



BSI Standards Publication

Semiconductor devices — Micro-electromechanical devices

Part 32: Test method for the nonlinear vibration of MEMS resonators



IEC 62047-32

Edition 1.0 2019-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Semiconductor devices – Micro-electromechanical devices –
Part 32: Test method for the nonlinear vibration of MEMS resonators**

**Dispositifs à semiconducteurs – Dispositifs microélectromécaniques –
Partie 32: Méthode d'essai pour la vibration non linéaire des résonateurs MEMS**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 31.080.99

ISBN 978-2-8322-6455-3

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	3
1 Scope.....	5
2 Normative references	5
3 Terms and definitions	5
4 Test parameters of nonlinear vibration of the resonators	5
5 Test method for the amplitude-frequency response and phase-frequency response of the nonlinear vibration	6
5.1 Test system	6
5.2 Test conditions	6
5.3 Test procedures	7
6 Test method for the bending factor of the nonlinear vibrating frequency response	7
7 Test method for the amplitude threshold for the nonlinear jump	7
8 Test method for the frequency deviation as a result of the nonlinear vibration	8
8.1 Frequency deviation of the self-excitation closed-loop system.....	8
8.2 Frequency deviation of the phase-locked closed-loop system	8
8.3 Frequency deviation of the burst-excited system	9
Annex A (normative) Model of nonlinear vibration of MEMS resonators and bending factor	10
A.1 Model of nonlinear vibration of MEMS resonators	10
A.2 Solution of the nonlinear vibration model	11
A.3 Bending factor of the amplitude-frequency response	11
Annex B (informative) Nonlinear jump of the frequency response of MEMS resonators	14
Annex C (normative) Frequency deviation of MEMS resonators in the closed-loop system.....	16
C.1 Effect of the frequency deviation of the MEMS resonator on the accuracy of the resonant sensor	16
C.2 Frequency deviation of the self-exciting closed-loop system	16
C.3 Frequency deviation of the phase-locked closed-loop system	16
C.4 Oscillation frequency deviation of the burst-excited closed-loop system	18
Figure 1 – Test system	6
Figure 2 – 3 dB bandwidth of the linear amplitude-frequency response	8
Figure A.1 – Typical amplitude-frequency response of the nonlinear vibration of the MEMS resonator	12
Figure A.2 – Change of the amplitude-frequency response with the bending factor	13
Figure B.1 – Jump phenomenon of the frequency response of a clamped-clamped MEMS bridge resonator	14
Figure B.2 – Three nonlinear amplitude-frequency responses with various amplitude level ...	15

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES –
MICRO-ELECTROMECHANICAL DEVICES –

Part 32: Test method for the nonlinear vibration of MEMS resonators

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.

International Standard IEC 62047-32 has been prepared by subcommittee 47F: Micro-electromechanical systems, of IEC technical committee 47: Semiconductor devices.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
47F/322/FDIS	47F/325/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 62047 series, published under the general title *Semiconductor devices – Micro-electromechanical devices*, 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
- 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 – MICRO-ELECTROMECHANICAL DEVICES –

Part 32: Test method for the nonlinear vibration of MEMS resonators

1 Scope

This part of IEC 62047 specifies the test method and test condition for the nonlinear vibration of MEMS resonators. The statements made in this document apply to the development and manufacture for MEMS resonators.

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 62047-1, *Semiconductor devices – Micro-electromechanical devices – Part 1: Terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62047-1 and the following apply.

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

3.1

nonlinear vibration

vibration whose displacement has a nonlinear relationship with the elastic restoring force, with the change of the vibration amplitude

3.2

nonlinear jump

jump phenomenon of the frequency response curve when the vibration amplitude exceeds a certain threshold

3.3

frequency deviation

deviation of the vibration frequency of the resonator in a closed-loop system from the natural frequency of the resonator

4 Test parameters of nonlinear vibration of the resonators

Test parameters of nonlinear vibration of the resonators are:

- a) amplitude-frequency response of the nonlinear vibration, $A(\omega)$;
- b) phase-frequency response of the nonlinear vibration, $P(\omega)$;

- c) bending factor of the amplitude-frequency response, b ;
- d) amplitude threshold for the nonlinear jump, a_c ;
- e) frequency deviation of the self-exciting closed-loop system, E_1 ;
- f) frequency deviation of the phase-locked closed-loop system, E_2 ;
- g) frequency deviation of the burst-exciting closed-loop system, E_3 .

