x is the percentage of harmonic distortion;

d_x is the difference in level of fundamental and harmonic (in decibels) as measured on the spectrum analyzer;

x is the harmonic number.

When using this test method it shall be necessary to observe the following precautions:

– care shall be taken to ensure that the distortion is not produced in the input mixer of the spectrum analyzer;

– non-linear distortion (having the appearance of harmonic distortion) will be produced if the input mixer is over-loaded. This may be checked by placing an attenuator between Oscillator and the spectrum analyzer, and taking measurements at various power levels. The attenuator setting should not affect the percentage of harmonic distortion.

NOTE The total harmonic distortion can be obtained from a summation of the individual harmonically related responses.

$$D_\mathrm{total} = 100\left[10^{\frac{d_2}{10}} + 10^{\frac{d_3}{10}} + \ldots + 10^{\frac{d_\mathrm{n}}{10}}\right]^{-1/2}$$

4.5.16 Oscillator output waveform (pulse)

4.5.16.1 General

Oscillator shall be connected, as shown in Figure 17, and with the specified load (see Annex A of IEC 60679-1:2017 for details of load circuits for logic drive).

4.5.16.2 Rise and decay times

Measurements shall be made on both the rising and falling edges between the limits of the input voltage over which the operation of the particular logic family is guaranteed, for example, for TTL and CMOS logic families between V_{OH} min. and V_{OL} max. or at the 10 % and 90 % points with respect to the flat portion of the maximum amplitude level, as shown in Figure 18. Overshoot shall be disregarded in this measurement if its peak does not exceed the limits specified for the steady-state levels, or if the cause for the overshoot can be traced to inductances external to Oscillator and oscilloscope.

Where higher accuracies are required, the following correction formula shall be used:

$$t_a = \sqrt{(t_i)^2 - (t_s)^2}$$

where

t_i is the measured rise or decay time;

t_s is the oscilloscope rise or decay time;

t_a is the actual time.

4.5.16.3 Pulse duration

The pulse duration of Oscillator shall be measured with the oscilloscope when the rise and decay times are measured. Unless otherwise specified, measurements shall be made at the midpoint between V_{OL} max. and V_{OH} min. or at the 50 % level, as shown in Figure 18.

4.5.16.4 Symmetry

When specified, the symmetry of the waveform from Oscillator shall be determined when the rise and decay times are measured. Unless otherwise specified, measurements shall be made at the midpoint between V_{OL} max. and V_{OH} min. or at the 50 % level, as shown in Figure 18.

4.5.17 Oscillator output power (sinusoidal)

The test procedure shall be carried out as for 4.5.13, output voltage. The output power shall be calculated from the r.m.s. output voltage and the load impedance or, alternatively, it may be read directly from an appropriate power meter. In the case of quasi-sinusoidal waveforms, the measurement of output power shall always be performed by a direct-reading power meter or by means of a true r.m.s. reading voltmeter.

4.5.18 Oscillator output impedance (sinusoidal)

Oscillator shall be connected, as shown in Figure 16, except that the load shall be a precision (±1 % non-reactive) resistor R_L, equal to the specified load minus 10 %. Oscillator shall be energized and allowed to stabilize for the specified period of time after which the output voltage V_L shall be measured. The load shall then be replaced with a precision (±1 % non-reactive) resistor R_H, equal to the specified load plus 10 % and the output voltage V_H measured. The output impedance shall be calculated using the expression:

$$Z = \frac{R_L R_H (V_H - V_L)}{V_L R_H - V_H R_L}$$

NOTE This method is only valid if the output impedance of Oscillator is resistive, and it is not accurate when the output resistance is considerably lower than the load impedance.

4.5.19 Re-entrant isolation

Oscillator shall be connected to the test circuit, as shown in Figure 22. The ports between which the isolation is to be measured shall be shorted together. The level and frequency of the re-entrant signal, as specified, shall be set on the signal generator. Using the spectrum analyzer (or selective voltmeter), the output level of this signal shall be measured at the port to which the signal is not being applied (or at the specified port in the case of oscillators with multiple ports). The shorting link shall then be removed and the output level again measured.

The ratio of the two signals measured with and without the shorting link (usually expressed in decibels) is the re-entrant isolation between the appropriate ports at that frequency. This ratio shall be as stated in the detail specification.

When carrying out this test, the following precautions shall be observed:

– the loads presented to Oscillator are a combination of the output impedance of the signal generator, the input impedance of the spectrum analyzer (or selective voltmeter) and any externally applied loads;

– care shall be taken to prevent overloading of the spectrum analyzer (or selective voltmeter), as this will cause signal limiting and an apparent reduction in re-entrant isolation;

– if isolation is to be measured at a frequency which is a harmonic of Oscillator, then a pessimistic value of re-entrant isolation will be obtained. However, if the harmonic level is considerably lower than the isolation to be measured, a usable result can still be achieved. Where the harmonic content of the output signal is high, it is necessary to disable Oscillator (that is, to cause the device to cease oscillation while still remaining energized) before measurements can be made.

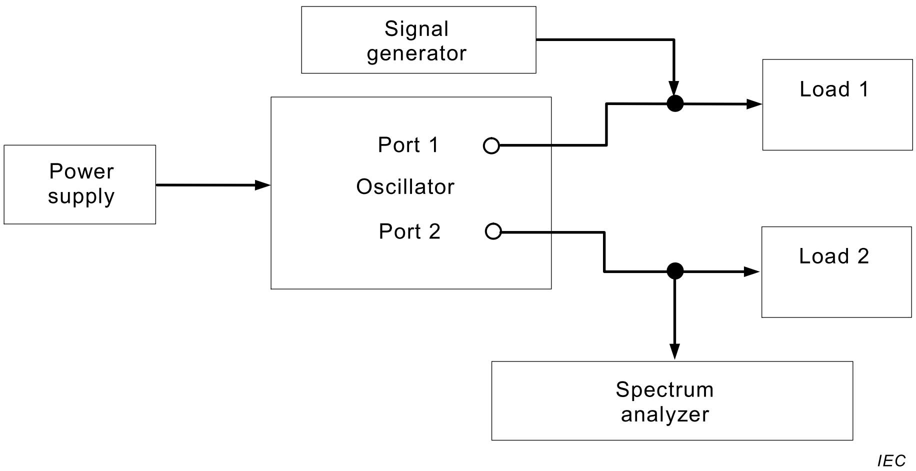


Figure 22 – Test circuit for the determination of isolation between output ports

4.5.20 Output suppression of gated oscillators

Oscillator shall be connected to the test circuit, as shown in Figure 23, and the tests carried out as follows.

The specified signal necessary to gate the ON output of Oscillator shall be applied, and the level of the output at its fundamental frequency and at any harmonic frequency or frequencies, as specified, shall be measured on the spectrum analyzer. The specified signal necessary to gate the OFF output of Oscillator shall then be applied and the new output level(s) measured.

The ratio of the ON and OFF output levels, usually expressed in decibels, is the output suppression at a particular frequency, and shall be as specified in the detail specification.

Care shall be taken to prevent overloading of the spectrum analyzer, as this will cause signal limiting and an apparent reduction in output suppression.

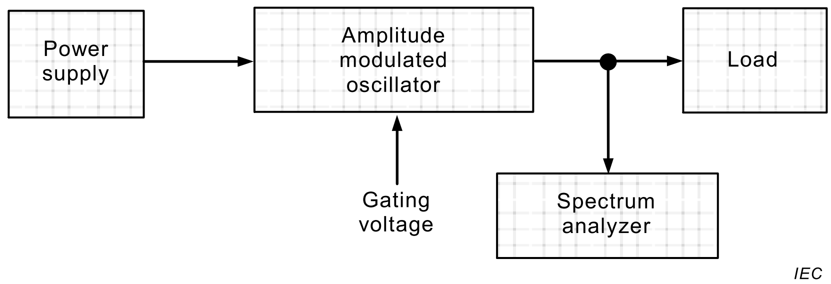


Figure 23 – Test circuit for measuring suppression of gated oscillators

4.5.21 3-state output characteristics

4.5.21.1 3-state disable mode output current

This test is used to determine the short-circuit output current drawn from Oscillator with a 3-state output when held in the disable mode.

Oscillator shall be connected as shown in Figure 24. With the enable/disable pin connected to the appropriate DC level via switch 1, that is to the specified supply voltage for oscillators designed for "enable low", or to earth for those designed for "enable high", the power to Oscillator shall be applied.

The enable/disable voltage levels shall be as specified in the detail specification. However, care shall be taken to ensure that the voltages applied to the enable/disable pin and the output pin cannot exceed the voltage applied to Oscillator.

Oscillator output is then switched, by switch 2, in turn between the supply voltage and earth, and the output current at each setting measured.

The maximum permissible output current in the disable mode, as specified in the detail specification, shall not be exceeded.

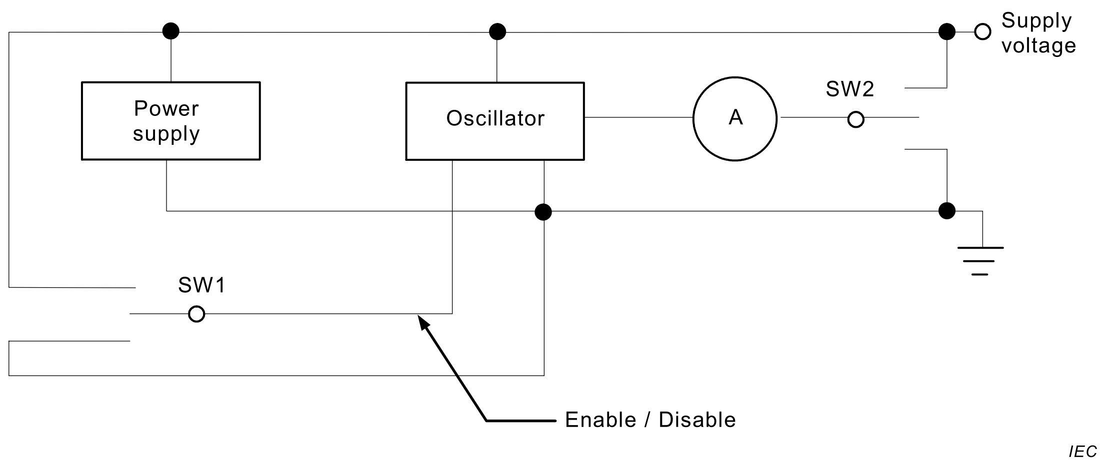


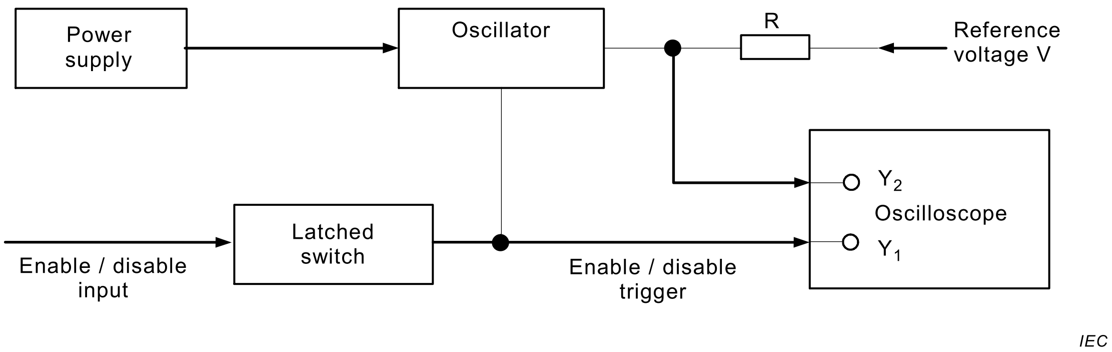
Figure 24 – Test circuit for 3-state disable mode output current

4.5.21.2 Output gating time

To measure the time taken for Oscillator output stage to switch between the enable and disable modes, Oscillator shall be connected as shown in Figure 25. The value of R shall be chosen so that the time constant formed by R and the oscilloscope input capacitance shall not affect the measurement accuracy.

The specified supply, reference, enable/disable voltages shall be applied to Oscillator, care being taken to ensure that the enable/disable voltages do not exceed the value of the supply voltage.

With an oscilloscope adjusted to trigger from either the enabling or disabling transition of the enable/disable input signal, as appropriate, and displaying the corresponding oscillator transition, together with the trigger transition, the gating time between the trigger transition and the time when Oscillator output stabilizes to the reference voltage shall be measured.



where

$V = \frac{(V_{OH} - V_{OL})}{2} + V_{OL}$	is the reference voltage;
V_{OL}	is Oscillator low level output voltage;
V_{OH}	is Oscillator high level output voltage.

Figure 25 – Test circuit for output gating time – 3-state

4.5.22 Amplitude modulation characteristics

4.5.22.1 Amplitude modulation index

The procedure of test A shall be used for a modulation index greater than 0,1 and less than 1,0. Oscillator shall be connected to the specified load, as shown in Figure 26, and the specified modulating signal applied. Measurements of x and y (see Figure 27) on the waveform shall be taken, and the modulation index (m) calculated from the expression:

$$m = \frac{y - x}{y + x}$$

The index obtained shall be as stated in the detail specification and the percentage modulation shall be 100 m %. This method of measurement shall not be used when m is less than 0,1 because of inherently low measurement accuracy.

