# TECHNICAL SPECIFICATION

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### Road vehicles — Multidimensional measurement and coordinate systems definition

*Véhicules routiers — Mesurage multidimensionnel et définition des systèmes de coordination* 

## iTeh STANDARD PREVIEW (standards.iteh.ai)

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### Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road Vehicles*, Subcommittee SC 36, *Safety aspects and impact testing*. https://standards.iteh.ai/catalog/standards/sist/cddffeb1-5c6e-46eb-973c-

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at <u>www.iso.org/members.html</u>.

### Introduction

This document provides a unified method to handle and process various types of multidimensional displacement sensors for use in crash dummies and automotive crash testing. The content covers existing sensors and dummies, but the document also offers a generic method to handle future new dummies and/or sensors.

Multidimensional measurement systems are used in crash dummies (ATD, or anthropomorphic test device) to monitor the position of dummy features (e.g. ribs, abdomen, etc.) for injury assessment. The dummy feature position is typically expressed in an orthogonal coordinate system which is fixed to the thoracic spine of the dummy, see <u>Annex A</u>. The systems covered in this document are an assembly of one distance sensor and one or two angle sensors, the axes of which are organised in a (rotating) spherical coordinate system, see <u>Figure C.1</u>. Other 2- and 3-dimensional position measurement systems are outside the scope of this document. Although in this document a suit of ATD's and their features are discussed to explain the methodology, its scope is not limited to these examples and can be applied to any other ATD and its features.

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### Road vehicles — Multidimensional measurement and coordinate systems definition

#### **1** Scope

This document defines the measurement coordinate systems and presents the protocol to determine the sensor offsets to the chosen coordinate system. Finally, the method is presented how to process the sensor spherical coordinate system data to calculate the position of a dummy feature in threedimensional space in the defined local orthogonal coordinate system.

#### Normative references 2

There are no normative references in this document.

#### **3** Terms and definitions

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

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

- ISO Online browsing platform: available at <a href="https://www.iso.org/obp">https://www.iso.org/obp</a>
- IEC Electropedia: available at <u>https://www.electropedia.org/</u>

#### ISO/TS 21002:2021

3.1

**3.1** https://standards.iteh.ai/catalog/standards/sist/cddffeb1-5c6e-46eb-973c-multidimensional measurement\_system 4ec/iso-ts-21002-2021 system that measures spatial position of a crash dummy feature (e.g. rib, abdomen, etc.) with respect to a defined reference feature (e.g. dummy spine) and its local coordinate system origin.

Note 1 to entry: Examples of multidimensional sensors and applications are given in the NOTES of Figure 1, Figure 2 and Figure 3.

#### 3.2

#### radius

distance between the centre of rotation at spine interface and centre of rotation at feature interface (e.g. dummy rib)

Note 1 to entry: The parameter radius (*R*) is associated with the ISO MME Code DC for Distance, ISO/TS 13499<sup>[2]</sup>.

#### 3.3

#### sensor Y-angle

angle of the multidimensional sensor along Y-axis with respect to local orthogonal coordinate system

Note 1 to entry: The positive rotation direction is defined following SAE sign convention right hand rule.

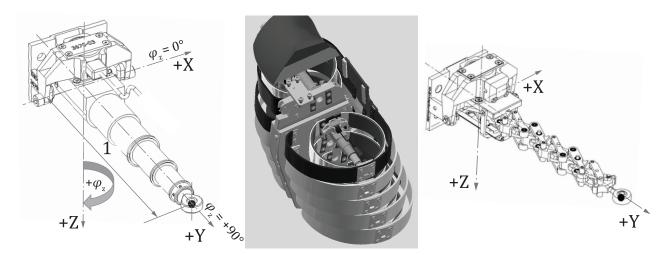
#### 3.4

#### sensor Z-angle

angle of the multidimensional sensor along Z-axis with respect to local orthogonal coordinate system

Note 1 to entry: The positive rotation direction is defined following SAE sign convention right hand rule.

Note 2 to entry: Examples of the angle definitions are given in the NOTES of Figure 1, Figure 2 and Figure 3.



#### Key

#### 1 radius, *R*<sub>i</sub>

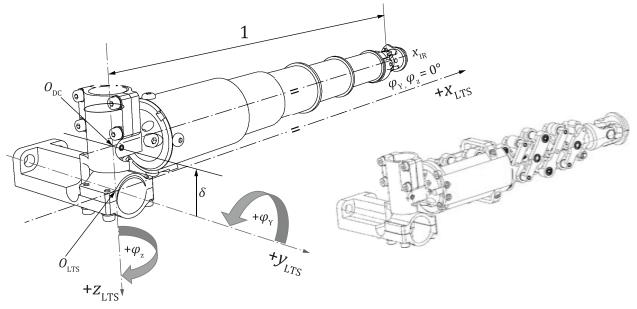
NOTE Two examples for WorldSID application are shown: left image 2D IR-TRACC, right image S-Track.



Figure 1 — Two-dimensional sensor mounted in right-hand side WorldSID 50M dummy

NOTE Two examples for THOR application are show: left image IR-TRACC, right image S-Track.

# Figure 2 — Three-dimensional sensors mounted in THOR 50M right-hand view and global coordinate system.



#### Key

1 radius, *R*<sub>i</sub>

NOTE Two informative examples for THOR application are shown: left image 3D IR-TRACC, right image 3D S-Track).

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# Figure 3 — Three-dimensional sensors for THOR lower right-hand thorax and their local orthogonal coordinate system

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#### 3.5 https://standards.iteh.ai/catalog/standards/sist/cddffeb1-5c6e-46eb-973c-

**zero-position** b710ccbe14ec/iso-ts-21002-2021 condition of multidimensional sensor when mounted by the spine interface and the distance sensor is aligned with (parallel to) the local orthogonal coordinate system axes and the feature interface is fixed at an accurately defined distance from the coordinate system origin

Note 1 to entry: By definition the angles of the multidimensional position sensor are zero.

#### 3.6

#### zero-position fixture

tool to set up a multidimensional position sensor in its *zero-position* (3.5)

Note 1 to entry: A zero-position fixture has accurately machined reproducible mountings to simulate the dummy spine and the feature mountings. These sensor mountings of the fixture are accurately positioned in (2D- and 3D) space such that the sensor is in its zero-position condition, called position 0 (position zero). The fixture has additional mounting positions for the feature interface, which are translated from zero position over a defined distance in a direction perpendicular to the distance sensor axis and parallel to at least one of the local orthogonal coordinate system axes.

Note 2 to entry: The fixture is considered adequately accurate if the overall dimensional tolerance stack ups of the sensor mountings are within  $\pm 0.3$ mm in all directions.

