INTERNATIONAL STANDARD

IEC 60747-14-3

First edition
2001-06

Semiconductor devices –

Part 14-3:
Semiconductor sensors –
Pressure sensors

Dispositifs à semiconducteurs –

Partie 14-3:
Capteurs à semiconducteurs –
Capteurs de pression

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –

Part 14-3: Semiconductor sensors – Pressure sensors

FOREWORD

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International Standard IEC 60747-14-3 has been prepared by subcommittee 47E: Discrete semiconductor devices, of IEC technical committee 47: Semiconductor devices.

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

FDIS	Report on voting
47E/191/FDIS	47E/195/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 3.

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

The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be

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- withdrawn;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

INTRODUCTION

This part of IEC 60747 should be read in conjunction with IEC 60747-1. It provides basic information on semiconductor

- terminology;
- letter symbols;
- essential ratings and characteristics;
- measuring methods;
- acceptance and reliability.

SEMICONDUCTOR DEVICES –

Part 14-3: Semiconductor sensors – Pressure sensors

1 Scope

This part of IEC 60747-14 specifies requirements for semiconductor pressure sensors measuring absolute, gauge or differential pressures.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60747-14. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60747-14 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

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

IEC 60747-14-1:2000, *Semiconductor devices – Part 14-1: Semiconductor sensors – General and classification*

3 Terminology and letter symbols

3.1 General terms

3.1.1 Semiconductor pressure sensors

A semiconductor pressure sensor converts the difference between two pressures into an electrical output quantity. One of the two pressures may be a reference pressure (see 3.2.3). It includes linear and on-off (switch) types of sensors.

A linear sensor produces electrical output quantity changes linearly with the pressure difference.

An on-off sensor switches an electrical output quantity on and off between two stable states when the increasing or decreasing pressure differences cross given threshold values.

In this standard, the electrical output quantity is described as a voltage: output voltage. However, the statements made in this standard are also applicable to other output quantities such as those described in 3.8 of IEC 60747-14-1: changes in impedance, capacitance, voltage ratio, frequency-modulated output or digital output.

3.1.2 Sensing methods

3.1.2.1 Piezoelectric sensing

The basic principle of piezoelectric devices is that a piezoelectric material induces a charge or induces a voltage across itself when it is deformed by stress. The output from the sensor is amplified in a charge amplifier which converts the charge generated by the transducer sensor into a voltage that is proportional to the charge. The main advantages of piezoelectric sensing are the wide operating temperature range (up to 300 °C) and high-frequency range (up to 100 kHz).

3.1.2.2 Piezoresistive sensing

The basic principle of a piezoresistor is the change of the resistor value when it is deformed by stress. The sensing resistors can be either p- or n-type doped regions. The resistance of piezoresistors is very sensitive to strain, and thus to pressure, when correctly placed on the diaphragm of a pressure sensor. Four correctly oriented resistors are used to build a strain gauge in the form of a resistor bridge.

An alternative to the resistor bridge is the transverse voltage strain gauge. It is a single resistive element on a diaphragm, with voltage taps centrally located on either side of the resistor. When a current is passed through the resistor, the voltages are equal when the element is not under strain, but when the element is under strain, a differential voltage output appears.

3.1.2.3 Capacitive sensing

A small dielectric gap between the diaphragm and a plate makes a capacitance which changes with the diaphragm movement. Single capacitance or differential capacitance techniques can be used in open- or closed-loop systems. Capacitance and capacitive changes can be measured either in a bridge circuit or using switched-capacitor techniques. Any of the capacitive sensing techniques used in a micromachined structure require an a.c. voltage across the capacitor being measured. Capacitive sensing has the following advantages: small size of elements, wide-operating temperature range, ease of trimming, good linearity, and compatibility to CMOS signal conditioning.

3.1.2.4 Silicon vibrating sensing

The vibrating element of a silicon micromachined structure is maintained in oscillation, either by piezoelectric or electrical field energy. The application of pressure to the silicon diaphragm produces strain on the micromachined structure and the vibration frequency is measured to determine applied pressure.

3.1.2.5 Signal conditioning

Semiconductor pressure sensors are mainly micromachined structures including a sensing element. Other electrical components or functions can be performed at the same time and in the same package on the process line. Most pressure sensors offer integrated signal conditioning.

Signal conditioning transforms a raw sensor output into a calibrated signal. This process may involve several functions, such as calibration of initial zero pressure offset and pressure sensitivity, compensation of non-linear temperature errors of offset and sensitivity, compensation of the non-linearity and output signal amplification of the pressure.

3.1.2.6 Temperature compensation

Semiconductor sensors are temperature sensitive. Some are temperature non-compensated sensors while others are compensated with added circuitry or materials designed to counteract known sources of error.

When non-compensated, the variations due to the temperature follow physical laws and a temperature coefficient (α) is representative of this physical phenomena.

When compensated, the temperature remaining error is also dependant on the way the compensation is performed. In this case, a maximum temperature deviation (Δ) better represents this error.

3.2 Definitions

For the purposes of this part of IEC 60747, the definitions in IEC 60747-1 and the following definitions apply.

3.2.1
piezoresistance coefficient
measure of the piezoresistance effect derived from the semiconductor materials under the application of strain

3.2.2
absolute pressure
pressure using absolute vacuum as the datum point

3.2.3
reference pressure
pressure against which pressures are defined, usually absolute vacuum or ambient atmospheric pressure

3.2.4
differential pressure
difference between the two (absolute) pressures that act simultaneously on opposite sides of the membrane

3.2.5
relative pressure
differential pressure when one of the two pressures is considered to be a reference pressure with respect to which the other pressure is being measured

3.2.6
gauge pressure
relative pressure when the ambient atmospheric pressure is used as the reference pressure

3.2.7
system pressure (or common-mode pressure)
static pressure that acts on the sensor but does not represent the pressure to be converted, in the case of a differential pressure sensor

3.2.8
over-pressure capability
maximum pressure that may be applied to the sensor without damage or loss of calibration accuracy

3.2.9
differential output resistance
first derivative of output voltage as a function of output current at the specified pressure. Refers to a basic sensor (without integrated signal amplification)

NOTE In practice, the differential resistance value can be expressed as the quotient of the change of the output voltage over the change in output current resulting from a small change in output load resistance.

3.2.10
input resistance
supply voltage divided by the supply current

3.2.11
isolation resistance
resistance between all the connected electrical terminals of the sensor and the sensor part which is in contact with the sensed element

NOTE In practice, this is not applicable when the sensed element, such as gas or oil, is not conductive.

3.2.12
calibrated pressure range
range of pressure within which the device is designed to operate and for which limit values of the conversion characteristics are specified

3.2.13
temperature coefficient of offset voltage
change in offset voltage relative to the change in temperature

3.2.14
temperature coefficient of full-scale span voltage
change in full-scale span voltage relative to the change in temperature

3.2.15
temperature coefficient of the pressure sensitivity
change in the pressure sensitivity relative to the change in temperature

3.2.16
maximum temperature deviation of the offset voltage
maximum deviation of the offset voltage for a specified temperature range, compared to the output offset voltage at the reference temperature

3.2.17
maximum temperature deviation of the full-scale span voltage
maximum deviation of the full-scale span voltage in a specified temperature range, compared to the full-scale span voltage at reference temperature

3.2.18
full-scale pressure
pressure that defines the upper limit for the calibrated pressure range

3.2.19
zero-scale pressure
pressure that defines the lower limit for the calibrated pressure range

3.2.20
null offset (also called zero pressure offset)
electrical output present when the pressure sensor is at null, i.e. when the pressure on each side of the sensing diaphragm is equal

3.2.21
burst pressure
pressure that causes an irreversible damage of the sensor

3.2.22
(end-point) linearity error
difference between the actual value of the output voltage and, at the given pressure, the value that would result if the output voltage changed linearly with pressure between the zero-scale pressure and the full-scale pressure

3.2.23
total error
difference between the actual value of the output voltage and, at the given pressure, the value that would result if the actual voltages were equal to their nominal values at the zero-scale pressure and at the full-scale pressure and changed linearly with pressure between these points

3.2.24
accuracy
maximum deviation of actual output from nominal output over the entire pressure range and temperature range, as a percentage of the full-scale span at 25 °C, due to all sources of error such as linearity, hysteresis, repeatability and temperature shifts

3.2.25
hysteresis
sensor's ability to reproduce the same output for the same input, regardless of whether the input is increasing or decreasing. Pressure hysteresis is measured at a constant temperature, while temperature hysteresis is measured at a constant pressure within the operating range

3.2.25.1
pressure-cycle hysteresis
difference in the output at any given pressure in the operating pressure range when this pressure is approached from the minimum operating pressure as compared to when approached from the maximum operating pressure at room temperature

3.2.25.2
temperature-cycle hysteresis
difference in the output at any temperature in the operating pressure range when the temperature is approached from the minimum operating temperature as compared to when approached from the maximum operating temperature, with fixed pressure applied

3.2.26
pressure-cycling drift of output voltage
difference between the final value of the output voltage at a given pressure after a series of pressure cycles and the initial value at that same pressure when all other operating conditions are being held constant

3.2.27
temperature-cycling drift of output voltage
difference between the final value of the output voltage at a given temperature after a series of temperature cycles and the initial value at that same temperature when all other operating conditions are being held constant

3.2.28
pressure-cycling instability range of output voltage
difference between the extreme values of output voltage that were observed at a given pressure during a series of pressure cycles when all other operating conditions are being held constant

3.2.29
temperature-cycling instability range of output voltage
difference between the extreme values of output voltage that were observed at a given temperature during a series of temperature cycles, when all other operating conditions are being held constant

3.2.30
full-scale span sensitivity
quotient of the full-scale span voltage over the calibrated pressure range

3.2.31
temperature coefficient of full-scale span sensitivity
full-scale span sensitivity relative to the change in temperature

3.3 Letter symbols

3.3.1 General

Clauses 2, 3 and 4 of IEC 60747-1, Chapter V, apply.

3.3.2 List of letter symbols

Name and designation	Letter symbol	Remarks
Piezoresistance coefficient	π_l, π_t	π_l for the longitudinal component of the coefficient, π_t for the transverse component of the coefficient
Absolute pressure	P_{abs}	
Reference pressure	P_{ref}	
Differential pressure	ΔP	
Relative pressure	P_{rel}	
Offset voltage	V_{os}	
Full-scale pressure	P_{fs}	
Zero-scale pressure	P_{zs}	
Burst pressure	P_{burst}	
Differential output resistance	R_{do}	
Isolation resistance	R_{iso}	
Full-scale span	V_{FSS}	
Response time	t_{resp}	
Sensitivity	S	
Temperature coefficient of sensitivity	α_S	
Total error	E_t, E_t(p)	E_t for any pressure, E_t(p) for a specified pressure
(End-point)linearity error	E_l, E_l(p)	E_l for any pressure, E_l(p) for a specified pressure
Pressure hysteresis of output voltage	H_{ohp}	
Temperature hysteresis of output voltage	H_{ohT}	
Temperature coefficient of offset voltage	α_{Vos}	
Temperature coefficient of full-scale span	α_{VFSS}	
Maximum temperature deviation of the offset voltage	ΔV_{os}	
Maximum temperature deviation of full-scale span	ΔV_{FSS}	
Pressure-cycling drift of output voltage	ΔV_{otp}	
Temperature-cycling drift of output voltage	ΔV_{otT}	
Pressure-cycling instability range of output voltage	ΔV_{oip}	
Temperature-cycling instability range of output voltage	ΔV_{oiT}	

4 Essential ratings and characteristics

4.1 General

4.1.1 Sensor materials – for piezoelectrical sensors

Materials used for semiconductor pressure sensors are semiconductor materials having large piezoresistance effects, such as Si, compound semiconductors and some of the metal oxide semiconductors. Ratings of pressure sensors depend upon the materials used.

4.1.2 Handling precautions

When handling sensors, the handling precautions given in IEC 60747-1, Chapter IX, clause 1, must be observed.

4.1.3 Types

Types of semiconductor pressure sensors in which pressure might be measured must be specified, i.e. absolute, gauge or differential pressures.

4.2 Ratings (limiting values)

4.2.1 Pressures

4.2.1.1 Maximum pressure (P_{max})

4.2.1.2 Burst pressure (P_{burst})

4.2.1.3 Over-pressure capability

4.2.1.4 Maximum number of pressure cycles up to a specified pressure

4.2.2 Temperatures

4.2.2.1 Minimum and maximum storage temperatures (T_{stg})

4.2.2.2 Minimum and maximum operating temperatures (T_{amb})

4.2.3 Voltage

Maximum supply voltage (V_{smax}) or current (I_{smax})

4.3 Characteristics

Except where otherwise stated, characteristics apply over the operating temperature range given in 4.2.2.2.

4.3.1 Full-scale span (V_{FSS})

The algebraic difference between the end points of the output, at an operating temperature of +25 °C.

4.3.2 Full-scale output (V_{FSO})

The upper limit of sensor output over the measuring range, at an operating temperature of +25 °C.

NOTE $V_{FSO} = V_{off} + V_{FSS}$

4.3.3 Sensitivity (S)

The change in output per unit change in pressure for a specified supply voltage or current.

4.3.4 Temperature coefficient of full-scale sensitivity (α_S)

The per cent change in sensitivity per unit change in temperature relative to the sensitivity at a specified temperature (typically +25 °C).

