INTERNATIONAL STANDARD

IEC 60747-4

1991

AMENDMENT 2
1999-04

Amendment 2

Semiconductor devices – Discrete devices

Part 4:
Microwave devices

Amendement 2

Dispositifs à semiconducteurs –
Dispositifs discrets

Quatrième partie:
Diodes et transistors hyperfréquences

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FOREWORD

This amendment has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

The text of this amendment is based on the following documents:

FDIS	Report on voting
47E/123/FDIS	47E/124/RVD

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

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

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Amend the title of this standard on the cover page, the title page, and on pages 7 and 11 as follows:

SEMICONDUCTOR DEVICES – DISCRETE DEVICES –

Part 4: Microwave devices

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CONTENTS

Add the title of Chapter VIII as follows and renumber chapter VIII as chapter IX:

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CHAPTER VII: FIELD EFFECT TRANSISTORS

2.1.4 Powers

Replace this subclause by the following new subclause:

2.1.4 Powers

Output power at 1 dB gain compression	$P_{o(1dB)}$
or:	
Output power at specified input power	P_o
Power gain at 1 dB gain compression	$G_{p(1dB)}$
Power added efficiency	η_{add}
Associated (power) gain	G_{as}
Maximum available gain (Note 1)	$G_{a(max)}$
Minimum noise figure	F_{min}
Source reflection factor for minimum noise figure (Notes 2 and 3)	r_{GFmin}
Equivalent input noise resistance	R_n

NOTE 1 – The abbreviation "MAG" is still in common use for maximum available gain.

NOTE 2 – For source reflection coefficient (factor), see 5.3.3 of IEC 60747-7, Chapter II*.

NOTE 3 – The symbol "Γ_{opt}" is still in common use for the source reflection factor for minimum noise figure.

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2.2.3 Power

Add the following definitions:

Minimum noise figure
The minimum value of the noise figure that can be obtained through adjustment of the source impedance under specified bias condition and a specified frequency.

Equivalent input noise resistance
The quotient of the equivalent input noise voltage and the equivalent input noise current (see 5.4.9 and 5.4.10 of IEC 60747-1, Chapter IV**).

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* IEC 60747-7 (all parts), *Semiconductor devices – Discrete devices – Part 7: Bipolar transistors*

** IEC 60747-1:1983, *Semiconductor devices – Discrete devices – Part 1: General*

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3.2.2 RF characteristics

Add the following new essential ratings and characteristics:

3.2.2.8 Minimum noise figure

Maximum value under specified conditions

3.2.2.9 Source reflection factor for minimum noise figure

Maximum and minimum values under specified conditions

NOTE – Maximum and minimum values respectively should be prescribed for magnitude and angle.

3.2.2.10 Equivalent input noise resistance

Maximum and minimum values under specified conditions

Categories	
A	B
	+
	+
	+

4 Measurement methods

Replace subclauses 4.10 and 4.11 by the following new subclause 4.10:

4.10 Noise figure (F) and associated gain (G_{as})

4.10.1 Purpose

To measure the noise figure of a microwave field-effect transistor under specified conditions.

