INTERNATIONAL STANDARD

ISO 10360-12

First edition
2016-10-01

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) —

Part 12: Articulated arm coordinate measurement machines (CMM)

Spécification géométrique des produits (GPS) — Essais de réception et de vérification périodique des systèmes de mesure tridimensionnels (SMT) —

Partie 12: Machines à mesurer tridimensionnelles à bras articulés (MMT)

Reference number
ISO 10360-12:2016(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 10360 consists of the following parts, under the general title *Geometrical Product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS)*:

— *Part 1: Vocabulary*

— *Part 2: CMMs used for measuring linear dimensions*

— *Part 3: CMMs with the axis of a rotary table as the fourth axis*

— *Part 4: CMMs used in scanning measuring mode*

— *Part 5: CMMs using single and multiple stylus contacting probing system*

— *Part 6: Estimation of errors in computing of Gaussian associated features*

— *Part 7: CMMs equipped with imaging probing systems*

— *Part 8: CMMs with optical distance sensors*

— *Part 9: CMMs with multiple probing systems*

— *Part 10: Laser trackers for measuring point-to-point distances*

— *Part 12: Articulated arm coordinate measuring machines (CMM)*

Introduction

This part of ISO 10360 is a general GPS standard (see ISO 14638). For more detailed information about the relation of this part of ISO 10360 to other standards and the GPS matrix model, see Annex I.

This part of ISO 10360 is included in the ISO/GPS Masterplan given in ISO 14638, which gives an overview of the ISO/GPS system. The fundamental rules of ISO/GPS given in ISO 8015 apply to this part of ISO 10360 and the default decision rules given in ISO 14253-1 apply to specifications made in accordance with this part of ISO 10360, unless otherwise indicated.

The objective of this part of ISO 10360 is to provide a well-defined testing procedure to

— enable manufacturers of articulated arm CMMs to provide specification MPEs, and

— enable users to test articulated arm CMMs to manufacturer specifications using calibrated traceable reference artefacts.

The benefits of these tests are that the measured result has a direct traceability to the unit length, the metre, and that they give information on how the articulated arm CMM will perform on similar length measurements.

Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) —

Part 12: Articulated arm coordinate measurement machines (CMM)

1 Scope

This part of ISO 10360 specifies the acceptance tests for verifying the performance of an articulated arm CMM by measuring calibrated test lengths as stated by the manufacturer. It also specifies the reverification tests that enable the user to periodically reverify the performance of the articulated arm CMM. It applies to articulated arm CMMs using tactile probes and optionally optical distance sensors (also referred to as laser line scanners or laser line probes). Details on tests for scanner accessories are given in Annex E.

This part of ISO 10360 does not specify how often or when testing is performed, if at all, nor does it specify which party should bear the cost of testing.

This part of ISO 10360 specifies

— performance requirements that can be assigned by the manufacturer or the user of the articulated arm CMM,

— the manner of execution of the acceptance and reverification tests to demonstrate the stated requirements,

— rules for proving conformance, and

— applications for which the acceptance and reverification tests can be used.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10360-8:2013, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) — Part 8: CMMs with optical distance sensors*

ISO 10360-9:2013, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring systems (CMS) — Part 9: CMMs with multiple probing systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions given in ISO 10360-1 and the following apply.

NOTE The definitions in this section are intended to concisely state the meaning of terms. For metrological characteristics that have numerical values, the complete description of the procedure and derivation of test results in Clause 6 and Annex E are to be followed in determining values.

3.1
articulated arm coordinate measuring machine
system that measures spatial coordinates and comprises

— an open chain of fixed-length segments,

— joint assemblies interconnecting the segments and the probing system and attaching them to the stationary environment, and

— a probing system at the free end of the chain

Note 1 to entry: The probing system may comprise a rigid probe or a sensing system such as a scanner.

Note 2 to entry: Rotary joint assemblies connected to the fixed-length segments are equipped with angular encoders. Cartesian coordinates of each measuring point are calculated from the measured angles and segment lengths.

3.2
joint
connection between adjacent elements of an articulated arm CMM that allows a single rotational degree of freedom between these elements

Note 1 to entry: There are two types of joints: hinge joints, which cause a hinging movement between adjacent arm segments, and swivel joints, which cause a rotary movement around the axis of the connected arm segment.