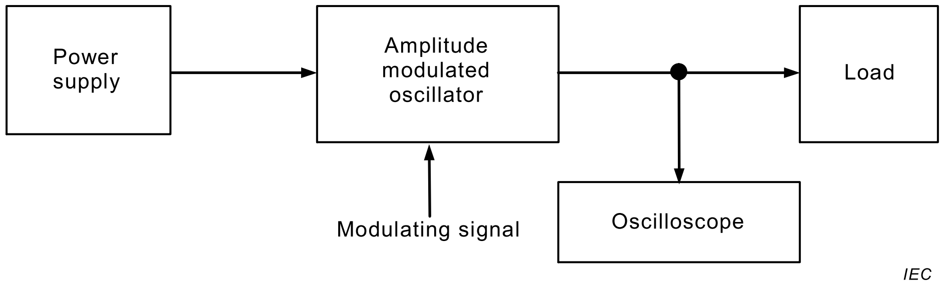


Figure 26 – Test circuit for modulation index measurement

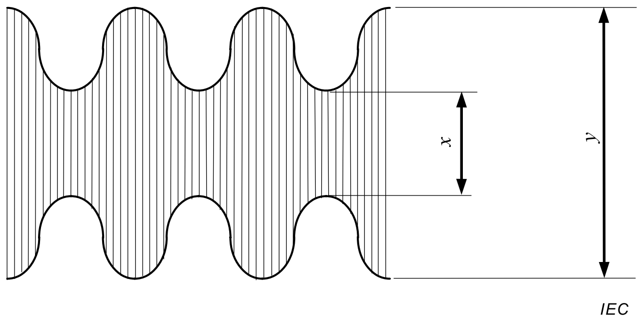


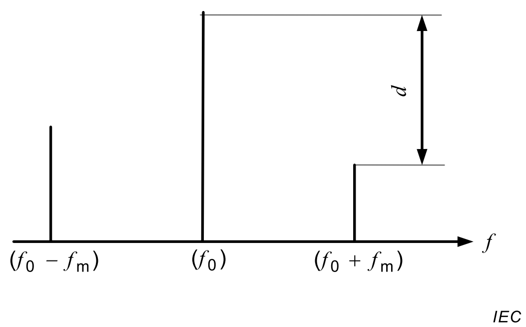
Figure 27 – Modulation waveform for index calculation

NOTE 1 The accuracy for this method is unaffected by the presence of frequency modulation.

NOTE 2 This method is valid for non-sinusoidal waveforms.

The procedure of test B shall be used for a modulation index less than 0,1.

Oscillator shall be connected to the specified load, as shown in Figure 26, except that the oscilloscope shall be replaced by a spectrum analyzer having an i.f. bandwidth sufficiently narrow to provide adequate discrimination between Oscillator output and its sideband signals. With the specified modulating signal applied to Oscillator, the spectrum analyzer shall be adjusted to present a display of the frequency spectrum in the region of the output frequency of Oscillator, using a logarithmic signal amplitude scale (see Figure 28).



f_0	is Oscillator output frequency;
f_m	is the frequency of the modulating signal;
$f_0 - f_m$	is the lower sideband signal frequency;
$f_0 + f_m$	is the upper sideband signal frequency;
d	is the difference between Oscillator output signal frequency (f_0) level and the level of either of the sideband signals, in decibels.

Figure 28 – Logarithmic signal amplitude scale

The modulation index (m) shall be calculated using the expression:

$$m = 10^{\frac{6-d}{20}} \quad (m < 0{,}1)$$

where d is the difference between Oscillator output signal frequency (f_0) level and the level of either of the sideband signals, in decibels.

The modulation index shall be as stated in the detail specification.

Care shall be taken to prevent overloading of the spectrum analyzer, causing signal limiting. This may be checked by placing an attenuator between Oscillator and the spectrum analyzer, and taking measurements at various power levels; the attenuator setting should not affect the value of d obtained.

NOTE 3 This method cannot readily be used if significant resultant frequency modulation is present (see 4.5.22.7), usually causing the two sideband signals to be unequal in amplitude. The effect of the resultant f.m. on the spectrum analyzer display can be reduced by choosing a high modulating signal frequency (frequency modulation index $\beta \propto \frac{1}{f_m}$).

NOTE 4 This method cannot readily be used if the modulation waveform is non-sinusoidal, whether because of harmonic content in the modulating signal or because of a.m. non-linear distortion (see 4.5.22.3).

4.5.22.2 Amplitude modulation sensitivity

Oscillator shall be connected to the specified road as shown in Figure 29. The signal generator providing a modulating signal at the specified frequency shall be connected to the external modulation terminal of Oscillator. Its output shall be set to the specified amplitude as measured by the oscilloscope or r.f. voltmeter. The modulation index of the output signal shall be measured as described in 4.5.22.1 (as appropriate).

In general, the amplitude modulation sensitivity is taken as the percentage modulation peak-to-peak voltage of the modulating signal and shall be as stated in the detail specification.

NOTE This method can be used to determine the immunity of an oscillator to power supply line ripple etc., by superimposing the modulating signal on the DC supply voltage.

4.5.22.3 Amplitude modulation distortion (non-linearity)

Oscillator shall be connected to the specified load as shown in Figure 29, except that the oscilloscope shall be replaced by a spectrum analyzer having an i.f. bandwidth sufficiently narrow to provide adequate discrimination between Oscillator output and its sideband signals.

A sinusoidal modulating signal at the specified frequency, and at a level such as to modulate Oscillator to the specified modulation index, shall be applied to the external modulation terminal of Oscillator; the spectrum analyzer shall be adjusted to present a display of the frequency spectrum in the region of the output frequency of Oscillator (see Figure 30).

The second, third, etc. harmonic distortions are usually expressed as d_2, d_3, etc. decibels, but may also be expressed as $\frac{100}{10^{\frac{d}{20}}}$ percentage distortion for each individual harmonic.

The distortion shall be within the limits stated in the detail specification.

When carrying out this test, the following precautions shall be observed:

– care shall be taken to prevent overloading of the spectrum analyzer, causing an apparent increase in modulation distortion. This may be checked by connecting an attenuator between Oscillator and the spectrum analyzer, and taking measurements at various power levels.

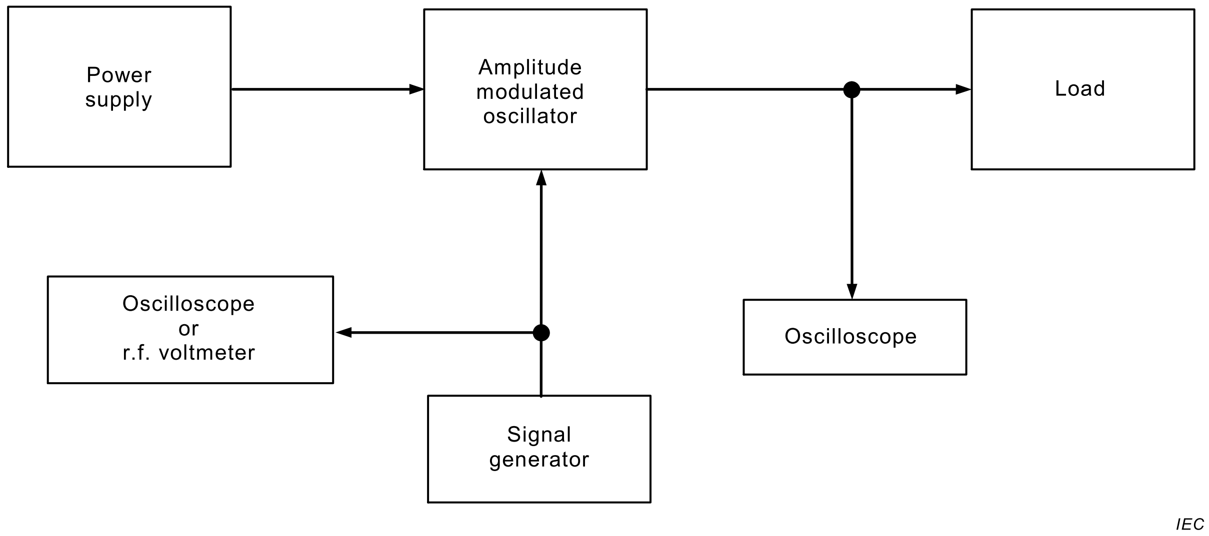
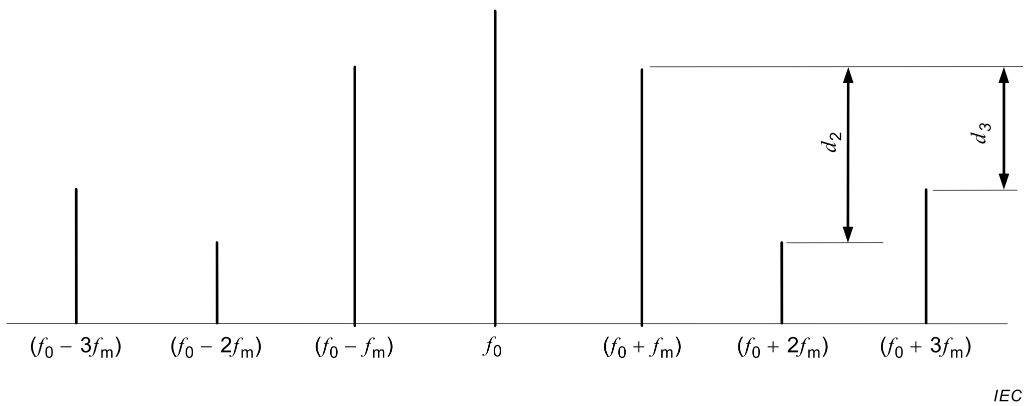


Figure 29 – Test circuit to determine amplitude modulation sensitivity



where

f_0	is Oscillator output frequency;
f_m	is the frequency of modulating signal;
$(f_0 - f_m)$	is the lower sideband caused by the modulating signal;
$(f_0 - 2f_m)$	is the lower sideband caused by the second harmonic of the modulation signal;
$(f_0 - 3f_m)$	is the lower sideband caused by the third harmonic of the modulation signal.

Figure 30 – Frequency spectrum of amplitude modulation distortion

The attenuator setting should not affect the measurement of modulation distortion, that is the values of d_2, d_3, etc. If the harmonic content of the modulating signal is significant, the results obtained shall be corrected, or the modulating signal filtered so as to reduce its harmonic content.

NOTE Total modulation distortion can be assessed by detecting the output of Oscillator and measuring this signal with an appropriate distortion analyzer; this method measures the total sideband content of an amplitude modulated signal. The result can be obtained from the measurements made with a spectrum analyzer by summation of the sideband signals.

4.5.22.4 Amplitude modulation frequency response

The test procedure given in 4.5.22.2 with a sinusoidal modulating signal applied shall be used. The amplitude modulation sensitivity at a specified reference frequency shall be measured. Measurements shall then be taken at the other specified frequencies, giving the change in modulation sensitivity, usually expressed in decibels, which shall be within the limits stated in the detail specification.

$$\text{Total distortion} = \frac{100}{\sqrt{10^{\frac{d_2}{10}} + 10^{\frac{d_3}{10}} + \cdots}}$$

4.5.22.5 Pulse amplitude modulation

Oscillator shall be connected to the specified load and as shown in Figure 31.

A pulse generator, providing a modulating signal of specified waveform and repetition frequency, and which shall not be harmonically related to Oscillator frequency, shall be connected to the modulation input terminal of Oscillator.

Both this signal and the output waveform of Oscillator shall be displayed simultaneously on the oscilloscope, with the peak-to-peak amplitude of the output waveform adjusted to be twice that of the modulating signal, as shown in Figure 32.

