IEC 62830-1

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INTERNATIONAL STANDARD

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Semiconductor devices – Semiconductor devices for energy harvesting and generation –
Part 1: Vibration based piezoelectric energy harvesting

Dispositifs à semiconducteurs – Dispositifs à semiconducteurs pour récupération et production d'énergie –
Partie 1: Récupération d'énergie piézoélectrique basée sur des vibrations

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Part 1: Vibration based piezoelectric energy harvesting

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

FDIS	Report on voting
47/2341/FDIS	47/2366/RVD

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

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

A list of all parts in the IEC 62830 series, published under the general title *Semiconductor devices – Semiconductor devices for energy harvesting and generation*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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SEMICONDUCTOR DEVICES – SEMICONDUCTOR DEVICES FOR ENERGY HARVESTING AND GENERATION –

Part 1: Vibration based piezoelectric energy harvesting

1 Scope

This part of IEC 62830 defines terms, definitions, symbols, configurations, and test methods that can be used to evaluate and determine the performance characteristics of vibration based piezoelectric energy harvesting devices for practical use. This document is applicable to energy harvesting devices for consumer, general industries, military and aerospace applications without any limitations on device technology and size.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60749-5:2003, *Semiconductor devices – Mechanical and climatic test methods – Part 5: Steady-state temperature humidity bias life test*

IEC 60749-12:2002, *Semiconductor devices – Mechanical and climatic test methods – Part 12: Vibration, variable frequency*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

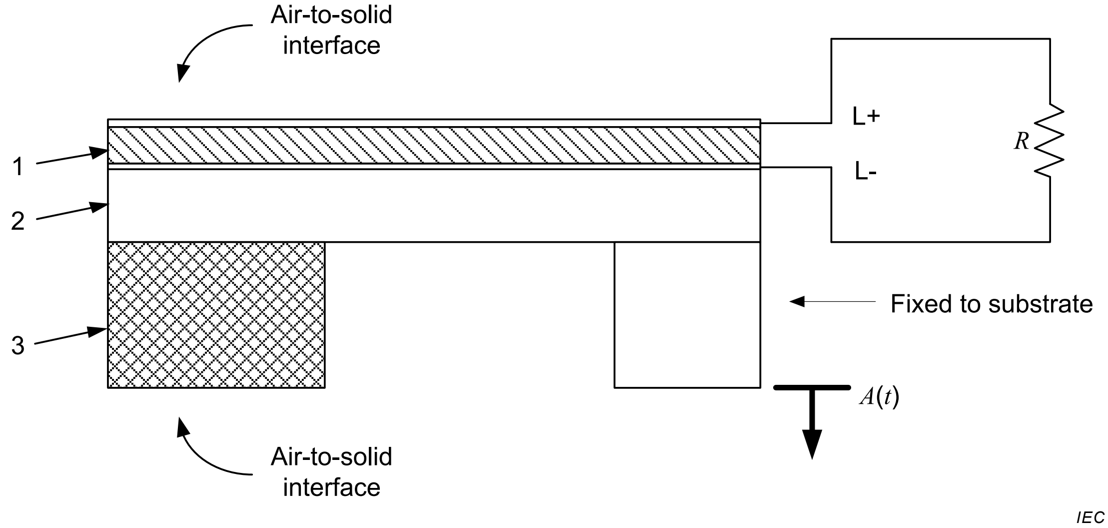
3.1 General terms

3.1.1
vibration
mechanical oscillation

3.1.2
vibration based energy harvester
energy transducer that transforms vibration energy into electric energy

Note 1 to entry: A vibration based energy harvester to convert vibration to electricity by using piezoelectric transducers comprises an inertial mass, spring, and piezoelectric transducer as shown in Figure 1. The piezoelectric transducer contains the two electrodes and a piezoelectric film. The induced vibration introduces the reciprocating motion to the mass. The spring which suspends the mass bends and the bending of the spring introduces tensile and compression of the piezoelectric film. The top and bottom electrodes of the piezoelectric film harvest charges generated from the piezoelectric effect.