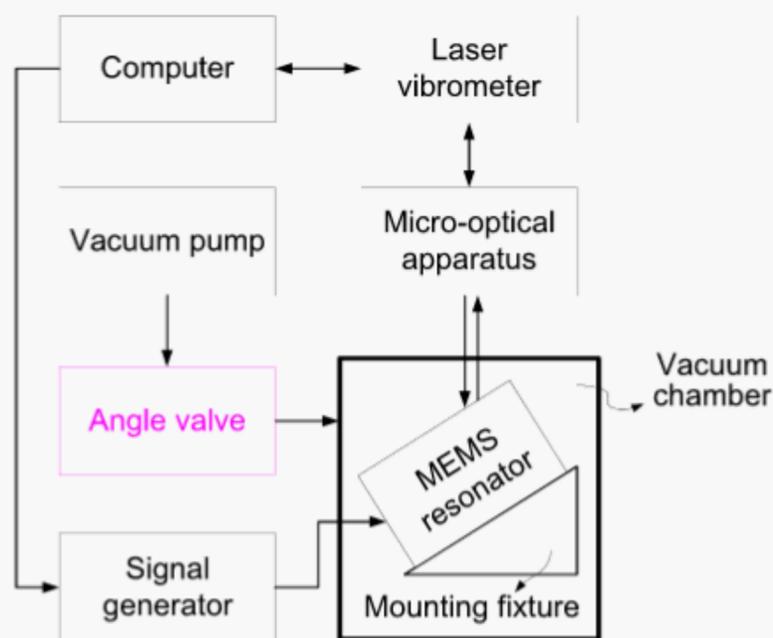
5 Test method for the amplitude-frequency response and phase-frequency response of the nonlinear vibration

5.1 Test system

A test system consists of the following equipments:

- a) laser vibrometer;
- b) micro-optical apparatus;
- c) signal generator;
- d) vacuum chamber;
- e) mounting fixture;
- f) vacuum pump;
- g) angle valve.

The test system is illustrated in Figure 1.



IEC

Figure 1 – Test system

5.2 Test conditions

- a) Keep the ambient temperature within $23\text{ °C} \pm 5\text{ °C}$.
- b) Maintain the vacuum degree of the vacuum chamber according to the actual operation of the resonator.
- c) Adjust the micro-optical apparatus to restrict the laser spot within the surface of the resonator.
- d) For transparent resonators, the laser beam should illuminate on the metal layer on the resonator to enhance the reflected laser intensity.
- e) The connection of the resonator, the installing base and the vacuum chamber should be strong enough.

- f) For out-of-plane vibrating resonators, the surface of the installing base should be parallel to the horizontal plane. For in-plane vibrating resonators, the surface of the installing base should be set to a certain angle about the horizon level, to ensure enough intensity of the reflected laser into the detector.
- g) The vacuum pump and the vacuum chamber should be connected with flexible bellows in case of the vibration propagation from the pump to the chamber.
- h) The angle valve should be tightly shut off to well maintain the vacuum level, and then the pump turned off before operating the test procedure.

5.3 Test procedures

- a) Set the frequency of the vibration excitation according to the estimated value of the natural frequency of the resonator. And then implement the initial frequency scan around the natural frequency within a wide range. The amplitude frequency response and the phase frequency response can be measured according to the vibration displacement of the resonators. And record the resonant frequency of the resonator.
- b) Reset the vibration excitation parameters to implement the frequency scan for the second time: reducing the interval of the frequency scan to half of that set in the initial frequency scan and reducing the range of the frequency scan to ten times of the half-power bandwidth of the amplitude frequency response. The amplitude frequency response and the phase frequency response can be measured according to the vibration displacement of the resonators. And record the resonant frequency of the resonator.
- c) Compare the resonant frequencies obtained by the initial and the second tests. If the discrepancy in the resonant frequencies is smaller than 1 ppm¹ of the resonant frequency measured in the second test, either the initial or the second test result can be deemed as the accurate amplitude frequency response and the phase frequency response. If the discrepancy in the resonant frequencies exceeds 1 ppm of the resonant frequency measured in the second test, the third time frequency scan with further small frequency interval should be implemented, until the discrepancy in last tested resonant frequency and the previous one is smaller than that 1 ppm of the resonant frequency measured in the last test.

6 Test method for the bending factor of the nonlinear vibrating frequency response

- a) Test the nonlinear vibrating amplitude frequency response of the MEMS resonator according to the method presented in Clause 5. And obtain the resonant frequency ω_r and the resonant amplitude a_r .
- b) The bending factor can be calculated by substituting the resonant frequency ω_r and the resonant amplitude a_r into Formula (A.11) as provided in Annex A. The value of ω_n can be determined by its design value.

$$b = \frac{\omega_r - \omega_n}{a_r^2} \quad (1)$$

7 Test method for the amplitude threshold for the nonlinear jump

- a) Obtain the bending factor of the amplitude frequency response of the MEMS resonator by the method set out in Clause 6.
- b) The nonlinear jump phenomenon is presented in Annex B. Figure B.1. The amplitude threshold for the nonlinear jump can be calculated by substituting the bending factor b into Formula (2).