4.10.2 Circuit diagram

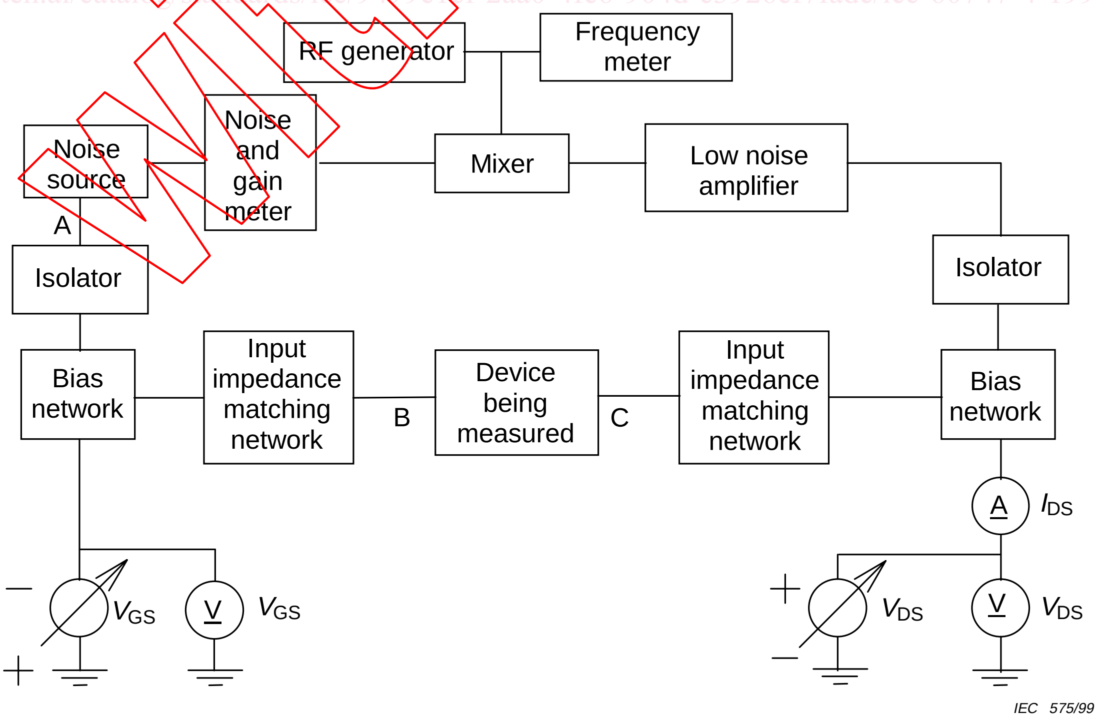

Figure 46 – Basic circuit for the measurement of the noise figure

4.10.3 Principle of measurements

The noise figure F of the device being measured is derived from the following equation.

$$F = 10\log\left(10^{(F_{12}-L_1)/10} - \frac{10^{F_2/10}-1}{10^{G_m/10}}\right) \qquad (1)$$

where

F_{12} is the overall noise figure;

L_1 is the circuit loss from point A to B;

F_2 is the noise figure after point C at the output stage, and

G_{as} is the associated gain of the device being measured.

F, F_{12}, F_2, L_1 and G_{as} are expressed in decibels. The noise figure measurement is carried out by using the hot and cold measurement method. F_{12}, F_2 and G_{as} are calculated as follows:

$$F_{12} = 10\log\left(\frac{10^{ENR/10}}{(P_{N1}/P_{N2})-1}\right) \qquad (2)$$

$$F_2 = 10\log\left(\frac{10^{ENR/10}}{(P_{N3}/P_{N4})-1}\right) \qquad (3)$$

$$G_{as} = 10\log\left(\frac{P_{N1}-P_{N2}}{P_{N3}-P_{N4}}\right) \qquad (4)$$

where

ENR is the excess noise ratio of the noise source;

P_{N1} and P_{N2} in W are the measured noise power under the hot and cold state of the noise source, respectively.

P_{N3} and P_{N4} in W are the measured noise powers under the hot and cold state of the noise source, respectively, in the case of directly connecting point B to C in figure 46.

The temperature of the measurement is 290 K.

4.10.4 Circuit description and requirements

The circuit loss L_1 from point A to B should be measured beforehand.

4.10.5 Precautions to be observed

The entire circuit shall be shielded and grounded to prevent undesired signals. For noise figure measurement under the single-side-band (SSB) condition, careful attention shall be paid to the image and other spurious responses which are generated by the mixer. These spurious responses should be reduced so as to be negligible.

4.10.6 Measurement procedure

The frequency of the r.f. generator is adjusted to the specified condition.

In order to measure the noise contribution of the measurement system, connect point B to C in figure 46 without the device being measured and set the input and output impedance matching networks to 50 Ω.

The noise power P_{N3} and P_{N4} corresponding to the noise source hot and cold, respectively, are measured.

The noise figure F_2 in decibels is calculated by equation (3).

The device being measured is inserted as shown in figure 46.

The gate-source voltage V_{GS} (near the gate-source cut-off voltage) is applied.

The specified drain-source voltage V_{DS} is applied.

The drain current I_{DS} is adjusted to the specified value by varying V_{GS}.

During the adjustment of the input and output matching networks, the noise power P_{N1} and P_{N2} corresponding to the noise source hot and cold, respectively, are measured.

The noise figure F_{12} in decibels is calculated by equation (2).

The associated gain G_{as} in decibels is calculated by equation (4).

The noise figure F in decibels is calculated by equation (1).

The input impedance matching network is adjusted to the minimum value of F.

The output impedance matching network is adjusted to the maximum value of G_{as}.

Repeat the above two steps until no further reduction in noise figure F is possible.

4.10.7 Specified conditions

– Ambient or reference point temperature
– Drain source voltage
– Drain current
– Frequency
– Single-side band or double-side band.

Renumber subclauses 4.12 as 4.11 and 4.13 as 4.12 and add the following new subclause 4.13:

4.13 Minimum noise figure (F_{min}), equivalent input noise resistance (R_n) and source reflection factor for minimum noise figure (r_{GFmin})

4.13.1 Purpose

To measure the minimum noise figure, equivalent input noise resistance and source reflection factor for the minimum noise figure of a microwave field-effect transistor under specified conditions.

