

Performance characteristics and calibration methods for digital data acquisition systems and relevant software

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British Standard

ICS 33.200

National foreword

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 47 and a back cover.

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Amendments issued since publication

Amd. No.	Date	Comments

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 24 January 2006

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**Performance characteristics and calibration methods
for digital data acquisition systems
and relevant software
(IEC 62008:2005)**

Caractéristiques de performance
et méthodes d'étalonnage
pour les systèmes d'acquisition
de données numériques
et logiciels appropriés
(CEI 62008:2005)

Leistungseigenschaften
und Kalibrierverfahren
für digitale Datenerfassungssysteme
und entsprechende Software
(IEC 62008:2005)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 85/267/FDIS, future edition 1 of IEC 62008, prepared by IEC TC 85, Measuring equipment for electrical and electromagnetic quantities, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62008 on 2005-10-01.

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2006-07-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2008-10-01 |

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62008:2005 was approved by CENELEC as a European Standard without any modification.

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INTRODUCTION

Totally automated measurement systems are becoming the norm for manufacturing test, research and any other area where measurements are made. Measurement automation leads to extensive data sharing, inter-instrument communication and remote measurement control. Multifunction data acquisition (DAQ) devices meet these measurement needs. They rely on standard computer technology, allowing measurement systems developers to leverage open computer standards. The measurements made by DAQ devices are accurate and traceable. The need for measurement integrity requires developing standards not only for the measurement hardware but also for the software that calibrates the hardware.

PERFORMANCE CHARACTERISTICS AND CALIBRATION METHODS FOR DIGITAL DATA ACQUISITION SYSTEMS AND RELEVANT SOFTWARE

1 Scope

This International Standard specifies performance characteristics and calibration methods for digital data acquisition systems and relevant software to ensure that all measurement systems relying on DAQ devices meet a common standard.

This standard covers:

- the minimum specifications that the DAQ device manufacturer must provide to describe the performance of the analogue-to-digital module (ADM) of the DAQ device;
- standard test strategies to verify the minimum set of specifications;
- the minimum calibration information required by the ADM that is stored on the DAQ device;
- the minimum calibration software requirements for external and self-calibration of the ADM of the DAQ device.

This standard deals with low frequency signal conversion, e.g. applications such as plant control, vibration measurement, vibro-diagnostics, acoustics, ultrasonic measurements, temperature measurements, pressure measurements, measurement in power electronics, etc.

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 60748-4:1997, *Semiconductor devices – Integrated circuits – Part 4: Interface integrated circuits*

IEC 60748-4-3:____¹⁾, *Semiconductor devices – Integrated circuits – Part 4-3: Interface integrated circuits – Dynamic criteria for analogue-to-digital converters (ADC)*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, *Guide to the Expression of Uncertainty in Measurement (GUM)*

¹⁾ To be published.

3 Terms, definitions, abbreviations and symbols

3.1 Terms and definitions

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

3.1.1

analogue-to-digital module

ADM

analogue input of a multifunction DAQ device

3.1.2

application program interface

API

standardized set of subroutines or functions along with the parameters that a program can call. An API for DAQ devices allows the programmer to communicate and control the operation of the device

3.1.3

code transition level

value of the input parameter of an ADM at the transition point between two adjacent output codes. The transition point is defined as the input value that causes 50 % of the output codes to be less than and 50 % to be greater than or equal to the upper code of the transition. The transition level $T[k]$ lies between code $k - 1$ and code k

3.1.4

data acquisition device

DAQ

device for entering or collecting data

NOTE Multifunction DAQ devices rely on a personal computer (commercial PC, Industrial PC, Compact PCI, notebook etc.) for control. These devices are designed to meet the needs of a general-purpose measurement system. They are not designed for a specific type of measurement. DAQ devices generally provide multiple measurement modes such as analogue input, analogue output, digital input, digital output, and counter-timer functionality. This standard only deals with the ADM of a DAQ device.