¹ ppm = part per million

$$a_c = \sqrt{\frac{4\omega_n}{3\sqrt{3}Q|b|}} \quad (2)$$

where

a_c is the amplitude threshold for the nonlinear jump;

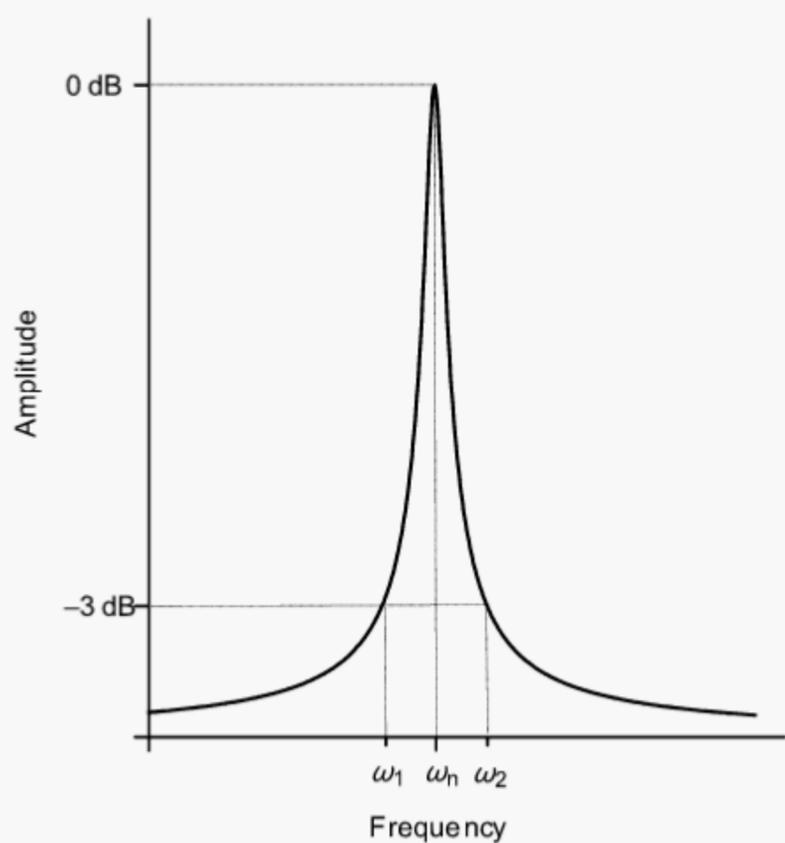
Q is the quality factor of the resonator with linear vibration.

The value of Q can be obtained by the following formula:

$$Q = \frac{\omega_n}{\omega_2 - \omega_1} \quad (3)$$

where

ω_1 and ω_2 are the boundary points of the -3 dB bandwidth of the linear amplitude-frequency response, which is shown in Figure 2.



IEC

Figure 2 – 3 dB bandwidth of the linear amplitude-frequency response

8 Test method for the frequency deviation as a result of the nonlinear vibration

8.1 Frequency deviation of the self-excitation closed-loop system

- Obtain the bending factor of the amplitude frequency response of the MEMS resonator by the method provided in Clause 6.
- Frequency deviation of the self-excitation closed-loop system can be calculated by substituting the bending factor b into Formula (C.3).

$$E_1 = \frac{ba_s^2}{\omega_n} \times 100 \% \quad (4)$$

8.2 Frequency deviation of the phase-locked closed-loop system

- Obtain the bending factor of the amplitude frequency response of the MEMS resonator by the method provided in Clause 6.

- b) Frequency deviation of the phase-locked closed-loop system can be calculated by substituting the bending factor b into Formula (C.12).

$$E_2 = \frac{ba^2}{\omega_n} \times 100 \% \quad (5)$$

8.3 Frequency deviation of the burst-excited system

- a) Obtain the bending factor of the amplitude frequency response of the MEMS resonator by the method provided in Clause 6.
- b) Frequency deviation of the burst-excited system can be calculated by substituting the bending factor b into Formula (6)

$$E_2 = \frac{ba^2}{\omega_n} e^{-\frac{1}{Q}\omega_n t} \quad (6)$$

where

t is the time with the definition of $t=0$ when disconnecting the excitation;

e is the natural constant.

Annex A (normative)

Model of nonlinear vibration of MEMS resonators and bending factor

A.1 Model of nonlinear vibration of MEMS resonators

The vibration behaviour of the MEMS resonators can be illustrated by the Duffing equation which is shown in Formula (A.1)

$$m\ddot{x} + c\dot{x} + k_1x + k_3x^3 = F^* \cos(\omega t) \quad (\text{A.1})$$

where

m is the equivalent mass of the resonator;

c is the coefficient of the damping;

k_1 is the linear stiffness coefficient;

k_3 is the nonlinear stiffness coefficient;

F^* is the amplitude of the driving force;

ω is the frequency of the driving force;

x is the vibration displacement;

t is the time.