4.13.2 Circuit diagram

See the circuit diagram in 4.10.2.

4.13.3 Principle of measurements

See the principle of measurements in 4.10.3.

The noise figure dependence on the source admittance can be expressed as:

$$F = F_{min} + \frac{R_n}{G_s}\left\{(G_s - G_0)^2 + (B_s - B_0)^2\right\} \qquad (1)$$

where

- F is the noise figure
- F_{min} is the minimum noise figure
- R_n is the equivalent input noise resistance
- G_s is the source conductance
- B_s is the source susceptance
- G_0 is the source conductance for F_{min}
- B_0 is the source susceptance for F_{min}

To determine the four parameters, F_{min}, R_n, G_0 and B_0, four dimensional simultaneous equations should be solved.

From equation (1)

$$F = F_{min} + \frac{R_n|Y_0|^2}{G_s} - 2\,R_n G_0 + \frac{R_n|Y_s|^2}{G_s} - 2\,R_n B_0\left(\frac{B_s}{G_s}\right) \qquad (2)$$

where

$$Y_0 = G_0 + jB_0 \qquad (3)$$

$$Y_s = G_s + jB_s \qquad (4)$$

In equation (2), X_1, X_2, X_3 and X_4 are defined as

$$X_1 = F_{min} - 2\,R_n G_0$$
$$X_2 = R_n|Y_0|^2$$
$$X_3 = R_n \qquad (5)$$
$$X_4 = R_n\,B_0$$

Then, equation (2) leads to the following equations for n different Y_s

$$F_{(1)} = X_1 + \frac{1}{G_{s(1)}}X_2 + \frac{|Y_{s(1)}|^2}{G_{s(1)}}X_3 - 2\left(\frac{B_{s(1)}}{G_{s(1)}}\right)X_4$$

$$\bullet$$
$$\bullet \qquad (6)$$
$$\bullet$$

$$F_{(n)} = X_1 + \frac{1}{G_{s(n)}}X_2 + \frac{|Y_{s(n)}|^2}{G_{s(n)}}X_3 - 2\left(\frac{B_{s(n)}}{G_{s(n)}}\right)X_4$$

Substituting X_1, X_2, X_3 and X_4 obtained from equation (6) into equation (5), the four parameters are determined as follows:

$$F_{min} = X_1 + 2\sqrt{X_2 X_3 - X_4{}^2} \quad (7)$$

$$R_n = X_3 \quad (8)$$

$$G_0 = \sqrt{X_2 / X_3 - (X_4 / X_3)^2} \quad (9)$$

$$B_0 = X_4 / X_3 \quad (10)$$

Γ_{Fmin}, source reflection factor for F_{min}, is determined from the above G_0 and B_0.

4.13.4 Circuit description and requirements

See the circuit description and requirements in 4.10.4.

4.13.5 Precautions to be observed

See the precaution to be observed in 4.10.5.

4.13.6 Measurement procedure

The frequency of the r.f. generator is adjusted to the specified condition.

The device being measured is inserted as shown in figure 46.

The gate-source voltage V_{GS} (near gate-source cut-off voltage) is applied.

The specified drain-source voltage V_{DS} is applied.

The drain current I_{DS} is adjusted to the specified value by varying V_{GS}.

The input impedance matching network is adjusted so that the source admittance becomes ($G_{s(1)}$, $B_{s(1)}$).

The output impedance matching network is adjusted so that the maximum power gain is achieved.

The noise figure $F_{(1)}$ is measured in accordance with the procedure described in 4.10.6.

Repeating the above procedure n times, $F_{(1)-(n)}$ are determined for the n source admittance ($G_{s(1)-(n)}$, $B_{s(1)-(n)}$).

The noise parameters: F_{min}, R_n and Γ_{Fmin} are determined from the equations (6) to (10).

4.13.7 Specified conditions

- Ambient or reference point temperature
- Drain source voltage
- Drain current
- Frequency
- Single-side band or double-side band.

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Add the following new chapter and renumber chapter VIII as chapter IX:

CHAPTER VIII – INTEGRATED CIRCUIT MICROWAVE AMPLIFIERS

1 Terminology

1.1 Linear (power) gain G_{lin}

The power gain in the linear region of the power transfer curve P_o (dBm) = $f(P_i)$.

NOTE – In this region, ΔP_o (dBm) = ΔP_i (dBm).

1.2 Linear (power) gain flatness ΔG_{lin}

The power gain flatness when the operating point lies in the linear region of the power transfer curve.

1.3 Power gain G_p, G

The ratio of the output power to the input power.

NOTE – Usually the power gain is expressed in decibels.