Note 3 to entry: Examples of 2D and 3D zero-position fixtures are given in <u>Annex B</u>.

Note 4 to entry: The zero-position fixtures are used in subsequent steps of the zero-position verification procedure:

- a) to find the offset of the sensors with respect to the local orthogonal coordinate system;
- b) to remove offsets (by adjustment or compensation in a data acquisition system);
- c) to check if sensor offsets are removed with a live data acquisition system;

- d) to check sensor polarities with respect to global orthogonal coordinate system;
- e) to check if calculations for coordinate system transformation are reproducing the design positions of the fixture in 2D or 3D space. See paragraph 7 and <u>Annex B</u>.

#### 3.7

#### offset angle

output in degrees of the angle sensor(s) when the multidimensional position sensor is in its *zero-position* (3.5) condition

Note 1 to entry: If the angle sensor has a positive offset according to the local orthogonal coordinate system, the offset angle is defined positive.

#### 3.8

#### orientation angle

correction angle for multidimensional sensors that can be mounted in sensor orientation for left hand and right-hand side impact operation, as well as for frontal impact operation

Note 1 to entry: Typically the two-dimensional sensors can be mounted in various orientations inside the dummy. In side impact dummies the sensors can be set up for left hand and right-hand impact (even simultaneously), and the Q10 child dummies can be set up for both frontal and lateral impacts.

Note 2 to entry: The two-dimensional sensors can be oriented inside the dummy with a rotated coordinate system about the Z-axis. The orientation angle can be implemented in Data Acquisition Systems Z-angle data channels as a fixed offset to correct for a rotated coordinate system, see <u>Table 1</u>.

#### Table 1 — Orientation angle definition per orientation in the dummy

|   | (StaSensor prientation for impact operation |  |  |  |
|---|---|--|--|--|
|   | Left Lateral Frontal Right Lateral          |  |  |  |
| Orientation angle -90° ISO/TS 21002:2021 0° +90°                          |   |  |  |  |
| https://standards.iteh.ai/catalog/standards/sist/cddfleb1-5c6e-46eb-973c- |   |  |  |  |

#### 3.9

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#### reference angle

orientation angle minus the *offset angle* (3.7)

Note 1 to entry: Calculate the reference angle with <u>Formula (1)</u>.

 $\varphi_{\rm REF} = \varphi_{\rm ORIENT} - \varphi_{\rm OSZ}$ 

(1)

Note 2 to entry: The reference angle can be used with data acquisition systems that can handle only one fixed offset parameter, see example in Figure 4.

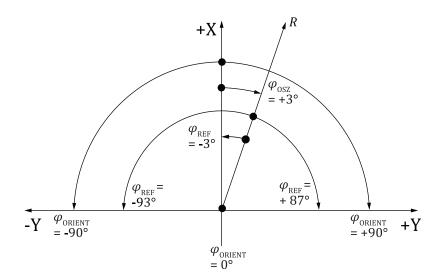


Figure 4 — Angle sensor parameter examples seen from top of dummy (looking over dummy shoulder)

| Table 2 — Examples for $\varphi_{\text{REF}}$ and $\varphi_{\text{ORIENT}}$ when offset angle is +3°, for left side, frontal and right- |
|---|
| iTeh side impact dummy set up, see Figure 4   |

|                        |           | Left lateral impact                        | Frontal impact                | Right lateral impact |
|------------------------|-----------|--|-------------------------------|----------------------|
| $arphi_{	ext{ORIENT}}$ |           | -90  | 0                             | +90                  |
| $\varphi_{ m OSZ}$     |           | +3 <u>ISO/TS 21002</u>                     | <u>;2021</u> +3               | +3                   |
| $arphi_{	ext{REF}}$    | https://s | andards.iteh.ai/ <b>93</b> alog/standards/ | sist/cddffeb1-5c3e-46eb-973c- | +87                  |
|                        |           | b710ccbe14ec/iso-ts-                       | 21002-2021                    |                      |

#### 3.10

#### angle sensor polarity

direction of rotation of the sensor shaft with reference to its fixed body in relation to its electrical (digital) signal output and sensor body and shaft orientation to the relevant coordinate system

Note 1 to entry: The polarity is defined positive when the far end of the shaft points in the positive orthogonal direction and the shaft (or internal wiper) is rotated in the positive rotation direction according to the relevant coordinate system, see example Figure 5.

Note 2 to entry: The value of the polarity can only be +1 or -1.

Note 3 to entry: Depending of the sensor assembly orientation in the dummy some sensors need to change the polarity sign to get a positive output in accordance with the relevant coordinate system.

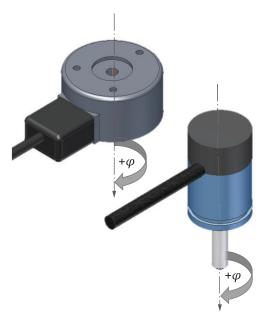


Figure 5 — Positive polarity for angle sensors

# 4 Symbols iTeh STANDARD PREVIEW

### Table 3 m List of symbols.ai)

| Parameter                | Symbol                  | Unit                 | Definition/description  | Application |
|--------------------------|-------------------------|----------------------|---|-------------|
| X-axis                   | https://sta             | ndards.iteh.ai/catak | Global orthogonal coordinate system<br>Standards/sisteddileb1-5c6e-46eb-9/5c-<br>X-axis<br>Hockey to 21002-2021 |             |
| Y-axis                   | у                       | -                    | Global orthogonal coordinate system<br>Y-axis   |             |
| Z-axis                   | Ζ                       | -                    | Global orthogonal coordinate system<br>Z-axis   |             |
| Origin of local orthogo- | 0 <sub>UTS</sub>        | -                    | Origin upper thoracic spine   |             |
| nal coordinate systems   | 0 <sub>LTS</sub>        |                      | Origin lower thoracic spine   |             |
|                          | $O_{\rm LS}$            |                      | Origin lumbar spine   |             |
|                          | O <sub>DC</sub>         |                      | Origin distance sensor  |             |
|                          | x <sub>UTS</sub>        | -                    | Local X-axis upper thoracic spine   | 3D-THOR     |
|                          | y <sub>UTS</sub>        | -                    | Local Y-axis upper thoracic spine   | 3D-THOR     |
|                          | $z_{\rm UTS}$           | -                    | Local Z-axis upper thoracic spine   | 3D-THOR     |
|                          | x <sub>DC</sub>         | -                    | Distance sensor axis  | 3D-THOR     |
|                          | y <sub>DC</sub>         |                      | Position sensor Y-pivot axis  | 3D-THOR     |
|                          | z <sub>DC</sub>         | -                    | Position sensor Z-pivot axis  | 3D-THOR     |
|                          | x <sub>LTS</sub>        | -                    | Local X-axis lower thoracic spine   | 3D-THOR     |
|                          | <i>Y</i> <sub>LTS</sub> | -                    | Local Y-axis lower thoracic spine   | 3D-THOR     |
|                          | $z_{ m LTS}$            | -                    | Local Z-axis lower thoracic spine   | 3D-THOR     |
|                          | x <sub>LS</sub>         | -                    | Local X-axis lumbar spine   | 3D-THOR     |
|                          | $y_{\rm LS}$            | -                    | Local Y-axis lumbar spine   | 3D-THOR     |
|                          | $z_{\rm LS}$            | -                    | Local Z-axis lumbar spine   | 3D-THOR     |
|                          |                         |                      |   |             |