Then transform Formula (A.1) by dividing it by the equivalent mass, m :

$$\ddot{x} + \omega_n^2 x = -\frac{c}{m} \dot{x} - \frac{k_3}{m} x^3 + \frac{F^*}{m} \cos(\omega t) \quad (\text{A.2})$$

For an actual resonator, the nonlinear term $-k_3x^3/m$ in Formula (A.2) is small. Therefore a small parameter ε is introduced to implement the multiple scales algorithm. Formula (A.2) is transformed to:

$$\ddot{x} + \omega_n^2 x = -2\varepsilon\mu\dot{x} - \varepsilon\alpha x^3 + F \cos(\omega t) \quad (\text{A.3})$$

where

$$\alpha = \frac{k_3}{m\varepsilon} \quad (\text{A.4})$$

$$\mu = \frac{c}{2m\varepsilon} \quad (\text{A.5})$$

$$F = \frac{F^*}{m} \quad (\text{A.6})$$

A.2 Solution of the nonlinear vibration model

The solution of the nonlinear vibration model is derived by the multiple scales algorithm, which is shown in Formula (A.7).

$$x = a \cos(\omega t - \varphi) + O(\varepsilon) \quad (\text{A.7})$$

where

a is the vibration amplitude of the MEMS resonators;

φ is the phase delay between the vibration displacement of the MEMS resonator and the force;

$O(\varepsilon)$ is the symbol of the same order infinitesimal of ε .

The amplitude-frequency response of the MEMS resonator is shown in Formula (A.8) in an implicit expression.

$$\omega = \omega_n + ba^2 \pm \sqrt{\frac{F^2}{4\omega_n^2 a^2} - \varepsilon^2 \mu^2} \quad (\text{A.8})$$

where

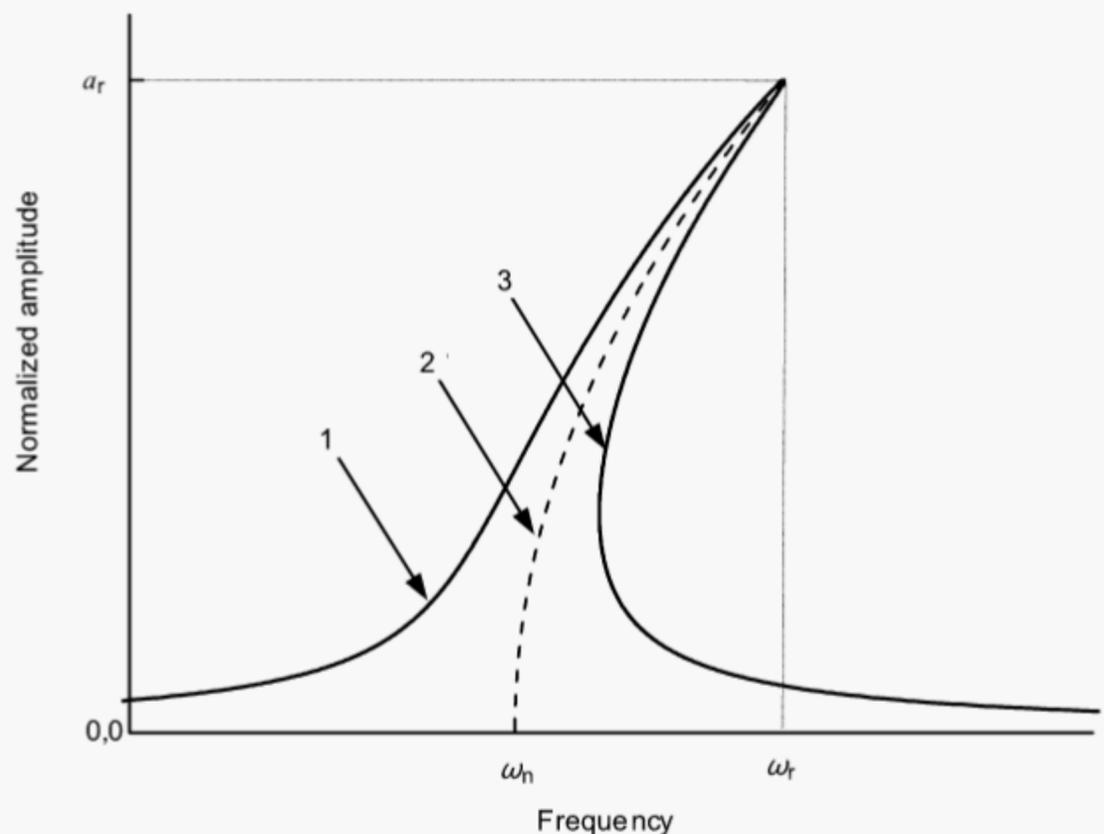
$$b = \frac{3a\varepsilon}{8\omega_n} \quad (\text{A.9})$$

The phase-frequency response of the MEMS resonator is shown in Formula (A.10) in an implicit expression.

$$\omega = \omega_n + b \frac{F^2}{4\varepsilon^2 \omega_n^2 \mu^2} \sin^2 \varphi - \mu \varepsilon \cot \varphi \quad (\text{A.10})$$

A.3 Bending factor of the amplitude-frequency response

The nonlinear amplitude-frequency response of the MEMS resonator can be derived from Formula (A.8), which is shown in Figure A.1. The curve between the left and the right branches is the bone curve.