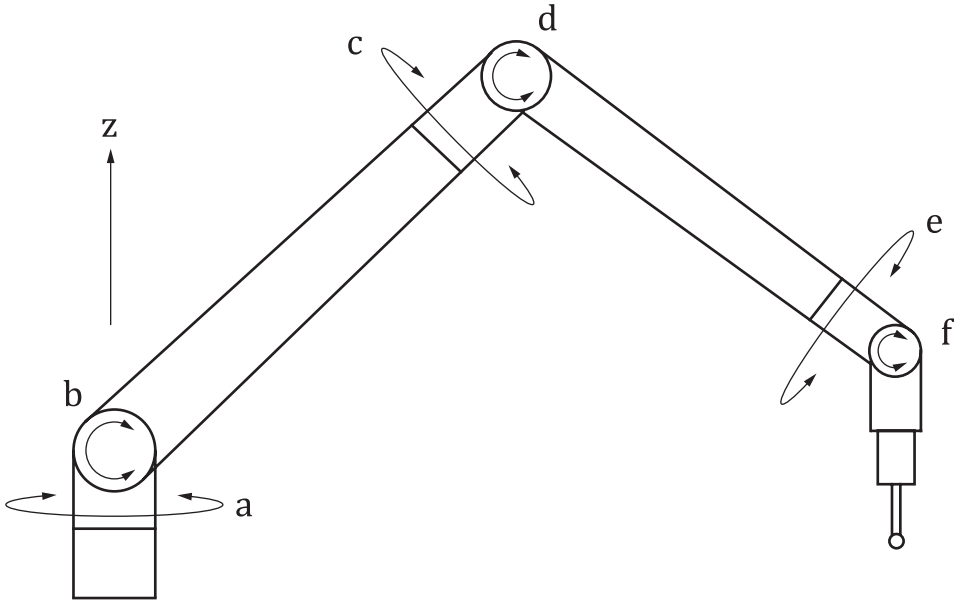
Note 2 to entry: Each joint ordinarily includes an angle measuring device (rotary encoder).

3.3
joint assembly
assembly of two or more joints between two adjacent elements of an articulated arm CMM

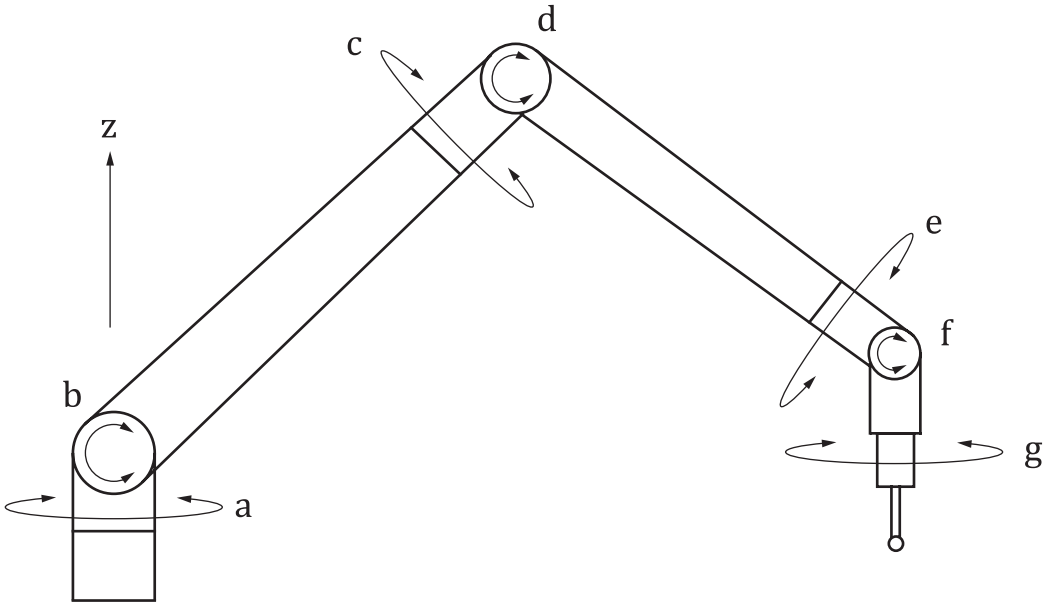
Note 1 to entry: Usually, a joint assembly includes at least a hinge joint and a swivel joint.

Note 2 to entry: In analogy to the human arm, the three main joint assemblies are designated the shoulder, elbow, and wrist.

Note 3 to entry: Current machines have 2 or 3 degrees of freedom each for shoulder (a, b), elbow (c, d), and wrist (e, f, g), as shown in Figure 1. Consequently, articulated arm CMMs are referred to as either six or seven axis machines.



a) With six rotary axes



b) With seven rotary axes

Figure 1 — Articulated arm CMM

3.4
measuring range
diameter of the spherical volume within which an articulated arm CMM is capable of measuring

Note 1 to entry: The measuring range is specified by the manufacturer.