3.1.5

midstep value

analogue value for the centre of the step excluding the steps at the two ends of the total range of analogue values

NOTE For the end steps, the midstep value is defined as the analogue value that results when the analogue value for the transition to the adjacent step is reduced or enlarged as appropriate by half the nominal value of the step width.

3.1.6

nominal midstep value

specified analogue value within a step that is ideally represented and free of error by the corresponding digital output code

3.1.7

rated operating conditions

set of conditions that must be fulfilled during the measurement in order that the parameters determining the measurement uncertainty may be valid.

3.1.8**step**

the fractional range of analogue input values and the corresponding digital output value.

3.1.9**step width**

the absolute value of the difference between the two ends of the range of analogue values corresponding to one step.

3.2 Abbreviations and symbols

ADM	Analogue to digital module
API	Application program interface
CMRR	Common mode rejection ratio
DAQ	Data acquisition device
DIFF	Differential
DNL	Differential non-linearity
ENOB	Effective number of bits
FS	Full scale
INL	Integral non-linearity
LSB	Least significant bit
NRSE	Non-referenced single ended
PC	Personal computer
RSE	Referenced single ended
SINAD	Signal to noise and distortion
SFDR	Spurious free dynamic range
V_{FS}	Full scale
V_{FSnom}	Nominal full scale range
V_{FSR}	Practical full scale range
V_Z	Zero
V_{ZS}	Zero scale

4 General requirements**4.1 Test procedures and measurement uncertainty estimation**

A common set of specifications must be presented for comparing the ADM of one DAQ device to the ADM of another DAQ device. This is especially true when different manufacturers produce the ADMs. This document includes a core set of information that allows a side-by-side comparison of ADM capabilities.

DAQ devices are designed to meet their published specifications. If there is a need to verify these specifications, this standard presents procedures for testing the ADM to confirm the specifications of the DAQ device.

Using the specifications listed in 4.2, the measurement uncertainty of the ADM of a DAQ device can be determined.

4.2 General requirements for ADMs

The required specifications listed below are a minimum subset of the possible specifications.

The basic parameters describing an ADM include:

- number of channels;
- types of inputs;
- full-scale input range;
- overvoltage protection;
- resolution;
- sampling rate;
- input impedance;
- maximum working voltage;
- rated operating conditions.

The measurable parameters that can be tested include the following²⁾:

- gain component of uncertainty;
- offset;
- common mode rejection ratio;
- temperature drift of gain and offset;
- integral non-linearity;
- differential non-linearity;
- noise;
- settling time;
- channel switching error;
- crosstalk;
- analogue input bandwidth.

Where appropriate the following parameters apply:

- signal-to-noise and distortion ratio (SINAD);
- effective number of bits (ENOB);
- spurious free dynamic range (SFDR);
- total harmonic distortion (THD);
- signal to non-harmonic ratio (SNHR).

4.3 Descriptions of parameters

NOTE It is assumed that the input value measured is voltage.

4.3.1 Number of channels

The number of input signals supported by the ADM that can be simultaneously or sequentially sampled.

²⁾ Other requirements specific for medium and high frequencies are treated by IEC 60748-4-3

4.3.2 Types of input

Type of input defines how input signals can be connected to the ADM. Possible modes include:

- referenced single ended (RSE) – an RSE connection is one in which the DAQ device's analogue input signal is referenced to a common ground that can be shared with other input signals;
- non-referenced single ended (NRSE) – an NRSE connection is one in which the DAQ device's analogue input signal is referenced to the signal local ground. In this case the local ground must be different from the analogue ground of the measurement system;
- differential (DIFF) – a DIFF connection is one in which the DAQ device's analogue input signal has its own reference signal or signal return path. An ADM with DIFF inputs may specify input impedance as the impedance between the positive input and negative input of the ADM. An ADM with DIFF inputs may also specify input impedance as the impedance between either the positive input and ground or the negative input and ground.