| Parameter                               | Symbol                | Unit   | Definition/description  | Application           |
|---|-----------------------|--|---|-----------------------|
| Distance                                | D                     | mm   | Design distance on zero-position fixture  | 2D                    |
| Distance position 0                     | D <sub>ZERO</sub>     |  | from 2D sensor origin to rib interface<br>centre in position-0, position-1, posi-   |                       |
| Distance position 1                     | $D_{\rm P1}$          |  | tion-2  |                       |
| Distance position 2                     | D <sub>P2</sub>       |  |   |                       |
| Distance positions                      |                       | mm   | Design distance on zero-position fixture  | 3D                    |
| ZERO-L, ZERO-R,                         | D <sub>ZERO</sub>     |  | from origin O <sub>UTS</sub> , O <sub>LTS</sub> , or O <sub>LS</sub> to rib<br>interface centre in position ZERO, posi-   |                       |
| PZL, PZR,                               | $D_{\rm PZ}$          |  | tion PZ (L and R), position PY (L and R),   |                       |
| PYL, PYR                                | D <sub>PY</sub>       |  | position PYZ (L and R)  |                       |
| PYZL, PYZR                              | D <sub>PYZ</sub>      |  |   |                       |
| Z-angle                                 | $\Theta_{\rm Z}$      | degrees  | Design Z-angles on zero-position fixture  | 2D                    |
| Angle position 0                        | $\Theta_{\rm ZZERO}$  |  | 2D sensor origin to rib interface centre<br>in zero-position, position-1, position-2                                      |                       |
| Angle position 1                        | $\Theta_{ m Z1}$      |  |   |                       |
| Angle position 2                        | $\Theta_{\rm Z2}$     |  |   |                       |
| Y-angle positions                       | $\Theta_{\mathrm{Y}}$ | degrees  | Design Y-angles on zero-position fixture  | 3D                    |
| ZERO-L, ZERO-R,                         | $\Theta_{ m YZERO}$   |  | origin $O_{UTS}$ , $O_{LTS}$ , or $O_{LS}$ to rib interface centre in position ZERO, position PZ (L                       |                       |
| PZL PZR,                                | OY PZ CY              |  | and R) , position PY (L and R), position  |                       |
| PYL, PYR                                |                       | IANDAI   | PYZ (Land R) V LL VV  |                       |
| PYZL, PYZR                              | $\Theta_{\rm YPYZ}$   | standard   | s.iteh.ai)  |                       |
| Z-angle positions                       | $\Theta_{\rm Z}$      | degrees  | Design Z-angles on zero-position fixture  | 3D                    |
| ZERO-L, ZERO-R,                         | $\Theta_{\rm ZZERO}$  | <u>ISO/TS 21(</u><br>eh.ai/catalog/standar         | origin O <sub>UTS</sub> , O <sub>LTS</sub> , or O <sub>LS</sub> to rib interface<br>centre in position ZERO, position +Z, |                       |
| PZL PZR,                                | $\Theta_{\rm ZPZ}$    | b710ccbe14ec/iso-                                  | position +Y position PYZ (L and R)  |                       |
| PYL, PYR                                | $\Theta_{\rm ZPY}$    |  |   |                       |
| PYZL, PYZR                              | $\Theta_{ m ZPYZ}$    |  |   |                       |
| Calibration range                       | $d_{\mathrm{E}}$      | mm   | Distance between starting and end point of displacement calibration   |                       |
| Distance sensor output                  | U <sub>DC</sub>       | V, LSB   | Distance sensor output  |                       |
| Tubes-IN output                         | U <sub>DC IN</sub>    | V, LSB   | Output at certain displacement with all floating tubes pushed IN  | IR-TRACC only         |
| Tubes-OUT output                        | U <sub>DC OUT</sub>   | V, LSB   | Output at certain displacement with all floating tubes pushed OUT   | IR-TRACC only         |
| Linearization exponent                  | EXP                   | [-]  | Optimized linearization exponent  | IR-TRACC only         |
| Linearized voltage                      | U <sub>LIN</sub>      | V <sub>lin</sub><br>LSB <sub>lin</sub>             | IR-TRACC output to power of exponent; calculated parameter  | IR-TRACC only         |
| Distance sensor calibra-<br>tion factor | C <sub>DC</sub>       | mm/V and<br>mm/LSB mm/                             | linear sensor mm displacement per<br>output   | Ratiometric<br>sensor |
|   |                       | V <sub>LIN</sub><br>mm/LSB <sub>LIN</sub>          | IR-TRACC mm displacement per line-<br>arized output   | IR-TRACC              |
| Distance sensor sensi-<br>tivity        | S <sub>DC</sub>       | V/mm and<br>LSB/mm                                 | linear sensor output per mm displace-<br>ment   | Ratiometric<br>sensor |
|   |                       | V <sub>LIN</sub> /mm and<br>LSB <sub>LIN</sub> /mm | IR-TRACC linearized output per mm<br>displacement   | IR-TRACC              |
| Angle sensor calibration                | C <sub>ANY</sub>      | degrees/V/V  | Angle sensor degrees rotation at 1V out-  |                       |
| factor                                  | C <sub>ANZ</sub>      | degrees/LSB  | put per 1V excitation or degree rotation<br>per digital output  |                       |