Note 2 to entry: The measuring range is twice the reach of the articulated arm. However, some of the regions that can be reached by the articulated arm may not be within the measuring volume.

3.5
measuring volume
region in space over which the manufacturer specifies the performance of the articulated arm CMM

Note 1 to entry: The measuring volume is restricted by inaccessible zones specified by the manufacturer. For example, there may be an inaccessible zone close to the vertical main axis.

Note 2 to entry: Manufacturers may specify more than one measuring volume for a machine, each measuring volume having a separate performance specification.

Note 3 to entry: Because of the possibility of binding up a joint when adjacent arm segments are brought close together, the size of the measuring volume may depend on the direction of the probe stylus in relation to the outside of the measuring volume or inaccessible zones within the measuring volume. The manufacturer may specify one or more measuring volumes according to the direction of the probe stylus.

3.6
useful arm length
half the measuring range

3.7
coefficient of thermal expansion
CTE
α
linear thermal expansion coefficient of a material at 20 °C

Note 1 to entry: The above definition for CTE does not imply that a user is required to make measurements at 20 °C.

3.8
normal CTE material
material with a CTE between 8×10^{-6}/°C and 13×10^{-6}/°C

Note 1 to entry: Some documents may express CTE in units 1/K, which is equivalent to 1/°C.

[SOURCE: ISO 10360-2]

3.9
kinematic seat
mechanical seat (nest) that repeatably holds the centre of a spherical surface in a fixed position in space

Note 1 to entry: An example of a kinematic seat is a trihedral seat that includes three hardened spheres, each sphere placed on a circle and separated from the other spheres by nominally 120°. Each of the three spheres contacts the surface of a larger sphere (or spherical surface) so as to permit repeatable positioning of the centre of the larger sphere in space.

Note 2 to entry: As used in this part of ISO 10360, a kinematic seat provides constraint for 3 degrees of freedom rather than 6 degrees of freedom.

3.10
single-point articulation test
test in which articulated arm CMM probe is held within a kinematic seat while the elbow location is rotated by 180°

Note 1 to entry: The single-point articulation test is an interim test described in Annex D.

3.11
articulated location error, tactile
$L_{\text{Dia.5x5:Art:Tact.AArm}}$
diameter of the minimum circumscribed sphere encompassing the points that are the centres of the five spheres obtained from performing the articulated location test when using a tactile probe

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $L_{\text{Dia.5x5:Art}}$ is used.

3.12
length measurement error, bidirectional
$E_{\text{Bi:0:Tact.AArm}}$
error of indication when performing a bidirectional point-to-point distance measurement

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation E_{Bi} is used.

Note 2 to entry: The subscript 0 indicates that there is no tip offset. There may be an offset in some other parts of ISO 10360.

3.13
length measurement error, unidirectional
$E_{\text{Uni:0:Tact.AArm}}$
error of indication when performing a unidirectional point-to-point distance measurement

Note 1 to entry: Annex B discusses unidirectional and bidirectional measurements.

Note 2 to entry: In the context of this part of ISO 10360, the local abbreviation E_{Uni} is used.

3.14
probing form error, tactile
$P_{\text{Form.Sph.1x25::Tact.AArm}}$
error of indication within which the range of Gaussian radial distances can be determined by a Gaussian (least-squares) fit of 25 points measured by a tactile probe on a test sphere

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $P_{\text{Form.Sph.1x25}}$ is used.

3.15
probing size error, tactile
$P_{Size.Sph.1x25::Tact.AArm}$
error of indication of the diameter of a spherical material standard of size as determined by a Gaussian (least-squares) fit of 25 points measured by a tactile probe

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $P_{Size.Sph.1x25}$ is used.

3.16
maximum permissible error of articulated location error, tactile
$L_{Dia.5x5:Art:Tact.AArm,MPE}$
extreme value of the articulated location error, tactile, $L_{Dia.5x5:Art:Tact.AArm}$, permitted by specifications

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $L_{Dia.5x5:Art,MPE}$ is used.

3.17
maximum permissible error of bidirectional length measurement
$E_{Bi:0:Tact.AArm,MPE}$
extreme value of the bidirectional length measurement error, $E_{Bi:0:Tact.AArm}$, permitted by specifications

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $E_{Bi,MPE}$ is used.

3.18
maximum permissible error of unidirectional length measurement
$E_{Uni:0:Tact.AArm,MPE}$
extreme value of the unidirectional length measurement error, $E_{Uni:0:Tact.AArm}$, permitted by specifications

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $E_{Uni,MPE}$ is used.

3.19
maximum permissible error of probing form, tactile
$P_{Form.Sph.1x25::Tact.AArm,MPE}$
extreme value of the probing form error for tactile probe, $P_{Form.Sph.1x25::Tact.AArm}$, permitted by specifications

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $P_{Form.Sph.1x25,MPE}$ is used.

3.20
maximum permissible error of probing size, tactile
$P_{Size.Sph.1x25::Tact.AArm,MPE}$
extreme value of the probing size error for a tactile probe, $P_{Size.Sph.1x25::Tact.AArm}$, permitted by specifications

Note 1 to entry: In the context of this part of ISO 10360, the local abbreviation $P_{Size.Sph.1x25,MPE}$ is used.

3.21
rated operating condition
operating condition that must be fulfilled during measurement in order that a measuring instrument or measuring system performs as designed

Note 1 to entry: Rated operating conditions generally specify intervals of values for a quantity being measured and for any influence quantity.

[SOURCE: ISO/IEC Guide 99:2007, 4.9]

Note 2 to entry: Within the ISO 10360 series, the term “as designed” means as specified by MPEs.

Note 3 to entry: If an MPE specification is thought of as a function (where different MPE values could be given for different conditions), then the rated operating conditions define the domain of that function.

4 Symbols

For the purpose of this part of ISO 10360, the symbols of Table 1 apply.

Table 1 — Symbols

Global symbols	Local abbreviations	Term
$L_{Dia.5x5:Art:Tact.AArm}$	$L_{Dia.5x5:Art}$	Articulated location error, tactile
$E_{Uni:0:Tact.AArm}$	E_{Uni}	Length measurement error, unidirectional
$E_{Bi:0:Tact.AArm}$	E_{Bi}	Length measurement error, bidirectional
$P_{Form.Sph.1x25::Tact.AArm}$	$P_{Form.Sph.1x25}$	Probing form error, tactile
$P_{Size.Sph.1x25::Tact.AArm}$	$P_{Size.Sph.1x25}$	Probing size error, tactile
$E_{Uni:0:Tact.AArm,MPE}$	$E_{Uni,MPE}$	Maximum permissible error of unidirectional length measurement
$E_{Bi:0:Tact.AArm,MPE}$	$E_{Bi,MPE}$	Maximum permissible error of bidirectional length measurement
$P_{Form.Sph.1x25::Tact.AArm,MPE}$	$P_{Form.Sph.1x25,MPE}$	Maximum permissible error for probing form, tactile
$P_{Size.Sph.1x25::Tact.AArm,MPE}$	$P_{Size.Sph.1x25,MPE}$	Maximum permissible error of probing size, tactile
$L_{Dia.5x5:Art:Tact.AArm,MPE}$	$L_{Dia.5x5:Art,MPE}$	Maximum permissible error of articulated location error, tactile
$P_{Form.Sph.1x25::ODS.AArm}$	$P_{Form.Sph.1x25::ODS}$	Probing form error, ODS (based on ISO 10360-8)[a]
$P_{Form.Sph.D95\%::ODS.AArm}$	$P_{Form.Sph.D95\%::ODS}$	Probing dispersion error (based on ISO 10360-8)[a]
$P_{Size.Sph.1x25::ODS.AArm}$	$P_{Size.Sph.1x25::ODS}$	Probing size error, ODS (based on ISO 10360-8)[a]
$P_{Size.Sph.All::ODS.AArm}$	$P_{Size.Sph.All::ODS}$	Probing size error All (based on ISO 10360-8)[a]
$P_{Form.Sph.1x25::ODS.AArm,MPE}$	$P_{Form.Sph.1x25::ODS,MPE}$	Maximum permissible error for probing form, ODS (based on ISO 10360-8)[a]
$P_{Form.Sph.D95\%::ODS.AArm,MPE}$	$P_{Form.Sph.D95\%::ODS,MPE}$	Maximum permissible error for probing dispersion (based on ISO 10360-8)[a]
$P_{Size.Sph.1x25::ODS.AArm,MPE}$	$P_{Size.Sph.1x25::ODS,MPE}$	Maximum permissible error for probing size, ODS (based on ISO 10360-8)[a]
$P_{Size.Sph.All::ODS.AArm,MPE}$	$P_{Size.Sph.All::ODS,MPE}$	Maximum permissible error for probing size All (based on ISO 10360-8)[a]
$P_{Form.Pla.D95\%::ODS.AArm}$	$P_{Form.Pla.D95\%::ODS}$	Probing flat form error (based on ISO 10360-8)[a]
$P_{Form.Pla.D95\%::ODS.AArm,MPE}$	$P_{Form.Pla.D95\%::ODS,MPE}$	Maximum permissible error for probing flat form error (based on ISO 10360-8)[a]
$P_{Form.Sph.1x25::MPS.AArm}$	$P_{Form.Sph.1x25::MPS}$	Multiple system probing form error (based on ISO 10360-9)[a]
$P_{Size.Sph.1x25::MPS.AArm}$	$P_{Size.Sph.1x25::MPS}$	Multiple system probing size error (based on ISO 10360-9)[a]
$L_{Dia.1x25::MPS.AArm}$	$L_{Dia.1x25::MPS}$	Multiple system probing location error (based on ISO 10360-9)[a]
$P_{Form.Sph.1x25::MPS.AArm,MPE}$	$P_{Form.Sph.1x25::MPS,MPE}$	Maximum permissible error for multiple system probing form error (based on ISO 10360-9)[a]