IEC

Key

- 1 left branch
- 2 bone curve
- 3 right branch

Figure A.1 – Typical amplitude-frequency response of the nonlinear vibration of the MEMS resonator

The bone curve is a parabolic form, which can be presented by Formula (A.11).

$$a = \sqrt{\frac{\omega - \omega_n}{b}} \quad (\text{A.11})$$

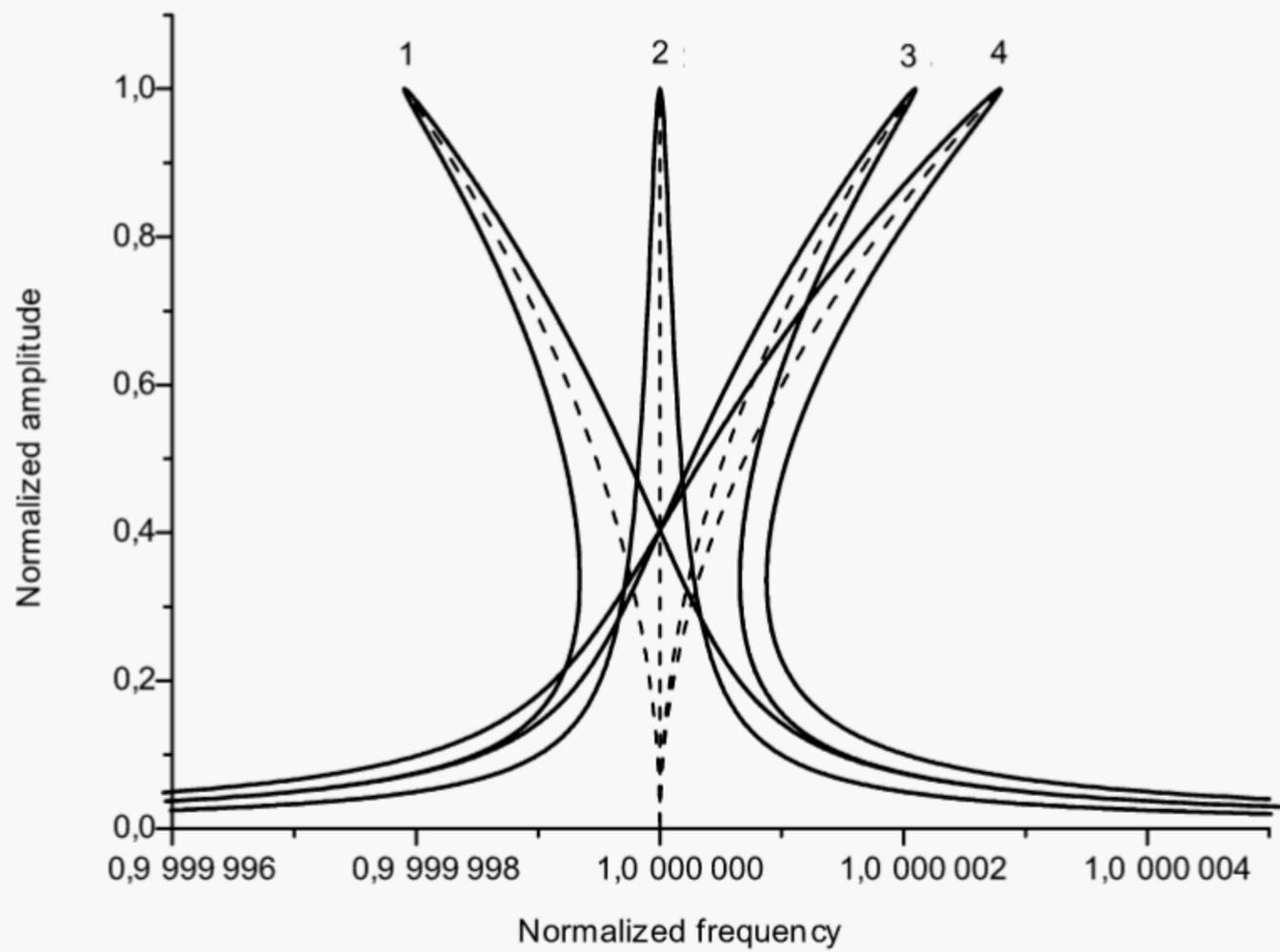
where

ω_n is the natural frequency of the resonator.