4.3.5 Offset voltage (V_{os})

Maximum and minimum values, at specified supply voltage or current without any pressure applied, at a fixed operating temperature.

4.3.6 Temperature coefficient of offset voltage (α_{Vos})

The per cent change in offset per unit change in temperature relative to the offset at a specified temperature (typically +25 °C).

4.3.7 Pressure hysteresis of output voltage (H_{ohp})

Maximum and minimum values as a percentage of full-scale output voltage, at specified supply voltage or current under specified pressure range.

4.3.8 Temperature hysteresis of output voltage (H_{ohT})

Maximum and minimum values as a percentage of full-scale output voltage, at specified supply voltage or current under specified temperature range.

4.3.9 Response time

Time interval between the moment when a stimulus is subjected to a specified abrupt change and the moment when the response reaches and remains within specified limits around its final value.

4.3.10 Warm-up

Warm-up is defined as the time required for the device to meet the specified output voltage after the pressure has been stabilized and the electrical supply has been applied.

4.3.11 Dimensions

Dimensions with specified tolerance shall be included on technical drawings.

4.3.12 Mechanical characteristics

- Weight
- Cavity volume
- Volumetric displacement
- Hermeticity

5 Measuring methods

5.1 General

5.1.1 General precautions

The general precautions listed in clause 2 of IEC 60747-1, Chapter VII, apply.

5.1.2 Measuring conditions

The measurements shall be made over the operating pressure range at 25 °C, unless otherwise specified.

5.2 Output voltage measurements

5.2.1 Purpose

To measure output voltage under specific conditions.

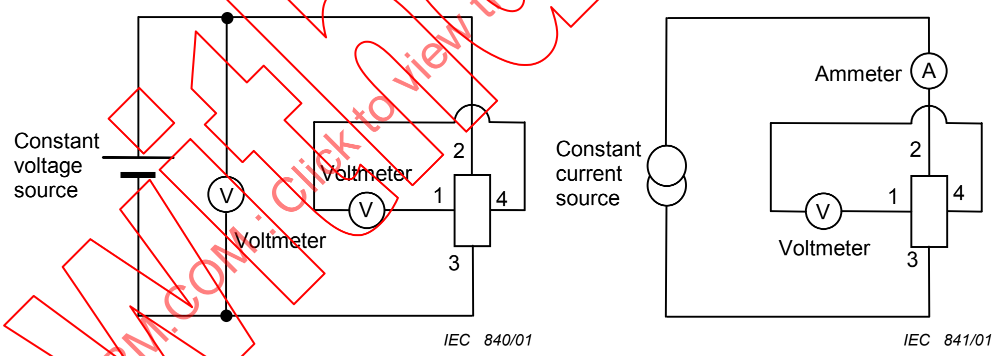
5.2.2 Principles of measurement

a) Circuit diagram – piezo resistive types

b) Circuit description and requirements

Internal impedance of the meters and/or measuring instrument must not affect the performance and the test results of the circuit to be measured.

NOTE Semiconductor pressure sensors are very sensitive to temperature; always wait for thermal stabilization of the device under test.



Key

1 Output +
2 Input +
3 Input –
4 Output –

Figure 1a – Constant voltage **Figure 1b – Constant current**

Figure 1 – Basic circuit for measurement of output voltage

5.2.2.1 Measurement procedure – full-scale span

Ambient temperature is stabilized.

Apply a specified voltage or current to the input terminals of the device, using the circuit shown in figure 1.

Place the device with connected terminals to the circuit at a specified pressure. Wait for thermal stabilization.

Measure full-scale output: V_{FSO} at P_{max}.

Measure V_{os} at zero pressure applied.

Calculate the full-scale span V_{FSS} with the equation:

$$V_{FSS} = V_{FSO} - V_{os}$$

5.2.2.2 Specified conditions

Ambient or reference temperature.

Applied pressure.

Supply voltage or current.

5.3 Sensitivity (S)

5.3.1 Purpose

To measure the sensitivity of the device under specified conditions.

5.3.2 Measuring procedure

Measure the voltage output for two pressures, P_1 and P_2, and calculate:

$$S = (V_2 - V_1) / (P_2 - P_1)$$

NOTE In practice, P_1 and P_2 are the end-points of the pressure range; reference temperature is 25 °C. The sensitivity can be called in that case full-scale sensitivity.

5.3.3 Specified conditions

Ambient or reference temperature.

Pressures at which the measurements are carried out.

Supply voltage or current.