 Table 3 (continued)

| Angle sensor sensitivity       S <sub>ANY</sub> V/V/degrees       Angle sensor output per degree rotation at V excitation or dit V excitation or deriver presented output the sensor Post 0       Up Co       V/V/degrees       Angle sensor output per degree       Angle sensor post 0       ZD-3D         Distance sensor Post 0       Up Co       V.LSB       Distance sensor average output at zero position on Zeroing Pisture       ZD-3D         Distance sensor Post 0       Up Co OUT       V.LSB       Distance sensor output at zero position IR-TRACC         Distance sensor Post 0       Up Co OUT       V.LSB       Distance sensor output at position 1       ZD         Distance sensor Post 0       Up Co OUT       V.LSB       Distance sensor output at position PY       3D         Distance sensor output 100 Cr PY       V.LSB       Distance sensor output at position PY       3D         Distance sensor output 100 Cr PY       V.LSB       Distance sensor output at position PYZ       3D         Distance sensor output 100 Cr PY       V.LSB       Distance sensor output at position PYZ       3D         Distance sensor output 100 Cr PY       V.LSB       Distance sensor output at position PYZ       3D         Distance sensor output 100 Cr PY       V.LSB       Distance sensor output at position PYZ       3D         Radius Pos0 <t< th=""><th>Parameter</th><th>Symbol</th><th>Unit</th><th>Definition/description</th><th>Application</th></t<>   | Parameter                | Symbol                | Unit                    | Definition/description                                 | Application |
|--|--------------------------|-----------------------|-------------------------|--|-------------|
| SANZ         LSB/degrees         digital output per degree           Angle sensor polarity         P         [-]         The value can be either +1 or -1         2D-3D           Distance sensor Pos0         U <sub>DC0</sub> V. LSB         Distance sensor output at zero position         IR-TRACC           Distance sensor Pos0         U <sub>DC0</sub> N         V. LSB         Distance sensor output at zero position         IR-TRACC           Distance sensor Pos0         U <sub>DC0</sub> OUT         V. LSB         Distance sensor output at zero position         IR-TRACC           Distance sensor Pos1         U <sub>DC0</sub> V. LSB         Distance sensor output at position 1         2D           Distance sensor Pos2         U <sub>DC2</sub> V. LSB         Distance sensor output at position PY         3D           Distance sensor output         U <sub>DC PY</sub> V. LSB         Distance sensor output at position PY         3D           Distance sensor output         U <sub>DC PYZ</sub> V. LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PYZ</sub> V. LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PYZ</sub> V. LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PYZ</sub> V. LSB         Distance senso   | Angle sensor sensitivity | S <sub>ANY</sub>      | V/V/degrees             |  |             |
| digital output per degree     digital output per degree       Distance sensor posl $U_{bC0}$ V. LSB     Distance sensor average output at zero position     2D-3D       Distance sensor Pos0 $U_{bC0}$ IN     V. LSB     Distance sensor output at zero position     IR-TRACC       Distance sensor Pos0 $U_{bC0}$ IN     V. LSB     Distance sensor output at zero position     IR-TRACC       Distance sensor Pos1 $U_{bC0}$ OUT     V. LSB     Distance sensor output at zero position     IR-TRACC       Distance sensor Pos2 $U_{bC1}$ V. LSB     Distance sensor output at position 1     2D       Distance sensor Pos2 $U_{bC2}$ V. LSB     Distance sensor output at position PY     3D       Distance sensor output $U_{bCPY}$ V. LSB     Distance sensor output at position PZ     3D       Distance sensor output $U_{DCPY}$ V. LSB     Distance sensor output at position PZ     3D       Distance sensor output $U_{DCPY}$ V. LSB     Distance sensor output at position PZ     3D       Distance sensor output $U_{DCPYZ}$ V. LSB     Distance sensor output at position PZ     3D       Distance sensor output $U_{DCPYZ}$ V. LSB     Distance sensor output at position PZ     3D       Distance sensor output $U_{DCPYZ}$ V. LSB     Distance sensor output at position PZ  |                          | S <sub>ANZ</sub>      | LSB/degrees             | at 1V excitation or                                    |             |
| Distance sensor Pos0<br>output       U <sub>DC0</sub> V, LSB       Distance sensor average output at zero<br>position on Zeroing Fixture       2D-3D         Distance sensor Pos0<br>output tubes-IN       U <sub>DC0</sub> output       V, LSB       Distance sensor output at zero position<br>tubes OUT       IR-TRACC         Distance sensor Pos0<br>output tubes-IN       U <sub>DC0</sub> output       V, LSB       Distance sensor output at zero position<br>tubes OUT       IR-TRACC         Distance sensor Pos1<br>output       U <sub>DC1</sub> V, LSB       Distance sensor output at position 1       2D         Distance sensor Pos2<br>output       U <sub>DC2</sub> V, LSB       Distance sensor output at position 2       2D         Distance sensor output       U <sub>DC2</sub> V, LSB       Distance sensor output at position PY       3D         Distance sensor output       U <sub>DC PYZ</sub> V, LSB       Distance sensor output at position PZ       3D         Distance sensor output       U <sub>DC PYZ</sub> V, LSB       Distance sensor output at position PYZ       3D         Distance sensor output       U <sub>DC PYZ</sub> V, LSB       Distance sensor output at position PYZ       3D         Distance sensor output       U <sub>DC PYZ</sub> V, LSB       Distance sensor output at position PYZ       3D         Radius Pos0       R <sub>10</sub> mm10cH stance from PL torb interface<br>rotation centre, see Figure 3. Distance<br>is genorput put in mat t <sub>0</sub> at t  |                          |                       |                         |  |             |
| Output         Dots         position on Zeroing Fixture           Distance sensor Pos0<br>output tubes-IN         U <sub>DC0 IN</sub> V, LSB         Distance sensor output at zero position<br>tubes 0UT         IR-TRACC           Distance sensor Pos1<br>output tubes-OUT         U <sub>DC1</sub> V, LSB         Distance sensor output at zero position 1         ZD           Distance sensor Pos2<br>output         U <sub>DC2</sub> V, LSB         Distance sensor output at position 2         ZD           Distance sensor output         U <sub>DC2</sub> V, LSB         Distance sensor output at position 72         ZD           Distance sensor output         U <sub>DC PZ</sub> V, LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PZ</sub> V, LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PZ</sub> V, LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PZ</sub> V, LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PZ</sub> V, LSB         Distance sensor output at position PZ         3D           Distance sensor output         U <sub>DC PZ</sub> V, LSB         Distance sensor output at position PZ         3D           Radius PS  |                          | Р                     |                         | The value can be either +1 or -1                       | 1           |
