# IEC 60747-4

Edition 2.0 2007-08

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

**Semiconductor devices – Discrete devices –**
**Part 4: Microwave diodes and transistors**

**Dispositifs à semiconducteurs – Dispositifs discrets –**
**Partie 4: Diodes et transistors hyperfréquences**



IEC 60747-4:2007

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## Semiconductor devices – Discrete devices – Part 4: Microwave diodes and transistors



## Dispositifs à semiconducteurs – Dispositifs discrets – Partie 4: Diodes et transistors hyperfréquences



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**SEMICONDUCTOR DEVICES –
DISCRETE DEVICES –**

**Part 4: Microwave diodes and transistors**

# FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60747-4 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

This second edition cancels and replaces the first edition, published in 1991, its amendments 1, 2 and 3 (1993, 1999 and 2001, respectively), and constitutes a technical revision.

The major technical changes with regard to the previous edition are as follows:

a) the clause of bipolar transistors has been added;
b) the clause of field-effect transistors has been amended.

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

| FDIS | Report on voting |
|---|---|
| 47E/330/FDIS | 47E/339/RVD |

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

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

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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 –
# DISCRETE DEVICES –

## Part 4: Microwave diodes and transistors

## 1 Scope

This part of IEC 60747 gives requirements for the following categories of discrete devices:

– variable capacitance diodes and snap-off diodes (for tuning, up-converter or harmonic multiplication, switching, limiting, phased shift, parametric amplification);
– mixer diodes and detector diodes;
– avalanche diodes (for direct harmonic generation, amplification);
– gunn diodes (for direct harmonic generation);
– bipolar transistors (for amplification, oscillation);
– field-effect transistors (for amplification, oscillation).

## 2 Normative references

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



IEC 60050-702:1992, *International Electrotechnical Vocabulary – Chapter 702: Oscillations, signals and related devices*

IEC 60747-1:2006, *Semiconductor devices – Part 1: General*

IEC 60747-7:2000, *Semiconductor devices – Part 7: Bipolar transistors*

IEC 60747-8:2000, *Semiconductor devices – Part 8: Field-effect transistors*

IEC 60747-16-1:2001, *Semiconductor devices – Part 16-1: Microwave integrated circuits – Amplifiers*
Amendment 1(2007)

## 3 Variable capacitance, snap-off diodes and fast-switching schottky diodes

### 3.1 Variable capacitance diodes

#### 3.1.1 General

The provisions of this part deal with diodes (excluding snap-off diodes) in which the variable capacitance effect is used; they cover four applications: tuning, harmonic multiplication, switching (including limiting), parametric amplification.

The devices for these applications are defined as follows:

*Diodes for tuning*

Diodes which are used to vary the frequency of a tuned circuit.

These diodes are usually characterized a frequency of resonance much higher than the frequency of use and have a known capacitance/voltage relationship.

*Diodes for harmonic multiplication*

These diodes must have a non-linear capacitance/voltage relationship at the frequency of operation and a high ratio of cut-off frequency to operating frequency.

*Diodes for switching (including limiting)*

These diodes exhibit a fast transition from a high impedance state to a low impedance state and vice versa and can be used to modulate or control the power level in microwave systems.

*Diodes for parametric amplification*

These diodes are intended to handle small amplitude signals and are most often used in low-noise amplifiers.

### 3.1.2 Terminology and letter symbols

See 3.1.3.3.



### 3.1.3 Essential ratings and characteristics

#### 3.1.3.1 General



##### 3.1.3.1.1 Rating conditions

Variable capacitance diodes may be specified either as ambient rated or case rated devices or, where appropriate, as both.

The ratings listed in 3.1.3.2 should be stated at the following temperatures:

– *ambient-rated devices:*

at an ambient temperature of 25 °C and at one higher temperature.

– *case-rated devices:*

at a reference point temperature of 25 °C and at another reference point temperature.

