IEC TR 62967

Edition 1.0 2018-08

TECHNICAL REPORT

Methods for calculating the main static performance indicators of transducers and transmitters

IEC TR 62967:2018-08(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 25.040.40 ISBN 978-2-8322-5980-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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METHODS FOR CALCULATING THE MAIN STATIC PERFORMANCE INDICATORS OF TRANSDUCERS AND TRANSMITTERS

FOREWORD

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IEC TR 62967, which is a technical report, has been prepared by subcommittee 65B: Measurement and control devices of IEC technical committee 65: Industrial-process measurement, control and automation.

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

Enquiry draft	Report on voting
65B/961/DTR	65B/1016/RVC

Full information on the voting for the approval of this technical report 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.

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- withdrawn,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.

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

INTRODUCTION

This technical report provides a comprehensive illustration of the methods for calculating the main static performance indicators of transducers, transmitters and similar measuring devices. First of all, in order to avoid any misunderstanding, we would like to review the commonly-accepted definition of transducers and transmitters. Generally speaking, in a measurement field, a transducer is a measuring device which converts the non-electrical quantity to be measured into corresponding electrical quantity, while a transmitter is a kind of transducer which is required to provide a previously-given linear output.

The common-in-use standards [01]-[06][1] listed in the relevant documents to be considered in this report, are useful in evaluating the main static performance indicators of measuring instruments and other similar devices. But the relevant descriptions of calculation methods in standards [01]-[05] are not complete and adequate in many ways. This fact was clearly stated in the Introduction of IEC 61298 [03].

On the whole, these publications [01]-[05] mainly contain relevant technical terms and definitions. Since in essence, they are not standards which are dedicated solely to the calculation of performance indicators, so they contain no or only very simple and inadequate illustrations of the calculation methods. Moreover, as these contents have existed for about tens of years, probably now is the time to make an all-round revision and improvement of them. Since there are many static performance indicators that should be calculated and the calculation methods can form a rather complete system. So it is better to create a separate report or a separate standard.

For the main static performance indicators, the existing relevant IEC standards have only theoretical definitions, but have no specific calculation methods. This does not mean that these methods are too simple to mention. But on the contrary, some of them are too difficult to be used in industry. Therefore, this report puts forward, improves and simplifies the existing relevant calculation methods, may probably serve as a good basis on which to create a new calculation-oriented IEC standard.

The report is intended for use by manufacturers to work out their factory-level test standards, by users to make rigorous acceptance tests and wise applications, and by authorized metrological establishments to verify the measuring device performance indicators of the manufacturers or of the users.

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[1] Numbers in square brackets refer to the Bibliography.

METHODS FOR CALCULATING THE MAIN STATIC PERFORMANCE INDICATORS OF TRANSDUCERS AND TRANSMITTERS

1 Scope

This Technical Report provides guidance on the assurance of reliability data of automation devices. If the source of this data is calculation, guidance is given on how to specify the methods used for this calculation. If the source is through observations, guidance is given on how to describe these observations and their evaluations. If the source is the outcome of laboratory tests, guidance is given on how to specify these tests and the conditions under which they have been carried out.

This document defines the form to present the data.

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 60050-300, *International Electrotechnical Vocabulary – Electrical and electronic measurements and measuring instruments*

Part 311: General terms relating to measurements

Part 312: General terms relating to electrical measurements

Part 313: Types of electrical measuring instruments

Part 314: Specific terms according to the type of instrument

IEC 60050-351, *International Electrotechnical Vocabulary – Part 351: Control technology*

IEC 60770-1:1999 *Transmitters for Use in Industrial-process Control Systems – Part 1: Methods for Performance Evaluation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-300, IEC 60050-351 and IEC 60770-1:1999, as well as the following 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 Basic terms

3.1.1
static characteristics
relationship of the output of a transducer to its input, when the measurand is at the state of stabilization or very slow variation

Note 1 to entry: There are many performance indicators under the title of static characteristics.

Note 2 to entry: Static performance indicators are applicable only under a given interval of temperature.

3.1.2
static calibration
process in which the static characteristics are obtained under given static conditions

3.1.3 Input terms

3.1.3.1
lower range-value
lowest value of the measurand

3.1.3.2
upper range-value
highest value of the measurand

3.1.3.3
measuring range
measuring region indicated by the upper and lowr range-values of the measurand

3.1.3.4
span
span, also called the full-span input, is the algebraic difference between the upper and lower range-values of the measurand.

3.1.4 Output terms

3.1.4.1
zero-range-value output
output when measurand is at its zero range-value

3.1.4.2
lower-range-value output
output when measurand is at its lowest range-value

3.1.4.3
upper-range-value outpu
output when measurand is at its highest range-value

3.1.4.4
full-span output
algebraic difference between the upper-range-value output and lower-range-value output of a device as defined by its working characteristics

3.1.5
linearity
closeness to which the output-input curve of a transducer approximates a straight line

Note 1 to entry: There should be no contribution of hysteresis and repeatability to linearity.

3.1.6
conformity
closeness to which the output-input curve of a transducer approximates a certain curve

Note 1 to entry: There should be no contribution of hysteresis and repeatability to conformity.

3.1.7
reference characteristics
straight line, curve or equation which is used as a reference or a contrast

Note 1 to entry: Under a certain application situation, reference characteristics can be accepted as the true characteristics of a transducer.

Note 2 to entry: In this Technical report, reference characteristics are mainly used in the calculation of linearities, conformities, and linearity (conformity) plus hysterresis.