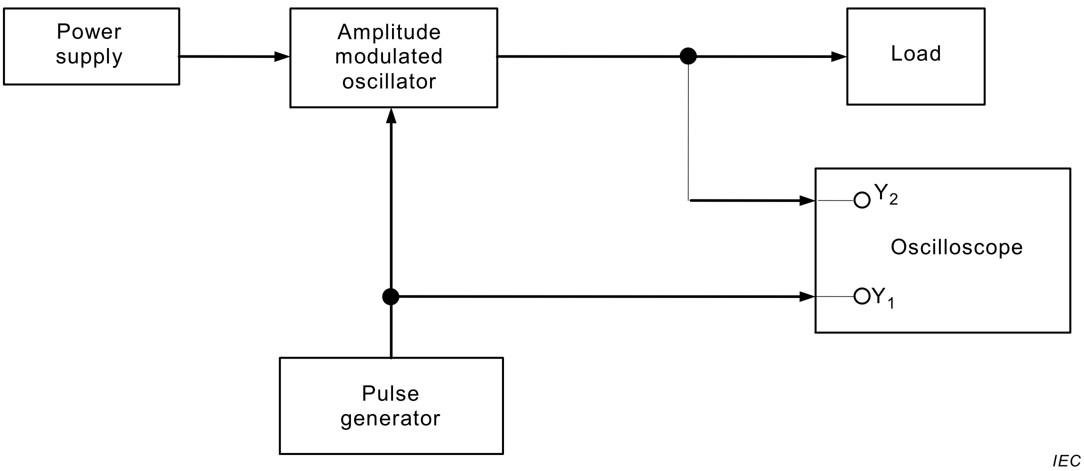


Figure 31 – Test circuit to determine pulse amplitude modulation

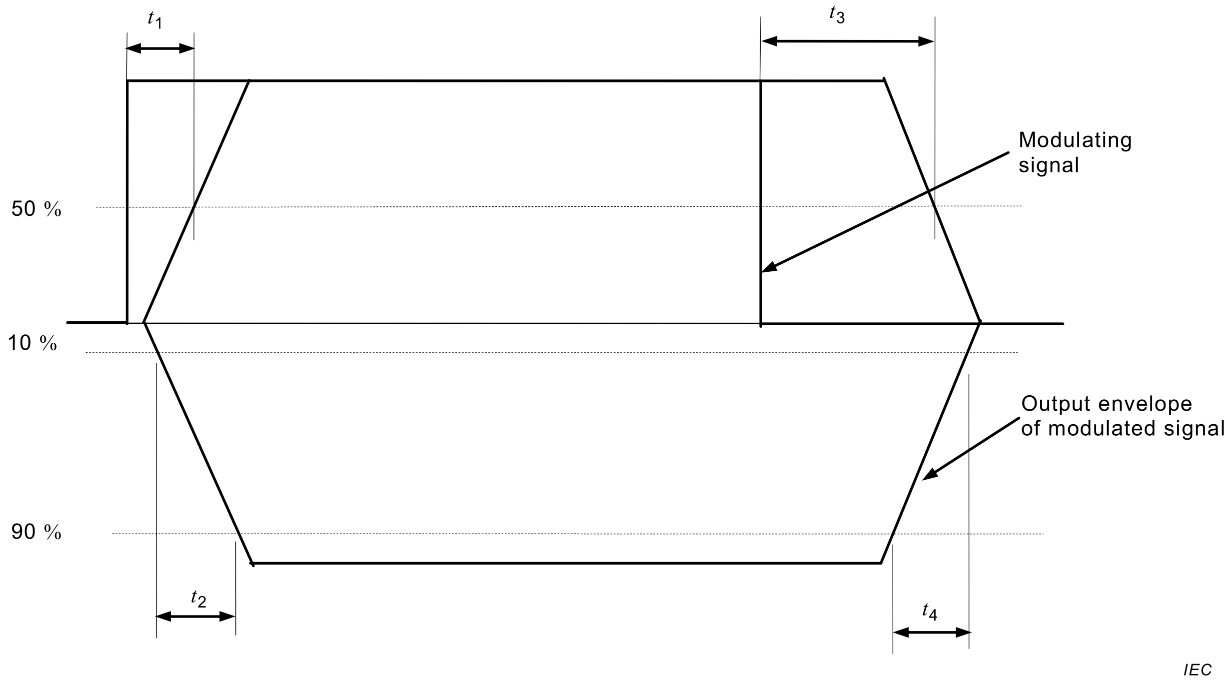


Figure 32 – Pulse modulation characteristic

The following parameters shall be determined and shall be as stated in the detail specification:

- t_1 is the turn-on time, the time interval between the 50 % value of the modulating signal and the 50 % value of the output waveform, at the leading edge;
- t_2 is the rise time, the time interval between the 10 % and 90 % values of the leading edge of the output waveform (assuming that the modulating signal rise time is negligible);
- t_3 is the turn-off time, the time interval between the 50 % value of the modulating signal and the 50 % value of the output waveform, at the trailing edge;
- t_4 is the decay time, the time interval between the 90 % and 10 % values of the trailing edge of the output waveform (assuming that the modulating signal fall time is negligible).

4.5.22.6 Amplitude modulation input impedance

A signal generator providing a modulating signal at the specified frequency shall be connected to the external modulation terminal of Oscillator and to a resistance box through a shielded transformer, as shown in Figure 33. The resistance box shall be non-reactive at the specified measurement frequency.

An oscilloscope (or suitable AC voltmeter) shall be connected so as to measure either the signal level across the resistance box (V_1) or the input level of the modulating signal to Oscillator (V_2).

The signal generator shall be adjusted so that the voltage level of the modulating signal at the input to Oscillator is at the specified level.

The modulation input impedance shall be calculated as:

$$Z = \frac{V_2}{V_1} R$$

and shall be as stated in the detail specification.

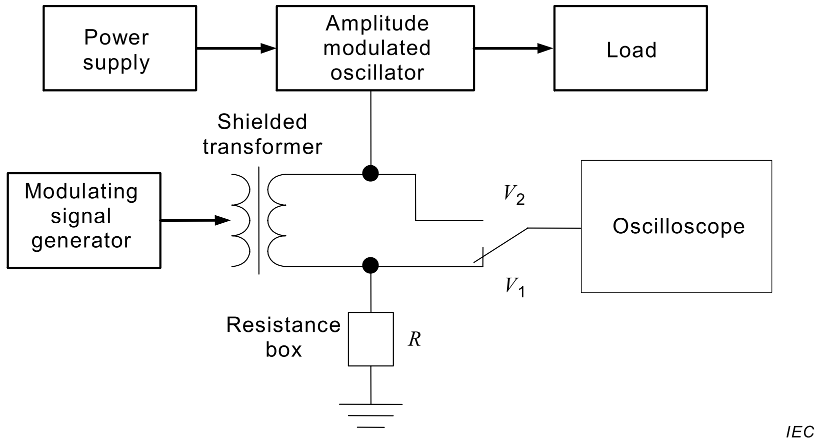


Figure 33 – Test circuit for the determination of modulation input impedance

4.5.22.7 Incidental frequency modulation on an amplitude modulation signal

The amplitude modulation shall be adjusted to the specified index, as described in 4.5.22.1. The resultant frequency modulation deviation shall then be measured, as described in 4.5.23.1. The magnitude of the deviation of the incidental frequency modulation of the amplitude modulated signal shall be within the limits stated in the detail specification. The limiting action of the frequency multiplier(s) will remove most of the amplitude modulation from the signal. However, care shall be taken to ensure that the residual a.m. is insufficient to affect the accuracy of the frequency modulation meter.

4.5.23 Frequency modulation characteristics

4.5.23.1 Frequency modulation deviation

Test A shall be used for a peak frequency deviation greater than 100 Hz.

Oscillator shall be connected to the specified load, as shown in Figure 34, with a modulating signal of specified frequency applied to its modulation input terminal.

The peak frequency deviation of the output signal shall be measured using an f.m. modulation (or deviation) meter, and shall be within the limits as stated in the detail specification.

When measuring very high frequency signals having a low peak frequency deviation, it may be necessary to use a local oscillator which is phase locked to a source having a low incidental f.m. content (for example a crystal oscillator), in order to reduce its f.m. noise deviation.

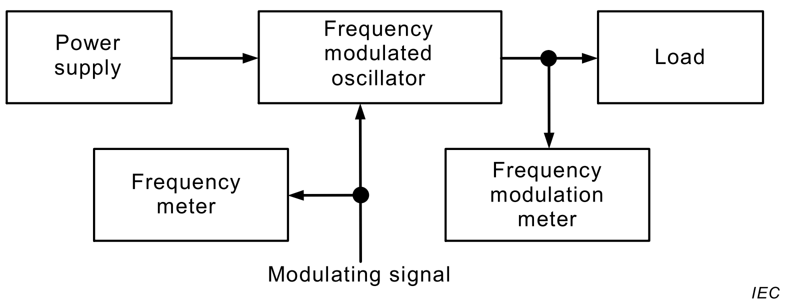


Figure 34 – Test circuit for the measurement of f.m. deviation

NOTE 1 Frequency modulation index:

$$\beta = \frac{\Delta f}{f_{\mathrm{m}}}$$

where

Δf is the actual peak frequency deviation;

f_{m} is the frequency of the modulating signal.

Test B shall be used for a peak frequency deviation smaller than 100 Hz.

Oscillator shall be connected to the specified load, as shown in Figure 34, with the addition of a frequency multiplier before the f.m. modulation meter (see Note 2).

A modulating signal of specified frequency shall be applied to the modulation input terminal of Oscillator and the peak frequency of the output signal measured through the frequency multiplier using an f.m. modulation (or deviation) meter.

Hence

$$\Delta f = \frac{\Delta f_{\mathrm{mult}}}{M}$$

where

Δf is the actual peak frequency deviation;

Δf_{mult} is the measured peak deviation;

M is multiplication factor.

The value obtained shall be within the limits stated in the detail specification.

When using this test method it shall be necessary to observe the following precautions:

– when measuring very high frequency signals having a low peak frequency deviation, it may be necessary to use a local oscillator which is phase locked to a source having a low incidental f.m. content (for example a crystal oscillator), in order to reduce its f.m. noise deviation;
– most oscillators are in some measure susceptible to ripple on the supply voltage; when measuring signals having a small frequency modulation index, great care shall be taken to ensure that supply voltage variations do not affect the measurement of peak frequency deviation.

NOTE 2 Frequency modulation index:

$$\beta = \frac{\Delta f}{f_{\mathrm{m}}}$$

where

Δf is the actual peak frequency deviation;

f_{m} is the frequency of the modulating signal.

NOTE 3 It can be necessary to use a mixer, before and/or after frequency multiplication, to down-convert the signal to bring it within the range of the frequency modulation meter.

4.5.23.2 Frequency modulation sensitivity

Oscillator shall be connected to the specified load, as shown in Figure 35. A signal generator providing a modulating signal at the specified frequency shall be connected to the modulation input terminal of Oscillator and its output set to the specified amplitude as measured by the oscilloscope or r.f. voltmeter. The specified modulation input level shall be such that the specified maximum permissible peak deviation of Oscillator is not exceeded. The peak frequency deviation of the output signal shall be measured as described in 4.5.23.1, tests A or B, as appropriate.

The frequency modulation sensitivity is defined as:

$$S_{\mathrm{FM}} = \frac{\Delta f_{\mathrm{p\text{-}p}}}{V_{\mathrm{p\text{-}p}}}$$

where

$\Delta f_{\mathrm{p\text{-}p}}$ is the peak-to-peak frequency deviation;

$V_{\mathrm{p\text{-}p}}$ is the peak-to-peak modulating signal voltage.

Its value shall be within the limits stated in the detail specification.

NOTE This method can be used to determine the immunity of an oscillator to power supply line ripple, etc. by superimposing the modulating signal on the DC supply voltage.

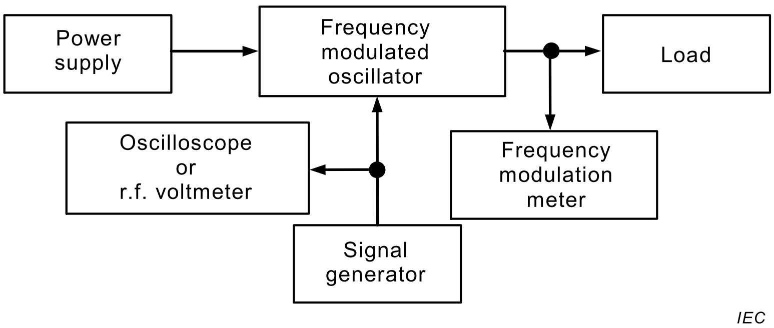


Figure 35 – Test circuit for the measurement of f.m. sensitivity

4.5.23.3 Frequency modulation distortion (non-linearity)

4.5.23.3.1 Test A (static test)

Oscillator shall be connected to the specified load, as shown in Figure 36a, with a variable voltage DC power supply connected to the modulation input terminal. Measurements of Oscillator output frequency at the specified DC modulation voltages shall be made. A graph of output frequency against control voltage shall be plotted and hence the linearity of the frequency modulation deviation determined. This shall be within the limits stated in the detail specification.

4.5.23.3.2 Test B (dynamic test)

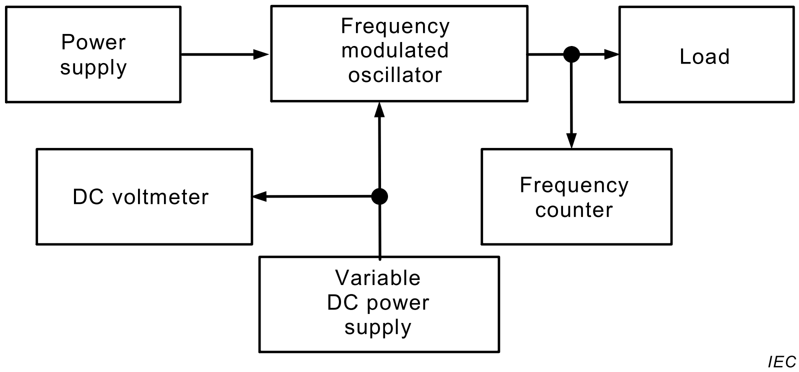
Oscillator shall be connected to the specified load, as shown in Figure 36b.

A sinusoidal signal, at the specified frequency and at a voltage level such as to produce the specified modulation frequency deviation (see 4.5.23.1, tests A or B, as appropriate), shall be applied to the external modulation terminal of Oscillator.

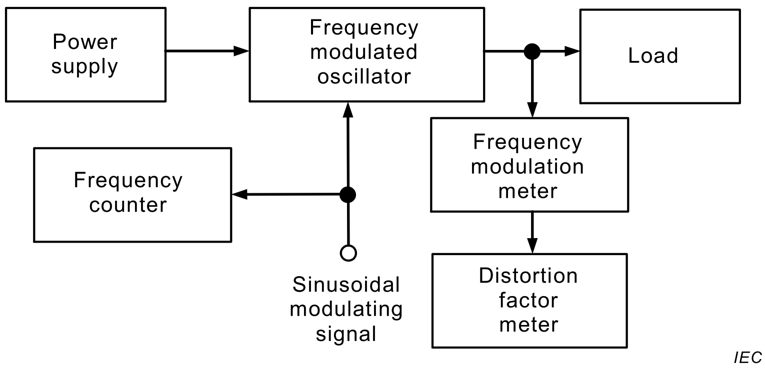
The distortion of the output signal from the modulation detector (in modulation meter) shall be measured with a distortion meter. The distortion shall be within the limits stated in the detail specification.

When using this test method, it shall be necessary to observe the following precautions:

– if the harmonic content of the modulating signal is significant, the results obtained shall be corrected, or filtering may be added to the modulating signal to reduce the harmonic content;
– the distortion introduced by the detector of the modulation meter shall be low compared with that of Oscillator under test.



a) Static test



b) Dynamic test

Figure 36 – Test circuit for the measurement of frequency modulation distortion

4.5.23.4 Frequency modulation frequency response

Using the procedures described in 4.5.23.2 with a sinusoidal modulating signal applied, the frequency modulation sensitivity at a specified reference frequency shall be measured. Measurements shall be made at other specified frequencies and the change in modulation sensitivity, usually expressed in decibels, determined. This change shall be within the limits stated in the detail specification.

4.5.23.5 Frequency modulation input impedance

This test shall be performed exactly as described in 4.5.22.6.

The resultant impedance shall be as specified in the detail specification.

4.5.24 Spurious response

The spurious response(s) shall be measured using the procedures exactly as described in 4.5.15, except that the measuring system shall be screened against any high level signals in the environment of Oscillator under test.

NOTE Spurious response(s) are, by definition, not harmonically related to the fundamental frequency and so it is difficult to differentiate between oscillator-generated spurious signals and those which can be picked up from the operating environment. This can be checked by removing the supply voltage from Oscillator.

4.5.25 Phase noise

4.5.25.1 General

Phase noise gives rise to a sideband distribution that consists of symmetrical pairs whose relative amplitude, compared to the carrier, is equal to half the peak phase deviation of that component in radians.

For the measurement of phase noise, synchronous signals are compared by means of a phase detector.

The output of the phase detector is the instantaneous voltage analog of the phase noise contribution. For the phase detector to be held to zero output, except for the phase noise contributions, it is essential that Oscillator under test (oscillator 2 in Figure 37) be kept in quadrature with the reference oscillator. This is achieved by using a DC amplifier to sense a zero phase detector output and hence drive the test oscillator to phase quadrature.

The output phase noise is monitored with a low frequency wave analyzer. The noise measured by the wave analyzer will be r.m.s. noise (it may be necessary to perform a conversion for average/r.m.s.) in both sidebands; this may be converted to a single-sideband phase noise by subtracting 6 dB.

Ideally, the reference oscillator (oscillator 1 in Figure 37) should have a very low noise contribution. It frequently occurs that both oscillators are of similar type; if this is so, it may be assumed that both oscillators have equal noise contributions, that is the signal-to-phase noise ratio will be degraded by 3 dB for similar oscillators. An appropriate allowance should be made when calculating the results.

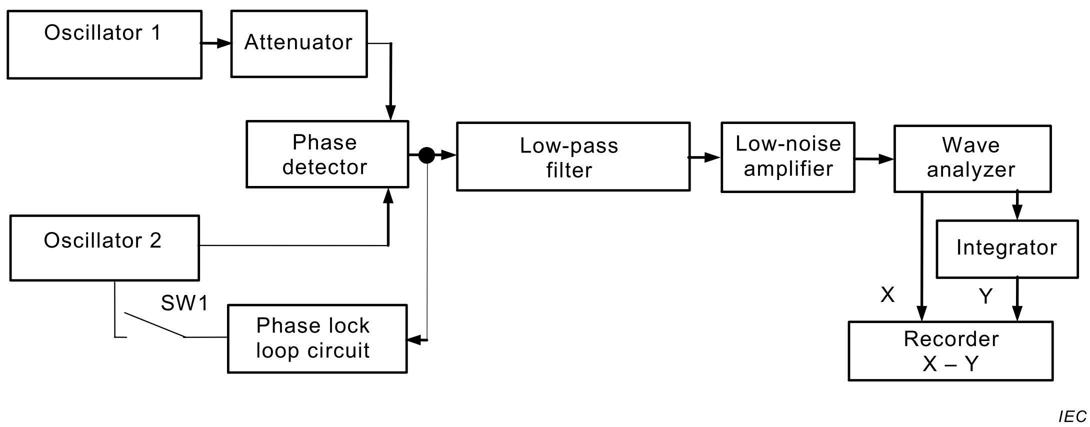


Figure 37 – Test circuit for the measurement of single-sideband phase noise

4.5.25.2 Procedure

The circuit shall be connected as shown in Figure 37. The feed-back loop from the phase detector shall be arranged such that oscillator 1 and oscillator 2 may be phase-locked in quadrature. The wave analyzer shall be set to the specified resolution bandwidth (frequency

1 Hz) and the integrator time constant to 1 s, unless otherwise stated in the detail specification.

Switch 1 shall be opened and a difference frequency will be established between oscillator 1 and oscillator 2. The wave analyzer shall be adjusted to the difference frequency and the scale of the X-Y recorder calibrated by means of the attenuator in the region –60 dB to –80 dB (high attenuation to prevent overloading of the low-noise amplifier).

Switch 1 shall then be closed. Oscillators 1 and 2 are phase locked in quadrature. The attenuator shall be set to –10 dB, unless otherwise stated in the detail specification, and the wave analyzer tracked in frequency over the specified range of offset frequencies over which the phase noise is to be measured.

4.5.25.3 Precautions

The response time of the frequency-control loop shall be very long compared with the period of the lowest sideband noise to be measured. For example, a 10 s response time (or 0,1 Hz cut-off frequency) would be indicated in order to measure phase noise sidebands at 1 Hz. Within the pass-band of the locking loop, the output signal is proportional to frequency noise; far outside the locking-loop pass-band, the output signal is proportional to phase noise, but in the transition region, the situation is somewhat complicated.

General precautions pertaining to the use of narrow-band tuned detectors shall be followed; in particular, the tuning rate (Hz/s) shall be small compared with the detector bandwidth (Hz) and the post-detector integration time shall be long compared with the inverse detector bandwidth.

For example, with a 10 Hz detector pass-band, the tuning (or slew) rate should be no greater than 1 Hz/s, and an integration time of at least 1 s should be used.

NOTE The limit of resolution of this measurement system is determined by the minimum bandwidth of the wave analyzer. In this case, spectral components having a Fourier frequency lower than the analyzer bandwidth cannot be measured.

It is assumed that the noise contribution from the phase locked loop is small compared with Oscillator contribution. An alternative circuit arrangement is to manufacture the two oscillators with, for example, a 4,5 kHz frequency separation and then to examine (with the wave analyzer) the noise distribution around the 4,5 kHz output from a mixer, which should be used in place of the phase detector. In this arrangement, a band-pass filter (centered on the difference frequency) should be used instead of the low-pass filter. The disadvantage of this system is that it has an inherently lower stability and, in general, it will not be possible to use such low resolution bandwidths.

4.5.26 Phase noise – vibration

Using the procedure described in 4.5.25, the phase noise shall be measured with Oscillator operating whilst being subjected to vibration, as described in 4.6.7.2 (sinusoidal) or 4.6.7.4 (random).

The phase noise (vibration) shall be as specified in the detail specification.

4.5.27 Phase noise – acoustic

Using the procedure described in 4.5.25, the phase noise shall be measured with Oscillator operating whilst being subjected to acoustic noise, as required by 4.6.12.

4.5.28 Noise pedestal

4.5.28.1 General

The noise pedestal refers to the relative level of Oscillator frequency and the far-out noise level from Oscillator.

The graph in Figure 38 shows a typical spectrum as obtained from a crystal oscillator as displayed on a spectrum analyzer. Subclause 4.5.25 relates to the measurement of the noise contribution close to Oscillator frequency, while this test relates to the far-out contribution, usually expressed in decibels, below Oscillator frequency.

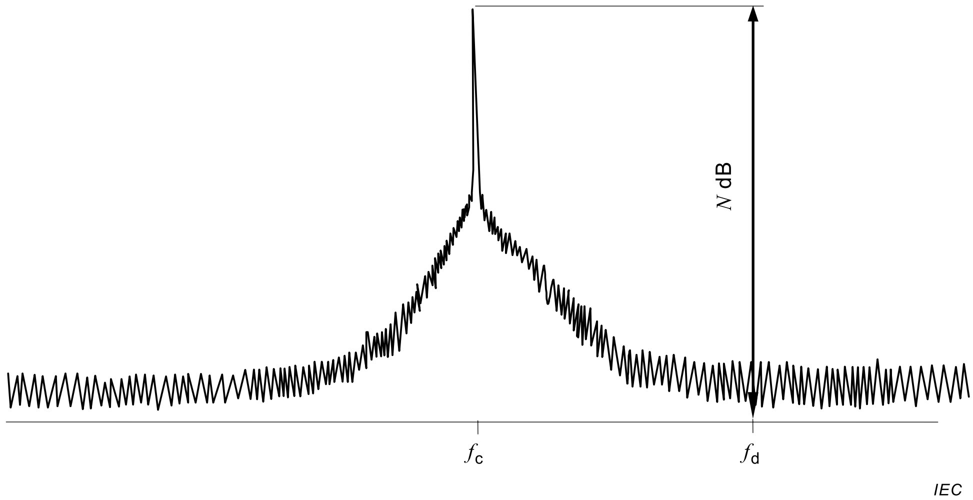


Figure 38 – Typical noise pedestal spectrum

4.5.28.2 Procedure

Oscillator shall be connected to the specified load and spectrum analyzer of specified resolution bandwidth, as shown in Figure 19.

From the output spectrum of Oscillator displayed on the spectrum analyzer, the noise pedestal shall be measured from the noise base line where it reaches asymptotic level, or at a specified frequency (f_d).

The measurement frequency (f_d) or separation from Oscillator frequency ($f_c - f_d$), if a specific frequency offset is relevant, shall be specified in the detail specification.

The mean level of the noise should be taken as the base line. This can be easily assessed if the spectrum analyzer incorporates a video filter which can be set for a long time constant, for example to a 10 Hz low-pass bandwidth.

4.5.28.3 Precautions

The following precautions shall be observed:

- care shall be taken to ensure that the noise contribution of the spectrum analyzer does not degrade the measurement of noise pedestal; this can be checked by changing the input attenuator setting of the spectrum analyzer. This should not change the value of N (see Figure 38), but rather reduce both Oscillator frequency level and the level of the far out noise. Spectrum analyzer noise will limit the applicability of this test to oscillators having a noise pedestal of about 70 dB to 90 dB (depending on the spectrum analyzer) or worse;
- should the noise pedestal be below the threshold level of the spectrum analyzer, the method described in 4.5.25 may be used to obtain an estimate of the noise pedestal; this

is perfectly valid because, at low levels, the major contribution to the overall noise results from frequency or phase effects.

4.5.29 Spectral purity

4.5.29.1 General

Out-band noise refers to the relative level of the noise of frequencies far from Oscillator frequency, including discrete harmonic or spurious single frequency tones, to the level of Oscillator frequency.

Subclause 4.5.25 deals with the measurement of phase noise in the enhancement region near (within several bandwidths) Oscillator frequency, while Subclause 4.5.25 refers to the flat additive noise region extending from several kilohertz to as much as several megahertz away from Oscillator frequency.

4.5.29.2 Procedure

Oscillator shall be connected as shown in Figure 19 and the spectrum analyzer adjusted to display the specified frequency range. The level of the noise pedestal may be determined directly from the spectrum analyzer display (in decibels), with appropriate correction for the analyzer bandwidth (that is 10 dB per decade bandwidth) in order to reduce the data to a 1 Hz basis.

4.5.29.3 Precautions

Care shall be taken to ensure that the noise contribution of the spectrum analyzer does not degrade the measurement. This can be checked by inserting a variable attenuator between Oscillator and the spectrum analyzer, and ensuring that both carrier and noise levels respond equally to attenuator setting.

In many cases, the signal-to-wideband noise ratio of crystal controlled oscillators will greatly exceed the dynamic range of available spectrum analyzers; in this case, it will be necessary to use a narrow-band elimination filter to attenuate the carrier to some known amount (that is 80 dB or 90 dB) in order to avoid saturation of the analyzer. Alternatively, some demodulation scheme may be used, such as the narrow-band phase locked loop of 4.5.25, to remove the carrier effectively.

Since the additive noise level from a crystal controlled oscillator can be comparable to the thermal noise generated by the load impedance itself, great care is recommended in the selection of any amplifier or signal processing equipment used in its measurement.

4.5.30 Incidental frequency modulation

Oscillator is connected as shown in Figure 39 and allowed to stabilize. The frequency discriminator shall provide a linear characteristic over a sufficiently wide band to prevent distortion of base-band spectral components in the specified frequency range. The incidental f.m. spectrum will be obtained directly on the X – Y recorder and shall be within the limits stated in the detail specification.

If it is specified to determine the total f.m. signal in a particular base-band region, a suitable band-pass filter and r.m.s. voltmeter may be substituted for the wave analyzer and X – Y recorder. In either case, it shall be necessary to determine the discriminator characteristic (volts/hertz deviation) in order to establish the calibration system.

It shall be necessary to take into consideration the following precaution.

The incidental f.m. of high-quality crystal controlled oscillators is commonly very small, especially at low base-band frequencies, requiring careful selection of low-noise discriminators and video amplifiers. Post-detection integration time and wave analyzer scanning rate shall be adjusted to be compatible with the wave analyzer bandwidth, in order to ensure accurate measurement of discrete f.m. tones, such as those produced by power supply ripple voltage, etc.

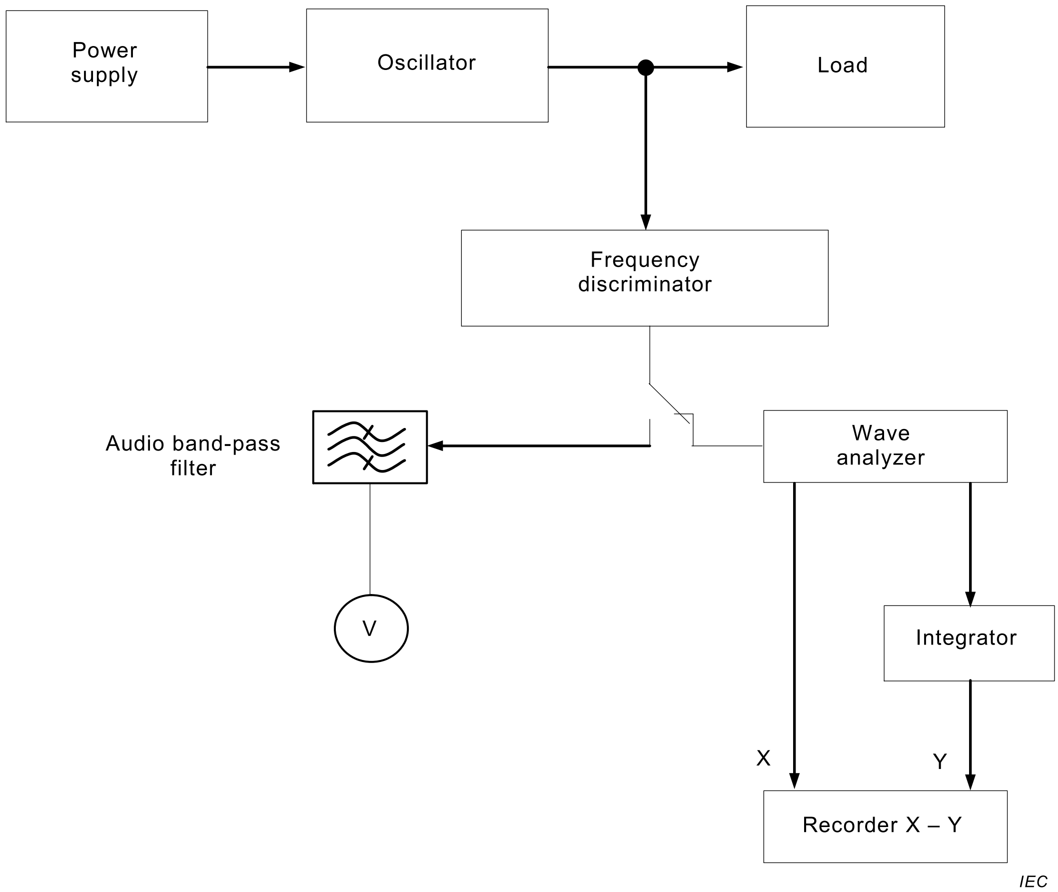


Figure 39 – Test circuit for the measurement of incidental frequency modulation

4.5.31 RMS fractional frequency fluctuations

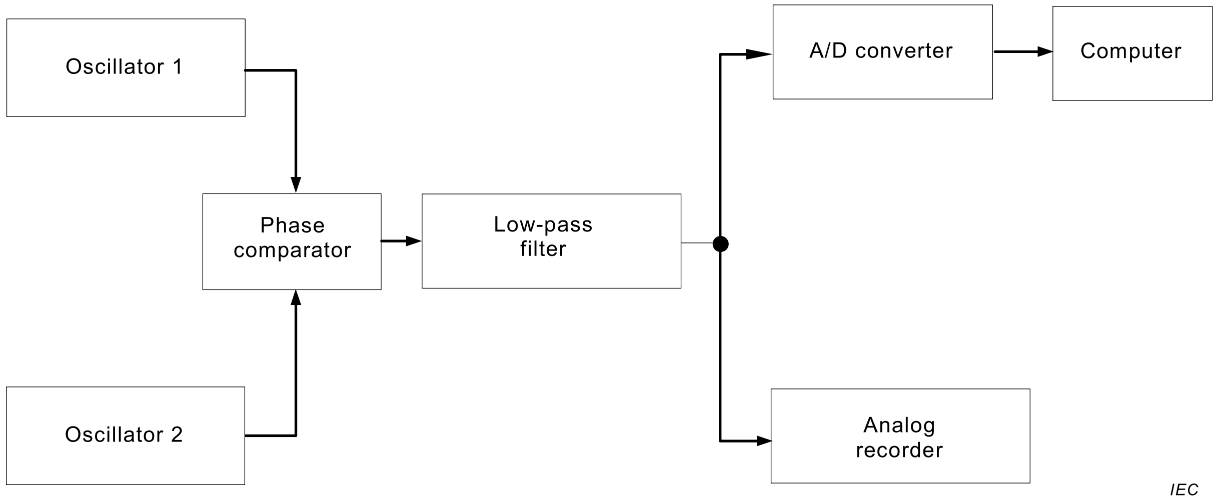
4.5.31.1 Procedure

In principle, time domain stability measurements are made with respect to a reference source having much better stability than the unit under test.

In general practice, however, comparisons are commonly made between two oscillators of similar design, and it is usually assumed that the probability densities and distribution functions of their random noise processes are nearly the same. Since the noise processes combine on a power basis, the fractional frequency fluctuations between the two similar oscillators shall be divided by $\sqrt{2}$ to arrive at an estimate of the fluctuation due to one of Oscillator alone. This is reflected in the formulae derived for each of the two methods:

- Method 1 – Two oscillators having exactly the same mean frequency.

  The two oscillators shall be connected as shown in Figure 40.



NOTE Phase comparators are often sensitive to both phase and amplitude deviations. In order to minimize sensitivity to amplitude, it is normal practice to use a double-balanced mixer as a quadrature detector.

Figure 40 – Test circuit for method 1

In the case of method 1, the phase comparator produces an analog signal which is directly proportional to the instantaneous phase fluctuations between the two oscillator signals (for Fourier frequencies below the cut-off of the low-pass filter). This signal may be examined by analog methods (such as continuous strip-chart recorder, r.m.s. voltmeter or spectrum analyzer), or it can be examined by time domain methods using a sampling type A/D converter with a controlled sample averaging time τ, and the repetitive sampled measurements stored for analysis by a computer. Using this method, there is no dead time introduced in the measurement system, and the r.m.s. fractional frequency fluctuation is:

$$\frac{\Delta \mathrm{F}}{\mathrm{F}}(\tau)_{rms} = \frac{1}{4\pi F_0 \tau}\left[\frac{1}{(M-1)}\sum_{k=1}^{M-1}\left[\left[\varphi(t_k+2\tau)-\varphi(t_k+\tau)\right]-\left[\varphi(t_k+\tau)-\varphi(t_k)\right]\right]^2\right]^{1/2}$$

where

M is the number of repetitive measurements;

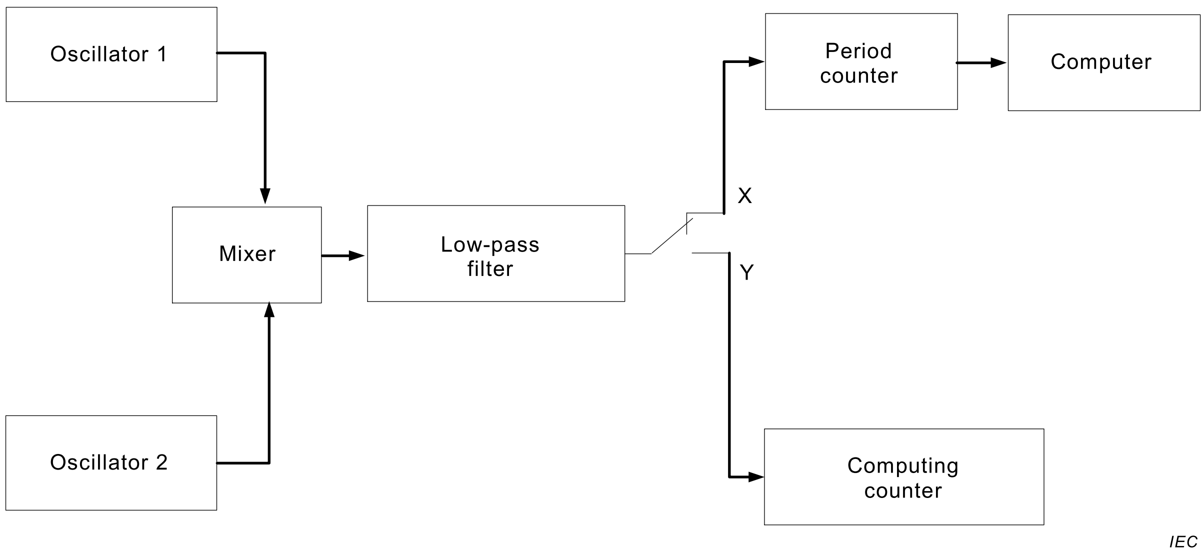
τ is the sample averaging time.

If, in fact, the reference oscillator used has much better stability than the unit under test, then all of the frequency fluctuations can be attributed to the unit under test and the equation above should be multiplied by $\sqrt{2}$.

- Method 2 – Two oscillators having slightly different frequencies.

  The two oscillators shall be connected as shown in Figure 41.

  In this case, the two oscillators being compared are usually made to be essentially identical, except that one of the controlling crystals is adjusted to a slightly different frequency. Therefore, the output of the mixer will have a sinusoidal waveform whose frequency is the difference between the two oscillator frequencies. This is commonly chosen to be somewhere in the range from 100 Hz to 10 kHz. It is assumed that the small difference in crystal unit adjustment will not significantly influence the random noise characteristics of Oscillator.



NOTE Position X or Y can be used to obtain the Allan variance and deviation. X allows determination of the standard deviation as well.

Figure 41 – Test circuit for method 2

The specified number of measurements M of the period of the beat frequency is made, using the specified averaging time τ (τ should be an integral number of periods of the beat frequency). The interval between successive measurements T will usually be at least one period of the beat frequency longer than the sample averaging time τ and may be two or more periods greater depending upon the beat frequency and the recycling time of the counter-data acquisition system. The fractional frequency fluctuation is:

$$\frac{\Delta F}{F_0}(\tau)_{\text{rms}} = \frac{1}{\sqrt{B_2(r,\mu)}} \times \frac{1}{2F_0}\left[\frac{1}{(M-1)}\sum_{k=1}^{M-1}(F_{k+1}-F_k)^2\right]^{1/2}$$

where

τ	is the sample averaging time;
$B_2(r,\mu)$	is the correction factor for dead time;
T	is the sampling period;
$\gamma = \dfrac{T}{\tau}$	is the ratio of sampling period to sample averaging time;
F_k, F_{k+1}	are the successive measurements of the beat frequency averaged for sample time τ, as described above.

As for method 1 above, if the reference oscillator has much better stability than the unit under test, all of the frequency fluctuations can be attributed to the unit under test and the value above should be multiplied by $\sqrt{2}$.

4.5.31.2 Modification of methods 1 and 2

In special instances (for example if only very short averaging times are of interest), a narrow-band crystal filter may be inserted between the reference oscillator and the mixer or phase comparator, as shown in Figure 42. For averaging times τ much less than the reciprocal of the filter bandwidth, this modification can remove the noise sidebands from the reference signal, so that only the frequency fluctuations of the unit under test will be observed. To be effective, however, the crystal filter itself shall be free from excess noise, protected from mechanical disturbances and maintained at constant temperature.