1.4 (Power) gain flatness ΔG_p

The difference between the maximum and minimum power gain for a specified input power in a specified frequency range.

1.5 (Maximum available) gain reduction, ΔG_{red}

The difference in decibels between the maximum and minimum power gains that can be provided by the gain control.

1.6 Output power limiting

1.6.1 Output power limiting range

The range in which, for rising input power, the output power is limiting.

NOTE – For specification purposes, the limits of this range are specified by specified lower and upper limit values for the input power.

1.6.2 Limiting output power $P_{o(ltg)}$

The output power in the range where it is limiting.

1.6.3 Limiting output power flatness $\Delta P_{o(ltg)}$

The difference between the maximum and minimum output power in the output power limiting range:

$$\Delta P_{o(ltg)} = P_{o(ltg,max)} - P_{o(ltg,min)}$$

1.7 Intermodulation distortion P_n/P_i

The ratio of

the output power of the *n*th order component to

the output power of the fundamental component,

at a specified input power.

1.8 Power at the intercept point (for intermodulation products) $P_{n(IP)}$

The output power at intersection between the extrapolated output powers of the fundamental component and the *n*th order intermodulation components, when the extrapolation is carried out in a diagram showing the output power of the components (in decibels) as a function of the input power (in decibels).

1.9 Magnitude of the input reflection coefficient (input return loss) $|s_{11}|$

See 5.2.1 of IEC 60747-7, Chapter II.

1.10 Magnitude of the output reflection coefficient (output return loss) $|s_{22}|$

See 5.2.2 of IEC 60747-7, Chapter II.

1.11 Magnitude of the reverse transmission coefficient (isolation) $|s_{12}|$

See 5.2.4 of IEC 60747-7, Chapter II.

1.12 Conversion coefficient of amplitude modulation to phase modulation $\alpha_{(AM-PM)}$

The quotient of

the phase deviation of the output signal (in degrees) by

the change in input power (in decibels) producing it.

1.13 Group delay time $t_{d(grp)}$

The ratio of the change, with angular frequency, of the phase shift through the amplifier.

NOTE – Usually group delay time is very close in value to input-to-output delay time.

2 Essential ratings and characteristics for integrated circuit microwave amplifiers

2.1 General

2.1.1 Circuit identification and types

2.1.1.1 Designation and types

Indication of type (device name), category of circuit and technology applied should be given.

Microwave amplifiers are divided into four categories:

Type A: Low-noise type.

Type B: Auto-gain control type.

Type C: Limiting type.

Type D: Power type.

2.1.1.2 General function description

A general description of the function performed by the integrated circuit microwave amplifiers, and the features for the application should be made.

2.1.1.3 Manufacturing technology

The manufacturing technology, for example, semiconductor monolithic integrated circuit, thin film integrated circuit, micro-assembly, should be stated. This statement should include details of the semiconductor technologies such as MESFET, MISFET, Si bipolar transistor, HBT, etc.

2.1.1.4 Package identification

The following statements should be made:

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

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

2.1.1.5 Main application

Main application should be stated, if necessary. If the device has restrictive applications, these should be stated here.

2.2 Application related description

Information on the application of the integrated circuit and its relation to the associated devices should be given.

2.2.1 Conformance to system and/or interface information

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

The detailed information about application systems, equipment and circuits such as VSAT systems, DBS receivers, microwave landing systems, etc., also should be given.

2.2.2 Overall block diagram

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

2.2.3 Reference data

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

2.2.4 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 of the type of the input and output circuits, for example, input/output impedances, d.c. block, open-drain, etc. Interchangeability with other devices, if any, should be given.

2.2.5 Associated devices

If applicable, the following should be stated here:

– devices necessary for correct operation (list with type number, name, and function);

– peripheral devices with direct interfacing (list with type number, name, and function).

2.3 Specification of the function

2.3.1 Detailed block diagram – Functional blocks

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

1) functional blocks;
2) mutual interconnections among the functional blocks;
3) individual functional units within the functional blocks;
4) mutual interconnections among the individual functional blocks;
5) function of each external connection;
6) interdependence between the separate functional blocks.

The block diagram should identify the function of each external connection and, where no ambiguity can arise, can also show the terminal symbols and/or numbers. If the encapsulation has metallic parts, any connection to them from external terminals should be indicated. The connections with any associated external electrical elements should 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. This may be obtained from a catalogue of standards of graphical symbols or designed according to the rules of IEC 60617-12 or IEC 60617-13*.

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* IEC 60617-12:1997, *Graphical symbols for diagrams – Part 12: Binary logic elements*

IEC 60617-13:1993, *Graphical symbols for diagrams – Part 13: Analogue elements*