[a] The trailing qualifier, ".AArm", indicates that this metrological characteristic as defined in the relevant ISO 10360 part is tested with an articulating arm CMM.

[b] These symbols relate to metrological characteristics for which specification and testing are optional (not normative).

Table 1 *(continued)*

Global symbols	Local abbreviations	Term
$P_{Size.Sph.1x25::MPS.AArm,MPE}$	$P_{Size.Sph.1x25::MPS,MPE}$	Maximum permissible error for multiple system probing size error (based on ISO 10360-9)[a]
$L_{Dia.1x25::MPS.AArm,MPE}$	$L_{Dia.1x25::MPS,MPE}$	Maximum permissible error for multiple system probing location error (based on ISO 10360-9)[a]
$R_{Uni.0::Tact.AArm}$	$R_{Uni.0::Tact}$	Repeatability range of the bidirectional length measurement errors[a, b]
$R_{Bi.0::Tact.AArm}$	$R_{Bi.0::Tact}$	Repeatability range of the unidirectional length measurement errors[a, b]
$P_{Size.5x5:Art:Tact.AArm}$	$P_{Size.5x5:Art:Tact}$	Probing articulated size error[a, b]
$P_{Form.5x5:Art:Tact.AArm}$	$P_{Form.5x5:Art:Tact}$	Probing articulated form error[a, b]
$R_{Uni.0::Tact.AArm,MPE}$	$R_{Uni.0::Tact,MPE}$	Maximum permissible error for the repeatability range of unidirectional length measurement errors[a, b]
$R_{Bi.0::Tact.AArm,MPE}$	$R_{Bi.0::Tact,MPE}$	Maximum permissible error for the repeatability range of bidirectional length measurement errors[a, b]
$P_{Size.5x5:Art:Tact.AArm,MPE}$	$P_{Size.5x5:Art:Tact,MPE}$	Maximum permissible error for probing articulated size error[a, b]
$P_{Form.5x5:Art:Tact.AArm,MPE}$	$P_{Form.5x5:Art:Tact,MPE}$	Maximum permissible error for probing articulated form error[a, b]

[a] The trailing qualifier, ".AArm", indicates that this metrological characteristic as defined in the relevant ISO 10360 part is tested with an articulating arm CMM.

[b] These symbols relate to metrological characteristics for which specification and testing are optional (not normative).

Local abbreviations are used in this part of ISO 10360 for the sake of simplicity; however, local abbreviations used in different part(s) of ISO 10360 may not be the same, i.e. the same abbreviation may refer to different complete symbols. Use of abbreviated symbols is not recommended outside the exclusive context of this part of ISO 10360.

5 Rated operating conditions

5.1 Environmental conditions

Limits for permissible environmental conditions such as temperature conditions, air pressure, humidity and vibration at the site of installation that influence the measurements shall be stated by

— the manufacturer, in the case of acceptance tests, and

— the user, in the case of reverification tests.

In both cases, the user is free to choose the environmental conditions under which the testing will be performed within the stated limits. (Form 1 in Annex A shows an example method for stating these conditions.) The manufacturer shall provide at a single location in published literature MPE values and operating conditions under which the MPE values are valid.

If the user wishes to have testing performed under environmental conditions other than the ambient conditions of the test site (e.g. at an elevated or lowered temperature), agreement between parties regarding who bears the cost of environmental conditioning should be obtained.