The parameter b in Formula (A.11) is the bending factor, which can be obtained by substituting the resonant point (ω_r, a_r) into Formula (A.11).

$$b = \frac{\omega_r - \omega_n}{a_r^2} \quad (\text{A.12})$$

The intensity of the nonlinear vibration is evaluated by the bending factor b . Figure A.2 shows the change of the nonlinear amplitude-frequency response with the bending factor. The amplitude-frequency response with negative bending factor bends towards the lower frequency, which is noted as the softening spring effect. And the one with the positive bending factor bends towards the higher frequency, which is known as the hardening spring effect. The amplitude-frequency response with $b = 0$ indicates the linear vibration.



IEC

Key

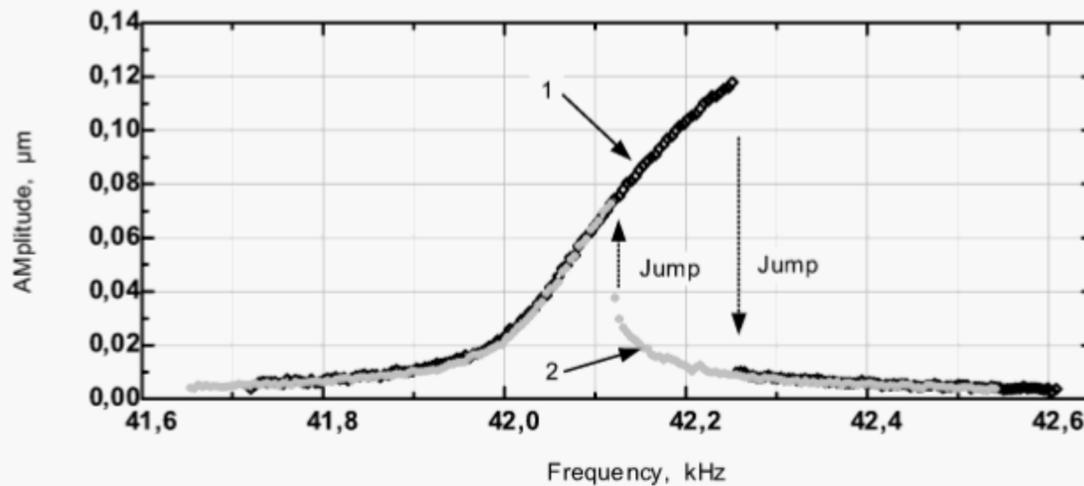
- 1 $b_1 < 0$
- 2 $b_2 = 0$
- 3 $b_3 > 0$
- 4 $b_4 > 0$, and $b_4 > b_3$

Figure A.2 – Change of the amplitude-frequency response with the bending factor

Annex B (informative)

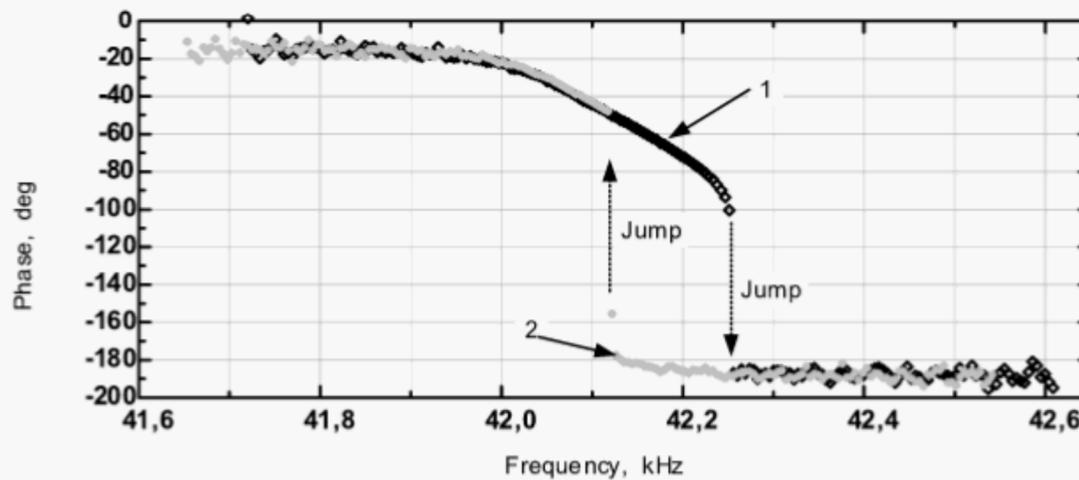
Nonlinear jump of the frequency response of MEMS resonators

The nonlinear jump occurs when the vibration amplitude exceeds a certain value, leading to the jump of the frequency response, which is shown in Figures B.1 a) and B.1 b). Amplitude and phase jumps would cause the breakdown of the resonator. Therefore, it is necessary to evaluate the amplitude threshold for the nonlinear jump to keep the vibration amplitude of the resonator in a resonant sensor smaller than the amplitude threshold.