| output tubes-IN       Down       tubes IN       tubes IN       tubes IN         Distance sensor Pos0 $U_{DC00UT}$ V, LSB       Distance sensor output at zero position       IR-TRACC         Distance sensor Pos1 $U_{DC1}$ V, LSB       Distance sensor output at position 1       2D         Distance sensor Pos2 $U_{DC2}$ V, LSB       Distance sensor output at position 2       2D         Distance sensor output $U_{DC PY}$ V, LSB       Distance sensor output at position PY       3D         Distance sensor output $U_{DC PY}$ V, LSB       Distance sensor output at position PZ       3D         Distance sensor output $U_{DC PYZ}$ V, LSB       Distance sensor output at position PZ       3D         Distance sensor output $U_{DC PYZ}$ V, LSB       Distance sensor output at position PZ       3D         Distance sensor output $D_{DC PYZ}$ V, LSB       Distance sensor output at position PZ       3D         Position PZ $W_{DC}$ $W_{DC}$ $W_{DC}$ $W_{DC}$ $W_{DC}$ $W_{DC}$ $W_{DC}$ Radius $R$ min 10cct       Nafler from $D_{D}$ for the interface rotation centre, see figure 3. Distance sensor output at position PZ $W_{DC}$ $W_{DC}$ $W_{D}$   |                          | U <sub>DC0</sub>      | V, LSB                  |  | 2D-3D       |
| Dutput tubes-OUT       Losson       tubes OUT       tubes OUT         Distance sensor Pos1       U <sub>DC1</sub> V, LSB       Distance sensor output at position 1       2D         Distance Sensor Pos2       U <sub>DC2</sub> V, LSB       Distance sensor output at position 2       2D         Distance sensor output       U <sub>DC PY</sub> V, LSB       Distance sensor output at position PY       3D         Distance sensor output       U <sub>DC PY</sub> V, LSB       Distance sensor output at position PY       3D         Distance sensor output       U <sub>DC PYZ</sub> V, LSB       Distance sensor output at position PYZ       3D         Distance sensor output       U <sub>DC PYZ</sub> V, LSB       Distance sensor output at position PYZ       3D         Distance sensor output       U <sub>DC PYZ</sub> V, LSB       Distance sensor output at position PYZ       3D         Radius       R       R       R       Interface rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation centre, see Figure 3. Distance sensor output at for the rotation c   |                          | U <sub>DC0 IN</sub>   | V, LSB                  |  | IR-TRACC    |
| output         OCL         OLD         Output   |                          | U <sub>DC0 OUT</sub>  | V, LSB                  |  | IR-TRACC    |
| output         Doz         Product         Pro   |                          | U <sub>DC1</sub>      | V, LSB                  | Distance sensor output at position 1                   | 2D          |
| position PY       Distance sensor output       UDC PZ       V, LSB       Distance sensor output at position PZ       3D         Distance sensor output       UDC PYZ       V, LSB       Distance sensor output at position PYZ       3D         Position PYZ       V, LSB       Distance sensor output at position PYZ       3D         Radius       R       R       Infinite and the probability of the pro |                          | U <sub>DC2</sub>      | V, LSB                  | Distance sensor output at position 2                   | 2D          |
| position PZ       Distance sensor output<br>position PYZ       Upc PYZ       V, LSB       Distance sensor output at position PYZ       3D         Radius       R<br>Ro       R<br>Ro       Distance sensor output at position PYZ       3D       2D 3D         Radius       R<br>Ro       Imm 2110 bistance from PyZ to be interface<br>rotation centre, see Figure 3. Distance<br>is sensor output in mm at to, at t <sub>i</sub> .       2D 3D         Radius Pos0       R <sub>10</sub> mm 10ccb       Radius at 2er0 position on zeroing<br>fixture calculated using average IN-OUT<br>output       2D-3D         Radius Pos0 tubes-IN       R <sub>1N</sub> mm       Radius at zero position calculated using<br>tubes IN output       IR-TRACC         Radius Pos0 tubes-OUT       R <sub>OUT</sub> mm       Radius at zero-position calculated using<br>tubes OUT output       IR-TRACC         Radius Pos0       R <sub>ZERO</sub> mm       Radius at zero-position       2D-3D         Radius Pos0       R <sub>ZERO</sub> mm       Radius at zero-position       2D         Radius Pos1       R <sub>1</sub> Radius at position-1       2D       2D         Radius PV       R <sub>PY</sub> Radius at position PY       3D         Radius PZ       R <sub>PYZ</sub> Radius at position PYZ       3D         Radius PY       R <sub>PYZ</sub> Radius at position PYZ       3D         Radius PYZ       <  |                          | U <sub>DC PY</sub>    | V, LSB                  | Distance sensor output at position PY                  | 3D          |
| position PYZPressureRadiusR<br>$R_0$ mm 211 Distance from $D_{02}$ to the interface<br>rotation centre, see Figure 3. Distance<br>is sensorioutput lin mm at $c_0$ at $t_1$ .<br>IPps://stindards/isid/diffsb1-Sc6e-46eb-973e-2D 3DRadius Pos0 $R_{10}$ mm 10 ccbRadius at 2ero position on zeroing<br>fix ture calculated using average IN-OUT<br>output2D 3DRadius Pos0 tubes-IN $R_{1N}$ mmRadius at zero position calculated using<br>tubes IN outputIR-TRACCRadius Pos0 tubes-OUT $R_{0UT}$ mmRadius at zero position calculated using<br>tubes IN outputIR-TRACCRadius Pos0 tubes-OUT $R_{0UT}$ mmRadius at zero position calculated using<br>tubes IN outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position PY3DRadius PY $R_{PY}$ Radius at position PY3DRadius PYZ $R_{PYZ}$ Radius at position PYZ3DExcitation $U_{EX}$ VExcitation voltage angle sensor during<br>zero-position verification2D 4.3DY-angle sensor output $U_{ANZ}$ V, LSBZ-angle sensor voltage3DZ-angle output 0 $U_{ANZ}$ V, LSBZ-angle sensor output at position-0 pull2D 4.3DZ-Angle output 0-Near $U_{ANZ}$ V, LSBZ   |                          | U <sub>DC PZ</sub>    | V, LSB                  | Distance sensor output at position PZ                  | 3D          |
| Rorotation centre, see Figure 3. Distance<br>ISX sensorioutput/in mm at $t_0$ , at $t_1$ .<br>IReps://stindards.iteh.ai/catule standards/skst/cddffbil-5c6e-46eb-973c-Radius Pos0 $R_{IO}$ mhillocolRadius at 2érô pôsition on zeroing<br>fixture calculated using average IN-OUT<br>output2D-3DRadius Pos0 tubes-IN $R_{IN}$ mmRadius at zero position calculated using<br>tubes IN outputIR-TRACCRadius Pos0 tubes-OUT $R_{OUT}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 tubes-OUT $R_{OUT}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position-22DRadius PY $R_{PY}$ Radius at position PY3DRadius PZ $R_{PZ}$ Radius at position PY3DRadius PYZ $R_{PY}$ Radius at position PYZ3DExcitation $U_{EX}$ VExcitation voltage angle sensor during<br>zero-position verification3DY-angle sensor output $U_{ANY}$ V, LSBZ-axis angle sensor voltage3DZ-angle sensor output $U_{ANZ}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0 $U_{ANZ}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0-Near $U_{ANZ}$ V, LSBZ-Angle sensor output at position-  |                          | U <sub>DC PYZ</sub>   | V, LSB<br><b>b STAN</b> | Distance sensor output at position PYZ<br>DARD PREVIEW | 3D          |