##### 3.1.3.1.2 Application categories

The essential ratings and characteristics to be stated for each category of diode are marked with a + sign in the following table:

– column 1: tuning applications;
– column 2: harmonic multiplication applications;
– column 3: switching (including limiting) applications;
– column 4: parametric amplification applications.

| | Categories | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| **3.1.3.2 Ratings (limiting values)** | | | | |
| The following ratings should be stated: | | | | |
| **3.1.3.2.1 Temperatures** | | | | |
| Range of operating temperatures | + | + | + | + |
| Range of storage temperatures | + | + | + | + |
| **3.1.3.2.2 Voltages and currents** | | | | |
| Maximum peak reverse voltage | + | + | + | + |
| Maximum mean forward current, where appropriate | | + | + | + |
| Maximum peak forward current, where appropriate | | + | + | + |
| **3.1.3.2.3 Power dissipation** | | | | |
| Maximum dissipation, under stated conditions, over the operating temperature range | + | + | + | + |
| **3.1.3.3 Electrical characteristics** | | | | |
| Unless otherwise specified, the following characteristics should be given at 25 °C (see Figure 1) | | | | |
| **3.1.3.3.1 Stray capacitance ($C_p$)** | | | | |
| Typical value under specified conditions | + | + | + | + |
| **3.1.3.3.2 Series inductance ($L_s$)** | | | | |
| Typical value and, where appropriate, maximum value under specified conditions | + | + | + | + |
| **3.1.3.3.3 Terminal capacitance ($C_{tot}$)** | | | | |
| a) Minimum and maximum values, at a specified bias voltage and at a specified frequency (note 2) | + | + | + | + |
| b) Typical curve showing the relationship between terminal capacitance and bias voltage | + | + | + | + |
| **3.1.3.3.4 Junction capacitance ($C_j$)** | | | | |
| Minimum and maximum values at a specified bias voltage (notes 2 and 3). When the order of magnitude of $C_p$ is the same as that of the terminal capacitance $C_{tot}$, a typical value should be given for $C_j$ instead of minimum and maximum values | + | + | + | + |
| **3.1.3.3.5 Effective quality factor ($Q$)** | | | | |
| Minimum values at two or more specified frequencies under specified bias conditions (note 4) | + | | | |

| | Categories | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| **3.1.3.3.6 Cut-off frequency** | | | | |
| Minimum value under specified conditions (notes 4 and 5) | | + | + | + |
| **3.1.3.3.7 Series resistance ($r_s$)** | | | | |
| Maximum and/or typical values under specified conditions (note 4) | + | + | + | + |
| **3.1.3.3.8 Reverse current** | | | | |
| Maximum value at a specified reverse voltage | + | + | + | + |
| **3.1.3.3.9 Thermal resistance** | | | | |
| Maximum value between junction and ambient, or between the junction and a specified reference point | + | + | + | |
| **3.1.3.3.10 Switching time** | | | | |
| Typical value under specified conditions | | | + | |
| **3.1.3.3.11 Stored charge or minority carrier life time** | | | | |
| Typical value, for either stored charge under specified conditions including bias, or minority carrier life time under specified conditions | | + | + | |
| **3.1.3.3.12 Transition time** | | | | |
| Typical value, under specified conditions, together with a specified measurement circuit (note 1) | | + | | |



NOTE 1 See definition in 3.2.2.

NOTE 2 For categories 1, 2 and 3, the specified bias voltage should be –6 V and for category 4, the specified bias voltage should be 0 V.

NOTE 3 The relationship between the junction capacitance and bias voltage should be represented either by a typical curve or by a mathematical form. The mathematical form should be as follows:

$$C_j = K (V + \phi)^{\gamma}$$

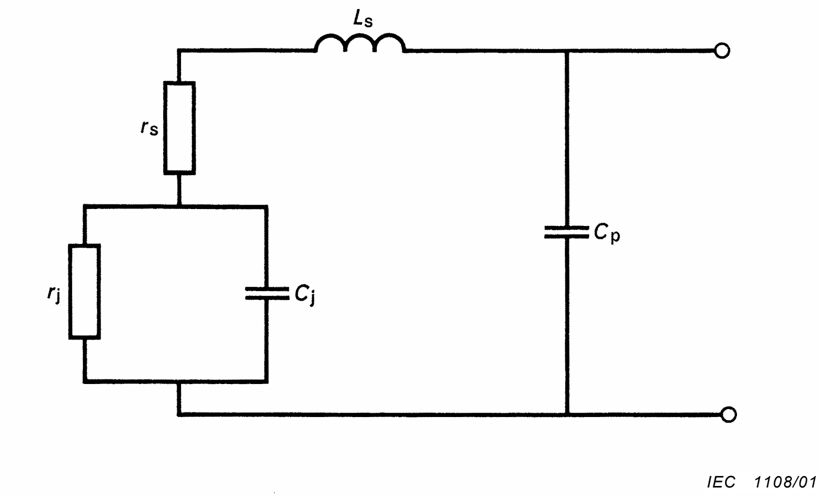
where $V$ is the magnitude of the applied reverse voltage and $K$, $\phi$ and $\gamma$ are three constants. The manufacturer should specify the typical values for $K$, $\phi$ and $\gamma$.