3.1.8
working characteristics
output-input equation or curve, which is adopted as the true characteristics of a transducer

Note 1 to entry: Working Characteristics has taken into consideration the combined contribution of linearity (conformity), hysteresis and repeatability.

3.1.9
utilization characteristics
relationship of the measurand to the output of a transducer

3.1.10
linear transducer
kind of transducers whose working characteristics are linear

3.1.11
non-linear transducer
kind of transducers whose working characteristics are non-linear

3.2 Static calibration characteristics

3.2.1
up-travel actual average characteristics
curve connecting all the arithmetic average points of a group of measured data at all the calibration points in the up-travel

3.2.2
down-travel actual average characteristics
curve connecting all the arithmetic average points of a group of measured data at all the calibration points in the down-travel

3.2.3
up-travel and down-travel actual average characteristics
curve connecting all the arithmetic average points of a group of measured data at all the calibration points in the up- and down-travel

Note 1 to entry: It is also called the actual average characteristics (or curve) of a transducer.

3.3 Definitions of static performance indicators

3.3.1
resolution
smallest change in input that can cause observable change in output in the whole input span

3.3.2
sensitivity
ratio of output change to its corresponding input change

3.3.3
hysteresis
for the same input and in the whole input span, difference between the values of the down-travel actual average characteristics and the up-travel actual average characteristics

3.3.4
repeatability
for a short time interval and in the same working condition, degree of scatterance of a group of readings obtained when the input is approaching the same measuring point in the same direction for a number of test cycles

3.3.5
linearity
maximum deviation of the actual average characteristics (curve) from the reference straight line

Note 1 to entry: Linearity is expressed as a percentage of full-span output.

Note 2 to entry: According to different reference straight lines taken, there are different kinds of linearities, with the following as the main ones.

Note 3 to entry: When expressed simply as linearity, it is assumed to be independent linearity.

Note 4 to entry: The choice of linearities depends on the application situations of transducers.

3.3.5.1
absolute linearity
also called theoretical linearity, it is calculated from the reference straight line or theoretical straight line that can be specified before the calibration test is made

Note 1 to entry: Absolute linearity actually shows the linearity accuracy of a transducer and is quite different from all the linearities that follow.

Note 2 to entry: Absolute linearity is exclusively used in transmitter applications.

3.3.5.2
terminal-based linearity
linearity calculated from the terminal-based straight line that is taken as the reference straight line

Note 1 to entry: Terminal-based straight line coincides with the actual average characteristics (curve) at its upper and lower limits.

Note 2 to entry: Terminal-based Linearity is easy to calculate, but its value is rather conserved.

3.3.5.3
shifted terminal-based linearity
linearity calculated from the shifted terminal-based straight line that is taken as the reference straight line

Note 1 to entry: The shifted terminal-based straight line has the same slope as the terminal-based straight line and can minimize its maximum deviation from the actual average characteristics (curve) by parallel shifting.

Note 2 to entry: If the device under test has a C-shaped actual average characteristics (curve), the shifted terminal-based straight line will become the best straight line, or best line in short.

3.3.5.4
zero-based linearity
linearity calculated from the zero-based straight line that is taken as the reference straight line

Note 1 to entry: Zero-based straight line goes through the theoretical zero point and can minimize its maximum deviation from the actual average characteristics (curve) by changing its slope.

Note 2 to entry: Sometimes zero-based straight line is also called the forced zero-intersecting best straight line.

3.3.5.5
front-terminal-based linearity
linearity calculated from the front-terminal-based straight line that is taken as the reference straight line

Note 1 to entry: The front-terminal-based straight line goes through the front end of the actual average characteristics (curve) and can minimize its maximum deviation from the actual average characteristics (curve) by changing its slope.

Note 2 to entry: Sometimes and in some references, the front-terminal-based straight line is also called the zero-based straight line.

3.3.5.6
independent linearity
linearity calculated from the best straight line that is taken as the reference straight line

Note 1 to entry: The best straight line is a straight-line midway between the two parallel straight lines closest together and enclosing the actual average characteristics (curve).

Note 2 to entry: The best straight line can minimize its maximum deviation from the actual average characteristics (curve).

3.3.5.7
least-squares linearity
linearity calculated from the least-squares straight line which is adopted as the reference straight line

Note 1 to entry: The least-squares straight line can guarantee that, the sum of the squares of the deviations of the actual average characteristics (curve) from it, is a minimum.

3.3.6
conformity
maximum deviation of the actual average characteristics (curve) from the reference curve

Note 1 to entry: Conformity is expressed as a percentage of full-span output.

Note 2 to entry: According to different reference curves taken, there are different kinds of conformities, with the following as the main ones.

Note 3 to entry: The reference curve is usually in the form of an algebraic polynomial of a certain degree.

Note 4 to entry: When expressed simply as conformity, it is assumed to be independent conformity.

Note 5 to entry: The choice of conformities depends on the application situations of transducers.

3.3.7
absolute conformity
also called theoretical conformity, it is calculated from the reference curve or theoretical curve that can be specified before the calibration test is made

Note 1 to entry: Absolute conformity actually shows the conformity accuracy of a transducer and is quite different from all the conformities that follow.

Note 2 to entry: The reference curve should be specified according to the application requirement of the transducer.

3.3.7.1
terminal-based conformity
conformity calculated from the terminal-based curve that is taken as the reference curve

Note 1 to entry: Terminal-based curve coincides with the actual average characteristics (curve) at its upper and lower limits and can minimize its maximum deviation from the actual average characteristics (curve).