| Rorotation centre, see Figure 3. Distance<br>IS sensor joutputin mm at $t_0$ , at $t_1$ .<br>Ideps:/strindards.itch.ai/canal.g/standards/sist/cddffbb1-Sc6ce-466b-973c-Radius Pos0 $R_{IO}$ mhilocobRadius at 2èrô pôsition on zeroing<br>fixture calculated using average IN-OUT<br>output2D-3DRadius Pos0 tubes-IN $R_{IN}$ mmRadius at zero position calculated using<br>tubes IN outputIR-TRACCRadius Pos0 tubes-OUT $R_{OUT}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position-22DRadius PY $R_{PY}$ Radius at position PY3DRadius PZ $R_{PZ}$ Radius at position PZ3DRadius PYZ $V_{EX}$ VExcitation voltage angle sensor during<br>zero-position verification3DY-angle sensor output $U_{ANY}$ V, LSBZ-angle sensor voltage3DZ-angle sensor output $U_{ANZD}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-angle output 0 $U_{ANZ}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0-Near $U_{ANZ}$ V, L  |                          |                       | (atom                   | londa itab ai)   |             |
| Indext of the algorithm at c_0, at c_1.Indext of the algorithm at c_0, at c_1.Radius Pos0 $R_{10}$ mhillocolRadius at zero position on zeroing<br>fixture calculated using average IN-OUT<br>outputRadius Pos0 tubes-IN $R_{1N}$ mmRadius at zero position calculated using<br>tubes IN outputRadius Pos0 tubes-OUT $R_{0UT}$ mmRadius at zero position calculated using<br>tubes OUT outputRadius Pos0 tubes-OUT $R_{0UT}$ mmRadius at zero position calculated using<br>tubes OUT outputRadius Pos0 $R_{ZER0}$ Radius Pos0 $R_{ZER0}$ Radius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position PY3DRadius PZ $R_{PY}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ Radius at position PYZ3DExcitation $U_{EX}$ VExcitation voltage angle sensor during<br>zero-position verificationY-angle sensor output $U_{ANZ}$ V, LSBZ-Angle sensor voltageZ-Angle output 0 $U_{ANZ}$ Q-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pullZ-Angle output 0-Far $U_{ANZ EAR}$ V, LSBZ-Angle sensor output at position-0 pullZ-Angle output 0-Far $U_{ANZ EAR}$ V, LSBZ-Angle sensor output at position-0 pullZ-Angle output 0-Far $U_{ANZ EAR}$ V, LSBZ-Angle sensor output at position-0 pull <tr< td=""><td>Radius</td><td></td><td></td><td>rotation centre, see <u>Figure 3</u>. Distance</td><td>2D 3D</td></tr<>   | Radius                   |                       |                         | rotation centre, see <u>Figure 3</u> . Distance        | 2D 3D       |
| Radius Pos0 $R_{IO}$ mhrilocod<br>Radius at 2éf0 pósition on zeroing<br>fixture calculated using average IN-OUT<br>output2D-3DRadius Pos0 tubes-IN $R_{IN}$ mmRadius at zero position calculated using<br>tubes IN outputIR-TRACCRadius Pos0 tubes-OUT $R_{OUT}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero-position<br>tubes OUT output2D-3DRadius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position-22DRadius PY $R_{PY}$ Radius at position PY3DRadius PZ $R_{PZ}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ VExcitation voltage angle sensor during<br>zero-position verification3DY-angle sensor output $U_{ANY}$ V, LSBZ-axis angle sensor voltage3DZ-angle output 0 $U_{ANZ}$ V, LSBZ-Angle sensor output at position-0 pull<br>tion-0 (ZERO)2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3D  |                          | -                     |                         |  |             |
| Indicatefixture calculated using average IN-OUT<br>outputRadius Pos0 tubes-IN $R_{IN}$ mmRadius at zero position calculated using<br>tubes IN outputIR-TRACCRadius Pos0 tubes-OUT $R_{OUT}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero-position2D-3DRadius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position-23DRadius PY $R_{PY}$ Radius at position PY3DRadius PZ $R_{PZ}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ Radius at position PYZ3DTexcitation $U_{EX}$ VExcitation voltage angle sensor during<br>zero-position verification3DY-angle sensor output $U_{ANY}$ V, LSBY-axis angle sensor voltage3DZ-angle sensor output $U_{ANZ}$ V, LSBZ-Angle sensor voltage2D & 3DZ-Angle output 0 $U_{ANZO}$ V, LSBZ-Angle sensor average output at position-0 pull2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0-Far $U_{ANZ TEAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0-Far $U_{ANZ TEAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3D   | Radius Pos0              |                       |                         |  | 20-30       |
| Inttubes IN outputRadius Pos0 tubes-OUT $R_{OUT}$ mmRadius at zero position calculated using<br>tubes OUT outputIR-TRACCRadius Pos0 $R_{ZERO}$ mmRadius at zero-position2D-3DRadius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position-22DRadius PY $R_{PY}$ Radius at position PY3DRadius PZ $R_{PZ}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ Radius at position PYZ3DExcitation $U_{EX}$ VExcitation voltage angle sensor during<br>zero-position verification3DY-angle sensor output $U_{ANY}$ V, LSBY-axis angle sensor voltage3DZ-angle output 0 $U_{ANZ0}$ V, LSBZ-Angle sensor output at posi-<br>tion-0 (ZERO)2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3D  |                          | 110                   |                         | fixture calculated using average IN-OUT                |             |
| tubes OUT outputtubes OUT outputRadius Pos0 $R_{ZER0}$ mmRadius at zero-position2D-3DRadius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position-22DRadius PY $R_{PY}$ Radius at position PY3DRadius PZ $R_{PZ}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ Radius at position PZ3DStatis PYZ $R_{PYZ}$ Radius at position PYZ3DStatis PYZ $R_{PYZ}$ Radius at position PYZ3DStatis PYZ $R_{PYZ}$ Radius at position PYZ3DStatis PYZ $R_{PYZ}$ Statis at position PYZ3DStatis PYZ $R_{PYZ}$ VExcitation voltage angle sensor during zero-position verification3DY-angle sensor output $U_{ANY}$ V, LSBZ-axis angle sensor voltage3DZ-angle output 0 $U_{ANZ}$ V, LSBZ-Angle sensor average output at position-0 pull2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0-Far $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3D   | Radius Pos0 tubes-IN     | R <sub>IN</sub>       | mm                      |  | IR-TRACC    |
| Radius Pos1 $R_1$ Radius at position-12DRadius Pos2 $R_2$ Radius at position-22DRadius PY $R_{PY}$ Radius at position PY3DRadius PZ $R_{PZ}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ Radius at position PYZ3DExcitation $U_{EX}$ VExcitation voltage angle sensor during zero-position verification3DY-angle sensor output $U_{ANY}$ V, LSBZ-axis angle sensor voltage3DZ-angle output 0 $U_{ANZ}$ V, LSBZ-axis angle sensor voltage2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pull2D & 3D  | Radius Pos0 tubes-OUT    | R <sub>OUT</sub>      | mm                      |  | IR-TRACC    |