4.3.3 Full-scale input range

The full-scale input range is the total range in analogue values that theoretically can be coded with constant accuracy by the total number of steps. The full-scale input range is expressed in volts (see 2.1.18 of IEC 60748-4, Chapter II). Refer to V_{FSnom} in Figures C.1 and C.2.

4.3.4 Overvoltage protection

Overvoltage protection is the protection of the input circuitry of an ADM from potentially damaging voltages. Overvoltage protection can be shown for the powered on and powered off states of the DAQ device. Overvoltage protection is expressed in volts.

4.3.5 Resolution

The degree to which nearly equal values of the analogue input quantity can be distinguished (see 2.2.1 of IEC 60748-4, Chapter II).

NOTE 1 Numerical resolution is the number (n) of bits necessary to express the total number of steps (see 2.2.2 of IEC 60748-4, Chapter II).

NOTE 2 Analogue resolution (Q) is the nominal value of the step width (see 2.2.3 of IEC 60748-4, Chapter II).

4.3.6 Sampling rate

The number of conversions per unit time. Sampling rate is usually expressed in samples per second.

4.3.7 Gain component of uncertainty

The difference between the actual and the ideal transition voltages in the transfer diagram at the specified gain point, after the offset has been adjusted to zero. Gain component of uncertainty is expressed in % of full-scale input range and should include the warranted time interval of calibration (see 2.2.5.3 of IEC 60748-4, Chapter II).

4.3.8 Offset

The difference between the actual and the ideal first transition levels (see Figure C.3). Offset is expressed in the units of measure for the ADM and should include the warranted time interval of calibration (see 2.2.5.2 of IEC 60748-4, Chapter II).

NOTE The first transition level is the transition level where the ADM output changes from 0 to 1. See 3.1.3 for the definition of code transition level.

4.3.9 Common mode rejection ratio (CMRR)

The ratio of the voltage applied between a specified reference point and the input terminals of the ADM, when connected together by a specified circuit, to the voltage required between the input terminals of the ADM to produce the same output.

NOTE The common mode rejection ratio is usually expressed in decibels and may depend upon frequency.

4.3.10 Input impedance

Input impedance is the impedance between the signal input of the ADM and signal common. Input impedance must be specified when the ADM is powered on, powered off, and when isolated input limits are overloaded (if applicable).

4.3.11 Temperature drift of gain and offset

Temperature drift of gain is expressed in % of full scale input range per degree Celsius. Temperature drift of offset is expressed in units of measure for the ADM per degree Celsius.

4.3.12 Integral non-linearity (INL)

The difference between the actual analogue value at the transition between any two adjacent steps and its ideal value, after offset and gain component of uncertainty have been adjusted to zero. Integral non-linearity describes the difference between the actual value and the ideal value of the analogue quantity. INL is expressed in LSB.

4.3.13 Differential non-linearity (DNL)

The difference between the actual step width and the ideal value. DNL is expressed in LSB.

4.3.14 Maximum working voltage

Maximum working voltage is the highest voltage that should be applied to an ADM in normal use. The working voltage is normally well under the breakdown voltage for safety margin. The maximum working voltage is the sum of the actual signal voltage and the common mode voltage and is expressed in volts.

4.3.15 Noise

Noise is any deviation between the ADM output signal (converted to input units) and the ADM input signal except for deviations caused by linear time invariant system response (gain and phase shift), a DC level shift, or a deviation in the sample rate. For example, noise includes the effects of random deviations, fixed pattern deviations, nonlinearities, time base deviations (fixed deviation in sample time and aperture uncertainty, also known as jitter) and the

undesirable infiltration of internal digital signals to the analogue part. Noise is expressed in the units of measure for the ADM.

NOTE 1 For DC or very low frequency input signals it is usual to describe system noise as measured in 4.4.7, which does not include the effect of non-linearity and time base deviations.

NOTE 2 SINAD and ENOB include the effects of non-linearity and time base deviations.

