# IEC 60747-16-5

Edition 1.1 2020-07
CONSOLIDATED VERSION

# INTERNATIONAL STANDARD

colour
inside

## Semiconductor devices –
## Part 16-5: Microwave integrated circuits – Oscillators

IEC 60747-16-5:2013-06+AMD1:2020-07 CSV(en)

**THIS PUBLICATION IS COPYRIGHT PROTECTED**
**Copyright © 2020 IEC, Geneva, Switzerland**

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

**About the IEC**
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

**About IEC publications**
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

**IEC publications search - webstore.iec.ch/advsearchform**
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

**IEC Just Published - webstore.iec.ch/justpublished**
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

**IEC Customer Service Centre - webstore.iec.ch/csc**
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

**Electropedia - www.electropedia.org**
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

**IEC Glossary - std.iec.ch/glossary**
67 000 electrotechnical terminology entries in English and French extracted from the Terms and definitions clause of IEC publications issued between 2002 and 2015. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IECNORM.COM : Click to view the full PDF of IEC 60747-16-5:2013+AMD1:2020 CSV

# IEC 60747-16-5

Edition 1.1 2020-07
CONSOLIDATED VERSION

# INTERNATIONAL STANDARD

colour
inside

## Semiconductor devices –
## Part 16-5: Microwave integrated circuits – Oscillators

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.080.99
ISBN 978-2-8322-8681-4

**Warning! Make sure that you obtained this publication from an authorized distributor.**

IEC 60747-16-5

Edition 1.1 2020-07

# REDLINE VERSION

colour
inside

# Semiconductor devices –
# Part 16-5: Microwave integrated circuits – Oscillators

IEC 60747-16-5:2013-06+AMD1:2020-07 CSV(en)

## CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

# SEMICONDUCTOR DEVICES –

# Part 16-5: Microwave integrated circuits – Oscillators

## 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.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

**This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.**

**IEC 60747-16-5 edition 1.1 contains the first edition (2013-06) [documents 47E/452/FDIS and 47E/454/RVD] and its amendment 1 (2020-07) [documents 47E/673/CDV and 47E/705/RVC] and its corrigendum (2020-09).**

**In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.**

IECNORM.COM : Click to view the full PDF of IEC 60747-16-5:2013+AMD1:2020 CSV

International Standard IEC 60747-16-5 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

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

A list of all parts of the IEC 60747 series, published under the general title *Semiconductor devices,* can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

**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.**

# SEMICONDUCTOR DEVICES –

# Part 16-5: Microwave integrated circuits – Oscillators

## 1 Scope

This part of IEC 60747 specifies the terminology, essential ratings and characteristics, and measuring methods of microwave integrated circuit oscillators.

This standard is applicable to the fixed and voltage-controlled semiconductor microwave oscillator devices, except the oscillator modules such as synthesizers which require external controllers.

NOTE This document is not applicable to the quartz crystal controlled oscillators. They are specified by IEC 60679-1.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60747-1:2006, *Semiconductor devices – Part 1: General* [1]
Amendment 1:2010

IEC 60747-4:2007, *Semiconductor devices – Discrete devices – Part 4: Microwave diodes and transistors*
IEC 60747-4:2007/AMD 1:2017

IEC 60747-16-3:2002, *Semiconductor devices – Part 16-3: Microwave integrated circuits – Frequency converters*
IEC 60747-16-3:2002/AMD 1:2009~~[2]~~
IEC 60747-16-3:2002/AMD 2:2017

IEC 61340-5-1, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC/TR 61340-5-2, *Electrostatics – Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide*

---

[1] A consolidated edition (2010) exists, including IEC 60747-1:2006 and its Amendment 1.

~~[2] A consolidated edition (2010) exists, including IEC 60747-16-3:2002 and its Amendment 1.~~

## 3 Terms and definitions

### 3.1
**oscillation frequency**

$f_{\mathrm{osc}}$

frequency measured at the output port

### 3.2
**output power**

$P_{\mathrm{o,osc}}$

power measured at the output port

### 3.3
**phase noise**

~~$\mathscr{L}(f)$~~

~~frequency-domain measure of the short-term frequency stability of an oscillator, normally expressed as the power spectral density of the phase fluctuations, $S_\varphi(f)$, where the phase fluctuation function is $\varphi(t) = 2\pi Ft - 2\pi F_0 t$~~

~~Note 1 to entry: The spectral density of phase fluctuation can be directly related to the spectral density of frequency fluctuation by~~

~~$S_\varphi(f)=\left(\frac{F_0}{f}\right)^2 S_y(f)\,\mathrm{rad}^2/\mathrm{Hz}$~~

~~where~~

~~$F$ is the oscillator frequency;~~

~~$F_0$ is the average oscillator frequency;~~

~~$f$ is the Fourier frequency.~~

~~Note 2 to entry: $\mathscr{L}(f)$ is pronounced "script-ell of f".~~

~~[SOURCE: IEC 60679-1:2007, 3.2.25, modified – A symbol and two notes have been added. The explanation of the spectral density of phase fluctuation has been moved to a note]~~

$\mathscr{L}(f)$

frequency-domain measure of the short-term frequency stability of an oscillator

Note 1 to entry: This phase noise is normally expressed as the power spectral density of the phase fluctuations, $S_\phi(f)$, where the phase fluctuation function is $\phi(t)=2\pi Ft-2\pi F_0t$. The spectral density of phase fluctuation can be directly related to the spectral density of frequency fluctuation by the following formula:

$$S_\phi(f)=\left(\frac{F_0}{f}\right)S_y(f)\ \mathrm{rad}^2/\mathrm{Hz}$$

where

$F$ is the oscillator frequency;

$F_0$ is the average oscillator frequency;

$f$ is the Fourier frequency.

Note 2 to entry: $\mathscr{L}(f)$ is pronounced "script-ell of f".

[SOURCE: IEC 60050-561:2014, 561-03-22, modified – A symbol and Note 2 to entry have been added.]

**3.4**
**tuning sensitivity**
$S_{\mathrm{f,v}}$
ratio of the change of oscillation frequency to the variation of the control voltage

**3.5**
**frequency pushing**
$f_{\mathrm{osc,push}}$
change of the oscillation frequency with the variation of the bias voltage

**3.6**
**frequency pulling**
$f_{\mathrm{osc,pull}}$
change of the oscillation frequency with all phase angles for constant load reflection coefficient

**3.7**
**n-th order harmonic distortion ratio**
$P_{\mathrm{nth}}/P_1$
ratio of the power of the n-th order harmonic component at the output port to the output power at the oscillation frequency

**3.8**
**oscillation frequency range**
difference between the oscillation frequencies at the maximum control voltage and at the minimum control voltage

**3.9**
**output power flatness**
$\Delta P_{\mathrm{o,osc}}$
difference between the maximum and the minimum output power within the control voltage range

**3.10**
**tuning linearity**
ratio of the maximum departure of the oscillation frequency from an ideal straight line between its values at the minimum and maximum control voltages to the oscillation frequency range

**3.11**
**oscillation frequency temperature coefficient**
$\alpha_{\mathrm{f,temp}}$
ratio of the change in oscillation frequency to the corresponding change in temperature

**3.12**
**output power temperature coefficient**
$\alpha_{\mathrm{P,temp}}$
ratio of the change in output power to the corresponding change in temperature

**3.13**
**spurious distortion ratio**
$P_{\mathrm{s}}/P_1$
ratio of the power of the maximum spurious component at the output port to the output power at the oscillation frequency

### 3.14
### load mismatch tolerance

~~$\Psi_L$~~

~~maximum load VSWR (voltage standing-wave ratio) in the range where the device oscillates with no unexpected spurious intensity and/or no discontinuity of frequency tuning characteristics (in case of VCO) at all phase angles~~

$\psi_L$

maximum load VSWR in the range where the device oscillates with no unexpected spurious intensity and/or no discontinuity of frequency tuning characteristics (in case of VCO) at all phase angles

Note 1 to entry: "VSWR" is an abbreviation of "voltage standing wave ratio".

Note 2 to entry: "VCO" is an abbreviation of "voltage controlled oscillator".

### 3.15
### load mismatch ruggedness

$\Psi_R$

maximum load VSWR in the range where the device withstand load mismatch with no degradation at all phase angles with specified conditions

[SOURCE: IEC 60747-4:2007, 7.2.22]

### 3.16
### modulation bandwidth

$B_{mod}$

modulating frequency at which the frequency deviation decreases by 3 dB from its dc value

### 3.17
### sensitivity flatness

ratio of the maximum departure of the tuning sensitivity from an ideal straight line between its values at the minimum and maximum control voltages to the oscillation frequency range

## 4 Essential ratings and characteristics

### 4.1 General requirements

#### 4.1.1 Circuit identification and types

The identification of type (device name), the category of circuit and technology applied shall be given.

Microwave oscillators are divided into two categories:

- type A: fixed oscillator;
- type B: voltage controlled oscillator.

#### 4.1.2 General function description

A general description of the function performed by the integrated circuit microwave oscillators and the features for the application shall be made.

#### 4.1.3 Manufacturing technology

The manufacturing technology, e.g. semiconductor monolithic integrated circuit, thin film integrated circuit, micro-assembly, etc. shall be stated. This statement shall include details of the semiconductor technologies such as Schottky barrier diode, MESFET, Si bipolar transistor, etc.

IEC 60747-4 shall be referred to for terminology and letter symbols, essential ratings and characteristics and measuring methods of such microwave devices.

#### 4.1.4 Package identification

The following statements shall be made:

a) chip or packaged form;

b) IEC and/or national reference number of the outline drawing, or drawing of non-standard package including terminal numbering;

c) principal package material, for example, metal, ceramic, plastic.

### 4.2 Application description

#### 4.2.1 Conformance to system and/or interface information

It should be stated whether the integrated circuit conforms to an application system and/or an interface standard or a recommendation.

Detailed information concerning application systems, equipment and circuits such as very small aperture terminal (VSAT) systems, broadcasting satellite (BS) receivers, microwave landing systems, etc. should also be given.

#### 4.2.2 Overall block diagram

A block diagram of the applied systems should be given if necessary.

#### 4.2.3 Reference data

The most important properties that permit comparison between derivative types should be given.

#### 4.2.4 Electrical compatibility

It should be stated whether the integrated circuit is electrically compatible with other particular integrated circuits, or families of integrated circuits, or whether special interfaces are required.

Details should be given concerning the type of output circuits, e.g. output impedances, d.c. block, open-drain, etc. Interchangeability with other devices, if any, should also be given.

#### 4.2.5 Associated devices

If applicable, the following should be stated:

- devices necessary for correct operation (list with type number, name and function);
- peripheral devices with direct interfacing (list with type number, name and function).

### 4.3 Specification of the function

#### 4.3.1 Detailed block diagram – Functional blocks

A detail block diagram or equivalent circuit information of the integrated circuit microwave oscillators shall be given. The block diagram shall be composed of the following:

a) functional blocks;

b) mutual interconnections among the functional blocks;

c) individual functional units within the functional blocks;

d) mutual interconnections among the individual functional blocks;

e) function of each external connection;

f) inter-dependence between the separate functional blocks.

The block diagram shall identify the function of each external connection and, where no ambiguity can arise, also show the terminal symbols and/or numbers. If the encapsulation has metallic parts, any connection to them from external terminals shall be indicated. The connections with any associated external electrical elements shall be stated, where necessary.

As additional information, the complete electrical circuit diagram can be reproduced, but not necessarily with indications of the values of the circuit components. The graphical symbol for the function shall be given. Rules governing such diagrams may be obtained from IEC 60617.

### 4.3.2 Identification and function of terminals

All terminals shall be identified on the block diagram (supply terminals, output terminals).

The terminal functions 1) to 4) shall be indicated in a table as follows:

| **Terminal number** | **Terminal symbol** | **1) Terminal designation** | **2) Function** | **Function of terminal** | |
|---|---|---|---|---|---|
| | | | | **3) Output identification** | **4) Type of output circuits** |
| | | | | | |

(1) Terminal designation

A terminal designation to indicate the function of the terminal shall be given. Supply terminals, ground terminals, blank terminals (with abbreviation NC), non-usable terminals (with abbreviation NU) shall be distinguished.

(2) Function

A brief indication of the terminal function shall be given:

- each function of multi-role terminals, i.e. terminals having multiple functions;
- each function of integrated circuit selected by mutual pin connections, programming and/or application of function selection data to the function selection pin, such as mode selection pin.

(3) Output identification

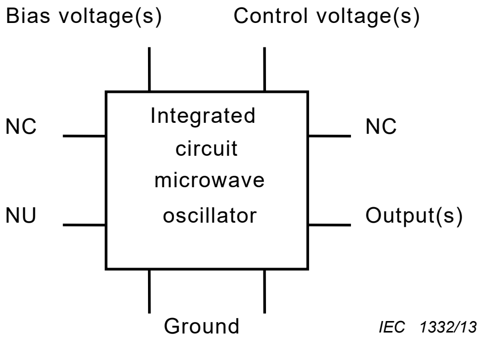
Output and multiplex output terminals shall be distinguished.