| Radius Pool $R_1$ Radius of position 1Radius Pool $R_2$ Radius of position 1Radius Pos2 $R_2$ Radius at position 2Radius PY $R_{PY}$ Radius at position PYRadius PZ $R_{PZ}$ Radius at position PZRadius PYZ $R_{PYZ}$ Radius at position PYZExcitation $U_{EX}$ VExcitation voltage angle sensor during zero-position verificationY-angle sensor output $U_{ANY}$ V, LSBY-axis angle sensor voltageZ-angle sensor output $U_{ANZ}$ V, LSBZ-axis angle sensor voltageZ-Angle output 0 $U_{ANZO}$ Z-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pullZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pullZD & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pullZD & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pullZD & 3D   | Radius Pos0              | R <sub>ZERO</sub>     | mm                      | Radius at zero-position                                | 2D-3D       |
| Radius PY $R_{PY}$ Radius at position 23DRadius PZ $R_{PZ}$ Radius at position PY3DRadius PYZ $R_{PZ}$ Radius at position PZ3DRadius PYZ $R_{PYZ}$ Radius at position PYZ3DExcitation $U_{EX}$ $V$ Excitation voltage angle sensor during zero-position verification3DY-angle sensor output $U_{ANY}$ $V, LSB$ Y-axis angle sensor voltage3DZ-angle sensor output $U_{ANZ}$ $V, LSB$ Z-axis angle sensor voltage3DZ-Angle output 0 $U_{ANZ0}$ $V, LSB$ Z-Angle sensor average output at position-0 pull<br>tion-0 (ZERO)2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ $V, LSB$ Z-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ $V, LSB$ Z-Angle sensor output at position-0 pull<br>2D & 3D2D & 3D  | Radius Pos1              |                       |                         | Radius at position-1                                   | 2D          |
| Radius PYR<br>PY<br>Redius PZRadius at position PY<br>Radius at position PZ<br>Radius at position PYZ3D<br>3D<br>3D<br>3DRadius PYZR<br>PYZRadius at position PZ<br>Radius at position PYZ3D<br>3DExcitationU<br>EXVExcitation voltage angle sensor during<br>zero-position verificationY-angle sensor outputU<br>ANYV, LSBY-axis angle sensor voltageZ-angle sensor outputU<br>ANZV, LSBZ-axis angle sensor voltageZ-Angle output 0U<br>ANZ NEARV, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-FarU<br>ANZ FARV, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3D  | Radius Pos2              | R <sub>2</sub>        |                         | Radius at position-2                                   | 2D          |
| Radius PZ $R_{PZ}$<br>$R_{PYZ}$ Radius at position PZ<br>Radius at position PYZ $3D$<br>$3D$ Radius PYZ $R_{PYZ}$ Radius at position PYZ $3D$ Excitation $U_{EX}$ $V$ Excitation voltage angle sensor during<br>zero-position verification $3D$ Y-angle sensor output $U_{ANY}$ $V$ , LSBY-axis angle sensor voltage $3D$ Z-angle sensor output $U_{ANZ}$ $V$ , LSBZ-axis angle sensor voltage $3D$ Z-Angle output 0 $U_{ANZ}$ $V$ , LSBZ-axis angle sensor voltage $2D \& 3D$ Z-Angle output 0-Near $U_{ANZ}$ $V$ , LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine) $2D \& 3D$ Z-Angle output 0-Far $U_{ANZ FAR}$ $V$ , LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine) $2D \& 3D$  | Radius PY                | _                     |                         | Radius at position PY                                  |             |
| Radius PYZ $R_{PYZ}$ Radius at position PYZ $^{3D}$ Excitation $U_{EX}$ $V$ Excitation voltage angle sensor during<br>zero-position verification $U_{EX}$ $V$ Y-angle sensor output $U_{ANY}$ $V$ , LSBY-axis angle sensor voltage $3D$ Z-angle sensor output $U_{ANZ}$ $V$ , LSBZ-axis angle sensor voltage $3D$ Z-Angle output 0 $U_{ANZ0}$ $V$ , LSBZ-Angle sensor average output at posi-<br>tion-0 (ZERO) $2D \& 3D$ Z-Angle output 0-Near $U_{ANZ NEAR}$ $V$ , LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine) $2D \& 3D$ Z-Angle output 0-Far $U_{ANZ FAR}$ $V$ , LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine) $2D \& 3D$  | Radius PZ                |                       |                         | Radius at position PZ                                  |             |
| Excitation $U_{\rm EX}$ VExcitation voltage angle sensor during<br>zero-position verificationY-angle sensor output $U_{\rm ANY}$ V, LSBY-axis angle sensor voltage3DZ-angle sensor output $U_{\rm ANZ}$ V, LSBZ-axis angle sensor voltage3DZ-Angle output 0 $U_{\rm ANZ0}$ V, LSBZ-Angle sensor average output at posi-<br>tion-0 (ZERO)2D & 3DZ-Angle output 0-Near $U_{\rm ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-Far $U_{\rm ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>2D & 3D2D & 3D  | Radius PYZ               |                       |                         | •  | 3D          |
| IAzero-position verificationY-angle sensor output $U_{ANY}$ V, LSBY-axis angle sensor voltage3DZ-angle sensor output $U_{ANZ}$ V, LSBZ-axis angle sensor voltage3DZ-Angle output 0<br>(ZERO) $U_{ANZ0}$ V, LSBZ-Angle sensor average output at posi-<br>tion-0 (ZERO)2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>2D & 3D2D & 3D   |                          | F12                   | I                       | , <b>,</b> -   | 1           |
| Z-angle sensor outputU<br>ANZV, LSBZ-axis angle sensor voltageZ-Angle output 0<br>(ZERO)U<br>ANZOV, LSBZ-Angle sensor average output at posi-<br>tion-0 (ZERO)2D & 3DZ-Angle output 0-Near<br>Z-Angle output 0-NearU<br>ANZ NEARV, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-FarU<br>ANZ FARV, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3D   | Excitation               | U <sub>EX</sub>       | V                       |  |             |
| Z-angle sensor output       UANZ       V, LSB       Z-axis angle sensor voltage         Z-Angle output 0<br>(ZERO)       UANZ0       V, LSB       Z-Angle sensor average output at posi-<br>tion-0 (ZERO)       2D & 3D         Z-Angle output 0-Near       UANZ NEAR       V, LSB       Z-Angle sensor output at position-0 pull<br>Near (3D away from spine)       2D & 3D         Z-Angle output 0-Far       UANZ FAR       V, LSB       Z-Angle sensor output at position-0 pull       2D & 3D   | Y-angle sensor output    | U <sub>ANY</sub>      | V, LSB                  | Y-axis angle sensor voltage                            | 3D          |
| Z-Angle output 0<br>(ZERO) $U_{ANZ0}$ V, LSBZ-Angle sensor average output at posi-<br>tion-0 (ZERO)2D & 3DZ-Angle output 0-Near $U_{ANZ NEAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>Near (3D away from spine)2D & 3DZ-Angle output 0-Far $U_{ANZ FAR}$ V, LSBZ-Angle sensor output at position-0 pull<br>2D & 3D2D & 3D   | Z-angle sensor output    | 1                     | V, LSB                  | Z-axis angle sensor voltage                            |             |
| Z-Angle output 0-Far     UANZ FAR     V, LSB     Z-Angle sensor output at position-0 pull     2D & 3D  |                          |                       | V, LSB                  |  | 2D & 3D     |
|  | Z-Angle output 0-Near    | U <sub>ANZ NEAR</sub> | V, LSB                  |  | 2D & 3D     |
|  | Z-Angle output 0-Far     | U <sub>ANZ FAR</sub>  | V, LSB                  |  | 2D & 3D     |