4.3.16 Settling time for single channel measurements

The time it takes the ADM to reach a certain accuracy and stay within that accuracy. Settling time is expressed in seconds required to achieve the given accuracy range. Settling time for single channel measurements is defined for an ADM measuring a step signal on a single channel.

4.3.17 Channel switching error

The maximum amplitude deviations introduced by switching the ADM between channels. Channel switching error is expressed in % FSR.

4.3.18 Signal-to-noise and distortion ratio (SINAD)

For a pure sine-wave input, ratio of the r.m.s. amplitude of the ADM output signal at the input frequency to the r.m.s. amplitude of all other signal in the ADM output (see 3.4 of IEC 60748-4-3).

NOTE SINAD information should be supplied at a range of gains over a range of input and sampling frequencies.

4.3.19 Crosstalk

The appearance of undesired energy in a channel caused by the presence of a signal on another channel, caused by for example, induction, conduction or non-linearity. Crosstalk is the ratio of the r.m.s. value on one channels output and the r.m.s. value of an input sine wave on another channel, expressed in dB.

NOTE Crosstalk information should be supplied at a range of gains of both channels and over a range of input frequencies.

4.3.20 Analogue input bandwidth

Analogue input bandwidth is the measure of an ADM's ability to pass a signal without significant attenuation over a range of frequencies. Analogue input bandwidth is normally measured between the lower and upper frequency points where the signal amplitude falls to –3 dB below the passband frequency. Analogue input bandwidth is expressed in Hz.

4.3.21 Effective number of bits (ENOB)

Practical limit of the resolution of an ADM due to inherent noise and non-linearity. Effective number of bits represents that the ADM performs as an ideal ADM with this number of bits (see 3.6 of IEC 60748-4-3).

NOTE Effective number of bits information should be supplied at a range of gains over a range of input and sampling frequencies.

4.3.22 Spurious free dynamic range (SFDR)

For a pure sine-wave input, ratio, expressed in dB, of the r.m.s. value of the output signal at the input frequency to the largest persistent r.m.s. value of the output at any other single frequency.

4.3.23 Total harmonic distortion (THD)

For a sine wave signal, the sum of power of all harmonics. It can be expressed in dBp = dB re 10^{-12} W.

4.3.24 Signal to non harmonic ratio (SNHR)

Ratio, expressed in dB of the power of the signal with all possible harmonics, to the overall noise.

4.4 Testing methods of measurable parameters

4.4.1 Measuring code transition levels

The measurement of the code transition levels can be used to determine several ADM parameters such as the ADM transfer function, gain component of uncertainty, offset, INL and DNL.

In many cases ADM figures of merit vary with input and clock frequencies. As a consequence they must be characterized at frequencies close to those at which they are expected to be used. When the ADMs are to be used for the measurement of time variable quantities, dynamic characterization should be performed (test methods for dynamic characterization are provided in IEC 60748-4-3). If the ADM is to be used to measure slow varying signals the characterization of the ADM through the static tests listed below is sufficient and desirable.

4.4.1.1 Static test (method A)

In this test a variable DC input is applied to the ADM in order to measure all code transition levels.

The variable DC input is generated by a programmable source with resolution at least two times better than the precision (P) required for the measurement of the code transition levels.

The programmable source begins to apply an input level slightly lower than the expected value for the first code transition level ($T[1]$) of the ADM. A record of M samples is taken. The number of samples greater or equal than code 1 are counted. If its value is less than $M/2$, the input level is incremented by $2P$ and the procedure repeated until the first transition level is found (50 % of samples greater or equal than output code 1). Subsequent code transition levels are found by applying successive input levels to the ADM under test. For each code transition level the percentage of codes that are greater than code k is evaluated and if it is less than 50 % the input level is raised by $2P$. When the percentage is greater than 50 %, the transition level is considered to be crossed. The code transition levels are computed by linear interpolation based on the record and percentages in the two last applied input levels. The starting point for the determination of transition level $T[k + 1]$ is the measured code transition level for $T[k]$.