IEC

a) Amplitude jump



IEC

b) Phase jump

Key

- 1 forward scan
- 2 backward scan

Figure B.1 – Jump phenomenon of the frequency response of a clamped-clamped MEMS bridge resonator

There are three amplitude-frequency response curves in Figure B.2. The one with the amplitude peak of ar_1 does not take on the nonlinear jump. With the increase of the amplitude peak, the one with the amplitude peak of ar_3 jumps around its peak. Between the peaks of ar_1 and ar_3 , a given amplitude peak of ar_2 demarcates the boundary between the nonlinear jump and the non-nonlinear jump. This given amplitude peak is referred to as the amplitude threshold for the nonlinear jump.

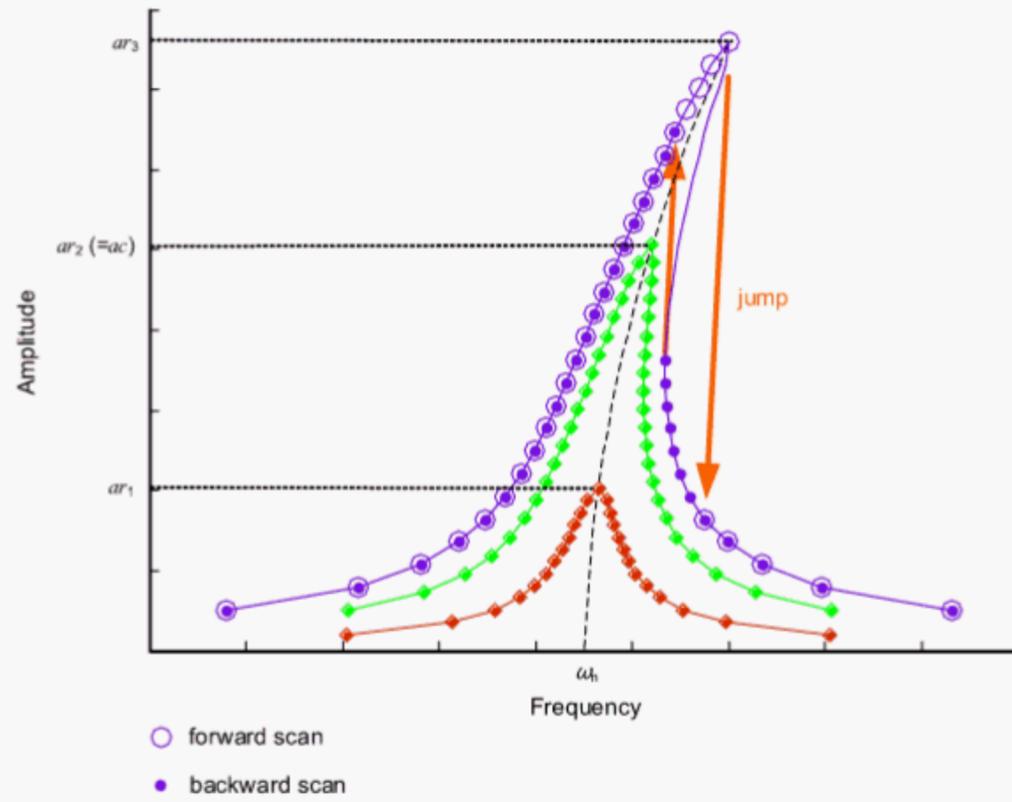


Figure B.2 – Three nonlinear amplitude-frequency responses with various amplitude level

For a resonator with natural frequency of 40 kHz, Q factor of 30 000, and measured bending factor of $1,228 \text{ E}+15 \text{ rad}/(\text{s}\cdot\text{m}^2)$, according to Formula (2), the amplitude threshold is 75,6 nm.

Annex C (normative)

Frequency deviation of MEMS resonators in the closed-loop system

C.1 Effect of the frequency deviation of the MEMS resonator on the accuracy of the resonant sensor

There are three kinds of closed-loop systems in the resonant sensors: the self-excited closed-loop, the phase-locked closed loop and the burst-excited closed loop. All these closed-loop systems take advantage of the linear frequency response characteristics to track the natural frequency of the resonator. However, under the nonlinear vibration, the frequency response would be changed. Consequently, the oscillation frequency of the closed-loop system drifts from the natural frequency of the resonator, which cause the measurement error of the resonant sensor.