(4) Type of output circuits

The type of output circuit, e.g. output impedances, with or without d.c. block, etc., shall be distinguished.

If the baseplate of the package is used as a ground terminal, the type of ground, e.g. analog ground, digital ground, shall be stated in the column of 2) Function.

EXAMPLE



### 4.3.3 Function description

The function performed by the circuit shall be specified, including the following information:

- basic function;
- relation to external terminals;
- operation mode (e.g., set-up method, preference, etc.).

## 4.4 Limiting values (absolute maximum rating system)

### 4.4.1 Requirements

The table for these values shall contain the following:

- Any interdependence of limiting conditions shall be specified.
- If externally connected and/or attached elements, for example heatsinks, have an influence on the values of the ratings, the ratings shall be prescribed for the integrated circuit with the elements connected and/or attached.
- If limiting values are exceeded for transient overload, the permissible excess and their durations shall be specified.
- Where minimum and maximum values differ during programming of the device, this shall be stated.
- All voltages are referenced to a specified reference terminal ($V_{SS}$, ground, etc.).
- In satisfying the following clauses, if maximum and/or minimum values are quoted, the manufacturer shall indicate whether he refers to the absolute magnitude or to the algebraic value of the quantity.
- The ratings given shall cover the operation of the multi-function integrated circuit over the specified range of operating temperatures. Where such ratings are temperature-dependent, these dependence shall be indicated.

### 4.4.2 Electrical limiting values

Limiting values shall be specified as follows:

| Parameters | Min. | Max. |
|---|---|---|
| Bias voltage(s) (where appropriate) | | + |
| Bias current(s) (where appropriate) | | + |
| Control voltage(s) (where appropriate) | | + |
| Control current(s) (where appropriate) | | + |
| Terminal voltage(s) (where appropriate) | + | + |
| Terminal current(s) (where appropriate) | | + |
| Power dissipation | | + |

It is necessary to select either Bias voltage(s) or Bias current(s), either Control voltage(s) or Control current(s), and either Terminal voltage(s) or Terminal current(s).

The detail specification may indicate those values within the table including footnotes a and b.

| Parameters [a], [b] | Symbols | Min. | Max. | Unit |
|---|---|---|---|---|
| | | | | |

[a] Where appropriate, in accordance with the type of circuit considered.

[b] For power supply voltage range:

- limiting value(s) of the continuous voltage(s) at the supply terminal(s) with respect to a special electrical reference point;
- where appropriate, limiting value between specified supply terminals;
- when more than one voltage supply is required, a statement shall be made as to whether the sequence in which these supplies are applied is significant: if so, the sequence shall be stated;
- when more than one supply is needed, it may be necessary to state the combinations of ratings for these supply voltages and currents.

### 4.4.3 Temperatures

a) Operating temperature (ambient or reference-point temperature)

b) Storage temperature

c) Channel temperature

d) Lead temperature (for soldering)

The detail specification may indicate those values within the table including the note.

| Parameters (Note) | Symbols | Min. | Max. | Unit |
|---|---|---|---|---|
| | | | | |

NOTE Where appropriate, in accordance with the type of circuit considered.

## 4.5 Operating conditions (within the specified operating temperature range)

Operating conditions are not to be inspected, but may be used for quality assessment purpose.

a) Power supplies – Positive and/or negative values

b) Initialization sequences (where appropriate)

If special initialization sequences are necessary, power supply sequencing and initialization procedure shall be specified.

c) Input voltage(s) (where appropriate)

d) Output current(s) (where appropriate)

e) Voltage and/or current of other terminal(s)

f) External elements (where appropriate)

g) Operating temperature range

### 4.6 Electrical characteristics

The characteristics shall apply over the full operating temperature range, unless otherwise specified. Each characteristic shall be stated either:

a) over the specified range of operating temperatures, or

b) at a temperature of 25 °C, and at maximum and minimum operating temperatures.

| **Parameters** | **Min.** | **Typ.** | **Max.** | **Types** | |
|---|---|---|---|---|---|
| | | | | **A** | **B** |
| Bias operating current | | + | + | + | + |
| Control operating current | | + | + | | + |
| Oscillation frequency, $f_{osc}$ | + | + | + | + | + |
| Output power, $P_{o,osc}$ | + | + | + | + | + |
| Phase noise, $\mathscr{L}(f)$ | | | + | + | + |
| Tuning sensitivity, $S_{f,v}$ | + | + | | | + |
| Frequency pushing, $f_{osc,push}$ | | | + | + | + |
| Frequency pulling, $f_{osc,pull}$ | | | + | + | + |
| n-th order harmonic distortion ratio, $P_{nth}/P_1$ | | | + | + | + |
| Oscillation frequency range | + | | + | | + |
| Output power flatness, $\Delta P_{o,osc}$ | | + | + | | + |
| Tuning linearity | | + | + | | + |
| Oscillation frequency temperature coefficient, $\alpha_{f,temp}$ | | + | + | + | + |
| Output power temperature coefficient, $\alpha_{P,temp}$ | | + | + | + | + |
| Spurious distortion ratio, $P_s/P_1$ | | | + | + | + |
| Load mismatch tolerance, $\Psi_L$ (where appropriate) | | | + | + | + |
| Load mismatch ruggedness, $\Psi_R$ (where appropriate) | | | + | + | + |
| Modulation bandwidth, $B_{mod}$ (where appropriate) | | + | | | + |
| Sensitivity flatness (where appropriate) | | | + | | + |

### 4.7 Mechanical and environmental ratings, characteristics and data

Any specific mechanical and environmental ratings applicable shall be stated (see also 5.10 and 5.11 of IEC 60747-1:2006).

### 4.8 Additional information

Where appropriate, the following information shall be given:

a) Equivalent output circuit: Detail information shall be given regarding the type of output circuits, e.g. output impedances, d.c. block, open-drain, etc.
b) Internal protection: A statement shall be given to indicate whether the integrated circuit contains internal protection against high static voltages or electrical fields.
c) Capacitors at terminals: If capacitors for the output d.c. block are needed, these capacitances shall be stated.
d) Thermal resistance;
e) Interconnections to other types of circuit: Where appropriate, details of the interconnections to other circuits shall be given.
f) Effects of externally connected component(s): Curves or data indicating the effect of externally connected component(s) that influence the characteristics may be given.
g) Recommendations for any associated device(s): For example, decoupling of power supply to a high-frequency device shall be stated.
h) Handling precautions: Where appropriate, handling precautions specific to the circuit shall be stated (see also IEC 61340-5-1 and IEC/TR 61340-5-2).
i) Application data;
j) Other application information;
k) Date of issue of the data sheet.

## 5 Measuring methods

### 5.1 General

#### 5.1.1 General precautions

The general precautions listed in 6.3, 6.4 and 6.6 of IEC 60747-1:2006 shall be applied. In addition, special care shall be taken to use low-ripple dc power supplies and to decouple adequately all supply terminals at the frequency of measurement. Although the level of the signal can be specified in either power or voltage, in this standard it is expressed in power unless otherwise specified.

#### 5.1.2 Characteristic impedance

The characteristic impedance of the measurement system, shown in the circuit in this standard, is 50 Ω. If it is not 50 Ω, it shall be specified.

#### 5.1.3 Handling precautions

When handling electrostatic-sensitive devices, the handling precautions given in IEC 61340-5-1 and IEC/TR 61340-5-2 shall be observed.

#### 5.1.4 Types

The devices in this standard are both packaged and chip types, measured using suitable test fixtures.

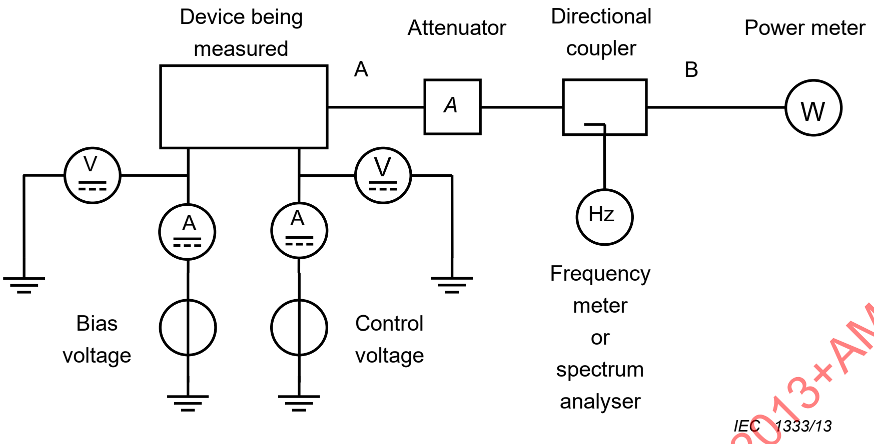
### 5.2 Oscillation frequency ($f_{osc}$)

#### 5.2.1 Purpose

To measure the oscillation frequency under specified conditions.

### 5.2.2 Circuit diagram

The measuring circuit is shown in Figure 1.



NOTE The device being measured can contain a resonance circuit.

**Figure 1 – Circuit diagram for the measurement of the oscillation frequency $f_{osc}$**

### 5.2.3 Principle of measurement

The oscillation frequency is the frequency of the signal generated from the device being measured under specified bias conditions.

### 5.2.4 Circuit description and requirements

The purpose of the attenuator is to reduce the change of the oscillation frequency from a mismatch with oscillator output and load impedance.

### 5.2.5 Precautions to be observed

Harmonics or spurious responses of the device being measured shall be negligible.

### 5.2.6 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the control voltage is set to the specified value.

The value $f_{osc}$ is measured at the frequency meter or spectrum analyser.

### 5.2.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- In case of VCO, control voltage

## 5.3 Output power ($P_{o,osc}$)

### 5.3.1 Purpose

To measure the output power $P_{o,osc}$ under specified conditions.

### 5.3.2 Circuit diagram

See the circuit diagram shown in Figure 1.

### 5.3.3 Principle of measurement

The output power $P_{\text{o,osc}}$ of the device being measured is derived from the following equation:

$$P_{\text{o,osc}} = P_1 + L_1 \tag{1}$$

where

$P_1$ is the value indicated by power meter in dBm;

$L_1$ is the insertion loss from the power at point A to the power at the point B in dB.

### 5.3.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The insertion loss $L_1$ shall be measured beforehand.

### 5.3.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.3.6 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The value $P_1$ is measured by the power meter, then $P_{\text{o,osc}}$ is derived from the Equation (1).

### 5.3.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- In case of VCO, oscillation frequency

## 5.4 Phase noise ($\mathscr{L}(f)$)

### 5.4.1 Purpose

To measure the phase noise under specified conditions.

### 5.4.2 Measuring methods

#### 5.4.2.1 General

Three measuring methods are given:

- Method 1, using a signal generator and phase locked loop (PLL);
- Method 2, using a delay line;
- Method 3, using a spectrum analyser.

Table 1 shows a comparison with those three phase noise measuring methods. Appropriate method shall be selected.

NOTE Method 3 is not rigorous but industrially practical as the evaluation method for the semiconductor oscillator device. Method 3 is applicable when AM noise is negligible.

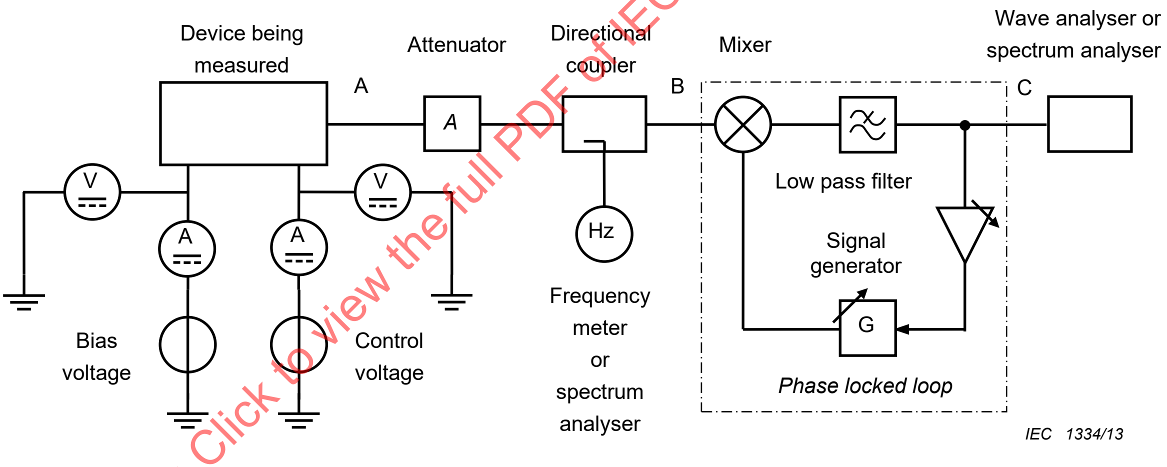
**Table 1 – Comparison of phase noise measuring methods**

| Measuring method | Advantages | Disadvantages |
|---|---|---|
| Method 1 | Applicable to broad offset range<br>Measures very low phase noise at close-in-carrier | Phase noise sensitivity is limited by noise of the signal generator |
| Method 2 | Measures very low noise at far-out-carrier offset<br>Suitable for measuring high drifting oscillators | Not applicable for close-in-carrier phase noise measurement |
| Method 3 | Easy operation<br>Enables quick check of locked signals | Cannot measure close-in-carrier phase noise<br>Cannot measure drifting signals<br>Cannot separate AM noise |

### 5.4.2.2 Measuring method 1

### 5.4.2.2.1 Circuit diagram

The measuring circuit is shown in Figure 2.