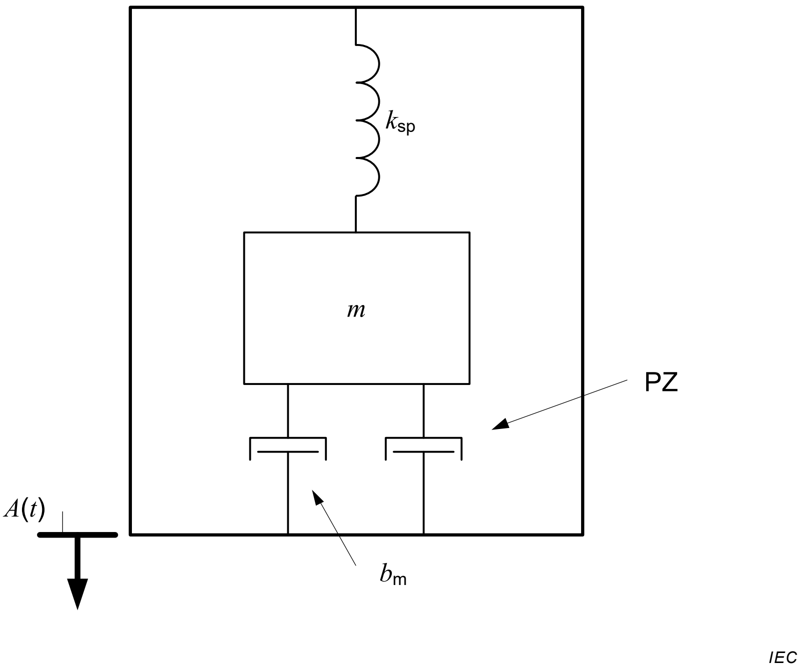
Note 2 to entry: A vibration based energy harvester is represented as shown in Figure 2. It is configured by mass, spring, damping, and piezoelectric transducer. The piezoelectric transducer consumes and transforms the kinetic energy of oscillated proof mass. Therefore, the piezoelectric transducer is generally viewed as damping.



Key

Configuration of energy harvester		**Components to operate an energy harvester**	
1	piezoelectric film which is a body layer of a piezoelectric transducer for energy harvesting	$A(t)$	vibration which is mechanically induced oscillation to fixed substrate to vibrate the mass of the energy harvester
2	spring to couple the induced vibration to the mass by suspending it	R	external load
3	inertial mass to introduce mechanical motion coupling from induced vibration	L+, L-	output of energy harvester

Figure 1 – A vibration based energy harvester using cantilever with piezoelectric film



Key

Configuration of energy harvester

k_{sp}	spring constant	m	effective mass
b_m	damping coefficient	PZ	piezoelectric transducer
$A(t)$	input vibration		

Figure 2 – Conceptual diagram of a vibration based piezoelectric energy harvester

3.1.3
mass-spring-damping system
system using effective mass, spring and damper to derive motion

3.1.4
effective mass
m
quantitative measure suspended by a spring to obtain kinetic energy by means of induced acceleration

3.1.5
spring
elastic object to store mechanical energy with spring constant, k_{sp}

3.1.6
parasitic damping
effect that reduces the acceleration of an oscillated object with damping coefficient, b_m

3.2 Piezoelectric transducer

3.2.1
piezoelectric transducer
energy converter to generate electricity from mechanical energy by means of piezoelectric effect

3.2.2
piezoelectric effect
effect by which a mechanical deformation of piezoelectric material produces a proportional change in the electric polarization of that material

3.2.3
piezoelectric constant
d
quantifying value of the polarization in the piezoelectric material on application of a stress

3.2.4
electromechanical coupling coefficient
k
value that describes the conversion rate of electrical energy to mechanical energy or vice versa

Note 1 to entry: The coefficient is a combination of elastic, dielectric and piezoelectric constants which appears naturally in the expression of a piezoelectric transducer.