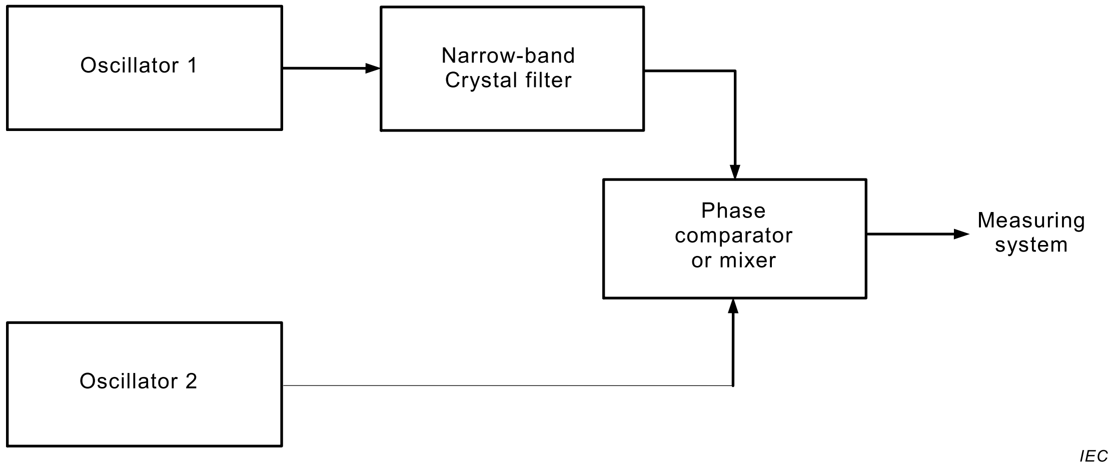


Figure 42 – Circuit modifications for methods 1 and 2

4.5.31.3 Precautions

The short-term frequency stability of Oscillator is a very sensitive measure of the spectral purity and, as such, should be performed under controlled conditions. For high orders of stability, screened enclosures should be used, the recording apparatus being outside the enclosure.

4.5.31.4 Results

The short-term frequency stability of Oscillator shall be given in a graphical form. An example is given in Figure 43.

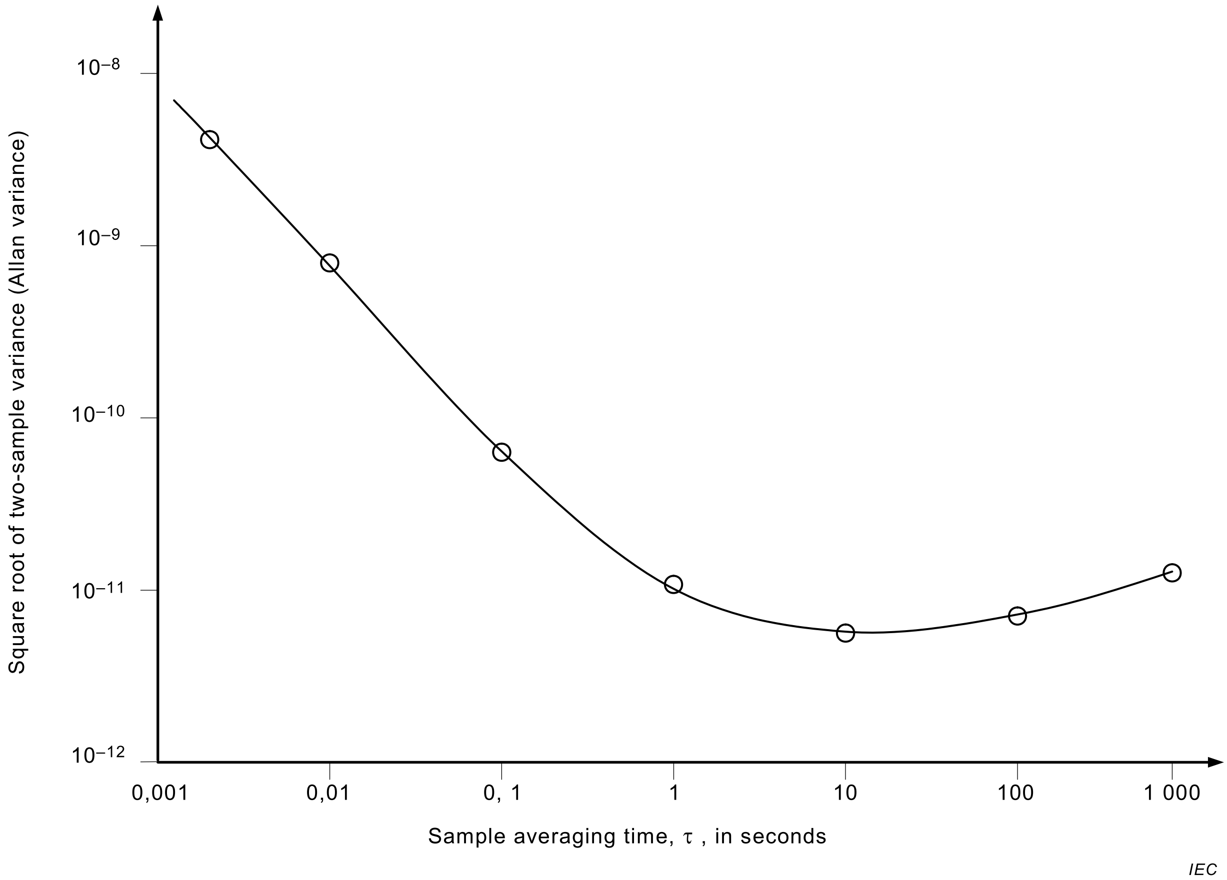


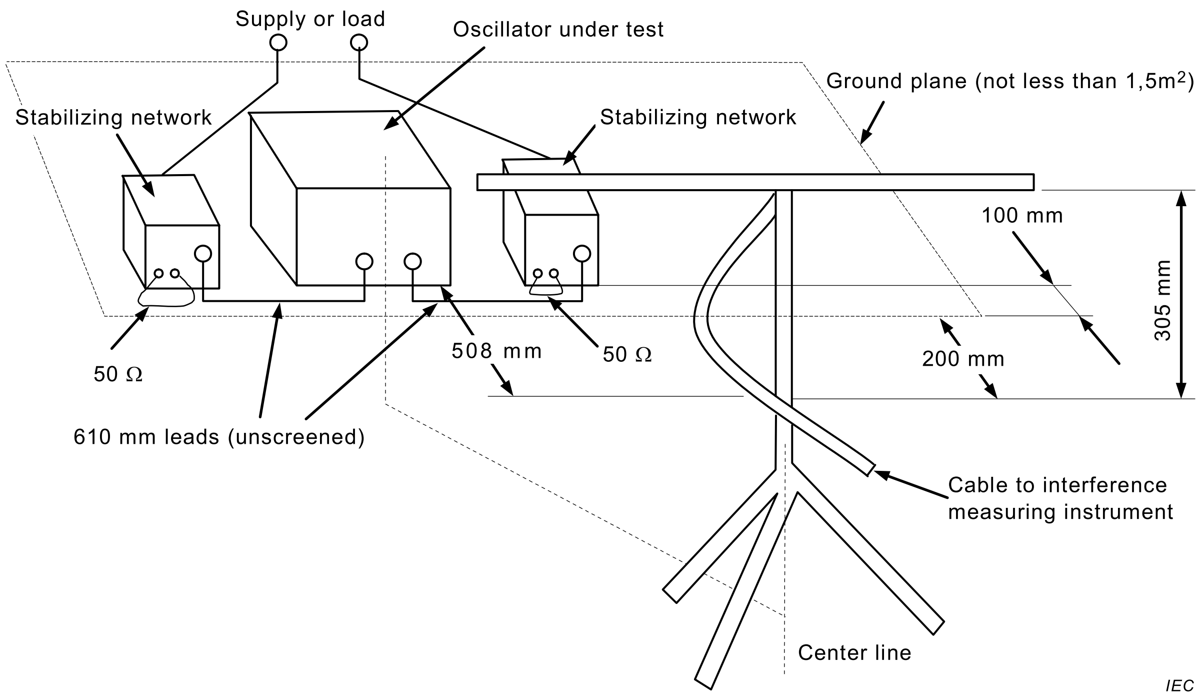
Figure 43 – Time-domain short-term frequency stability of a typical 5 MHz precision oscillator

4.5.32 Electromagnetic interference (radiated)

4.5.32.1 General

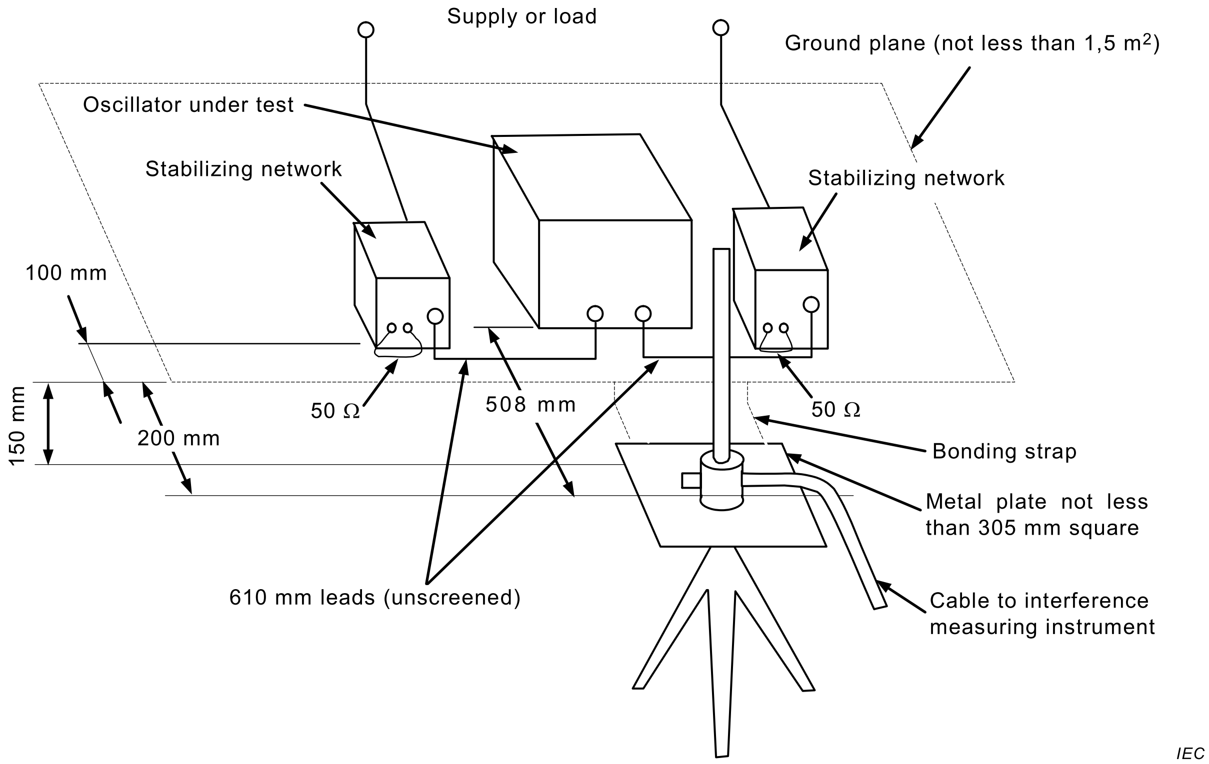
This method shall be used, unless otherwise specified by national regulations.

The test arrangements shall be as described in Figures 44a) and 44b).



NOTE Stabilizing network to be bonded to the ground plane.

a) – Typical arrangement for radiated interference tests, 30 MHz and above



NOTE Stabilizing network to be bonded to the ground plane.

b) – Typical arrangement for radiated interference tests, below 30 MHz

Figure 44 – Radiated interference tests

4.5.32.2 Test conditions

For tests of radiated interference, it is essential that the test should be made in a screened room having dimensions not less than 2,4 m high, 2,1 m wide, and 4,6 m long.

Ideally, the tests for radiated interference should be made in a screened room having adequate filters in all incoming supply lines. If this is impracticable, precautions should be taken to ensure that the results are not affected by noise voltages and fields other than those due to Oscillator under test. This will involve the use of additional filters in the supply and/or load circuits.

Oscillator under test should be mounted on the ground plane. The ground plane shall be bonded to the screened room at points not more than 0,9 m apart, and at the ends of the ground plane.

The leads from Oscillator under test to the line impedance stabilizing network shall be 610 mm in length, and shall be screened or unscreened, as shown in the appropriate figure. The stabilizing networks in the lines not being measured shall be terminated by 50 Ω non-reactive resistors.

The impedance characteristics of the stabilizing network shall be within the limits of Figure 45. One practical method of attaining this impedance is shown in Figure 46.