NOTE The device being measured can contain a resonance circuit.

**Figure 2 – Circuit diagram for the measurement of the phase noise $\mathscr{L}(f)$ (method 1)**

### 5.4.2.2.2 Principle of measurement

The phase noise $\mathscr{L}(f)$ is derived from the following equation:

$$\mathscr{L}(f) = P_{\mathrm{SSB}} - P_{\mathrm{o,osc}} \quad (2)$$

where

$P_{\mathrm{SSB}}$ is the single sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, in dBm/Hz.

NOTE $\mathscr{L}(f)$ is indicated in dBc/Hz.

The single sideband noise power density $P_{\mathrm{SSB}}$ is derived from the following equation:

$$P_{\mathrm{SSB}} = P_{\mathrm{DSB}} - 3 + L_2 \tag{3}$$

where

$P_{\mathrm{DSB}}$ is the double sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, indicated by the wave analyser or spectrum analyser, in dBm/Hz;

$L_2$ is the ~~conversion gain~~ circuit loss from point A to point C.

$L_2$ is expressed in dB.

#### 5.4.2.2.3 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The signal generator and device being measured will naturally lock so that their signals have a phase difference of 90 degrees, and the PLL output voltage fluctuations correspond to phase fluctuations between the signal generator and device being measured. The value of $L_2$ shall be measured beforehand (See 6.2 of IEC 60747-16-3:2002).

#### 5.4.2.2.4 Precautions to be observed

See the precautions to be observed in 5.2.5.

The phase noise of the signal generator shall be as good or better than that of device being measured.

~~The value of the output oscillation power $P_{\mathrm{o,osc}}$ shall be measured at the point B beforehand (see 5.3).~~

The value of the output power $P_{\mathrm{o.osc}}$ defined at the point A shall be measured beforehand (see 5.3).

#### 5.4.2.2.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

A frequency of the signal generator is set at the oscillation frequency of device being measured.

The double sideband noise power density $P_{\mathrm{DSB}}$ at the frequency shifted by the specified offset is measured by the wave analyser or spectrum analyser.

The single sideband noise power density $P_{\mathrm{SSB}}$ is derived from Equation (3).

The phase noise $\mathscr{L}(f)$ is derived from Equation (2).

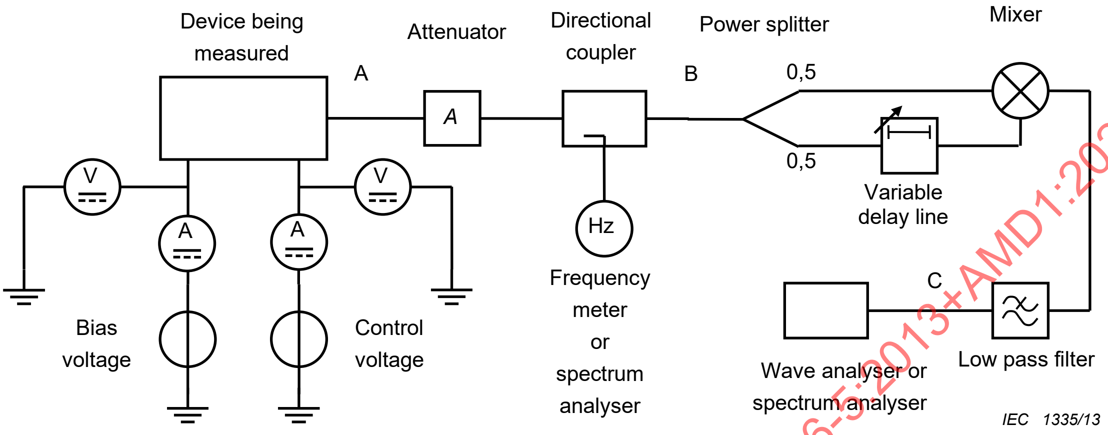
#### 5.4.2.2.6 Specified conditions

- Ambient or reference-point temperature
- In case of VCO, oscillation frequency
- Bias conditions
- Offset frequency

### 5.4.2.3 Measuring method 2

#### 5.4.2.3.1 Circuit diagram

The measuring circuit is shown in Figure 3.



NOTE The device being measured can contain a resonance circuit.

**Figure 3 – Circuit diagram for the measurement of the phase noise $\mathscr{L}(f)$ (method 2)**

#### 5.4.2.3.2 Principle of measurement

See the principle of measurement in 5.4.2.2.2.

#### 5.4.2.3.3 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The variable delay line is adjusted to set the phase between divided signals at 90 degrees. The value of $L_2$ shall be measured beforehand (see 6.2 of IEC 60747-16-3:2002).

#### 5.4.2.3.4 Precautions to be observed

See the precautions to be observed in 5.2.5.

~~The value of the output oscillation power $P_{o,osc}$ shall be measured at the point B beforehand (see 5.3).~~

The value of the output power $P_{o.osc}$ defined at the point A shall be measured beforehand (see 5.3).

#### 5.4.2.3.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The double sideband noise power density $P_{DSB}$ at the frequency shifted by the specified offset is measured by the wave analyser or spectrum analyser.

The single sideband noise power density $P_{SSB}$ is derived from Equation (3).

The phase noise $\mathscr{L}(f)$ is derived from Equation (2).

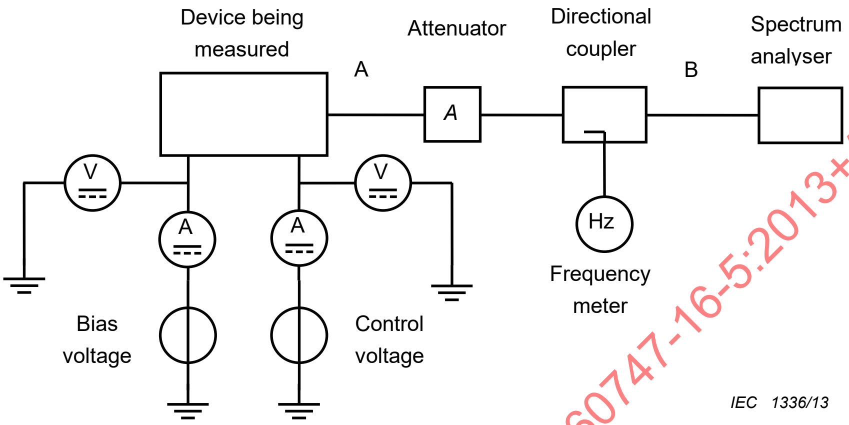
#### 5.4.2.3.6 Specified conditions

See the specified conditions in 5.4.2.2.6.

### 5.4.2.4 Measuring method 3

#### 5.4.2.4.1 Circuit diagram

The measuring circuit is shown in Figure 4.



NOTE The device being measured can contain a resonance circuit.

**Figure 4 – Circuit diagram for the measurement of the phase noise $\mathscr{L}(f)$ (method 3)**

#### 5.4.2.4.2 Principle of measurement

The phase noise $\mathscr{L}(f)$ is derived from the following equation:

$$\mathscr{L}(f) = P_{\mathrm{SSB}} - P_{\mathrm{o,osc}} \tag{4}$$

where

$P_{\mathrm{SSB}}$ is the single sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, in dBm/Hz.

NOTE $\mathscr{L}(f)$ is indicated in dBc/Hz.

The single sideband noise power density $P_{\mathrm{SSB}}$ is derived from the following equation:

$$P_{\mathrm{SSB}} = P_{\mathrm{SSB2}} + L_2 \tag{5}$$

where

$P_{\mathrm{SSB2}}$ is the single sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, indicated by the spectrum analyser, in dBm/Hz;

~~$L_2$ is the power at the point B in dBm, less the power at the point A in dBm.~~

$L_2$ is the circuit loss from point A to point B.

$L_2$ is expressed in dB.

#### 5.4.2.4.3 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The value of $L_2$ shall be measured beforehand.

#### 5.4.2.4.4 Precautions to be observed

See the precautions to be observed in 5.2.5.

~~The value of the output oscillation power $P_{o,osc}$ shall be measured at the point B beforehand (see 5.3).~~

The value of the output power $P_{o.osc}$ defined at the point A shall be measured beforehand (see 5.3).

#### 5.4.2.4.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The resolution band width of the spectrum analyser is set to a sufficiently small value which compared with a specified offset frequency value.

The single sideband noise power density $P_{SSB2}$ at the frequency shifted by the specified offset, is measured by the spectrum analyser.

The single sideband noise power density $P_{SSB}$ is derived from Equation (5).

The phase noise $\mathscr{L}(f)$ is derived from Equation (4).

#### 5.4.2.4.6 Specified conditions

See the specified conditions in 5.4.2.2.6.

### 5.5 Tuning sensitivity ($S_{f,v}$)

#### 5.5.1 Purpose

To measure the tuning sensitivity under specified conditions.

#### 5.5.2 Circuit diagram

See the circuit diagram shown in Figure 1.

#### 5.5.3 Principle of measurement

The tuning sensitivity $S_{f,v}$ is derived from the following equation:

$$S_{f,v} = \frac{f_{osc}(V_1) - f_{osc}(V_2)}{V_1 - V_2} \tag{6}$$

where

| | |
|---|---|
| $V_1$ | is the specified control voltage; |
| $V_2$ | is the specified control voltage; |
| $f_{osc}(V_1)$ | is the oscillation frequency at the specified control voltage $V_1$; |
| $f_{osc}(V_2)$ | is the oscillation frequency at the specified control voltage $V_2$. |

### 5.5.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

### 5.5.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.5.6 Measurement procedure

The bias under specified conditions is supplied.

The value $f_{\text{osc}}(V_1)$ is measured by the frequency meter or spectrum analyser at the specified control voltage $V_1$.

The value $f_{\text{osc}}(V_2)$ is measured by the frequency meter or spectrum analyser at the specified control voltage $V_2$.

The tuning sensitivity $S_{\text{f,v}}$ is derived from the Equation (6).

### 5.5.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Control voltages

## 5.6 Frequency pushing ($f_{\text{osc,push}}$)

### 5.6.1 Purpose

To measure the frequency pushing under specified conditions.

### 5.6.2 Circuit diagram

See the circuit diagram shown in Figure 1.

### 5.6.3 Principle of measurement

The frequency pushing $f_{\text{osc,push}}$ is derived from the following equation:

$$f_{\text{osc,push}} = f_{\text{osc,max}} - f_{\text{osc,min}} \tag{7}$$

where

$f_{\text{osc,max}}$ is the maximum oscillation frequency through the specified bias voltage range;

$f_{\text{osc,min}}$ is the minimum oscillation frequency through the specified bias voltage range.

### 5.6.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

### 5.6.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.6.6 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The maximum and minimum oscillation frequencies are measured by varying the bias voltage through the specified voltage range.

The frequency pushing $f_{\text{osc,push}}$ is derived from Equation (7).