$$k = \sqrt{\frac{Ed^2}{\varepsilon}} \quad (1)$$

where

E is Young's modulus,

d is the piezoelectric constant, and

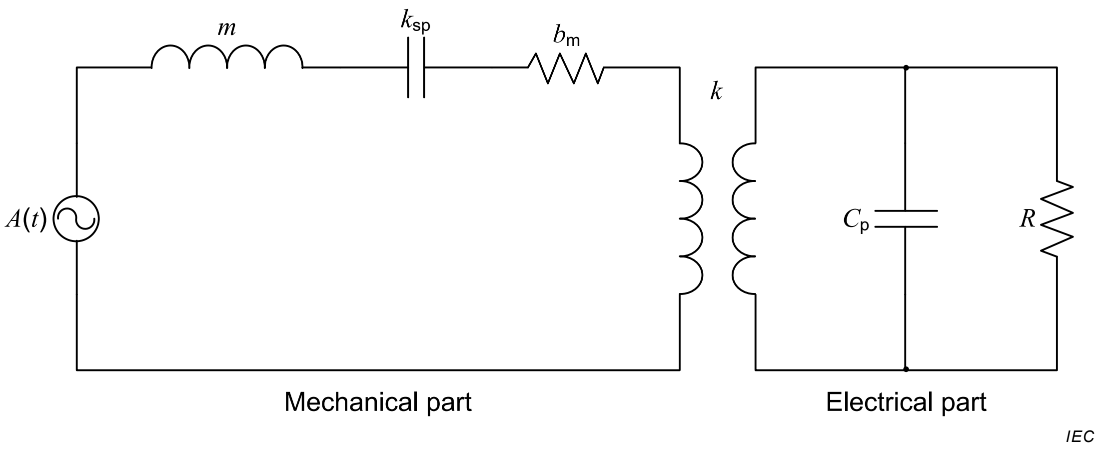
ε is the dielectric constant

3.2.5
capacitance
C_p
capacitance between two electrodes of a piezoelectric transducer

3.3 Characteristic parameters

3.3.1
equivalent circuit
<vibration based piezoelectric energy harvester> electrical circuit which has the same output voltage from induced vibration as a piezoelectric vibration energy harvester in the immediate neighbourhood of resonance

Note 1 to entry: A vibration based piezoelectric energy harvester can be divided into mechanical and electrical parts as shown in Figure 3. The mechanical part consists of series elements m, k_{sp}, b_m, and a transformer. m, k_{sp}, and b_m represent the effective mass, spring constant, damping coefficient, and piezoelectric effect to convert mechanically induced strain to electrical charge density with coupling coefficient k. The electrical part comprises parallel connected C_p, R, and transformer. C_p represents the capacitance between two electrodes of the piezoelectric transducer and R is the external load.



Key

Mechanical part

m	effective mass
k_{sp}	spring constant
b_m	damping coefficient
$A(t)$	induced vibration

Electrical part

C_p	capacitance of piezoelectric transducer
R	external load
k	electromechanical coupling coefficient

Figure 3 – Equivalent circuit of a vibration based piezoelectric energy harvester

3.3.2
resonant frequency
f_o
lowest frequency of the induced vibration of the energy harvester to generate largest output power:

$$f_o = \frac{1}{2\pi}\sqrt{\frac{k_{sp}}{m}} \quad (2)$$

3.3.3
bandwidth
f_{BW}
separation of frequencies between which the output power is equal to or larger than a specified value

3.3.4
open circuit voltage
V
electrical potential difference relative to a reference node of an energy harvester when there is no external load connected to the terminal of the energy harvester

3.3.5
output power
P
electrical power transferred to the external load connected to the terminal of an energy harvester

3.3.6
output current
I
current through the external load connected to the terminal of an energy harvester

3.3.7
optimal load
R_{opt}
specified value of the external load for transferring the largest electrical energy from the energy harvester

3.3.8
settling time
τ
time necessary for the measured output signal to reach a specified value in the transient response

3.3.9
temperature range
range of temperatures as measured on the enclosure over which the energy harvester will not sustain permanent damage though not necessarily functioning within the specified tolerances

3.3.10
input vibration
range of accelerations of induced vibration to the energy harvester as measured on the enclosure over which the energy harvester will not sustain permanent damage though not necessarily functioning within the specified tolerances

4 Essential ratings and characteristic parameters

4.1 Identification and type

The vibration energy harvester shall be clearly and durably marked in the order given below:

a) year and week (or month) of manufacture;
b) manufacturer's name or trademark;
c) terminal identification (optional);
d) serial number;
e) factory identification code (optional).

4.2 Limiting values and operating conditions

Characteristic parameters should be listed as shown in Table 1. The manufacturer shall clearly announce the operating conditions and their limitation for energy harvesting. Limiting value is the maximum induced vibration to ensure the operation of vibration energy harvester for power generation without any damage.

Table 1 – Specification parameters for vibration based piezoelectric energy harvesters

Parameter	Symbol	Min.	Max.	Unit	Measuring conditions
Insert name of characteristic parameters					

4.3 Additional information

Some additional information should be given such as equivalent circuits (resonant frequency, internal impedance, frequency response, output voltage and power, etc.), handling precautions, physical information (outline dimensions, terminals, etc.), accessories,