NOTE 4 If the $Q$ value and the series resistance are not specified for category 1, then the cut-off frequency must be specified.

NOTE 5 The cut-off frequency $f_c$ is defined as:

$$f_c = \frac{1}{2\pi \, r_s \, C_j}$$

where $r_s$ is the series resistance and $C_j$ is the capacitance of the junction measured at a specified bias point $r_s$ is determined by the equivalent circuit shown in Figure 1 below; its value depends on the measuring method used and on the bias voltage.




**Key**

$C_j$ junction capacitance

$r_s$ series resistance

$r_j$ low frequency resistance of the junction

In general, $r_j$ is sufficiently high to be neglected.

$C_p$ stray capacitance

$L_s$ series inductance

**Figure 1 – Equivalent circuit**



### 3.1.3.4 Application data

For harmonic multiplication applications, the *efficiency* should be stated.



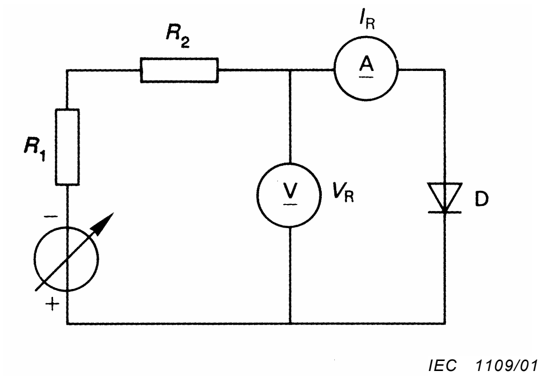
### 3.1.4 Measuring methods

### 3.1.4.1 Reverse current $I_R$

a) *Purpose*

To measure the reverse current of a diode under specified reverse voltage.

b) *Circuit diagram*




**Key**

D diode being measured

**Figure 2 – Circuit for the measurement of reverse current $I_R$**

c) *Circuit description and requirements*

$R_1$ is a calibrated resistor (pulse measurement only).

$R_2$ is a protective resistor.

If a pulse measurement is required, the variable voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument and the ammeter is replaced by a peak-reading voltmeter across the calibrated resistor $R_1$.

d) *Measurement procedure*

The temperature is set to the specified value.

The variable voltage generator is adjusted to obtain the specified value of reverse voltage $V_R$ across the diode.

The reverse current $I_R$ is read from the ammeter A.

e) *Specified conditions*

– Ambient, case or reference-point temperature ($t_{amb}$, $t_{case}$, $t_{ref}$).

– Reverse voltage ($V_R$).

– Pulse width and duty cycle, where applicable.

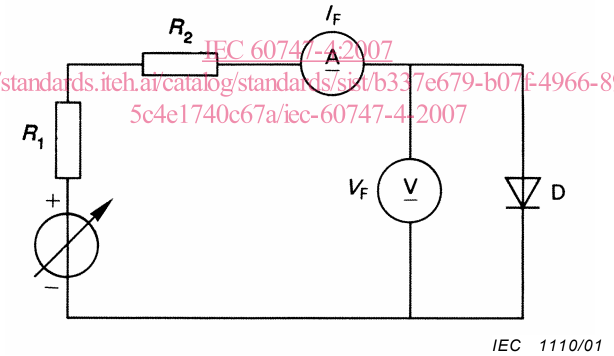
### 3.1.4.2 Forward voltage $V_F$

a) *Purpose*

To measure the forward voltage across a signal or switching diode under specified conditions.



b) *Circuit diagram*






**Key**
D diode being measured

**Figure 3 – Circuit for the measurement of forward voltage $V_F$**

c) *Circuit description and requirements*

$R_1$ is a calibrated resistor (pulse measurement only).

$R_2$ is a high value resistor.

If a pulse measurement is required, the variable voltage generator is replaced by a voltage pulse generator, the voltmeter is replaced by a peak-reading instrument and the ammeter is replaced by a peak-reading voltmeter across the calibrated resistor $R_1$.