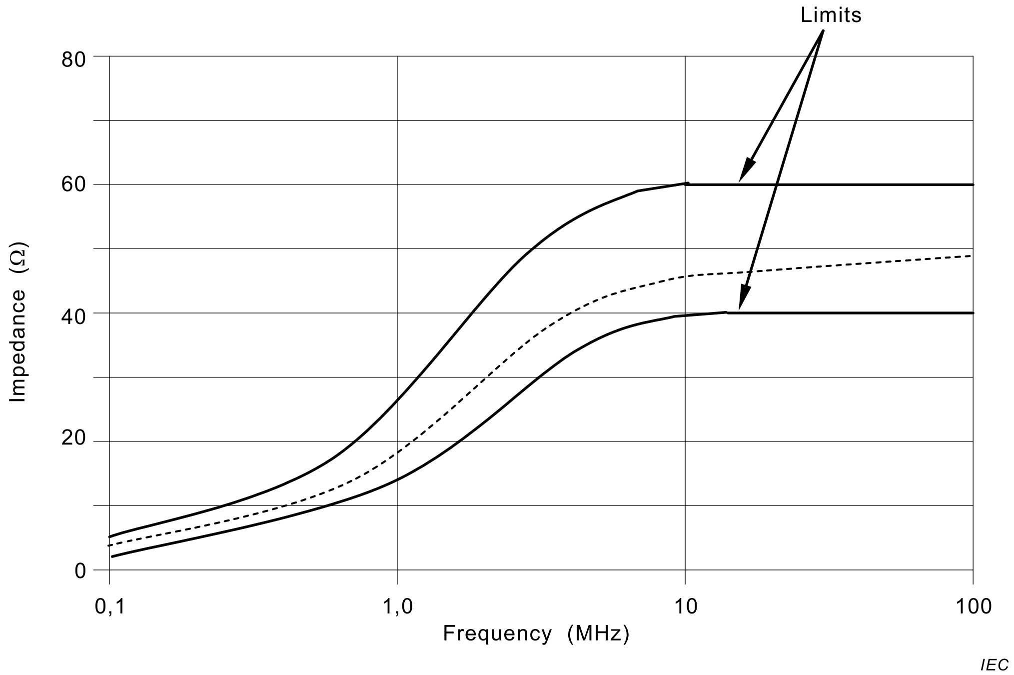
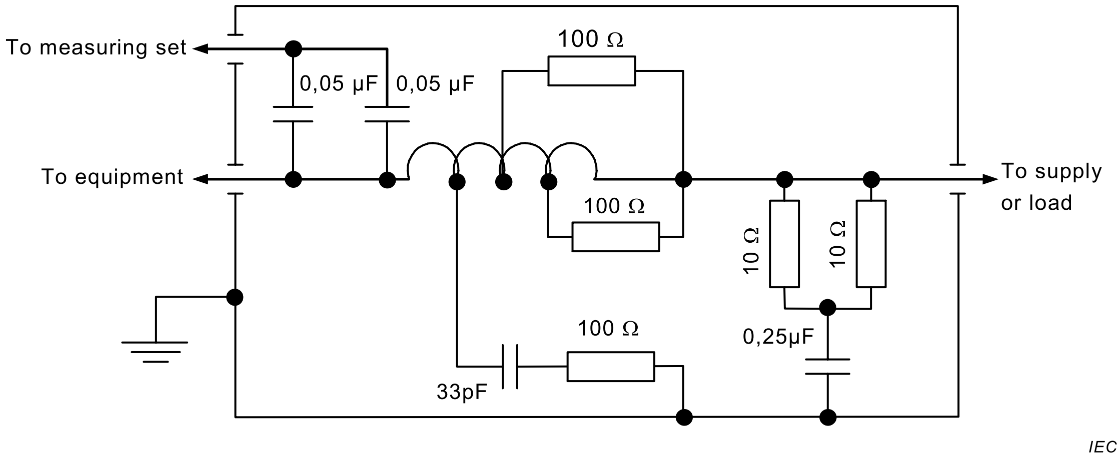


Figure 45 – Characteristics of line impedance of stabilizing network



Coil characteristics:

5µH, 10 turns, 5,89 mm (0,232 in) 4 SWG[1] wound on 51,0 mm(2 in) diameter former.

Figure 46 – Circuit diagram of line impedance of stabilizing network

4.5.32.3 Procedure

Oscillator shall be set up in a screened room and with a measuring system as described above.

The measurements shall be made under the load conditions producing the worst operating conditions from the point of view of radio interference.

A vertical rod aerial of 1 016 mm ± 25 mm long shall be used at frequencies below 30 MHz. It shall be located at the point where maximum interference is obtained when it is moved along a line parallel to the front edge of the ground plane. At 30 MHz and above, a horizontal dipole aerial shall be used; over the frequency range 30 MHz to 50 MHz, a 50 MHz dipole shall be used and above 50 MHz a resonant dipole shall be used. It shall be placed parallel to the front edge of the ground plane. Its height shall be 305 mm ± 25 mm above the level of the ground plane and its center shall be adjacent to the geometrical center of the unit under test. The rod or the dipole aerial shall be located 508 mm from the nearest point on the surface of Oscillator under test. When the length of the dipole is less than that of the test layout, it shall be moved parallel to the edge of the ground plane to the point of maximum response.

4.5.32.4 Measuring sets

Measuring sets having facilities for the measurement of peak values and having bandwidths within the limits shown in Table 1 are preferred for measurements specified in this standard. Measuring sets having other bandwidths are acceptable, when suitable correlation factors are used.

1 British standard wire gauge.

Table 1 – Measuring sets bandwidth

Frequency range MHz	Bandwidths limits, at –6 dB
0,05 to 0,15	200 Hz ± 100 Hz
0,15 to 30	9 kHz ± 1 kHz
30 to 300	150 kHz ± 50 kHz
300 to 1 000	150 kHz ± 50 kHz

All voltages measured shall be referred to 50 Ω.

If the input impedance of the measuring set differs from this value, a suitable matching network shall be used and the appropriate correction factor applied.

When a measuring set has a quasi-peak voltmeter only, it will need to be modified to read peak voltages.

As the impulse bandwidth of measuring sets normally differs from 1 kHz, appropriate correction factor shall be applied on a linear basis.

In all cases, the measuring set shall be tuned for a maximum response to the interfering signal.

4.6 Mechanical and environmental test procedures

4.6.1 Robustness of terminations (destructive)

4.6.1.1 Tensile and thrust tests on terminations

The tests shall be performed in accordance with test Ua_1 (tensile) and test Ua_2 (thrust) of IEC 60068-2-21.

Unless otherwise stated in the detail specification, the values of tensile force shall be as given in Table 2 below and the values of thrust force shall be as given in Table 3 below.

Table 2 – Tensile force

Nominal cross-sectional area[a)] mm^2	Corresponding diameter for circular-section wires mm	Force with tolerance of ±10 % N
0,1 < s ≤ 0,2	0,35 < d ≤ 0,5	5
0,2 < s ≤ 0,5	0,5 < d ≤ 0,8	10
0,5 < s ≤ 1,2	0,8 < d ≤ 1,25	20

[a)] For circular-section wires, strips or pins :

the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification.

For stranded wires:

the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the relevant specification.

Table 3 – Thrust force

Nominal cross-sectional area[a)] mm^2	Corresponding diameter for circular-section wires mm	Force with tolerance of ±10 % N
$0,1 < s \leq 0,2$	$0,35 < d \leq 0,5$	1
$0,2 < s \leq 0,5$	$0,5 < d \leq 0,8$	2
$0,5 < s \leq 1,2$	$0,8 < d \leq 1,25$	4

a) For circular-section wires, strips or pins :

the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification.

4.6.1.2 Flexibility of wire terminations

The test shall be performed in accordance with test Ub (bending) of IEC 60068-2-21.

Unless otherwise stated in the detail specification, the load shall be so restricted that the bend starts 2,5 mm ±0,5 mm from the body of Oscillator, the number of bends shall be three, and the loading mass and the values of bending force shall be as given in Table 4.

Table 4 – Bending force

Section modulus mm^3	Diameter of corresponding round leads mm	Force with tolerance of ±10% N
$4,2 \times 10^{-3} < Zx \leq 1,2 \times 10^{-2}$	$0,35 < d \leq 0,5$	2,5
$1,2 \times 10^{-2} < Zx \leq 0,5 \times 10^{-1}$	$0,5 < d \leq 0,8$	5
$0,5 \times 10^{-1} < Zx \leq 1,9 \times 10^{-1}$	$0,8 < d \leq 1,25$	10

NOTE 1 For round terminations, the section modulus is given by the following formula:

$$Z_X = \frac{\pi d^3}{32}$$

where

d is the lead diameter;

Z_X is the section modulus.

For strip terminations, the section modulus is given by the following formula:

$$Z_X = \frac{ba^2}{6}$$

where

a is the thickness of the rectangular strip perpendicular to bending axis;

b is the other dimension of the rectangular strip;

Z_X is the section modulus.

NOTE 2 The section modulus is defined in 3-21 of ISO 80000-4:2006 and the derivation of the above formulae can be found in standard textbooks on mechanical engineering.

4.6.1.3 Torque test on mounting studs

The test shall be performed in accordance with test Ud (torque) of IEC 60068-2-21.

Unless otherwise stated in the detail specification, the value of the torque force to be applied is given in Table 5.

Table 5 – Torque force

Nominal thread diameter mm	2,6	3,0	3,5	4,0	5,0	6,0
Torque Nm Severity 2	0,2	0,25	0,4	0,6	1,0	1,25

4.6.2 Sealing test (non-destructive)

4.6.2.1 Gross leak test

This test shall be performed in accordance with the procedure specified in test method 1 or 2 of test Qc of IEC 60068-2-17.

Method 1:

The liquid shall be degassed water and the pressure of air above the water shall be reduced to 8,5 kPa (85 mbar) or less. It shall not be necessary to drain or remove the specimen from the water before breaking the vacuum.

Method 2:

The liquid shall be maintained at 125 °C ± 5 °C. The immersion time shall be 30 s, unless otherwise specified in the relevant detail specification.

During the test, there shall be no evidence of leakage of gas or air from the inside of Oscillator. The continuous formation of bubbles shall be evidence of leakage.

4.6.2.2 Fine leak test

The test shall be performed in accordance with 6.4, test method 1 of test Qk of IEC 60068-2-17:1994. Unless otherwise stated in the detail specification, the pressure in the pressure vessel shall be 200 kPa (2 bar).

The maximum leak rate shall not exceed the value specified in 3.3.6 of IEC 60679-1:2017, unless otherwise stated in the detail specification.

4.6.3 Soldering (solderability and resistance to soldering heat) (destructive)

4.6.3.1 Solderability

Test A (lead terminations):

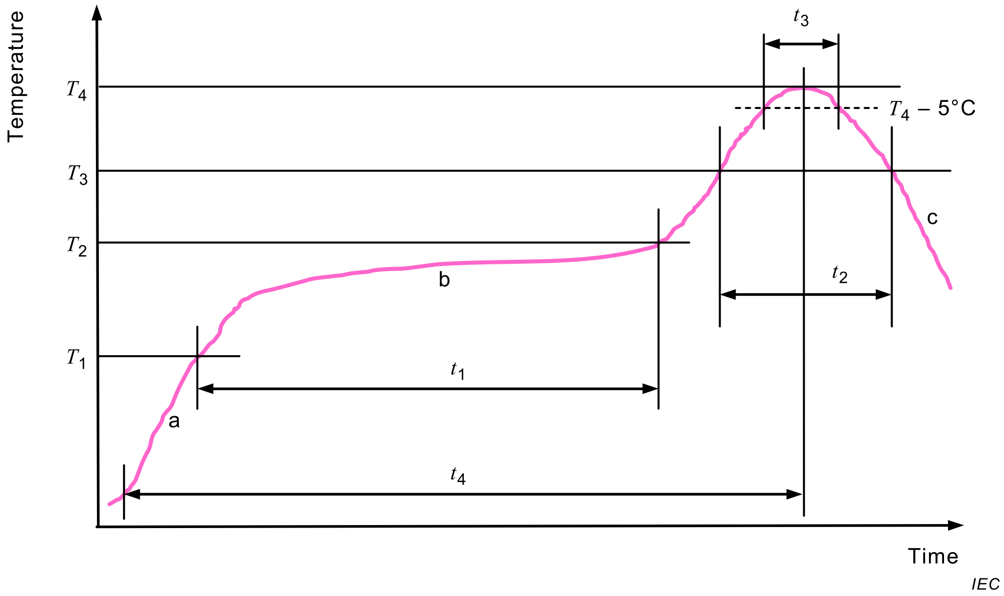
This test shall be performed in accordance with method 1 of test Ta of IEC 60068-2-20. The terminations shall be examined for good tinning, as evidenced by free flowing of the solder with wetting of the terminations.

Test B (surface mounted devices) solder bath method:

This test shall be performed in accordance with method 1: Solder bath of Td_1 of IEC 60068-2-58. The immersion time shall be 3 s ± 0,3 s at a temperature of 245 °C ± 5 °C which is used by lead-free solder alloys (e.g. Sn96,5Ag3,0Cu0,5), unless otherwise specified in the detail specification. The terminations shall be examined for good wetting of the terminations.

Test C (surface mounted devices) reflow method:

This test shall be performed in accordance with method 2: Reflow of Td_1 of IEC 60068-2-58. The reflow temperature profile shall be as illustrated in Figure 47 and Table 6 which is used by lead-free solder alloys (e.g. Sn96,5Ag3,0Cu0,5), unless otherwise specified in the detail specification. The terminations shall be examined for good wetting of the terminations.



Key

T_1	Minimum preheating temperature
T_2	Maximum preheating temperature
T_3	Liquidus temperature
T_4	Peak temperature
t_1	Preheating duration
t_2	Time above liquidus temperature
t_3	Time above (T_4 -5°C)
t_4	Time to T_4
a	The temperature gradient of the increasing slope shall not exceed 3 K/s.
b	Preheat area
c	The temperature gradient of the decreasing slope shall not exceed 6 K/s.

Figure 47 – Reflow temperature profile for solderability

Table 6 – Solderability – Test condition, reflow method

Solder alloy	T_1 °C	T_2 °C	t_1 s	T_3 °C	t_2 s	T_4 [a] °C	t_3 [b] s
Sn96,5Ag3,0Cu0,5	150	180	60 to 120	217	40 ± 5	235	10

[a] The peak temperature (T_4) is defined as minimum for acceptance testing and maximum for qualification testing.

[b] Time above (T_4 – 5°C) is defined as minimum for acceptance testing and maximum for qualification testing.

4.6.3.2 Resistance to soldering heat

Test A (lead terminations):

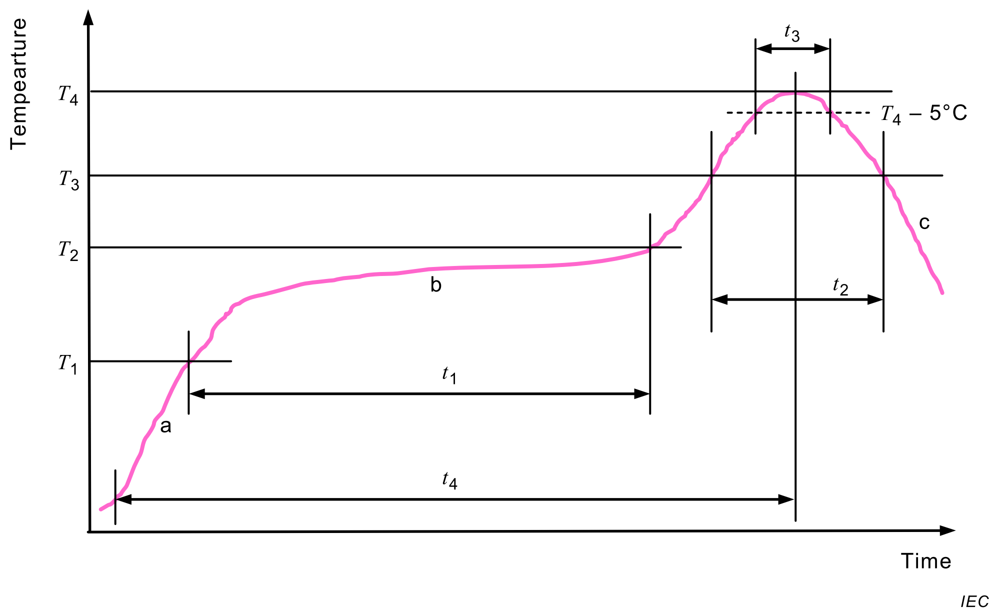
This test shall be performed in accordance with method 1 of test Tb of IEC 60068-2-20. The immersion time shall be 5 s ± 0,5 s, unless otherwise specified in the detail specification. A screen of thermally insulating material shall be used to prevent the component being heated by direct radiation from the solder bath. It shall also allow the immersion of the terminations up to a point 2 mm from the emergence of the terminations from the body, unless otherwise specified in the detail specification.

Test B (surface mounted devices) solder bath method:

This test shall be performed in accordance with method 1: Solder bath of Td_2 of IEC 60068-2-58. The immersion time shall be 10 s ± 1 s or 5 s ± 1 s at a temperature of 260 °C ± 5 °C which is used by lead-free solder alloys (e.g. Sn96,5Ag3,0Cu0,5), unless otherwise specified in the detail specification.

Test C (surface mounted devices) reflow method:

This test shall be performed in accordance with method 2: Reflow of Td_2 of IEC 60068-2-58. The reflow temperature profile shall be as illustrated in Figure 48 and Table 7 which is used by lead-free solder alloys (e.g. Sn96,5Ag3,0Cu0,5), unless otherwise specified in the detail specification.



Key

T_1 Minimum preheating temperature

T_2 Maximum preheating temperature

T_3 Liquidus temperature

T_4 Peak temperature

t_1 Preheating duration

t_2 Time above liquidus temperature

t_3 Time above (T_4 – 5°C)

t_4 Time to T_4

a The temperature gradient of the increasing slope shall not exceed 3 K/s.

b Preheat area

c The temperature gradient of the decreasing slope shall not exceed 6 K/s.

Figure 48 – Reflow temperature profile for resistance to soldering heat

Table 7 – Resistance to soldering heat – Test condition and severity, reflow method

<table>
<tr><th>Solder alloy</th><th>T_1
°C</th><th>T_2
°C</th><th>t_1[f]
s</th><th>T_3
°C</th><th>t_2[g]
s</th><th>T_4[a]
°C</th><th>t_3[b,a]
s</th><th>t_4
s</th></tr>
<tr><td rowspan="3">Sn96,5Ag3,0Cu0,5</td><td rowspan="3">150</td><td rowspan="3">200</td><td rowspan="3">60 to 120</td><td rowspan="3">217</td><td rowspan="3">30 to 60[e]
60 to 150</td><td>220 to 235[c]</td><td>20 to 40[c]</td><td rowspan="3">480 max</td></tr>
<tr><td>230 to 260[e]</td><td>5 max[e]
10 max[e]</td></tr>
<tr><td>245
250
260</td><td>20 ± 1
30 ± 1[d]</td></tr>
</table>

[a] The combination of temperature and time determined by the thermal mass of the component shall be given by the relevant specification. Further information on how to determine applicable test conditions, see are provided in IEC TR 60068-3-12.

Peak temperature (T_4) measured at the specimen's top body surface is defined as maximum for acceptance testing and minimum for qualification testing.

[b] Tolerance for above (T_4 – 5°C) is defined maximum as for acceptance testing and minimum for qualification testing.

[c] Components with high thermal mass can require this severity; details shall be provided by the relevant specification.

[d] A more severe t_3 of (40 ± 1) s is also in use for certain applications with high package density / high thermal mass PCB.

[e] Applicable for high thermal sensitivity.

[f] Depending on the thermal mass of the components, the time t_1 may be extended.

[g] The time t_2 depends on the thermal mass of the components.

4.6.4 Rapid change of temperature: severe shock by liquid immersion (non-destructive)

The test shall be performed in accordance with test Nc of IEC 60068-2-14. The units shall be subjected to one cycle in a downward direction 98 °C ± 3 °C to 1 °C ± 1 °C for 5 s.

4.6.5 Rapid change of temperature: thermal shock in air (non-destructive)

The test shall be performed in accordance with test Na of IEC 60068-2-14.

For Oscillator, the low and high test chamber temperatures shall be the extreme temperatures of the operating range stated in the detail specification.

Oscillator shall be maintained at each extreme of temperature for 30 min, unless otherwise specified in the detail specification.

Oscillator shall be subjected to 10 complete thermal cycles and then exposed to standard atmospheric conditions for recovery for not less than 2 h.

4.6.6 Bump (destructive)

The test shall be performed in accordance with test Ea of IEC 60068-2-27. Oscillator shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the bump is to be applied shall include:

– an axis parallel with the terminations;
– an axis parallel to the base of Oscillator unit.

For surface mounted devices (SMD):

– an axis parallel with the terminal land plane;
– an axis perpendicular with the terminal land plane.

Unless otherwise specified, the combination of acceleration, duration and number of bumps shall be as specified in 3.3.3 of IEC 60679-1:2017.

4.6.7 Vibration (destructive)

4.6.7.1 Vibration, sinusoidal (oscillator not operating)

The test shall be performed in accordance with test Fc of IEC 60068-2-6. Oscillator shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the acceleration is to be applied shall include:

– an axis parallel with the terminations;
– an axis parallel to the base of Oscillator unit.

For surface mounted devices (SMD):

– an axis parallel with the terminal land plane;
– an axis perpendicular with the terminal land plane.

The detail specification shall state the acceleration spectral density (ASD), the frequency range and duration.

4.6.7.2 Vibration, sinusoidal (oscillator operating)

The test shall be as described in 4.6.7.1, except that, during the test, Oscillator shall be energized and electrical tests, as defined in the detail specification, shall be performed.

Unless otherwise stated, the combination of frequency range, vibration amplitude and duration of endurance for the above tests shall be as stated in 3.3.4 of IEC 60679-1:2017.

4.6.7.3 Random vibration (oscillator not operating)

The test shall be performed in accordance with test Fh of IEC 60068-2-64. Oscillator shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the acceleration is to be applied shall include:

– an axis parallel to the terminations;
– an axis parallel to the base of Oscillator unit.

For surface mounted devices (SMD):

– an axis parallel with the terminal land plane;
– an axis perpendicular with the terminal land plane.

The detail specification shall state the acceleration spectral density (ASD), frequency range and duration.

4.6.7.4 Random vibration (oscillator operating)

The test shall be as described in 4.6.7.3 except that, during the test Oscillator shall be energized and electrical tests, as defined in the detail specification, shall be performed.

4.6.8 Shock (destructive)

The test shall be performed in accordance with test Ea of IEC 60068-2-27. Oscillator shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the shock is to be applied shall include:

– an axis parallel with the terminations;
– an axis parallel to the base of Oscillator unit.

For surface mounted devices (SMD):

– an axis parallel with the terminal land plane;
– an axis perpendicular with the terminal land plane.

The degree of severity shall be as stated in 3.3.5 of IEC 60679-1:2017, unless otherwise stated in the detail specification.

4.6.9 Free fall (destructive)

The test shall be performed in accordance with procedure 1 of test Ec of IEC 60068-2-31. Oscillator shall be suspended by its terminations at a height of 1 000 mm. The number of falls shall be two, unless otherwise stated in the detail specification.

4.6.10 Acceleration, steady-state (non-destructive)

4.6.10.1 Acceleration, steady-state (oscillator not operating)

The test shall be performed in accordance with test Ga of IEC 60068-2-7. Oscillator shall be mounted or clamped as required by the detail specification. The procedure and severity shall be as stated in the detail specification.

4.6.10.2 Acceleration, steady-state (oscillator operating)

The test shall be as described in 4.6.10.1, except that, during the test, Oscillator shall be energized and electrical tests, as defined in the detail specification, shall be performed.

The procedure and severity shall be as stated in the detail specification.

4.6.11 Acceleration – 2g tip over

To be agreed upon by the customer and the supplier.

4.6.12 Acceleration noise

To be agreed upon by the customer and the supplier.

4.6.13 Low air pressure (non-destructive)

This test shall be performed in accordance with test M of IEC 60068-2-13. The procedure and severity shall be as stated in the detail specification.

4.6.14 Dry heat (non-destructive)

This test shall be performed in accordance with test B of IEC 60068-2-2. The conditioning shall be carried out at the upper temperature indicated by the climatic category, for a duration of 16 h, unless otherwise stated in the detail specification.

4.6.15 Damp heat, cyclic (destructive)

This test shall be performed in accordance with test Db, variant 1, of IEC 60068-2-30, at severity b) and 55 °C for six cycles.

4.6.16 Cold (non-destructive)

This test shall be performed in accordance with test Aa of IEC 60068-2-1, at the lower temperature indicated by the climatic category, for a duration of 2 h, unless otherwise stated in the detail specification.

4.6.17 Climatic sequence (destructive)

The tests and measurements shall be performed in the following order:

dry heat	see 4.6.14;
damp heat, cyclic	see 4.6.15 (first cycle only);
cold	see 4.6.16;
damp heat, cyclic	see 4.6.15 (remaining five cycles).

In the climatic sequence, an interval of not more than three days is permitted between any of these tests, except between damp heat cyclic (first cycle) and cold tests.

In such a case, the cold test shall follow immediately after the recovery period specified for the damp heat test.

4.6.18 Damp heat, steady-state (destructive)

This test shall be performed in accordance with test Cab of IEC 60068-2-78, for 56 days, unless otherwise stated in the detail specification.

4.6.19 Salt mist, cyclic (destructive)

This test shall be performed in accordance with test Kb of IEC 60068-2-52. Severity 1 shall be used, unless otherwise stated in the detail specification.

4.6.20 Mould growth (non-destructive)

This test shall be performed in accordance with test J, variant 2, of IEC 60068-2-10.

WARNING – This test can constitute a health hazard, therefore special precautions should be observed (see Annex A of IEC 60068-2-10:2005).

4.6.21 Immersion in cleaning solvent (non-destructive)

This test is applicable to superficial marking only. To establish the permanence of marking, this test shall be performed in accordance with method 1 of test XA of IEC 60068-2-45. The detail specification shall prescribe the solvent, the temperature of the solvent, the rubbing material and its dimensions, and the force to be used.

The marking shall be legible.

4.6.22 Radiation hardness

To be agreed upon by the customer and supplier.

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