| Table 3 | (continued) |
|---------|-------------|
| Table 5 | (continueu) |

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| Parameter                     | Symbol  | Unit                                      | Definition/description   | Application |
|-------------------------------|---|---|--|-------------|
| Z-Angle output 1              | U <sub>ANZ1</sub>   | V, LSB                                    | Z-axis angle sensor output at position-1   | 2D          |
| Z-Angle output 2              | U <sub>ANZ2</sub>   | V, LSB                                    | Z-axis angle sensor output at position-2   | 2D          |
| Z-Angle output PZR            | U <sub>ANZ PZ</sub>   | V, LSB                                    | Z-Angle sensor output at position PZ   | 3D          |
| Y-Angle output zero           | U <sub>ANY0</sub>   | V, LSB                                    | Y- Angle sensor average output at posi-<br>tion-zero   | 3D          |
| Y-Angle output zero-<br>Down  | U <sub>ANY DOWN</sub>   | V, LSB                                    | Y- Angle sensor output at position-zero<br>pull Down   | 3D          |
| Y-Angle output zero-Up        | U <sub>ANY UP</sub>   | V, LSB                                    | Y- Angle sensor output at position-0 pull<br>Up  | 3D          |
| Y-Angle output PY             | U <sub>ANY PY</sub>   | V, LSB                                    | Y-Angle sensor output at position PY   | 3D          |
| Y-Offset Angle                | $\varphi_{\mathrm{OSY}}$  | degrees                                   | Y-angle sensor average offset between<br>extremes (Up-Down) when at fixture<br>zero-position   |             |
| Z-Offset Angle                | $\varphi_{ m OSZ}$  | degrees                                   | Z-angle sensor average offset between<br>extremes (Near-Far) when at fixture<br>zero-position  |             |
| Sensor Y-angle                | $arphi_{ m Y} \ arphi_{ m Y0} \ arph_{ m Y0} \ arphi_{ m Y0} \ arphi_{ m Y0} \ arphi$ | degrees                                   | Distance sensor angle along y-axis with respect to local orthogonal coordinate system, see Figure 3, and at $t_0$ and at $t_i$ .                     |             |
| Sensor Z-angle                | $\begin{array}{c} \varphi_{\mathrm{Yi}} \\ \varphi_{\mathrm{Z}} \\ \varphi_{\mathrm{Z0}} \end{array} \left( \begin{array}{c} \varphi_{\mathrm{Yi}} \\ \varphi_{\mathrm{Z0}} \end{array} \right)$  | randard                                   | Distance sensor angle along z-axis with respect to local orthogonal coordinate system, see Figure 3, and, at $t_0$ and at $t_i$ .                    |             |
|                               | $\varphi_{ m Zi}$   | 180/18/210                                | 02:2021  |             |
| https                         | <del>y//standards.it</del> e  | eh.ai/catalog/standar                     | <del></del>  | 1           |
| Distance intercept            | I <sub>DC</sub>   | b710ccbe14ec/iso-                         | Distance sensor offset in mm from coor-<br>dinate system origin.   |             |
| Distance intercept<br>voltage | I <sub>DCV</sub>  | V, V <sub>lin</sub><br>LSB <sub>lin</sub> | Calculated (linearized) output at 0mm radius   |             |
| Axis offset                   | δ   | mm  | Mechanical offset distance between $O_{\rm DC}$ distance sensor origin and coordinate system origin, see Figure 3.                                   | 3D thoracic |
| Orientation angle             | $\varphi_{ m ORIENT}$   | degrees                                   | Orientation angle of 2D position sensor<br>assembled inside dummy. For definition<br>see also <u>Figure 4</u> and <u>Table 1</u> .                   | 2D          |
| Reference angle               | $arphi_{	ext{REF}}$   | degrees                                   | Orientation angle minus offset angle. For definition see also <u>Figure 4</u> and <u>Table 1</u> .   | 2D          |
| n.                            |   |   | [  |             |
| Гіте                          | t   | S   | time   |             |
|                               | t <sub>0</sub>  |   | time zero, start of the test   |             |
|                               | t <sub>i</sub>  |   | time i   |             |
| x coordinate                  | <i>x</i> , <i>x</i> <sub>0</sub> , <i>x</i> <sub>i</sub>  | mm  | Feature interface rotation centre x-<br>coordinate, x at $t_0$ , x at $t_i$ , see NOTES of<br>Figure 1, Figure 2 and Figure 3.                       |             |
| y coordinate                  | <i>y</i> , <i>y</i> <sub>0</sub> , <i>y</i> <sub>i</sub>  | mm  | Feature interface rotation centre y-<br>coordinate, y at $t_0$ , y at $t_i$ , see NOTES of<br>Figure 1, Figure 2 and Figure 3.                       |             |
| z coordinate                  | <i>z, z</i> <sub>0</sub> , <i>z</i> <sub>i</sub>  | mm  | Feature interface rotation centre <i>z</i> -<br>coordinate, <i>z</i> at $t_0$ , <i>z</i> at $t_i$ , see NOTES of<br>Figure 1, Figure 2 and Figure 3. |             |

### Table 3 (continued)