### 5.6.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Bias voltage range
- In case of VCO, oscillation frequency

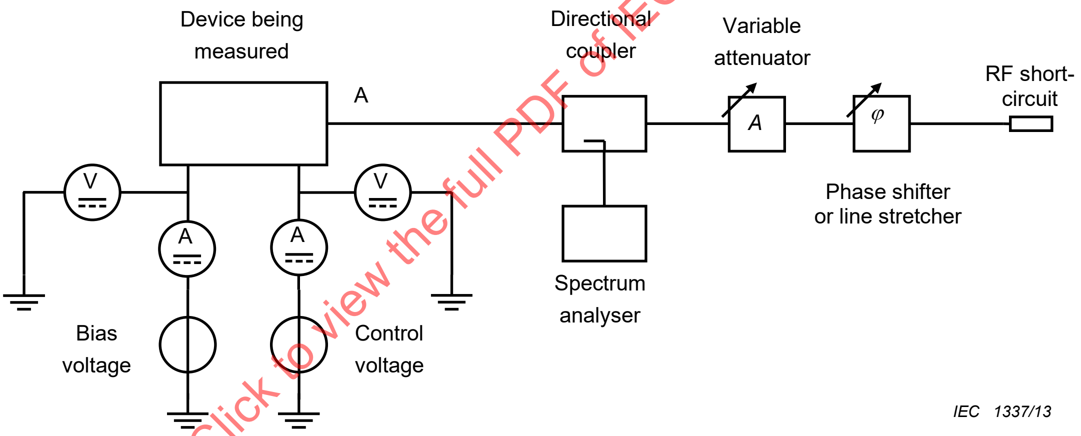
## 5.7 Frequency pulling ($f_{\text{osc,pull}}$)

### 5.7.1 Purpose

To measure the frequency pulling under specified conditions.

### 5.7.2 Circuit diagram

The measuring circuit is shown in Figure 5.



NOTE The device being measured can contain a resonance circuit.

**Figure 5 – Circuit diagram for the measurement of the frequency pulling $f_{\text{osc,pull}}$**

### 5.7.3 Principle of measurement

The frequency pulling $f_{\text{osc,pull}}$ is derived from the following equation:

$$f_{\text{osc,pull}} = f_{\text{osc,max}} - f_{\text{osc,min}} \tag{8}$$

where

| | |
|---|---|
| $f_{\text{osc,max}}$ | is the maximum oscillation frequency for all phase angles with the specified reflection coefficient or VSWR; |
| $f_{\text{osc,min}}$ | is the minimum oscillation frequency for all phase angles with the specified reflection coefficient or VSWR. |

### 5.7.4 Circuit description and requirements

The spectrum analyser shall be capable of operating within specified frequency range for checking no unexpected oscillation and no spurious intensity. The spectrum analyser shall have a specified dynamic range.

The phase shifter shall be capable of keeping the load VSWR or the magnitude of the load reflection coefficient constant. The line stretcher is suitable for this purpose. The output port of the phase shifter shall be shorted.

The purpose of the variable attenuator is to realize the specified reflection coefficient or VSWR.

### 5.7.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

The reflection coefficient or VSWR shall be kept constant at all phase angles of the phase shifter.

### 5.7.6 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The variable attenuator is adjusted to have the specified load reflection coefficient at point A.

The maximum and minimum oscillation frequencies are measured by varying the phase of the variable phase shifter for all phase angles.

The frequency pulling $f_{\text{osc,pull}}$ is derived from the Equation (8).

### 5.7.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- In case of VCO, oscillation frequency
- Load reflection coefficient or VSWR

## 5.8 n-th order harmonic distortion ratio ($P_{\text{nth}}/P_1$)

### 5.8.1 Purpose

To measure the n-th order harmonic distortion ratio under specified conditions.

### 5.8.2 Circuit diagram

See the circuit diagram shown in Figure 4.

### 5.8.3 Principle of measurement

~~The n-th order harmonic distortion ratio $P_{\text{nth}}/P_1$ is derived from the following equation:~~

~~$P_{\text{nth}}/P_1 = P_{\text{nth}} - P_1$ (9)~~

~~where~~

~~$P_1$ is the output power of the fundamental (or desired) frequency in dBm;~~

~~$P_{nth}$ is the output power of the n-th order harmonic frequency in dBm;~~

~~$P_{nth}/P_1$ is expressed in dBc.~~

~~NOTE For example, in case of doubling oscillator, the harmonics includes n-th/2 subharmonics.~~

The $n$-th order harmonic distortion ratio $P_{nth}/P_1$ is derived from the following equations:

$$P_{nth}/P_1 = P_{nth} - P_1 \tag{9}$$

$$P_1 = P(f_1) + L(f_1)$$

$$P_{nth} = P(f_{nth}) + L(f_{nth})$$

where

| | |
|---|---|
| $P_1$ | is the output power of the fundamental (or desired) frequency; |
| $P_{nth}$ | is the power of the n-th order harmonic frequency; |
| $P(f_1)$ | is the value indicated by the spectrum analyser at the output frequency $f_1$; |
| $P(f_{nth})$ | is the value indicated by the spectrum analyser at the n-th order harmonic frequency $f_{nth}$; |
| $L(f_1)$ | is the circuit loss from point A to point B at the output frequency $f_1$; |
| $L(f_{nth})$ | is the circuit loss from point A to point B at the n-th order harmonic frequency $f_{nth}$; |

$P_1$, $P_{nth}$, $P(f_1)$ and $P(f_{nth})$ are expressed in dBm, $P_{nth}/P_1$, $L(f_1)$ and $L(f_{nth})$ are expressed in dB.

NOTE For example, in case of doubling oscillator the harmonics include n-th/2 subharmonics.

### 5.8.4 Circuit description and requirements

See the circuit description and requirements in 5.4.2.4.3.

### 5.8.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The value $P_1$ and $P_{nth}$ are measured at the spectrum analyser.

The n-th order harmonic distortion ratio $P_{nth}/P_1$ is derived from the Equation (9).

### 5.8.6 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- In case of VCO, oscillation frequency

## 5.9 Output power flatness ($\Delta P_{o,osc}$)

### 5.9.1 Purpose

To measure the output power flatness under specified conditions.

### 5.9.2 Circuit diagram

See the circuit diagram shown in Figure 1.

### 5.9.3 Principle of measurement

See the principle of measurement in 5.3.3.

Output power flatness is derived from the following equation:

$$\Delta P_{\mathrm{o,osc}} = P_{\mathrm{o,osc(max)}} - P_{\mathrm{o,osc(min)}} \tag{10}$$

where $P_{\mathrm{o,osc(max)}}$ and $P_{\mathrm{o,osc(min)}}$ are the maximum and the minimum output power in the specified control voltage range, respectively.

### 5.9.4 Circuit description and requirements

See the circuit description and requirements in 5.3.4.

### 5.9.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.9.6 Measurement procedure

The bias under specified conditions is supplied.

Vary the control voltage in the specified voltage range.

Obtain the maximum output power and the minimum output power in the specified control voltage range.

Output power flatness is derived from Equation (10).

### 5.9.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Control voltage range

## 5.10 Tuning linearity

### 5.10.1 Purpose

To measure the tuning linearity under specified conditions.

### 5.10.2 Circuit diagram

See the circuit diagram shown in Figure 1.

### 5.10.3 Principle of measurement

See the principle of measurement in 5.2.3.

Tuning linearity $\delta_{\mathrm{f}}$ is derived from following equation:

$$\delta_\mathrm{f} = \frac{f_\mathrm{dev}}{f_\mathrm{osc,range}} \times 100 \qquad (11)$$

$$f_\mathrm{osc,range} = f_\mathrm{osc}(V_\mathrm{max}) - f_\mathrm{osc}(V_\mathrm{min})$$

where

| | |
|---|---|
| $f_\mathrm{osc}(V_\mathrm{max})$ | is the oscillation frequency at the specified maximum control voltage $V_\mathrm{max}$; |
| $f_\mathrm{osc}(V_\mathrm{min})$ | is the oscillation frequency at the specified minimum control voltage $V_\mathrm{min}$; |
| $f_\mathrm{dev}$ | is the maximum difference of the oscillation frequency from the ideal oscillation frequency on the straight line that is obtained by connecting the oscillation frequency at the minimum and the maximum control voltage. |

NOTE A best-fit straight line obtained by regression method can be used for the ideal straight line. See Figure 6.

Tuning linearity $\delta_\mathrm{f}$ is the value indicated in %.

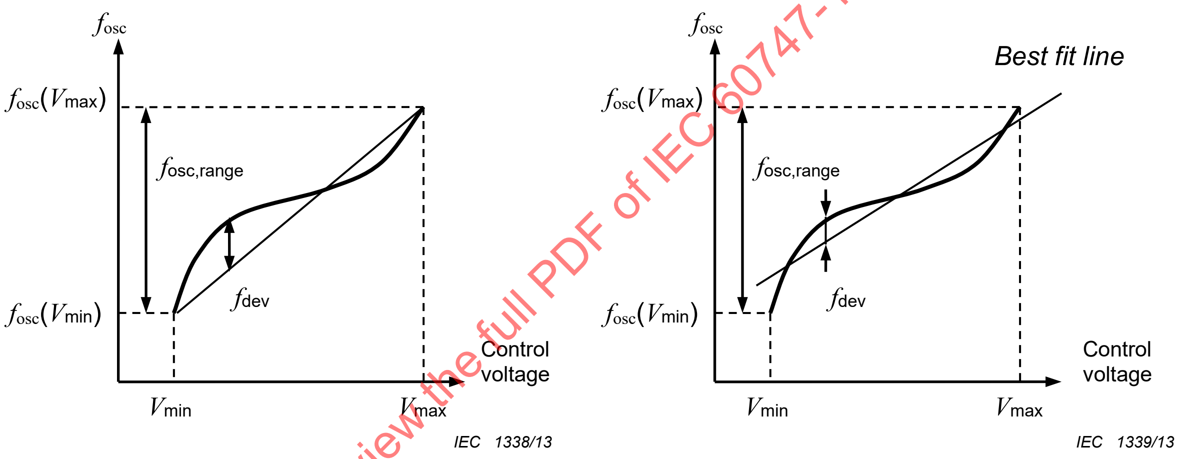


Figure 6 – Tuning linearity

### 5.10.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

### 5.10.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.10.6 Measurement procedure

The bias under specified conditions is supplied.

Vary the control voltage in the specified voltage range.

Plot the oscillation frequency versus the control voltage characteristics in the specified control voltage range.

Tuning linearity $\delta_\mathrm{f}$ is derived from Equation (11).

### 5.10.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Control voltage range

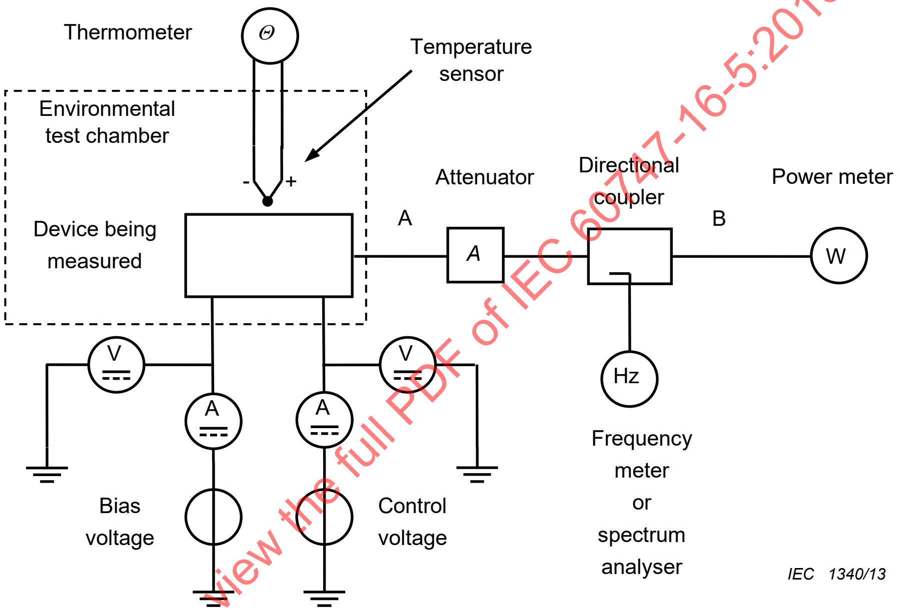
## 5.11 Frequency temperature coefficient ($\alpha_{\mathrm{f,temp}}$)

### 5.11.1 Purpose

To measure the oscillation frequency temperature coefficient under specified conditions.

### 5.11.2 Circuit diagram

The measuring circuit is shown in Figure 7.



NOTE The device being measured can contain a resonance circuit.

**Figure 7 – Circuit diagram for the measurement of the oscillation frequency temperature coefficient $\alpha_{\mathrm{f,temp}}$**

### 5.11.3 Principle of measurement

The oscillation frequency temperature coefficient is derived from the following equation:

$$\alpha_{\mathrm{f,temp}} = \frac{f_{\mathrm{osc}}(T_1) - f_{\mathrm{osc}}(T_2)}{T_1 - T_2} \tag{12}$$

where

$T_1$ and $T_2$ are the ambient or reference-point temperatures;
$f_{\mathrm{osc}}(T_1)$ is the oscillation frequency at the temperature $T_1$;
$f_{\mathrm{osc}}(T_2)$ is the oscillation frequency at the temperature $T_2$.

### 5.11.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

### 5.11.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.11.6 Measurement procedure

The bias under specified conditions is supplied.

The ambient temperature is set to the specified value $T_1$ by the environmental chamber, the temperature sensor and the thermometer.

In case of VCO, the oscillation frequency is set to the specified value.

The value $f_{\mathrm{osc}}(T_1)$ is measured by the frequency meter or spectrum analyser at the specified temperature $T_1$.

The ambient temperature is set to the specified value $T_2$ by the environmental chamber, the temperature sensor and the thermometer.

The value $f_{\mathrm{osc}}(T_2)$ is measured by the frequency meter or spectrum analyser at the specified temperature $T_2$.

The oscillation frequency temperature coefficient $\alpha_{\mathrm{f,temp}}$ is derived from Equation (12).

### 5.11.7 Specified conditions

- Ambient or reference-point temperatures, $T_1$ and $T_2$
- Bias conditions
- In case of VCO, oscillation frequency

## 5.12 Output power temperature coefficient ($\alpha_{\mathrm{P,temp}}$)

### 5.12.1 Purpose

To measure the output power temperature coefficient under specified conditions.

### 5.12.2 Circuit diagram

See the circuit diagram shown in Figure 7.

### 5.12.3 Principle of measurement

The output power temperature coefficient is derived from the following equation:

$$P_{\mathrm{o,osc}}(T_1) = P_1 + L_1 \tag{13}$$

$$P_{\mathrm{o,osc}}(T_2) = P_2 + L_1 \tag{14}$$

$$\alpha_{\mathrm{P,temp}} = \frac{P_{\mathrm{o,osc}}(T_1) - P_{\mathrm{o,osc}}(T_2)}{T_1 - T_2} = \frac{P_1 - P_2}{T_1 - T_2} \tag{15}$$

where

| | |
|---|---|
| $L_1$ | is the insertion loss from point A to point B in dB; |
| $T_1$ and $T_2$ | are the ambient or reference-point temperatures; |
| $P_1$ | is the value indicated by power meter in dBm at the temperature $T_1$; |
| $P_2$ | is the value indicated by power meter in dBm at the temperature $T_2$. |

### 5.12.4 Circuit description and requirements

See the circuit description and requirements in 5.3.4.

### 5.12.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.12.6 Measurement procedure

The bias under specified conditions is supplied.

The ambient temperature is set to the specified value $T_1$ by the environmental chamber, the temperature sensor and the thermometer.

In case of VCO, the oscillation frequency is set to the specified value.

The value $P_1$ is measured by the power meter at the specified temperature $T_1$.

The ambient temperature is set to the specified value $T_2$ by the environmental chamber, the temperature sensor and the thermometer.

In case of VCO, the oscillation frequency is set to the specified value once more.

The value $P_2$ is measured by the power meter at the specified temperature $T_2$.

The output power temperature coefficient $\alpha_{\mathrm{P,temp}}$ is derived from Equations (13) to (15).

### 5.12.7 Specified conditions

See the specified conditions in 5.11.7.

## 5.13 Spurious distortion ratio ($P_s/P_1$)

### 5.13.1 Purpose

To measure the spurious distortion ratio under specified conditions.

### 5.13.2 Circuit diagram

See the circuit diagram shown in Figure 4.

### 5.13.3 Principle of measurement

~~The spurious distortion ratio $P_s/P_1$ is derived from the following equation:~~

$$\cancel{P_s/P_1 = P_s - P_1} \qquad \cancel{(16)}$$

~~where~~

~~$P_1$ is the output power of the fundamental (or desired) frequency in dBm;~~

~~$P_s$ is the maximum power of the spurious output, except harmonic components, in dBm;~~

~~$P_s/P_1$ is expressed in dBc.~~

The spurious distortion ratio $P_s/P_1$ is derived from the following equations:

$$P_{s/}P_1 = P_s - P_1 \qquad (16)$$

$$P_1 = P(f_1) + L(f_1)$$

$$P_s = P(f_s) + L(f_s)$$

where

| | |
|---|---|
| $P_1$ | is the output power of the fundamental (or desired) frequency; |
| $P_s$ | is the maximum power of the spurious output, except harmonic components; |
| $P(f_1)$ | is the value indicated by the spectrum analyser at the output frequency $f_1$; |
| $P(f_s)$ | is the value indicated by the spectrum analyser at the spurious frequency $f_s$; |
| $L(f_1)$ | is the circuit loss from point A to point B at the output frequency $f_1$; |
| $L(f_s)$ | is the circuit loss from point A to point B at the spurious frequency $f_{s;}$ |

$P_1$, $P_s$, $P(f_1)$ and $P(f_s)$ are expressed in dBm, $P_{s/}P_1$, $L(f_1)$ and $L(f_s)$ are expressed in dB.

### 5.13.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

### 5.13.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The value $P_1$ and $P_s$ are measured at the spectrum analyser within the specified observing frequency range.

The spurious distortion ratio $P_s/P_1$ is derived from the Equation (16).

### 5.13.6 Specified conditions

– Ambient or reference-point temperature
– Bias conditions
– In case of VCO, oscillation frequency
– Observing frequency range

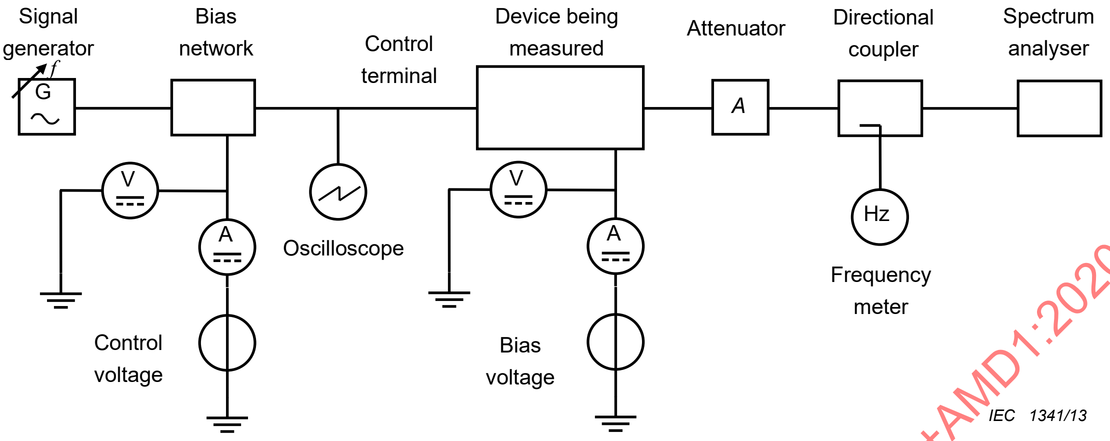
## 5.14 Modulation bandwidth ($B_{mod}$)

### 5.14.1 Purpose

To measure the modulation bandwidth under specified conditions.

### 5.14.2 Circuit diagram

The measuring circuit is shown in Figure 8.



NOTE The device being measured can contain a resonance circuit.

**Figure 8 – Circuit diagram for the measurement of the modulation bandwidth $B_{\text{mod}}$**

### 5.14.3 Principle of measurement

In a practical VCO, frequency deviation for a constant modulation signal voltage $V_{\text{mod}}$ reduces as the frequency of modulation signal $f_{\text{mod}}$ increases. The frequency at which the frequency deviation reduces to −3 dB (or 0,707) of the dc value is a measure of the frequency response of the control terminal. It is defined as the modulation bandwidth $B_{\text{mod}}$.

In terms of frequency modulation (FM) system, the spectral response of a carrier follows a Bessel function characteristics. The amplitude of the sideband signal is proportional to the n-th order Bessel function $J_n(\beta)$. The carrier amplitude is proportional to the $J_0(\beta)$, the first sideband amplitude is to $J_1(\beta)$, etc.

Where $\beta$ is named "modulation index" and defined by the following equation:

$$\beta = (\text{frequency deviation}) / f_{\text{mod}}$$

$$= (S_{\text{f,v}} \times V_{\text{mod}}) / f_{\text{mod}} \tag{17}$$

And the amplitude of the modulation signal is derived from:

$$V_{\text{mod}} = (\beta \times f_{\text{mod}}) / S_{\text{f,v}} \tag{18}$$

where $S_{\text{f,v}}$ is the tuning sensitivity of the VCO, $V_{\text{mod}}$ and $f_{\text{mod}}$ are the amplitude and frequency of the modulation signal respectively.

With certain values of $\beta$, there are nulls of the magnitude.

### 5.14.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The output impedance of the signal generator is usually 50 Ω. It can be transformed to an appropriate value by a transformer.

### 5.14.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

The whole voltage applied to control terminal shall not exceed its range.

### 5.14.6 Measurement procedure

The bias under specified conditions is supplied.

The oscillation frequency is set to the specified value.

The value $P_{\mathrm{osc}}(V_{\mathrm{mod}} = 0)$ is measured by the spectrum analyser as the power of the unmodulated carrier.

The frequency of the modulation signal $f_{\mathrm{mod}}$ is adjusted to a tenth of the anticipated modulation bandwidth $B_{\mathrm{mod}}$ and the magnitude of modulation signal $V_{\mathrm{mod}}$ is set to achieve a modulation index $\beta$ of 2,4 using Equation (18).

Ensure that the magnitude of the carrier is suppressed to less than −30 dB of $P_{\mathrm{osc}}(V_{\mathrm{mod}} = 0)$ by tuning $V_{\mathrm{mod}}$ finely.

Increase the modulation frequency $f_{\mathrm{mod}}$ and the amplitude of modulation signal $V_{\mathrm{mod}}$ slowly, keeping the ratio of $V_{\mathrm{mod}}/f_{\mathrm{mod}}$ constant.

When the magnitude of carrier increases to −8 dB of $P_{\mathrm{osc}}(V_{\mathrm{mod}} = 0)$, the modulation index $\beta$ is equal to 1,697 (= 2,4 × 0,707) and the frequency deviation is reduced to −3 dB (or 0,707) from Equation (17).

The value $f_{\mathrm{mod}}(\beta = 1{,}697)$ is read from the signal generator.

The modulation bandwidth $B_{\mathrm{mod}}$ is equal to $f_{\mathrm{mod}}(\beta = 1{,}697)$.

### 5.14.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Oscillation frequency

## 5.15 Sensitivity flatness

### 5.15.1 Purpose

To measure the sensitivity flatness under specified conditions.

### 5.15.2 Circuit diagram

See the circuit diagram shown in Figure 1.

### 5.15.3 Principle of measurement

See the principle of measurement in 5.5.3.

Sensitivity flatness $\delta_{\mathrm{S}}$ is derived from following equation:

$$\delta_{\mathrm{S}} = \frac{S_{\mathrm{dev}}}{S_{\mathrm{ref}}} \times 100 \qquad (20)$$

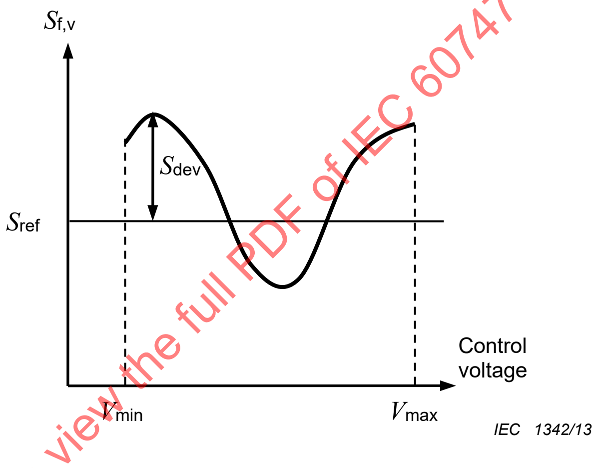
$$S_{\text{ref}} = \frac{f_{\text{osc,range}}}{V_{\text{max}} - V_{\text{min}}}$$

$$f_{\text{osc,range}} = f_{\text{osc}}(V_{\text{max}}) - f_{\text{osc}}(V_{\text{min}})$$

where

| | |
|---|---|
| $V_{\text{max}}$ | is the specified maximum control voltage; |
| $V_{\text{min}}$ | is the specified minimum control voltage; |
| $f_{\text{osc}}(V_{\text{max}})$ | is the oscillation frequency at the specified maximum control voltage $V_{\text{max}}$; |
| $f_{\text{osc}}(V_{\text{min}})$ | is the oscillation frequency at the specified minimum control voltage $V_{\text{min}}$; |
| $S_{\text{dev}}$ | is the maximum difference of the tuning sensitivity from the ideal tuning sensitivity $S_{\text{ref}}$ obtained as the ratio of the oscillation frequency range to the control voltage range. See Figure 9. |

Sensitivity flatness $\delta_{\text{S}}$ is the value indicated in %.



IEC 1342/13

Figure 9 – Sensitivity flatness

### 5.15.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

### 5.15.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.15.6 Measurement procedure

The bias under specified conditions is supplied.

Vary the control voltage in the specified range.

Obtain the maximum difference of the tuning sensitivity in the specified control voltage by using the measurement procedure in 5.5.6.

The sensitivity flatness $\delta_{\text{S}}$ is derived from Equation (20).

#### 5.15.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Control voltage range

## 6 Verifying methods

### 6.1 Load mismatch tolerance ($\Psi_L$)

#### 6.1.1 Purpose

To verify the load mismatch tolerance under specified conditions.

#### 6.1.2 Verifying method 1 (spurious intensity)

##### 6.1.2.1 Circuit diagram

See the circuit diagram shown in Figure 5.

##### 6.1.2.2 Circuit description and requirements

See the circuit description and requirements in 5.7.4.

##### 6.1.2.3 Precautions to be observed

See the precautions to be observed in 5.7.5.

##### 6.1.2.4 Test procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The load VSWR is set to the specified value by adjusting variable attenuator.

The phase angle is swept continuously by varying the length of the line stretcher.

Spurious components less than the specified intensity are confirmed by using the spectrum analyser at all phase angles.

NOTE Instead of the line stretcher, slide screw tuner can be used. An automatic stub-tuner or an electronic tuner is also used to enable the specified VSWR for convenience. The demerit of the tuners is that phase condition is discrete and cannot be swept continuously.

##### 6.1.2.5 Specified conditions

- Ambient or reference-point temperature
- Load VSWR
- Bias conditions
- In case of VCO, oscillation frequency
- Spurious intensity

### 6.1.3 Verifying method 2 (no discontinuity of frequency tuning characteristics of VCO)

#### 6.1.3.1 Circuit diagram

See the circuit diagram shown in Figure 5.

#### 6.1.3.2 Circuit description and requirements

See the circuit description and requirements in 5.7.4.

The control supply (voltage source) shall be capable of sweeping the output voltage electronically.

#### 6.1.3.3 Precautions to be observed

See the precautions to be observed in 5.7.5.

#### 6.1.3.4 Test procedure

The bias under specified conditions is supplied.

The sweep voltage range of the control supply is set to the specified value.

The load VSWR is set to the specified value by adjusting variable attenuator.

The phase angle is swept continuously by varying the length of the line stretcher.

The oscillation frequency is swept continuously and repeatedly by varying the control voltage from minimum voltage to the maximum voltage during all that time.

No discontinuity of the frequency tuning characteristics is confirmed by using the spectrum analyser at all phase angles.

NOTE Instead of the line stretcher, slide screw tuner can be used. An automatic stub-tuner or an electronic tuner is also used to enable the specified VSWR for convenience. The demerit of the tuners is that phase condition is discrete and cannot be swept continuously.

#### 6.1.3.5 Specified conditions

- Ambient or reference-point temperature
- Load VSWR
- Bias conditions
- Control voltage range

## 6.2 Load mismatch ruggedness ($\Psi_R$)

### 6.2.1 Purpose

To verify the load mismatch ruggedness under specified conditions.

### 6.2.2 Circuit diagram

See the circuit diagram shown in Figure 5.

### 6.2.3 Circuit description and requirements

See the circuit description and requirements in 5.7.4.

### 6.2.4 Precautions to be observed

See the precautions to be observed in 5.7.5.

### 6.2.5 Test Procedure

DC and RF characteristics are measured under specified conditions before the following load mismatch test procedure.

The load reflection coefficient or VSWR is set to the specified value by adjusting variable attenuator.

The bias under specified conditions is supplied.

The phase angle is swept continuously by varying the length of the line stretcher.

The device is kept in operation during the specified operation time at all phase angles.

DC and RF characteristics are measured under specified conditions once more.

Load mismatch ruggedness $\Psi_R$ is verified using specified degradation criteria of DC and RF characteristics.

### 6.2.6 Specified conditions

- Ambient or reference-point temperature
- Load reflection coefficient or VSWR
- Bias conditions
- Operation time
- Degradation criteria of DC and RF characteristics
- Measurement conditions of DC and RF characteristics

# Bibliography

IEC 60679-1:2007, *Quartz crystal controlled oscillators of assessed quality – Part 1: Generic specification*

# IEC 60747-16-5

Edition 1.1 2020-07

# FINAL VERSION

## Semiconductor devices –
## Part 16-5: Microwave integrated circuits – Oscillators

IEC 60747-16-5:2013-06+AMD1:2020-07 CSV(en)

# CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

# SEMICONDUCTOR DEVICES –

## Part 16-5: Microwave integrated circuits – Oscillators

## 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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

**This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.**

**IEC 60747-16-5 edition 1.1 contains the first edition (2013-06) [documents 47E/452/FDIS and 47E/454/RVD] and its amendment 1 (2020-07) [documents 47E/673/CDV and 47E/705/RVC] and its corrigendum (2020-09).**

**This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.**

International Standard IEC 60747-16-5 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

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

A list of all parts of the IEC 60747 series, published under the general title *Semiconductor devices,* can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

# SEMICONDUCTOR DEVICES –

# Part 16-5: Microwave integrated circuits – Oscillators

## 1 Scope

This part of IEC 60747 specifies the terminology, essential ratings and characteristics, and measuring methods of microwave integrated circuit oscillators.

This standard is applicable to the fixed and voltage-controlled semiconductor microwave oscillator devices, except the oscillator modules such as synthesizers which require external controllers.

NOTE This document is not applicable to the quartz crystal controlled oscillators. They are specified by IEC 60679-1.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60747-1:2006, *Semiconductor devices – Part 1: General* [1]
Amendment 1:2010

IEC 60747-4:2007, *Semiconductor devices – Discrete devices – Part 4: Microwave diodes and transistors*
IEC 60747-4:2007/AMD 1:2017

IEC 60747-16-3:2002, *Semiconductor devices – Part 16-3: Microwave integrated circuits – Frequency converters*
IEC 60747-16-3:2002/AMD 1:2009
IEC 60747-16-3:2002/AMD 2:2017

IEC 61340-5-1, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC/TR 61340-5-2, *Electrostatics – Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide*

---

[1] A consolidated edition (2010) exists, including IEC 60747-1:2006 and its Amendment 1.

## 3 Terms and definitions

### 3.1
### oscillation frequency

$f_{\mathrm{osc}}$
frequency measured at the output port

### 3.2
### output power

$P_{\mathrm{o,osc}}$
power measured at the output port

### 3.3
### phase noise

$\mathscr{L}(f)$
frequency-domain measure of the short-term frequency stability of an oscillator

Note 1 to entry: This phase noise is normally expressed as the power spectral density of the phase fluctuations, $S_\phi(f)$, where the phase fluctuation function is $\phi(t)=2\pi Ft-2\pi F_0t$. The spectral density of phase fluctuation can be directly related to the spectral density of frequency fluctuation by the following formula:

$$S_\phi(f)=\left(\frac{F_0}{f}\right)S_y(f)\ \mathrm{rad}^2/\mathrm{Hz}$$

where

$F$ is the oscillator frequency;

$F_0$ is the average oscillator frequency;

$f$ is the Fourier frequency.

Note 2 to entry: $\mathscr{L}(f)$ is pronounced "script-ell of f".

[SOURCE: IEC 60050-561:2014, 561-03-22, modified – A symbol and Note 2 to entry have been added.]

### 3.4
### tuning sensitivity

$S_{\mathrm{f,v}}$
ratio of the change of oscillation frequency to the variation of the control voltage

### 3.5
### frequency pushing

$f_{\mathrm{osc,push}}$
change of the oscillation frequency with the variation of the bias voltage

### 3.6
### frequency pulling

$f_{\mathrm{osc,pull}}$
change of the oscillation frequency with all phase angles for constant load reflection coefficient

### 3.7
### n-th order harmonic distortion ratio

$P_{\mathrm{nth}}/P_1$
ratio of the power of the n-th order harmonic component at the output port to the output power at the oscillation frequency

**3.8**
**oscillation frequency range**
difference between the oscillation frequencies at the maximum control voltage and at the minimum control voltage

**3.9**
**output power flatness**
$\Delta P_{\mathrm{o,osc}}$
difference between the maximum and the minimum output power within the control voltage range

**3.10**
**tuning linearity**
ratio of the maximum departure of the oscillation frequency from an ideal straight line between its values at the minimum and maximum control voltages to the oscillation frequency range

**3.11**
**oscillation frequency temperature coefficient**
$\alpha_{\mathrm{f,temp}}$
ratio of the change in oscillation frequency to the corresponding change in temperature

**3.12**
**output power temperature coefficient**
$\alpha_{\mathrm{P,temp}}$
ratio of the change in output power to the corresponding change in temperature

**3.13**
**spurious distortion ratio**
$P_{\mathrm{s}}/P_{1}$
ratio of the power of the maximum spurious component at the output port to the output power at the oscillation frequency

**3.14**
**load mismatch tolerance**
$\psi_{\mathrm{L}}$
maximum load VSWR in the range where the device oscillates with no unexpected spurious intensity and/or no discontinuity of frequency tuning characteristics (in case of VCO) at all phase angles

Note 1 to entry: "VSWR" is an abbreviation of "voltage standing wave ratio".

Note 2 to entry: "VCO" is an abbreviation of "voltage controlled oscillator".

**3.15**
**load mismatch ruggedness**
$\Psi_{\mathrm{R}}$
maximum load VSWR in the range where the device withstand load mismatch with no degradation at all phase angles with specified conditions

[SOURCE: IEC 60747-4:2007, 7.2.22]

**3.16**
**modulation bandwidth**
$B_{\mathrm{mod}}$
modulating frequency at which the frequency deviation decreases by 3 dB from its dc value

### 3.17
**sensitivity flatness**
ratio of the maximum departure of the tuning sensitivity from an ideal straight line between its values at the minimum and maximum control voltages to the oscillation frequency range

## 4 Essential ratings and characteristics

### 4.1 General requirements

#### 4.1.1 Circuit identification and types

The identification of type (device name), the category of circuit and technology applied shall be given.

Microwave oscillators are divided into two categories:

- type A: fixed oscillator;
- type B: voltage controlled oscillator.

#### 4.1.2 General function description

A general description of the function performed by the integrated circuit microwave oscillators and the features for the application shall be made.

#### 4.1.3 Manufacturing technology

The manufacturing technology, e.g. semiconductor monolithic integrated circuit, thin film integrated circuit, micro-assembly, etc. shall be stated. This statement shall include details of the semiconductor technologies such as Schottky barrier diode, MESFET, Si bipolar transistor, etc.

IEC 60747-4 shall be referred to for terminology and letter symbols, essential ratings and characteristics and measuring methods of such microwave devices.

#### 4.1.4 Package identification

The following statements shall be made:

a) chip or packaged form;
b) IEC and/or national reference number of the outline drawing, or drawing of non-standard package including terminal numbering;
c) principal package material, for example, metal, ceramic, plastic.

### 4.2 Application description

#### 4.2.1 Conformance to system and/or interface information

It should be stated whether the integrated circuit conforms to an application system and/or an interface standard or a recommendation.

Detailed information concerning application systems, equipment and circuits such as very small aperture terminal (VSAT) systems, broadcasting satellite (BS) receivers, microwave landing systems, etc. should also be given.

#### 4.2.2 Overall block diagram

A block diagram of the applied systems should be given if necessary.

### 4.2.3 Reference data

The most important properties that permit comparison between derivative types should be given.

### 4.2.4 Electrical compatibility

It should be stated whether the integrated circuit is electrically compatible with other particular integrated circuits, or families of integrated circuits, or whether special interfaces are required.

Details should be given concerning the type of output circuits, e.g. output impedances, d.c. block, open-drain, etc. Interchangeability with other devices, if any, should also be given.

### 4.2.5 Associated devices

If applicable, the following should be stated:

- devices necessary for correct operation (list with type number, name and function);
- peripheral devices with direct interfacing (list with type number, name and function).

## 4.3 Specification of the function

### 4.3.1 Detailed block diagram – Functional blocks

A detail block diagram or equivalent circuit information of the integrated circuit microwave oscillators shall be given. The block diagram shall be composed of the following:

a) functional blocks;
b) mutual interconnections among the functional blocks;
c) individual functional units within the functional blocks;
d) mutual interconnections among the individual functional blocks;
e) function of each external connection;
f) inter-dependence between the separate functional blocks.

The block diagram shall identify the function of each external connection and, where no ambiguity can arise, also show the terminal symbols and/or numbers. If the encapsulation has metallic parts, any connection to them from external terminals shall be indicated. The connections with any associated external electrical elements shall be stated, where necessary.

As additional information, the complete electrical circuit diagram can be reproduced, but not necessarily with indications of the values of the circuit components. The graphical symbol for the function shall be given. Rules governing such diagrams may be obtained from IEC 60617.

### 4.3.2 Identification and function of terminals

All terminals shall be identified on the block diagram (supply terminals, output terminals).

The terminal functions 1) to 4) shall be indicated in a table as follows:

| **Terminal number** | **Terminal symbol** | **1) Terminal designation** | **2) Function** | **Function of terminal** | |
|---|---|---|---|---|---|
| | | | | **3) Output identification** | **4) Type of output circuits** |
| | | | | | |

(1) Terminal designation

A terminal designation to indicate the function of the terminal shall be given. Supply terminals, ground terminals, blank terminals (with abbreviation NC), non-usable terminals (with abbreviation NU) shall be distinguished.

(2) Function

A brief indication of the terminal function shall be given:

- each function of multi-role terminals, i.e. terminals having multiple functions;
- each function of integrated circuit selected by mutual pin connections, programming and/or application of function selection data to the function selection pin, such as mode selection pin.

(3) Output identification

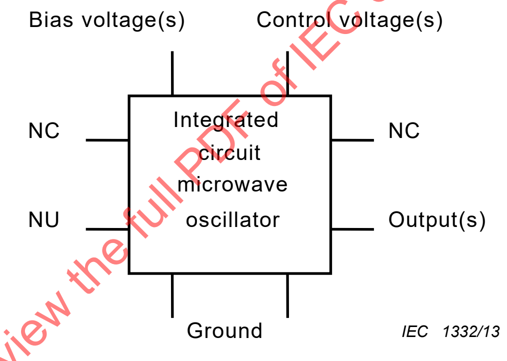
Output and multiplex output terminals shall be distinguished.

(4) Type of output circuits

The type of output circuit, e.g. output impedances, with or without d.c. block, etc., shall be distinguished.

If the baseplate of the package is used as a ground terminal, the type of ground, e.g. analog ground, digital ground, shall be stated in the column of 2) Function.

EXAMPLE



### 4.3.3 Function description

The function performed by the circuit shall be specified, including the following information:

- basic function;
- relation to external terminals;
- operation mode (e.g., set-up method, preference, etc.).

## 4.4 Limiting values (absolute maximum rating system)

### 4.4.1 Requirements

The table for these values shall contain the following:

- Any interdependence of limiting conditions shall be specified.
- If externally connected and/or attached elements, for example heatsinks, have an influence on the values of the ratings, the ratings shall be prescribed for the integrated circuit with the elements connected and/or attached.
- If limiting values are exceeded for transient overload, the permissible excess and their durations shall be specified.
- Where minimum and maximum values differ during programming of the device, this shall be stated.

- All voltages are referenced to a specified reference terminal ($V_{SS}$, ground, etc.).
- In satisfying the following clauses, if maximum and/or minimum values are quoted, the manufacturer shall indicate whether he refers to the absolute magnitude or to the algebraic value of the quantity.
- The ratings given shall cover the operation of the multi-function integrated circuit over the specified range of operating temperatures. Where such ratings are temperature-dependent, these dependence shall be indicated.

### 4.4.2 Electrical limiting values

Limiting values shall be specified as follows:

| **Parameters** | **Min.** | **Max.** |
|---|---|---|
| Bias voltage(s) (where appropriate) | | + |
| Bias current(s) (where appropriate) | | + |
| Control voltage(s) (where appropriate) | | + |
| Control current(s) (where appropriate) | | + |
| Terminal voltage(s) (where appropriate) | + | + |
| Terminal current(s) (where appropriate) | | + |
| Power dissipation | | + |
| It is necessary to select either Bias voltage(s) or Bias current(s), either Control voltage(s) or Control current(s), and either Terminal voltage(s) or Terminal current(s). | | |

The detail specification may indicate those values within the table including footnotes a and b.

| **Parameters** [a, b] | **Symbols** | **Min.** | **Max.** | **Unit** |
|---|---|---|---|---|
| | | | | |

[a] Where appropriate, in accordance with the type of circuit considered.

[b] For power supply voltage range:

- limiting value(s) of the continuous voltage(s) at the supply terminal(s) with respect to a special electrical reference point;
- where appropriate, limiting value between specified supply terminals;
- when more than one voltage supply is required, a statement shall be made as to whether the sequence in which these supplies are applied is significant: if so, the sequence shall be stated;
- when more than one supply is needed, it may be necessary to state the combinations of ratings for these supply voltages and currents.

### 4.4.3 Temperatures

a) Operating temperature (ambient or reference-point temperature)

b) Storage temperature

c) Channel temperature

d) Lead temperature (for soldering)

The detail specification may indicate those values within the table including the note.

| **Parameters (Note)** | **Symbols** | **Min.** | **Max.** | **Unit** |
|---|---|---|---|---|
| | | | | |

NOTE Where appropriate, in accordance with the type of circuit considered.

### 4.5 Operating conditions (within the specified operating temperature range)

Operating conditions are not to be inspected, but may be used for quality assessment purpose.

a) Power supplies – Positive and/or negative values
b) Initialization sequences (where appropriate)

If special initialization sequences are necessary, power supply sequencing and initialization procedure shall be specified.

c) Input voltage(s) (where appropriate)
d) Output current(s) (where appropriate)
e) Voltage and/or current of other terminal(s)
f) External elements (where appropriate)
g) Operating temperature range

### 4.6 Electrical characteristics

The characteristics shall apply over the full operating temperature range, unless otherwise specified. Each characteristic shall be stated either:

a) over the specified range of operating temperatures, or
b) at a temperature of 25 °C, and at maximum and minimum operating temperatures.

| **Parameters** | **Min.** | **Typ.** | **Max.** | **Types** | |
|---|---|---|---|---|---|
| | | | | **A** | **B** |
| Bias operating current | | + | + | + | + |
| Control operating current | | + | + | | + |
| Oscillation frequency, $f_{osc}$ | + | + | + | + | + |
| Output power, $P_{o,osc}$ | + | + | + | + | + |
| Phase noise, $\mathscr{L}(f)$ | | | + | + | + |
| Tuning sensitivity, $S_{f,v}$ | + | + | | | + |
| Frequency pushing, $f_{osc,push}$ | | | + | + | + |
| Frequency pulling, $f_{osc,pull}$ | | | + | + | + |
| n-th order harmonic distortion ratio, $P_{nth}/P_1$ | | | + | + | + |
| Oscillation frequency range | + | | + | | + |
| Output power flatness, $\Delta P_{o,osc}$ | | + | + | | + |
| Tuning linearity | | + | + | | + |
| Oscillation frequency temperature coefficient, $\alpha_{f,temp}$ | | + | + | + | + |

| Parameters | Min. | Typ. | Max. | Types | |
|---|---|---|---|---|---|
| | | | | A | B |
| Output power temperature coefficient, $\alpha_{P,\mathrm{temp}}$ | | + | + | + | + |
| Spurious distortion ratio, $P_s/P_1$ | | | + | + | + |
| Load mismatch tolerance, $\Psi_L$<br>(where appropriate) | | | + | + | + |
| Load mismatch ruggedness, $\Psi_R$<br>(where appropriate) | | | + | + | + |
| Modulation bandwidth, $B_{\mathrm{mod}}$<br>(where appropriate) | | + | | | + |
| Sensitivity flatness<br>(where appropriate) | | | + | | + |

### 4.7 Mechanical and environmental ratings, characteristics and data

Any specific mechanical and environmental ratings applicable shall be stated (see also 5.10 and 5.11 of IEC 60747-1:2006).

### 4.8 Additional information

Where appropriate, the following information shall be given:

a) Equivalent output circuit: Detail information shall be given regarding the type of output circuits, e.g. output impedances, d.c. block, open-drain, etc.

b) Internal protection: A statement shall be given to indicate whether the integrated circuit contains internal protection against high static voltages or electrical fields.

c) Capacitors at terminals: If capacitors for the output d.c. block are needed, these capacitances shall be stated.

d) Thermal resistance;

e) Interconnections to other types of circuit: Where appropriate, details of the interconnections to other circuits shall be given.

f) Effects of externally connected component(s): Curves or data indicating the effect of externally connected component(s) that influence the characteristics may be given.

g) Recommendations for any associated device(s): For example, decoupling of power supply to a high-frequency device shall be stated.

h) Handling precautions: Where appropriate, handling precautions specific to the circuit shall be stated (see also IEC 61340-5-1 and IEC/TR 61340-5-2).

i) Application data;

j) Other application information;

k) Date of issue of the data sheet.

## 5 Measuring methods

### 5.1 General

#### 5.1.1 General precautions

The general precautions listed in 6.3, 6.4 and 6.6 of IEC 60747-1:2006 shall be applied. In addition, special care shall be taken to use low-ripple dc power supplies and to decouple adequately all supply terminals at the frequency of measurement. Although the level of the signal can be specified in either power or voltage, in this standard it is expressed in power unless otherwise specified.

### 5.1.2 Characteristic impedance

The characteristic impedance of the measurement system, shown in the circuit in this standard, is 50 Ω. If it is not 50 Ω, it shall be specified.

### 5.1.3 Handling precautions

When handling electrostatic-sensitive devices, the handling precautions given in IEC 61340-5-1 and IEC/TR 61340-5-2 shall be observed.

### 5.1.4 Types

The devices in this standard are both packaged and chip types, measured using suitable test fixtures.

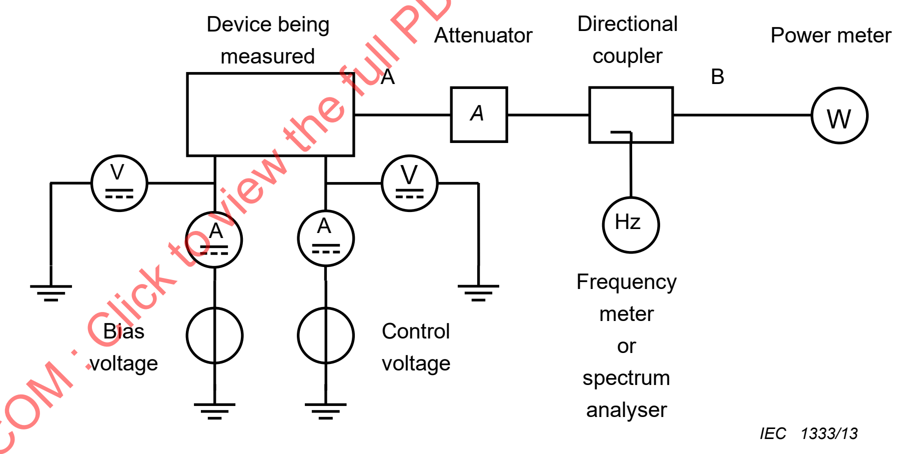
## 5.2 Oscillation frequency ($f_{osc}$)

### 5.2.1 Purpose

To measure the oscillation frequency under specified conditions.

### 5.2.2 Circuit diagram

The measuring circuit is shown in Figure 1.



NOTE The device being measured can contain a resonance circuit.

**Figure 1 – Circuit diagram for the measurement of the oscillation frequency $f_{osc}$**

### 5.2.3 Principle of measurement

The oscillation frequency is the frequency of the signal generated from the device being measured under specified bias conditions.

### 5.2.4 Circuit description and requirements

The purpose of the attenuator is to reduce the change of the oscillation frequency from a mismatch with oscillator output and load impedance.

### 5.2.5 Precautions to be observed

Harmonics or spurious responses of the device being measured shall be negligible.

### 5.2.6 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the control voltage is set to the specified value.

The value $f_{\mathrm{osc}}$ is measured at the frequency meter or spectrum analyser.

### 5.2.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- In case of VCO, control voltage

## 5.3 Output power ($P_{\mathrm{o,osc}}$)

### 5.3.1 Purpose

To measure the output power $P_{\mathrm{o,osc}}$ under specified conditions.

### 5.3.2 Circuit diagram

See the circuit diagram shown in Figure 1.

### 5.3.3 Principle of measurement

The output power $P_{\mathrm{o,osc}}$ of the device being measured is derived from the following equation:

$$P_{\mathrm{o,osc}} = P_1 + L_1 \qquad (1)$$

where

$P_1$ is the value indicated by power meter in dBm;

$L_1$ is the insertion loss from the power at point A to the power at the point B in dB.

### 5.3.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The insertion loss $L_1$ shall be measured beforehand.

### 5.3.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.3.6 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The value $P_1$ is measured by the power meter, then $P_{\mathrm{o,osc}}$ is derived from the Equation (1).

#### 5.3.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- In case of VCO, oscillation frequency

### 5.4 Phase noise ($\mathscr{L}(f)$)

#### 5.4.1 Purpose

To measure the phase noise under specified conditions.

#### 5.4.2 Measuring methods

##### 5.4.2.1 General

Three measuring methods are given:

- Method 1, using a signal generator and phase locked loop (PLL);
- Method 2, using a delay line;
- Method 3, using a spectrum analyser.

Table 1 shows a comparison with those three phase noise measuring methods. Appropriate method shall be selected.

NOTE Method 3 is not rigorous but industrially practical as the evaluation method for the semiconductor oscillator device. Method 3 is applicable when AM noise is negligible.

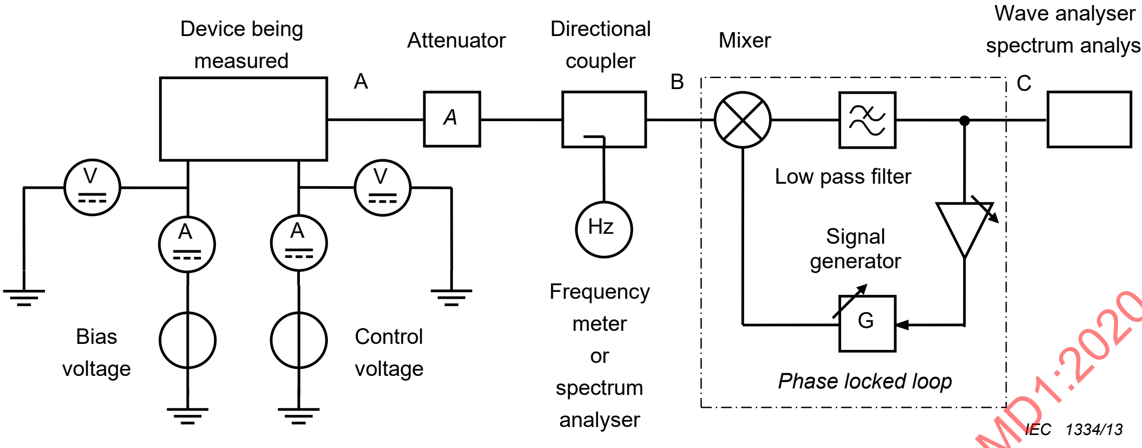
**Table 1 – Comparison of phase noise measuring methods**

| Measuring method | Advantages | Disadvantages |
|---|---|---|
| Method 1 | Applicable to broad offset range<br>Measures very low phase noise at close-in-carrier | Phase noise sensitivity is limited by noise of the signal generator |
| Method 2 | Measures very low noise at far-out-carrier offset<br>Suitable for measuring high drifting oscillators | Not applicable for close-in-carrier phase noise measurement |
| Method 3 | Easy operation<br>Enables quick check of locked signals | Cannot measure close-in-carrier phase noise<br>Cannot measure drifting signals<br>Cannot separate AM noise |

##### 5.4.2.2 Measuring method 1

##### 5.4.2.2.1 Circuit diagram

The measuring circuit is shown in Figure 2.



NOTE The device being measured can contain a resonance circuit.

**Figure 2 – Circuit diagram for the measurement of the phase noise $\mathscr{L}(f)$ (method 1)**

#### 5.4.2.2.2 Principle of measurement

The phase noise $\mathscr{L}(f)$ is derived from the following equation:

$$\mathscr{L}(f) = P_{\mathrm{SSB}} - P_{\mathrm{o,osc}} \tag{2}$$

where

$P_{\mathrm{SSB}}$ is the single sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, in dBm/Hz.

NOTE $\mathscr{L}(f)$ is indicated in dBc/Hz.

The single sideband noise power density $P_{\mathrm{SSB}}$ is derived from the following equation:

$$P_{\mathrm{SSB}} = P_{\mathrm{DSB}} - 3 + L_2 \tag{3}$$

where

$P_{\mathrm{DSB}}$ is the double sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, indicated by the wave analyser or spectrum analyser, in dBm/Hz;
$L_2$ is the circuit loss from point A to point C.
$L_2$ is expressed in dB.

#### 5.4.2.2.3 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The signal generator and device being measured will naturally lock so that their signals have a phase difference of 90 degrees, and the PLL output voltage fluctuations correspond to phase fluctuations between the signal generator and device being measured. The value of $L_2$ shall be measured beforehand (See 6.2 of IEC 60747-16-3:2002).

#### 5.4.2.2.4 Precautions to be observed

See the precautions to be observed in 5.2.5.

The phase noise of the signal generator shall be as good or better than that of device being measured.

The value of the output power $P_{\text{o.osc}}$ defined at the point A shall be measured beforehand (see 5.3).

#### 5.4.2.2.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

A frequency of the signal generator is set at the oscillation frequency of device being measured.

The double sideband noise power density $P_{\text{DSB}}$ at the frequency shifted by the specified offset is measured by the wave analyser or spectrum analyser.

The single sideband noise power density $P_{\text{SSB}}$ is derived from Equation (3).

The phase noise $\mathscr{L}(f)$ is derived from Equation (2).

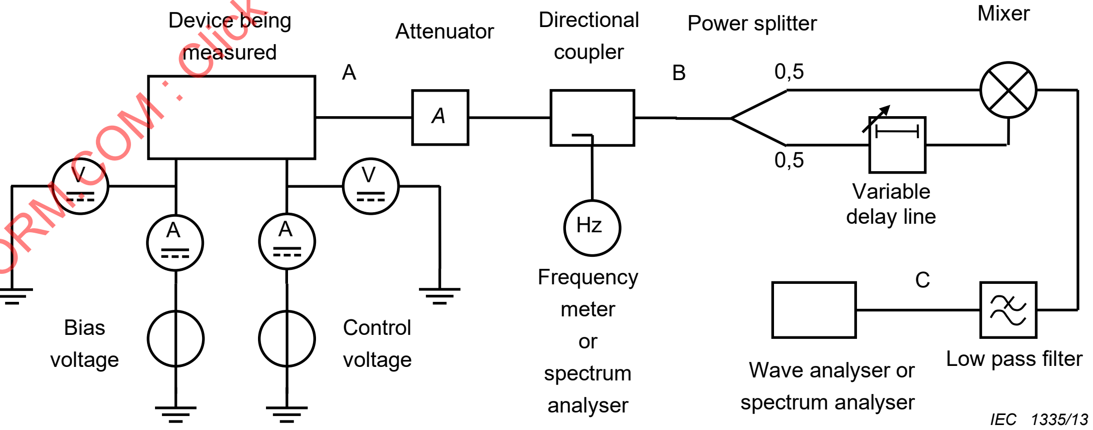
#### 5.4.2.2.6 Specified conditions

- Ambient or reference-point temperature
- In case of VCO, oscillation frequency
- Bias conditions
- Offset frequency

### 5.4.2.3 Measuring method 2

#### 5.4.2.3.1 Circuit diagram

The measuring circuit is shown in Figure 3.



NOTE The device being measured can contain a resonance circuit.

**Figure 3 – Circuit diagram for the measurement of the phase noise $\mathscr{L}(f)$ (method 2)**

#### 5.4.2.3.2 Principle of measurement

See the principle of measurement in 5.4.2.2.2.

#### 5.4.2.3.3 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The variable delay line is adjusted to set the phase between divided signals at 90 degrees. The value of $L_2$ shall be measured beforehand (see 6.2 of IEC 60747-16-3:2002).

#### 5.4.2.3.4 Precautions to be observed

See the precautions to be observed in 5.2.5.

The value of the output power $P_{\mathrm{o.osc}}$ defined at the point A shall be measured beforehand (see 5.3).

#### 5.4.2.3.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The double sideband noise power density $P_{\mathrm{DSB}}$ at the frequency shifted by the specified offset is measured by the wave analyser or spectrum analyser.

The single sideband noise power density $P_{\mathrm{SSB}}$ is derived from Equation (3).

The phase noise $\mathscr{L}(f)$ is derived from Equation (2).

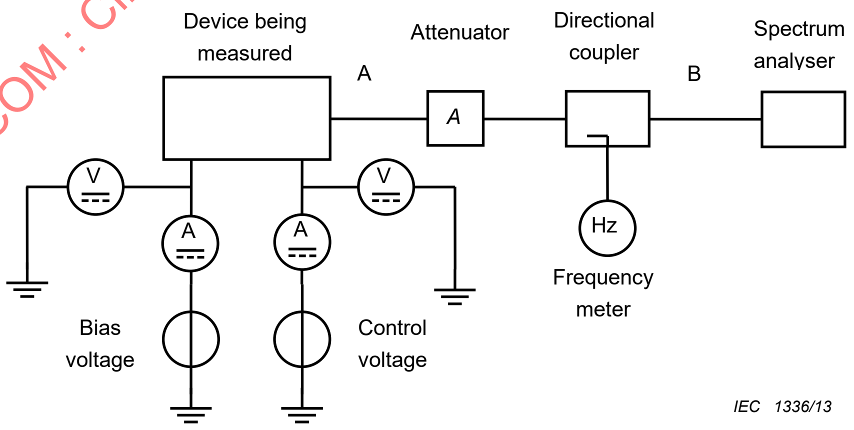
#### 5.4.2.3.6 Specified conditions

See the specified conditions in 5.4.2.2.6.

### 5.4.2.4 Measuring method 3

#### 5.4.2.4.1 Circuit diagram

The measuring circuit is shown in Figure 4.



NOTE The device being measured can contain a resonance circuit.

**Figure 4 – Circuit diagram for the measurement of the phase noise $\mathscr{L}(f)$ (method 3)**

#### 5.4.2.4.2 Principle of measurement

The phase noise $\mathscr{L}(f)$ is derived from the following equation:

$$\mathscr{L}(f) = P_{\mathrm{SSB}} - P_{\mathrm{o,osc}} \tag{4}$$

where

$P_{\mathrm{SSB}}$ is the single sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, in dBm/Hz.

NOTE $\mathscr{L}(f)$ is indicated in dBc/Hz.

The single sideband noise power density $P_{\mathrm{SSB}}$ is derived from the following equation:

$$P_{\mathrm{SSB}} = P_{\mathrm{SSB2}} + L_2 \tag{5}$$

where

$P_{\mathrm{SSB2}}$ is the single sideband noise power density at the frequency shifted from $f_{\mathrm{osc}}$ by a specified offset, indicated by the spectrum analyser, in dBm/Hz;

$L_2$ is the circuit loss from point A to point B.

$L_2$ is expressed in dB.

#### 5.4.2.4.3 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

The value of $L_2$ shall be measured beforehand.

#### 5.4.2.4.4 Precautions to be observed

See the precautions to be observed in 5.2.5.

The value of the output power $P_{\mathrm{o.osc}}$ defined at the point A shall be measured beforehand (see 5.3).

#### 5.4.2.4.5 Measurement procedure

The bias under specified conditions is supplied.

In case of VCO, the oscillation frequency is set to the specified value.

The resolution band width of the spectrum analyser is set to a sufficiently small value which compared with a specified offset frequency value.

The single sideband noise power density $P_{\mathrm{SSB2}}$ at the frequency shifted by the specified offset, is measured by the spectrum analyser.

The single sideband noise power density $P_{\mathrm{SSB}}$ is derived from Equation (5).

The phase noise $\mathscr{L}(f)$ is derived from Equation (4).

#### 5.4.2.4.6 Specified conditions

See the specified conditions in 5.4.2.2.6.

## 5.5 Tuning sensitivity ($S_{\mathrm{f,v}}$)

### 5.5.1 Purpose

To measure the tuning sensitivity under specified conditions.

### 5.5.2 Circuit diagram

See the circuit diagram shown in Figure 1.

### 5.5.3 Principle of measurement

The tuning sensitivity $S_{\mathrm{f,v}}$ is derived from the following equation:

$$S_{\mathrm{f,v}} = \frac{f_{\mathrm{osc}}(V_1) - f_{\mathrm{osc}}(V_2)}{V_1 - V_2} \qquad (6)$$

where

$V_1$ is the specified control voltage;

$V_2$ is the specified control voltage;

$f_{\mathrm{osc}}(V_1)$ is the oscillation frequency at the specified control voltage $V_1$;

$f_{\mathrm{osc}}(V_2)$ is the oscillation frequency at the specified control voltage $V_2$.

### 5.5.4 Circuit description and requirements

See the circuit description and requirements in 5.2.4.

### 5.5.5 Precautions to be observed

See the precautions to be observed in 5.2.5.

### 5.5.6 Measurement procedure

The bias under specified conditions is supplied.

The value $f_{\mathrm{osc}}(V_1)$ is measured by the frequency meter or spectrum analyser at the specified control voltage $V_1$.

The value $f_{\mathrm{osc}}(V_2)$ is measured by the frequency meter or spectrum analyser at the specified control voltage $V_2$.

The tuning sensitivity $S_{\mathrm{f,v}}$ is derived from the Equation (6).

### 5.5.7 Specified conditions

- Ambient or reference-point temperature
- Bias conditions
- Control voltages

## 5.6 Frequency pushing ($f_{\mathrm{osc,push}}$)

### 5.6.1 Purpose

To measure the frequency pushing under specified conditions.