C.2 Frequency deviation of the self-exciting closed-loop system

In a self-exciting closed-loop system, the driving force and the damping force nearly balance each other. The vibration behaviour of the resonator is shown in Formula (C.1).

$$\ddot{x} + \omega_n^2 x = -\varepsilon a x^3 \quad (\text{C.1})$$

By the Lindstedt-Poincaré algorithm, the solution of Formula (C.1) is obtained. And the vibration frequency is:

$$\begin{aligned} \omega_s &= \omega_n + \frac{3a a_s^2}{8\omega_n} \varepsilon + O(\varepsilon^2) \\ &= \omega_n + b a_s^2 + O(\varepsilon^2) \end{aligned} \quad (\text{C.2})$$

where

ω_s is the vibration frequency of a resonator in the self-exciting closed-loop system;

a_s is the vibration amplitude of a resonator in the self-exciting closed-loop system;

$O(\varepsilon^2)$ is the symbol of the same order infinitesimal of ε^2 .

The frequency deviation of the self-exciting closed-loop system is:

$$E_1 = \frac{\omega_s - \omega_n}{\omega_n} \approx \frac{b a_s^2}{\omega_n} \times 100 \% \quad (\text{C.3})$$

C.3 Frequency deviation of the phase-locked closed-loop system

In the phase-locked loop, the vibration displacement maintains $\pi/2$ delay relative to the driving force. Substitute $\varphi = \pi/2$ into Formula (A.9):

$$\omega_{\pi/2} = \omega_n + b \frac{F^2}{4\varepsilon^2 \omega_n^2 \mu^2} \quad (\text{C.4})$$

where

$\omega_{\pi/2}$ is the vibration frequency of a resonator in the phase-locked closed-loop system.

The frequency deviation of the phase-locked closed-loop system is:

$$E_2 = \frac{\omega_{\pi/2} - \omega_n}{\omega_n} = b \frac{F^2}{4\varepsilon^2 \omega_n^3 \mu^2} \times 100 \% \quad (\text{C.5})$$

F , in Formula (C.5), could be obtained from Formula (A.8):

$$F = 2\omega_n a_r \varepsilon \mu \quad (\text{C.6})$$

Therefore, Formula (C.5) could be rewritten as:

$$E_2 = \frac{b a_r^2}{\omega_n} \times 100 \% \quad (\text{C.7})$$

Substitute Formula (C.6) into Formula (C.4):

$$\omega_{\pi/2} = \omega_n + b a_r^2 \quad (\text{C.8})$$

Formula (A.11) could be rewritten as:

$$\omega_r = \omega_n + b a_r^2 \quad (\text{C.9})$$

Comparing Formula (C.8) and (C.9), it could be deduced that:

$$\omega_{\pi/2} = \omega_r \quad (\text{C.10})$$

Therefore

$$a_{\pi/2} = a_r \quad (\text{C.11})$$

where

$a_{\pi/2}$ is the vibration amplitude of a resonator in the phase-locked closed-loop system.

Substitute Formula (C.11) into Formula (C.7). The frequency deviation of the phase-locked closed-loop system could be rewritten as:

$$E_2 = \frac{b a_{\pi/2}^2}{\omega_n} \times 100 \% \quad (\text{C.12})$$

C.4 Oscillation frequency deviation of the burst-excited closed-loop system

In the burst-excited system, the excitation and the detection of the resonator are separated in the time domain. The detected free oscillation frequency is the frequency output of the burst-excited system. The frequency deviation can be obtained by the comparison of the frequency output of the burst-excited system with the natural frequency.

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards-based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Copyright in BSI publications

All the content in BSI publications, including British Standards, is the property of and copyrighted by BSI or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use.

Save for the provisions below, you may not transfer, share or disseminate any portion of the standard to any other person. You may not adapt, distribute, commercially exploit, or publicly display the standard or any portion thereof in any manner whatsoever without BSI's prior written consent.

Storing and using standards

Standards purchased in soft copy format:

- A British Standard purchased in soft copy format is licensed to a sole named user for personal or internal company use only.
 - The standard may be stored on more than 1 device provided that it is accessible by the sole named user only and that only 1 copy is accessed at any one time.
 - A single paper copy may be printed for personal or internal company use only.
- Standards purchased in hard copy format:
- A British Standard purchased in hard copy format is for personal or internal company use only.
 - It may not be further reproduced – in any format – to create an additional copy. This includes scanning of the document.

If you need more than 1 copy of the document, or if you wish to share the document on an internal network, you can save money by choosing a subscription product (see 'Subscriptions').

Reproducing extracts

For permission to reproduce content from BSI publications contact the BSI Copyright & Licensing team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email subscriptions@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Useful Contacts

Customer Services

Tel: +44 345 086 9001

Email (orders): orders@bsigroup.com

Email (enquiries): cservices@bsigroup.com

Subscriptions

Tel: +44 345 086 9001

Email: subscriptions@bsigroup.com

Knowledge Centre

Tel: +44 20 8996 7004

Email: knowledgecentre@bsigroup.com

Copyright & Licensing

Tel: +44 20 8996 7070

Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK