ROBOTICS

Operating manual

Calibration Pendulum

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Operating manual
Calibration Pendulum
IRC5, OmniCore

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Original instructions.

Table of contents

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Overview of this manual

About this manual

This manual contains procedures for calibrating a robot, using the tool calibration pendulum. Both the Calibration Pendulum II and Reference Calibration routine are described.

Usage

This manual should be used during calibration with the calibration pendulum.

Who should read this manual?

This manual is intended for:

- installation personnel on the installation site.
- repairing personnel during repair or maintenace.

Prerequisites

The reader should have...

- the required knowledge of how the robot works
- a basic understanding of what calibration does and how it is performed.

Organization of chapters

The manual is organized in the following chapters:

Chapter	Contents
Introduction to calibration	General information about the calibration method, including information about the required tools.
Preparing the equipment	Information about how to prepare the equipment prior to calibration.
Calibrating	Procedures that detail how to perform the calibration. The chapter is divided in two sections, one for each routine (Calibration Pendulum II and Reference Calibration). The sections specify to which robot system the routine is applicable.

References

Document name	Document ID
Product manual - IRB 52	*3HNA011253-001*
Product manual - IRB 460	*3HAC039842-001*
Product manual - IRB 660	*3HAC025755-001*
Product manual - IRB 760	*3HAC039838-001*
Product manual - IRB 1200	*3HAC046983-001*
Product manual - IRB 1410	*3HAC026320-001*
Product manual - IRB 1510	*3HAC087870-001*
Product manual - IRB 1520	*3HAC043435-001*
Product manual - IRB 1600/1660	*3HAC026660-001*
Product manual - IRB 2400	*3HAC022031-001*

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Document name	Document ID
Product manual - IRB 2600	*3HAC035504-001*
Product manual - IRB 4400	*3HAC022032-001*
Product manual - IRB 4600	*3HAC033453-001*
Product manual - IRB 6620	*3HAC027151-001*
Product manual - IRB 6650S	*3HAC020993-001*
Product manual - IRB 6660	*3HAC028197-001*
Product manual - IRB 6700	*3HAC044266-001*
Product manual - IRB 7600	*3HAC022033-001*
Product manual - IRC5 IRC5 with main computer DSQC1000 or later.	*3HAC047136-001*
Product manual - OmniCore C30 Type A	*3HAC089064-001*
Product manual - OmniCore C90XT	*3HAC073706-001*
Product manual - OmniCore V250XT Type B	*3HAC087112-001*
Product manual - OmniCore V400XT	*3HAC081697-001*

Revisions

Revision	Description
-	First edition.
A	Information on IRB 7600-2.3/500 added. Paths to calibration software revised. Minor editorial changes.
B	Minor editorial changes. Methods to calibrate the pendel tool added. Changes in Information about IRB 7600-2.3/500.
C	Calibration Pendulum II added. Methods to calibrate the pendel tool added for IRC5. Changes in Information about IRB 7600-2.3/500.
D	Reference Calibration introduced. Manual restructured. Robot models IRB 1600, IRB 260, IRB 660, IRB 4450S and IRB 6600ID/6650ID added to the calibration procedure.
E	Robot model IRB 1600 ID added to the calibration pocedure.
F	This revision includes the following additions and/or changes: • S4Cplus/M2000 phased out. • IRB4450S, IRB6600/6650, and IRB940 phased out. • Added IRB2600, IRB4600, IRB6620, IRB6620LX, IRB6640, IRB6660.

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Revision	Description
G	This revision includes following additions and/or changes: • Added IRB 760 and IRB 460. • Changed denomination "Backward bending robots" to "Serial link robots" throughout manual. • Added section *Correct calibration position of axis 4 and 6 on page 71*. • Added IRB 1600ID to equipment list, for the turning disk adapter, see *Calibration equipment on page 35*. • Added information about connection point in cabinet for Levelmeter 2000, see *Start up of Levelmeter 2000 on page 42*.
H	This revision includes following additions and/or changes: • IRB 1520ID added. • Changed the list of content in the Calibration Pendulum Tool kit • Added picture of IRB 2600ID upper arm. See *Synchronization marks and synchronization position for axes on page 15*.
J	This revision includes following additions and/or changes: • Added IRB 52. • Adjusted information in the calibration procedure, see *Calibration Pendulum II procedure on FlexPendant on page 126*. • Added information about different mounting positions of the robot, see *Calibrating the robot at different mounting positions on page 12*. • Added figure that shows the extra calibration plate required for IRB 2600ID, see *Calibration equipment on page 35*. • Added complementary text to the instruction for identifying the sensors, see *Identify sensors on page 44*. • Added complementary text to the instruction for calibrating and checking the sensors, see *Calibrating sensors on page 54* and *Checking sensors on page 60*.
K	This revision includes following additions and/or changes: • Added information about where to find the calibration label on IRB 52, see *Verifying the calibration on page 128*.
L	This revision includes following additions and/or changes: • IRB 6700 added.
M	This revision includes following additions and/or changes: • Added information on how to use the Levelmeter with main computer DSQC1000, see *Connecting the Levelmeter through a USB port on page 43*.
N	This revision includes following additions and/or changes: • Added calibration scales and images for installation of calibration pendulum for IRB 6700. • Added information and images with reference sensor calibration bracket on the base, for robots IRB 4600, IRB 6620, IRB 6640, IRB 6650S, IRB 6700, IRB 7600, see section *Calibration sensor mounting positions, CalPend on page 78*. • Added information about importance of pressing the pendulum gently downwards for vertical installation. • Added information about reference surfaces, see *Reference surfaces on page 134*.
P	This revision includes following additions and/or changes: • Added the article number for the USB to RS232 adapter cable, see *Calibration equipment on page 35*.
Q	Published in release R16.2. The following updates are done in this revision: • Added information about standard calibration method Axis Calibration, see *To which robots does this apply? on page 11*.

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Revision	Description
R	Published in release R18.1. The following updates are made in this revision: • Updated figure of axis-6 synchronization mark for IRB 4600.
S	Published in release R18.2. The following updates are made in this revision: • Added turning disc adapter for IRB 1660ID, see *Calibration equipment on page 35*. • Added synchronization marks for IRB 1600ID and IRB 1660ID. • Added robot model IRB 1660 in applicable robot models. • Added IRB 6660 to supported robot for flange adapter usage.
T	Published in release 22A. The following updates are made in this revision: • New calibration equipment (Bluemeter SIGMA) is described in the manual.
U	Published in release 24A. The following updates are made in this revision: • The calibration pendulum equipment can now be used on OmniCore for specific robots. Information about valid calibration method is found on the calibration label or in the calibration menu on the FlexPendant. • Removed the robots that are phased out from the product offer. • Removed information for M2000/M2000A.

1 Introduction to calibration

1.1 To which robots does this apply?

Applicable robot models

Calibration Pendulum is available for the following ABB robots.

Robot	IRC5	OmniCore[i]
IRB 52	✓	
IRB 460	✓	
IRB 660	✓	
IRB 760	✓	
IRB 1410	✓	
IRB 1510ID, IRB 1520ID	✓	✓
IRB 1600/IRB 1660	✓	
IRB 2400	✓	✓
IRB 2600	✓	
IRB 4400	✓	✓
IRB 4600	✓	
IRB 6620	✓	
IRB 6650S	✓	
IRB 6660	✓	
IRB 6700	✓	
IRB 7600	✓	

[i] Not all robots in the list are available with the OmniCore controller. Only those marked in the column can use the Calibration Pendulum method.

Availability of Axis Calibration

Many of the robots listed above have Axis Calibration as the valid calibration method, instead of Calibration Pendulum.

If the robot has been calibrated with Axis Calibration at factory, Calibration Pendulum is not an applicable calibration method in the field.

Always use the same calibration method as used at the factory.

Information about valid calibration method is found on the calibration label or in the calibration menu on the FlexPendant.

How to calibrate the robot with Axis Calibration method is described in the robot product manual.

1.2 Calibrating the robot at different mounting positions

Mounting positions

Some robots can be mounted in a tilted, suspended or wall position. See the Product manual or the Product specification for the specific robot to see available mounting positions.

The mounting position of the robot must be taken in consideration when calibrating the robot with the Calibration Pendulum routine.

Calibration information for different mounting positions

Mounting position of robot	Calibration Pendulum II	Additional information to the calibration procedure
Floor mounted	Applicable	The robot can not lean more than ±5°.
Tilted	Applicable, but the maximum tilt is ±5°.	If the robot is tilted more than ±5° it must be taken down and fastened to the floor, at a horizontal position.
Wall mounted	Not applicable, the robot must be taken down and fastened to the floor.	Take down the robot and fasten it to the floor.
Suspended	Applicable	The robot can not lean more than ±5°. The parameter *Gravity Beta* must be set so that the Calibration Pendulum II can detect that the robot is suspended. When calibrating axis 1: press the pendulum against the locating pin and secure its position with for example a rubber band.

1.3 When to calibrate

When to calibrate

The system must be calibrated if one or more of the listed failures below occurs.

Changed resolver values

Calibrate the measurement system carefully as described in *Calibrating on page 65*, if any of the resolver values have been changed. This can occur when parts affecting the calibration position have been replaced on the robot.

Contents of the revolution counter memory are lost

Calibrate the system roughly as detailed in *Updating revolution counters on IRC5 robots on page 70*, if the contents of the revolution counter memory are lost. This can occur when:

- the battery has been discharged
- a resolver error occurs
- the signal between a resolver and measurement board is interrupted
- a robot axis has been moved while the control system was disconnected.

1.4 Types of calibration

Calibration Pendulum II (robot home calibration)

The routine Calibration Pendulum II (CalPend) is used to move the robot to zero position for fine calibration of motor calibration offset. The calibration is fully automatic and will move the robot to the position read from the sensors.

See *About Calibration Pendulum II on page 66*.

Reference Calibration

With the routine Reference Calibration (RefCal) references are taken of the robot's zero position once the robot is installed. These reference values are then used if the robot needs to be recalibrated in the future, that is, when recalibration of the motor calibration offset is required. See *About Reference Calibration on page 132*.

The Reference Calibration includes features regarding:

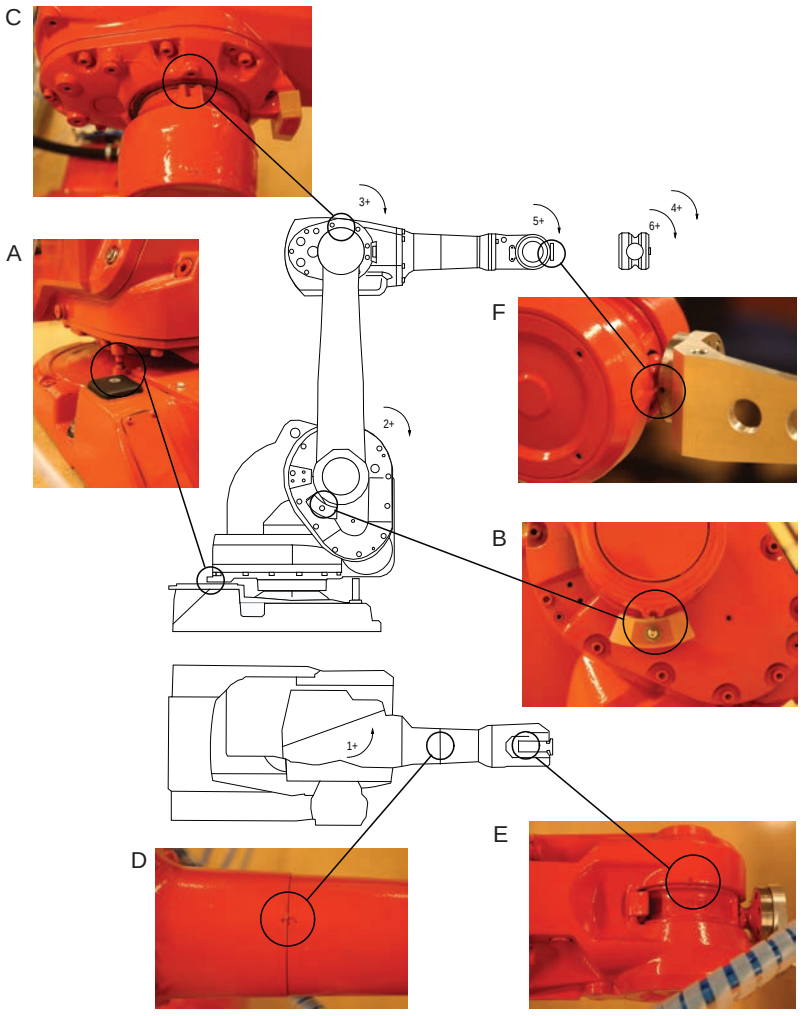
- axis 1 position: axis 1 can be put in any position, to avoid obstacles. (Not available in Calibration Pendulum II.)
- tool and process equipment: all tool and process equipment can stay fitted during calibration. (Not available in Calibration Pendulum II.)
- hanging robot: a reference can be used also on hanging robots.

1.5 Synchronization marks and synchronization position for axes

Introduction

This section shows the position of the synchronization marks and the synchronization position for each axis.

Synchronization marks, IRB 52



xx1100000632

A	Calibration mark, axis 1
B	Calibration mark, axis 2
C	Calibration mark, axis 3
D	Calibration mark, axis 4
E	Calibration mark, axis 5
F	Calibration mark, axis 6

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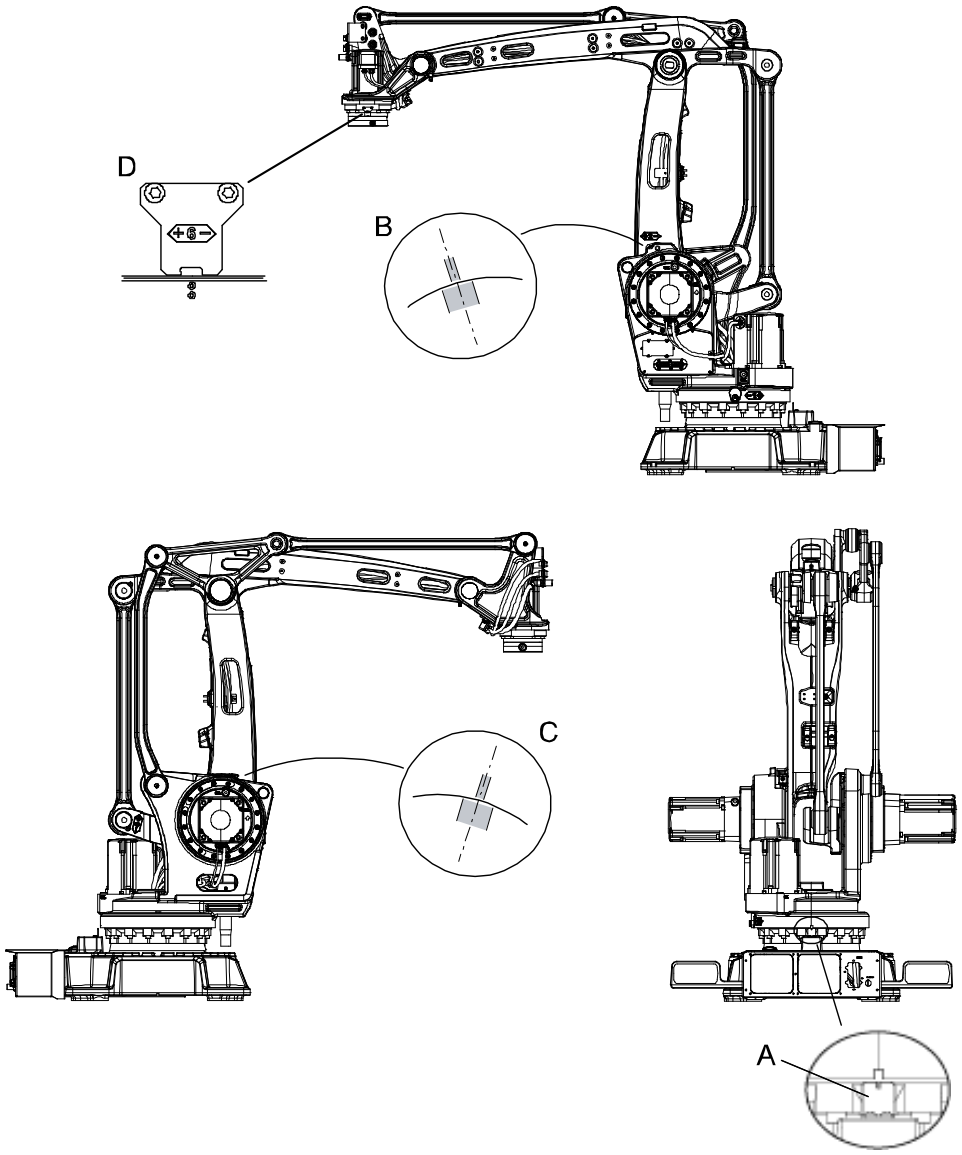
1.5 Synchronization marks and synchronization position for axes
Continued

Synchronization marks, IRB 460



xx1000001433

A	Calibration plate, axis 1
B	Calibration mark, axis 2
C	Calibration mark, axis 3
D	Calibration plate and marking, axis 6

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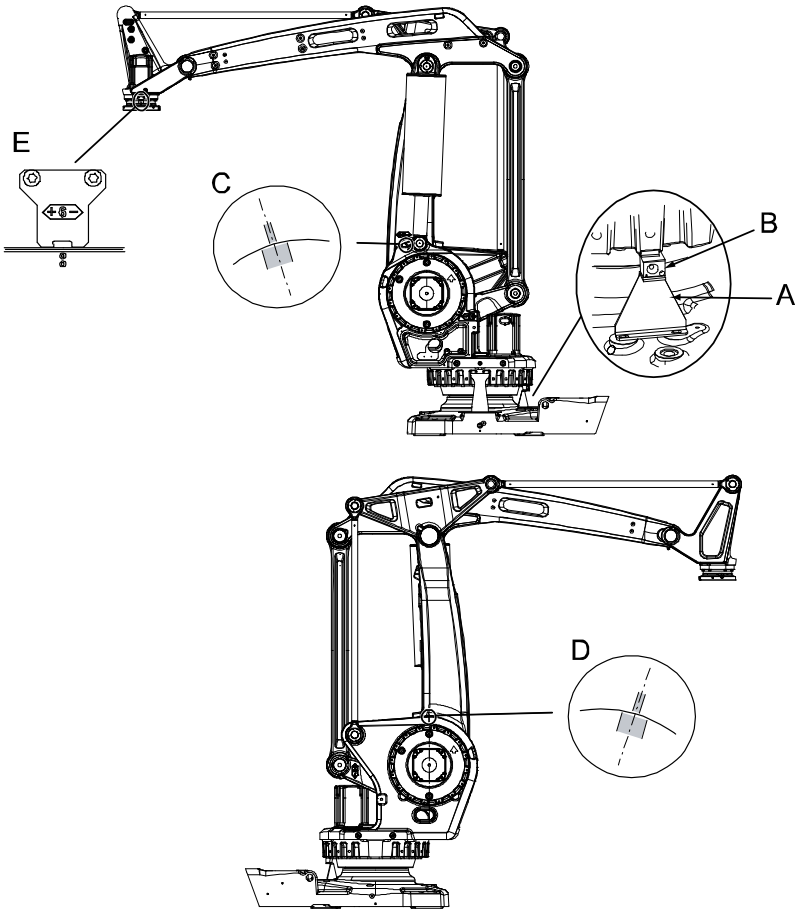
Synchronization marks, IRB 660



xx0500002487

A	Synchronization plate, axis 1
B	Synchronization tab on robot
C	Synchronization mark, axis 2
D	Synchronization mark, axis 3
E	Synchronization plate and mark, axis 6

Synchronization marks at axes 2 and 3

The synchronization marks at axes 2, 3 and 6, shown in the figure above, consist of two single marks that should be positioned opposite to one another when the robot is standing in its synchronization position. One of the marks is more narrow than the other and should be positioned within the limits of the wider mark.

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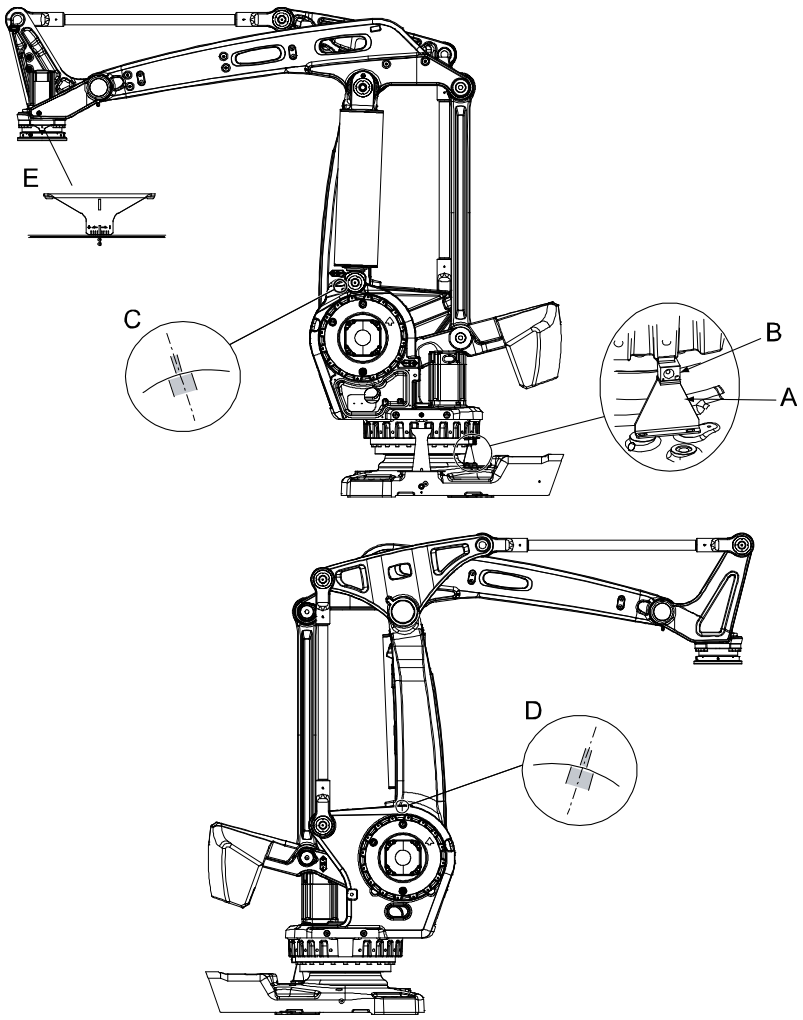
1.5 Synchronization marks and synchronization position for axes
Continued

Synchronization marks, IRB 760



xx1000001146

A	Synchronization plate, axis 1
B	Synchronization tab on robot
C	Synchronization mark, axis 2
D	Synchronization mark, axis 3
E	Synchronization plate and mark, axis 6

Synchronization marks at axes 2, 3 and 6

The synchronization marks at axes 2, 3 and 6, shown in the figure above, consist of two single marks that should be positioned opposite to one another when the robot is standing in its synchronization position. One of the marks is more narrow than the other and should be positioned within the limits of the wider mark.

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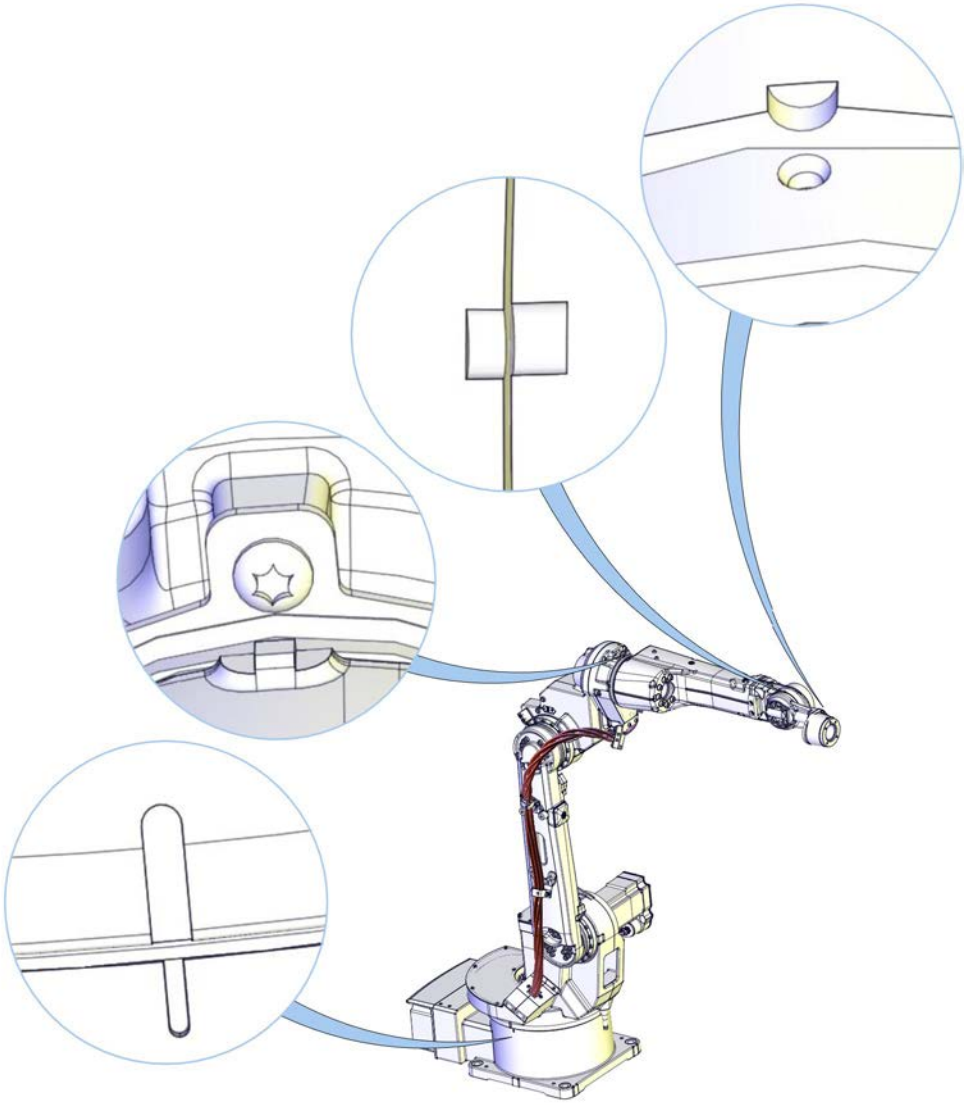
Synchronization marks, IRB 1510, IRB 1520



xx1100000363

Figure 1.1: Calibration marks (from bottom left to top right): Axis 1, axis 4, axis 5 and axis 6.

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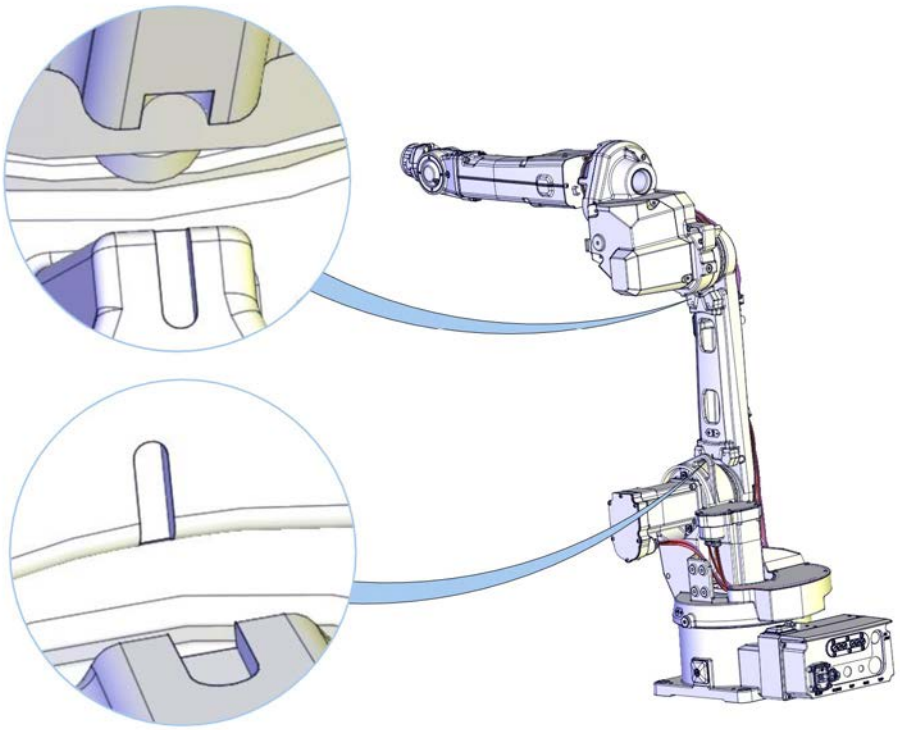
1.5 Synchronization marks and synchronization position for axes

Continued



xx1100000364

Figure 1.2: Calibration marks (from top to bottom): Axis 3 and axis 2.

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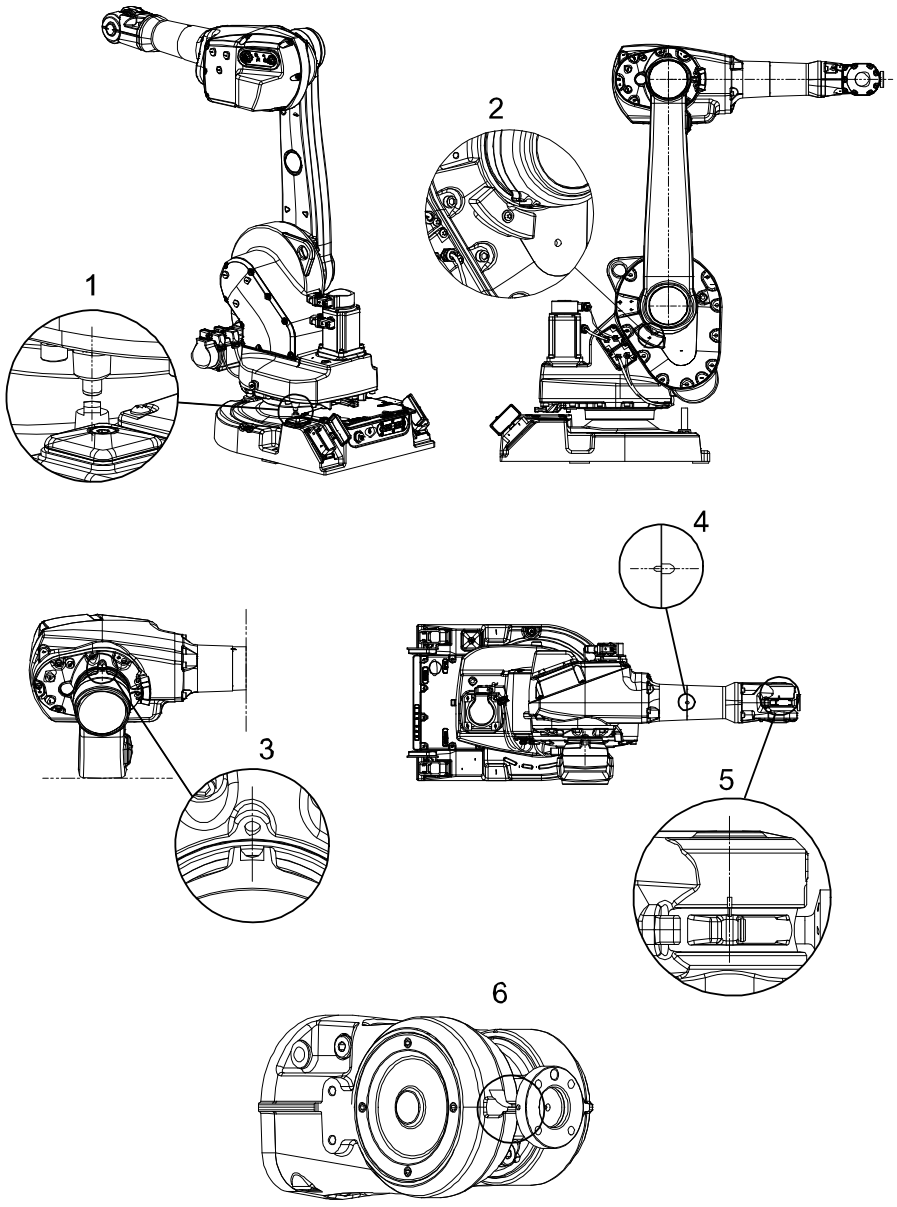
Synchronization marks, IRB 1600/IRB 1660ID

IRB 1600



xx0600002876

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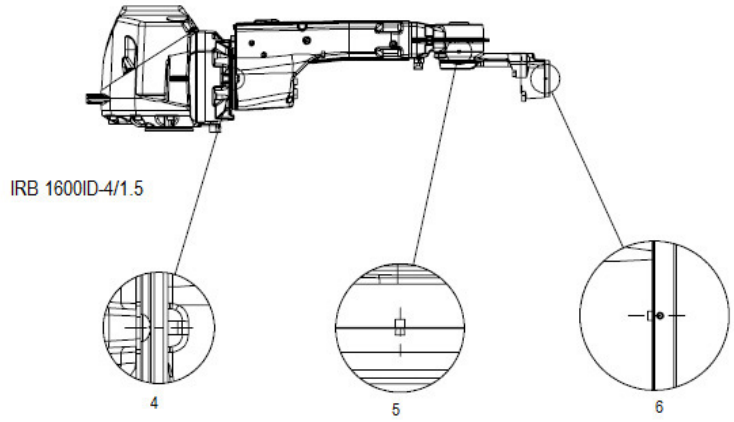
1.5 Synchronization marks and synchronization position for axes
Continued

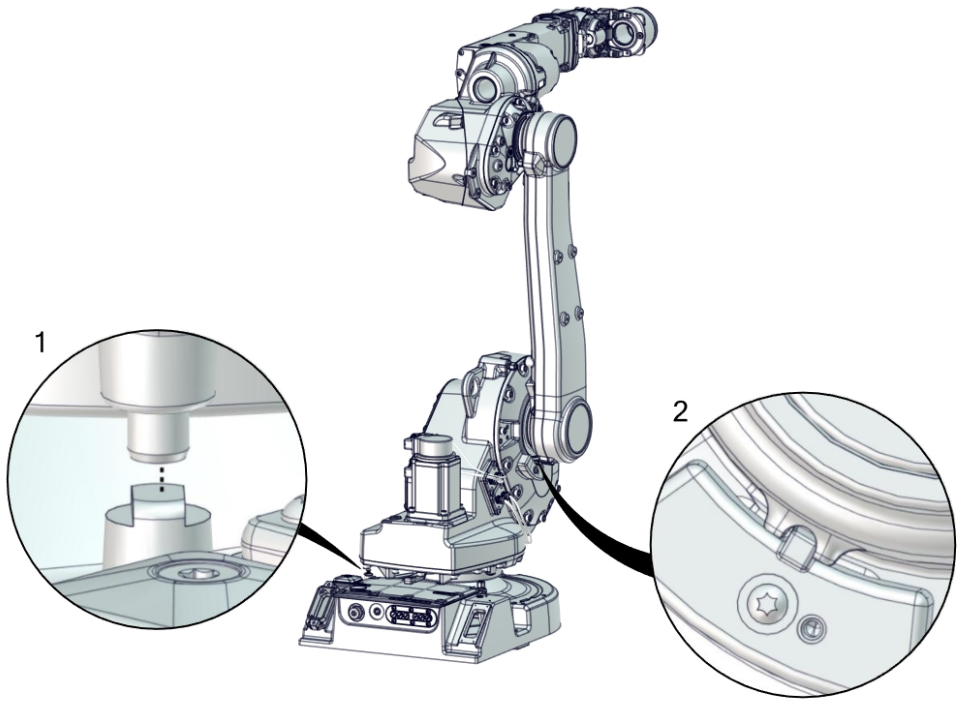
IRB 1600ID

The illustration shows the synchronization marks of axes 4, 5 and 6 for IRB 1600ID. Refer to illustration valid for IRB 1600 for axes 1, 2 and 3.



xx1500001256

IRB 1660ID



xx1700000115

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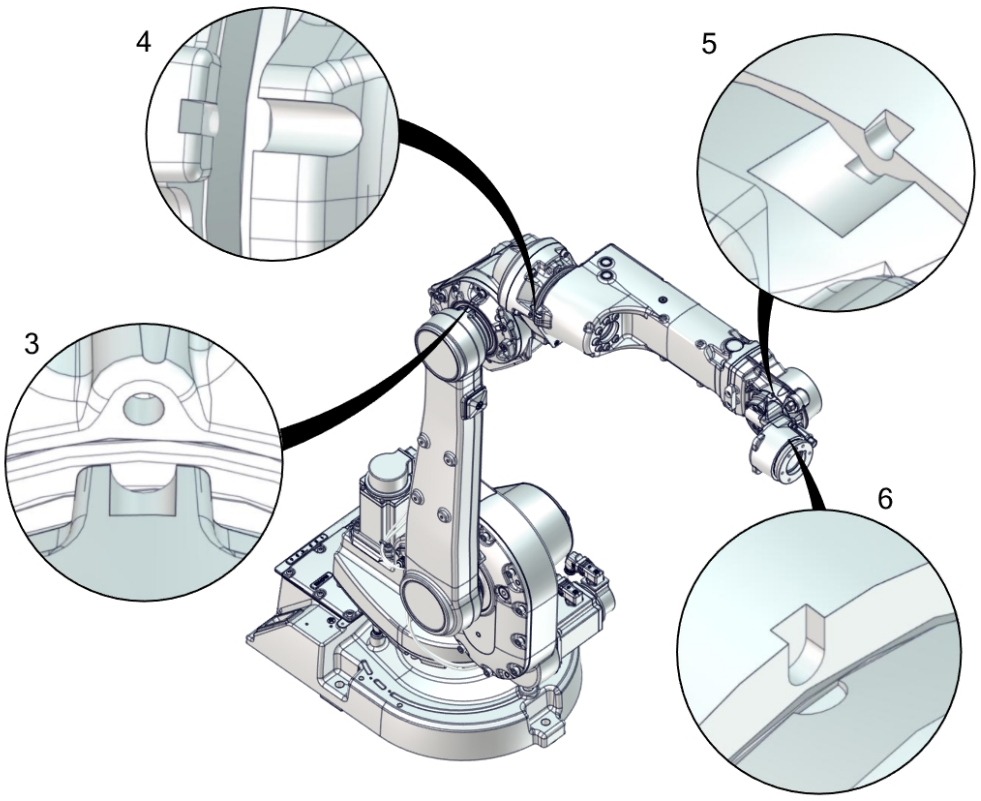

xx1700000116

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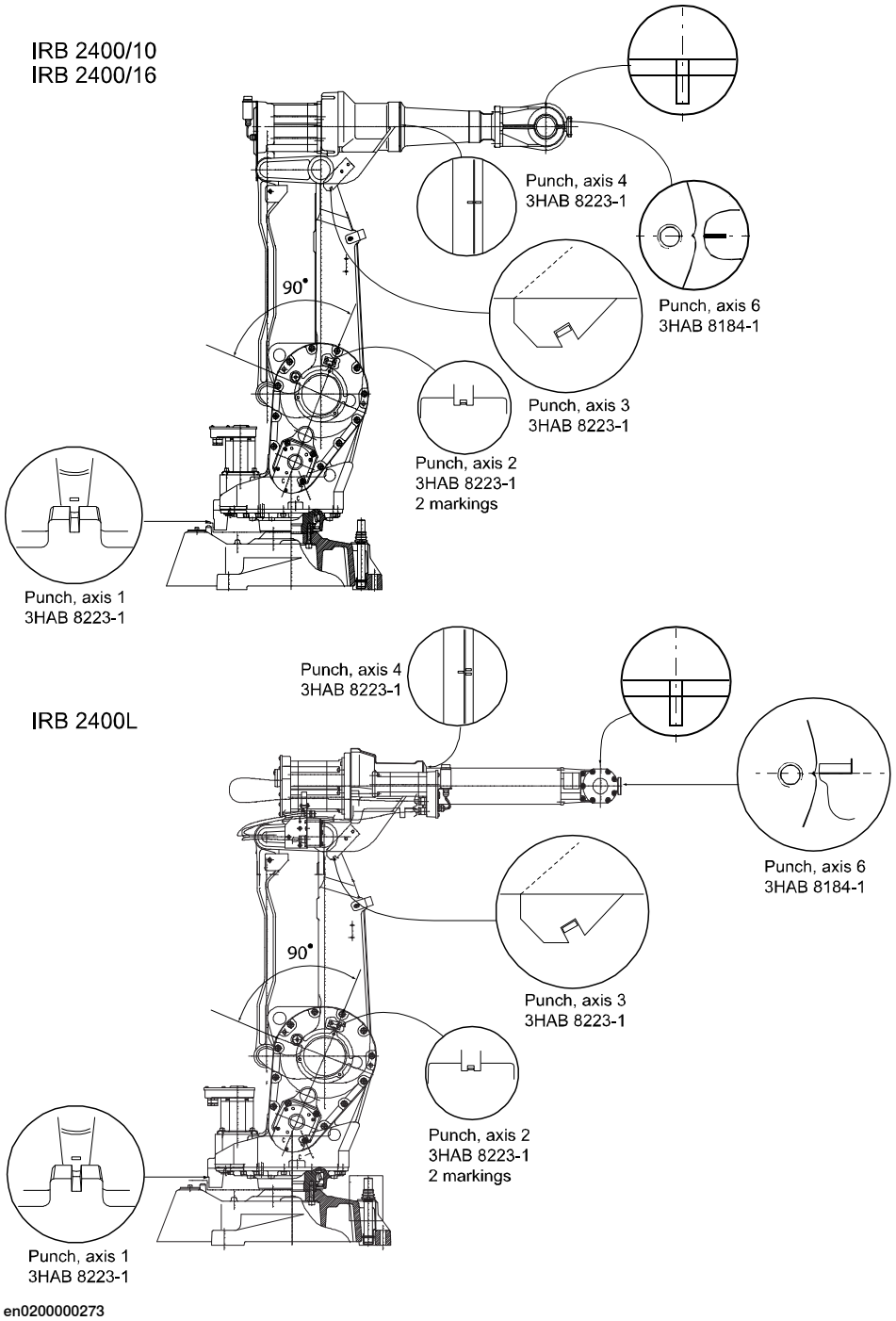
1.5 Synchronization marks and synchronization position for axes
Continued

Synchronization marks, IRB 2400



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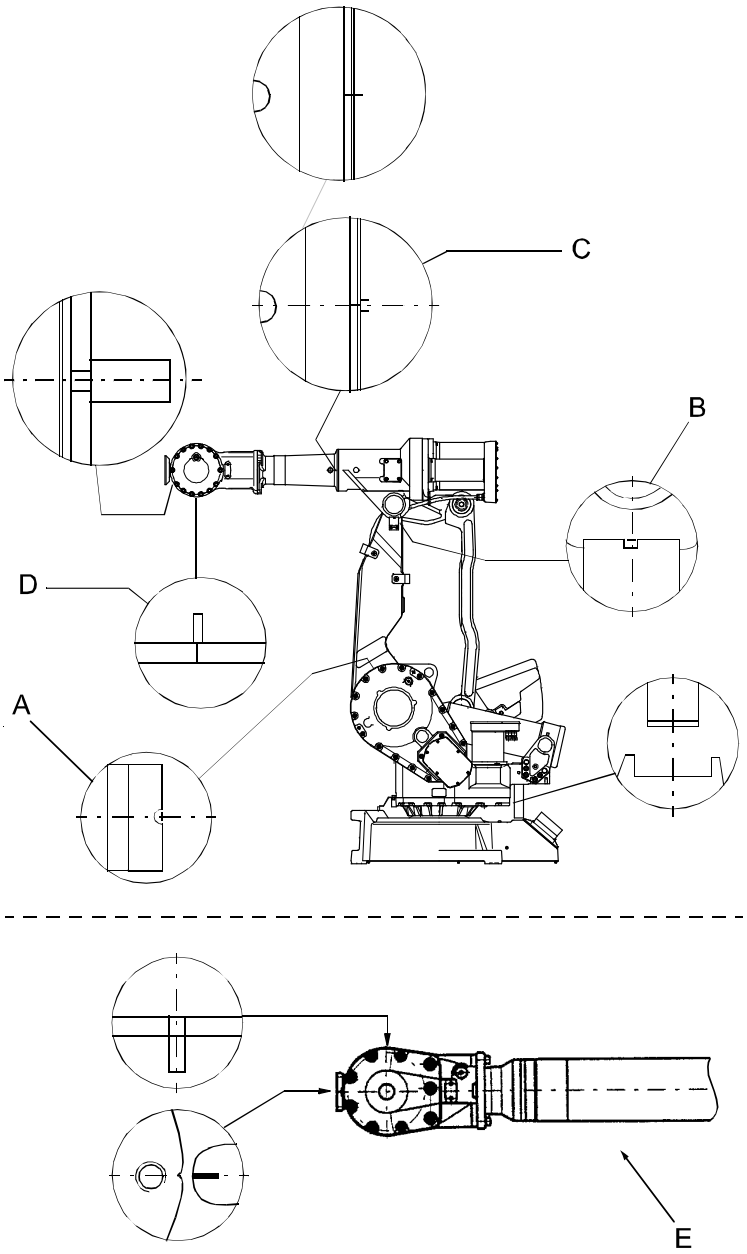
Synchronization marks, IRB 4400

The calibration marks for axes 2, 3, 4 and 5 are marked using punch mark tools.



xx0300000209

A	Punch, axis 2, 3HAB 1521-1
B	Punch, axis 3, 3HAB 1522-1
C	Punch, axis 4, 3HAB 1523-1 (there are two different versions of the marks, as shown in the figure)
D	Punch, axis 5, 3HAB 1524-1

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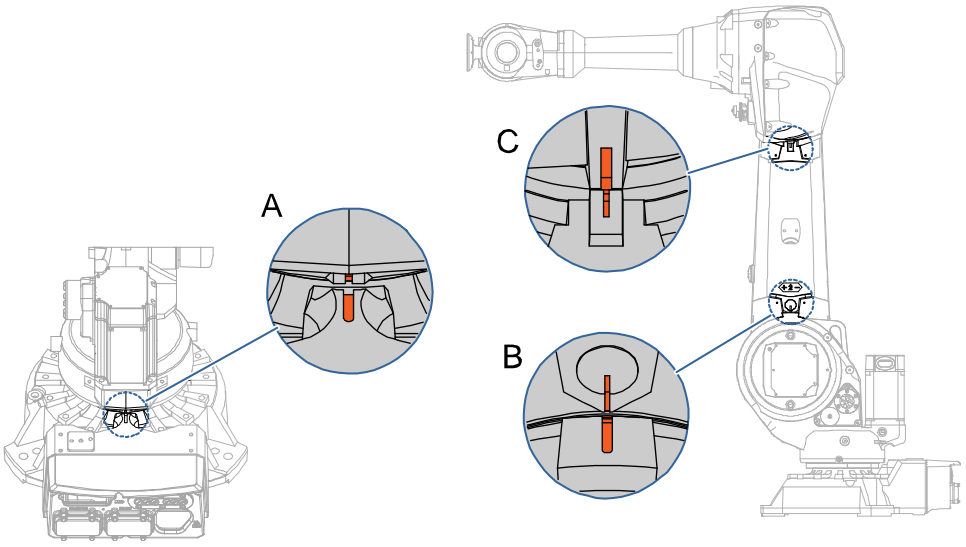
Synchronization marks, IRB 4600, IRB 2600 and 2600ID

IRB 4600-60/2.05, -45/2.05, -40/2.55, -20/2.50and IRB 2600-20/1.65, -12/1.65, -12/1.85



xx0800000312

A	Synchronization mark, axis 1
B	Synchronization mark, axis 2
C	Synchronization mark, axis 3

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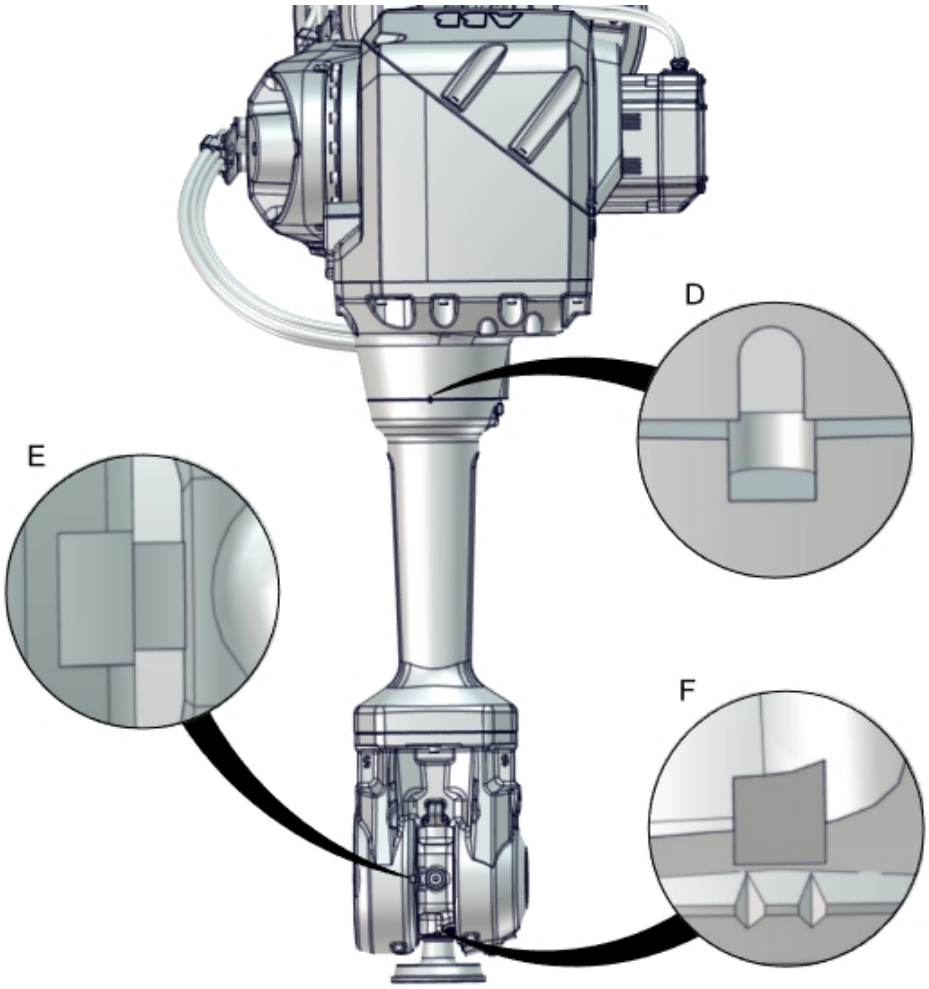
IRB 4600 - 60/2.05, -45/2.05, 40/2.55



xx1700001814

D	Synchronization mark, axis 4
E	Synchronization mark, axis 5
F	Synchronization mark, axis 6 The two tips of the arrows should be inside the corresponding groove on the tilt housing when in synchronization position.

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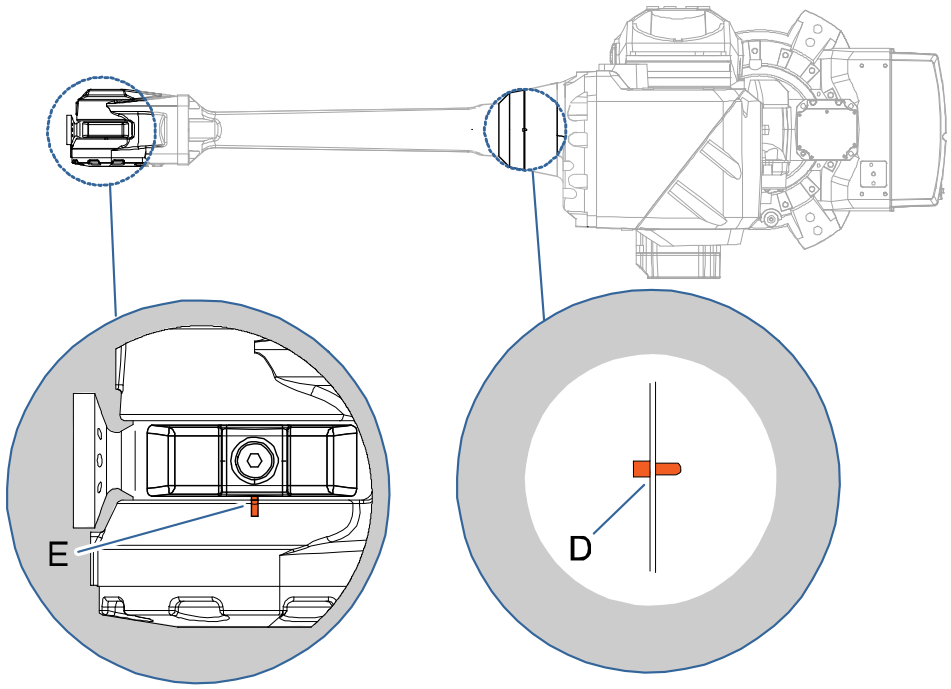
1.5 Synchronization marks and synchronization position for axes
Continued

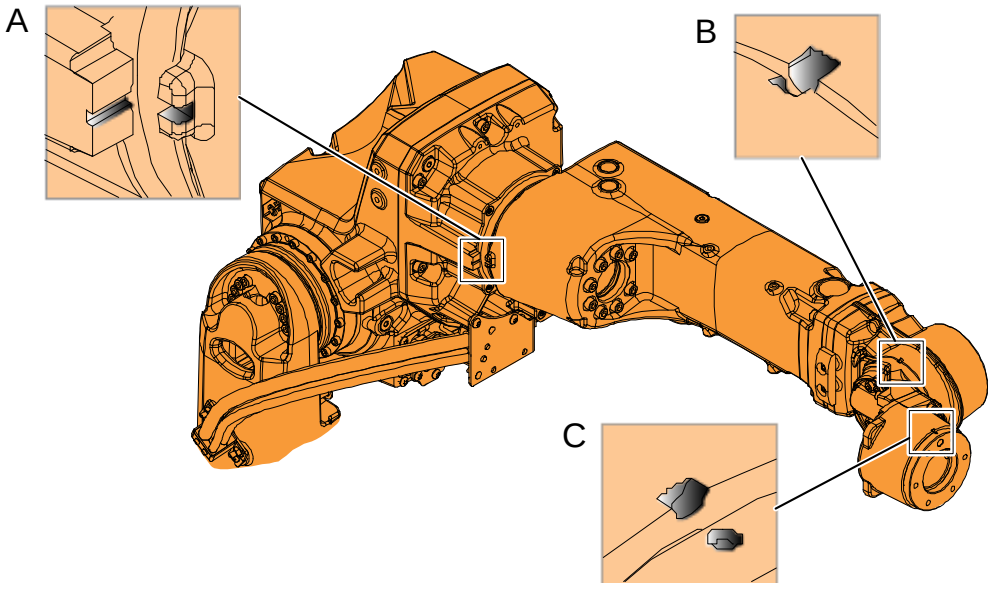
IRB 4600 -20/2.50 and IRB 2600 -20/1.65, -12/1.65, -12/1.85



xx0800000320

D	Synchronization mark, axis 4
E	Synchronization mark, axis 5

IRB 2600ID -15/1.85, -8/2.00



xx1000000445

A	Synchronization mark, axis 4
B	Synchronization mark, axis 5
C	Synchronization mark, axis 6

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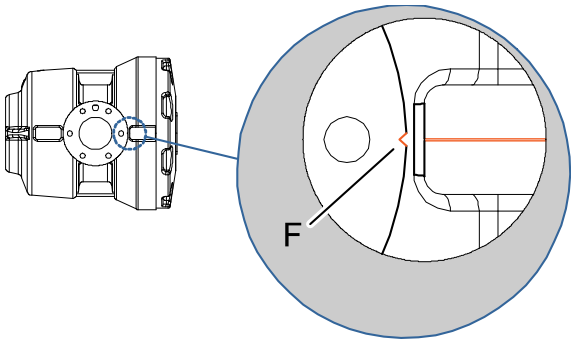
IRB 4600 -20/2.50 and IRB 2600 -20/1.65, -12/1.65, -12/1.85

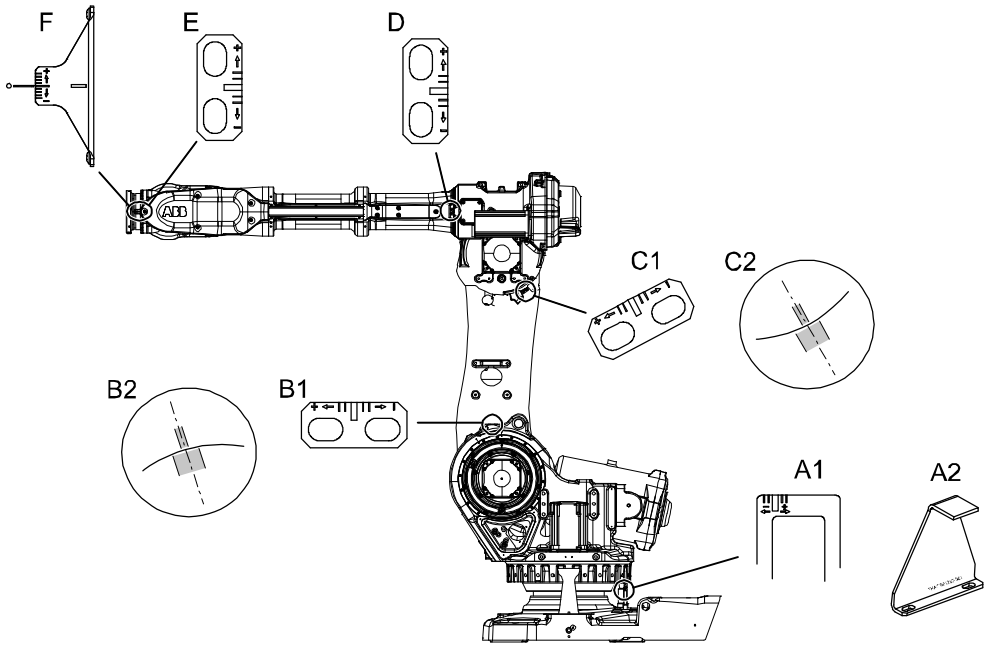


xx0800000321

F	Synchronization mark, axis 6

Synchronization marks, IRB 6650S, IRB 7600

The figure shows IRB 6600, but the scales and their positions are the same.



xx0200000176

A1	Synchronization mark, axis 1 (early design)
A2	Synchronization mark, axis 1 (later design)
B1	Synchronization mark, axis 2 (early design)
B2	Synchronization mark, axis 2 (later design)
C1	Synchronization mark, axis 3 (early design)
C2	Synchronization mark, axis 3 (later design)
D	Synchronization mark, axis 4
E	Synchronization mark, axis 5
F	Synchronization mark, axis 6

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1.5 Synchronization marks and synchronization position for axes
Continued

Synchronization marks at axes 2 and 3

The synchronization marks at axes 2, 3 and 6, shown in the figure above, consist of two single marks that should be positioned opposite to one another when the robot is standing in its synchronization position. One of the marks is more narrow than the other and should be positioned within the limits of the wider mark.

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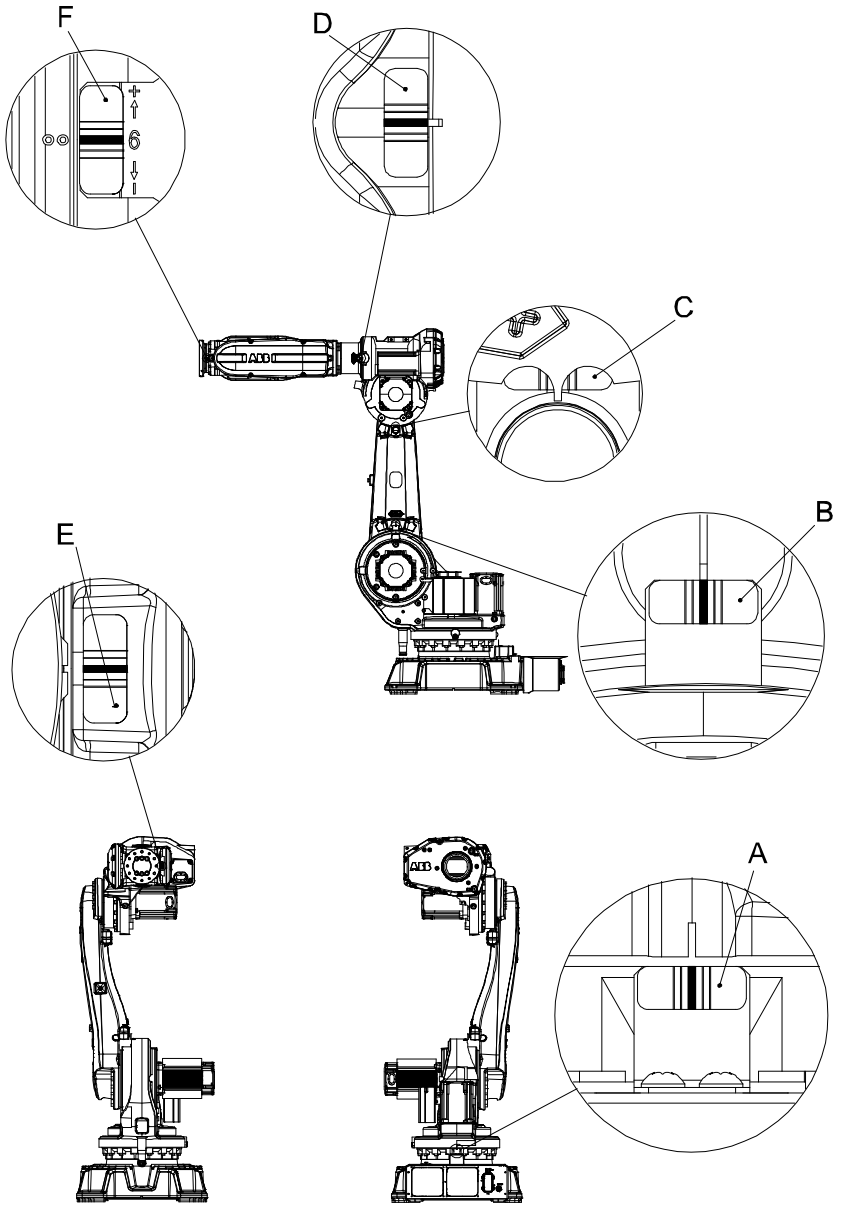
Synchronization marks, IRB 6620



xx0600003096

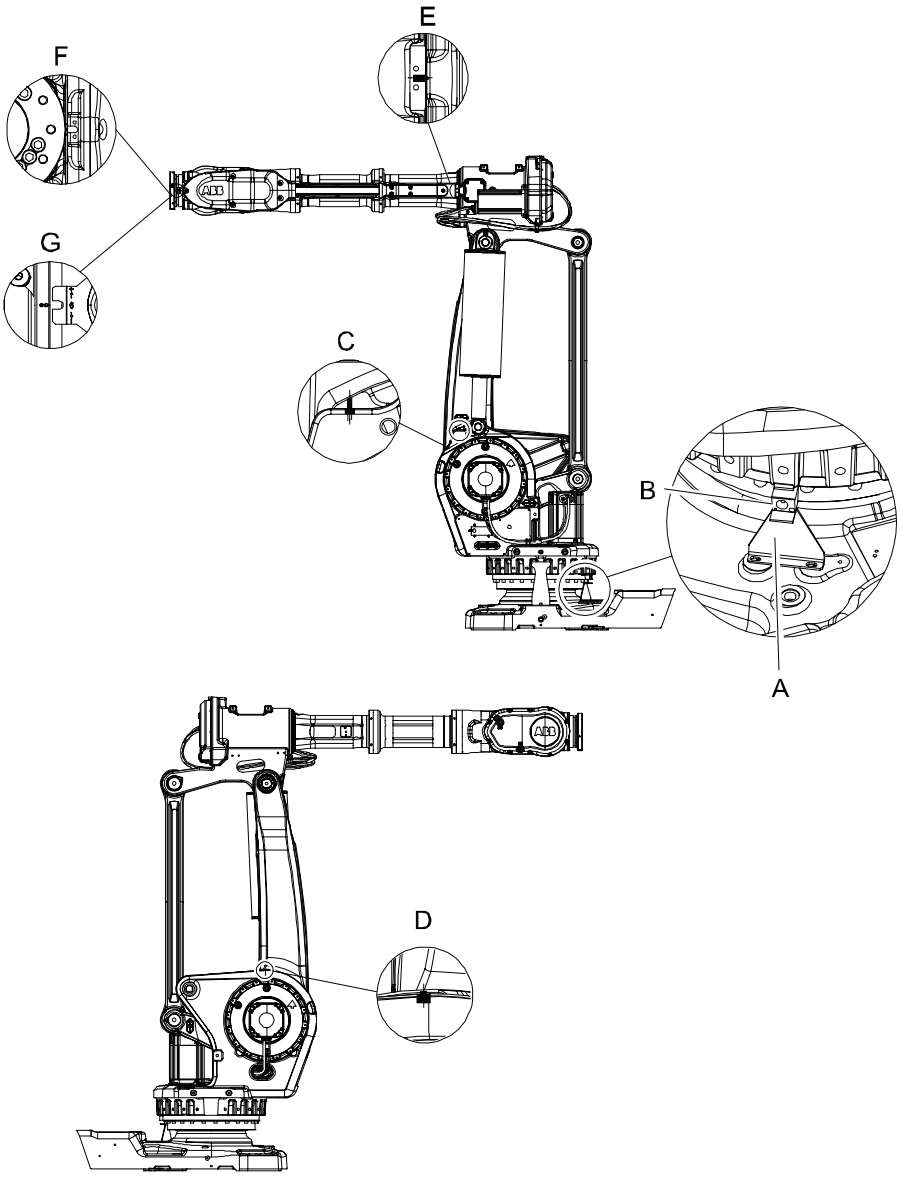
A	Synchronization mark, axis 1
B	Synchronization mark, axis 2
C	Synchronization mark, axis 3
D	Synchronization mark, axis 4
E	Synchronization mark, axis 5
F	Synchronization mark, axis 6

Continues on next page

1.5 Synchronization marks and synchronization position for axes
Continued

Synchronization marks, IRB 6660

The figure shows robot variant IRB 6660 - 130/3.1 but the position of the marks are the same on all IRB 6660 robot variants.



xx0700000148

A	Synchronization plate, axis 1
B	Synchronization tab on robot
C	Synchronization mark, axis 2
D	Synchronization mark, axis 3
E	Synchronization mark, axis 4
F	Synchronization mark, axis 5
G	Synchronization mark, axis 6

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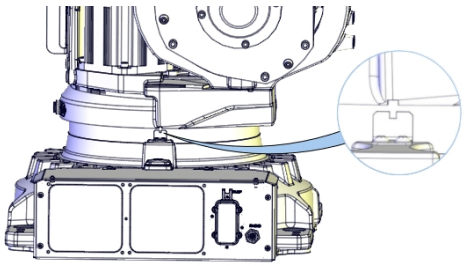
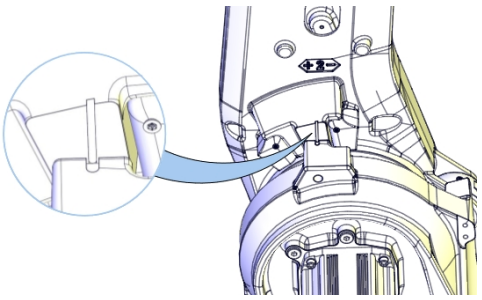
Synchronization marks, IRB 6700, IRB 6700Inv

Axis 1



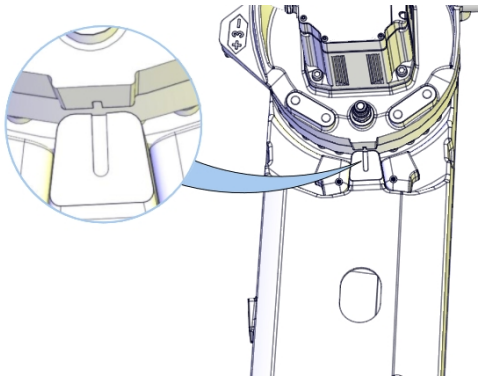
xx1300000868

Axis 2



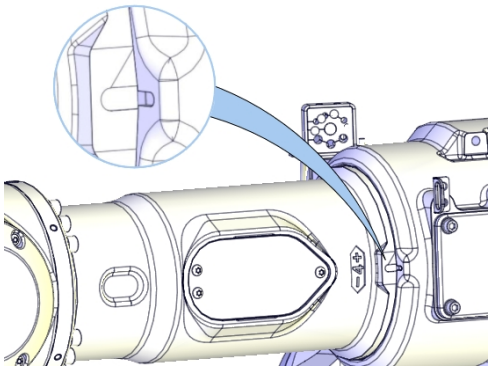
xx1300000869

Axis 3



xx1300000870

Axis 4



xx1300000871

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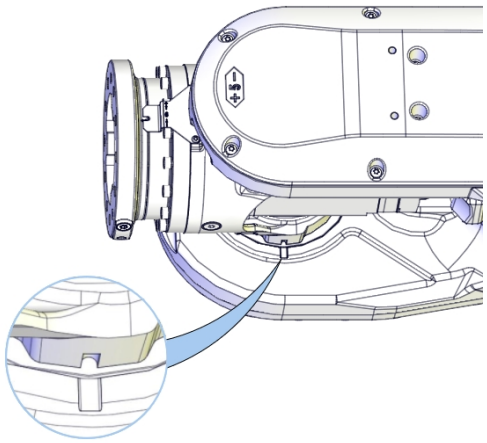
1.5 Synchronization marks and synchronization position for axes

Continued

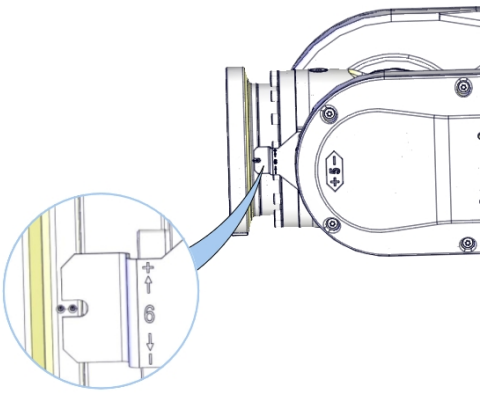
Axis 5



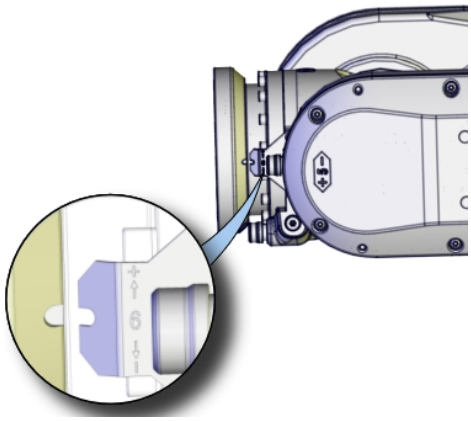
xx1300000872

Axis 6

Two variants of synchronization mark plates.



xx1300000873



xx1500000845

1.6 Calibration equipment

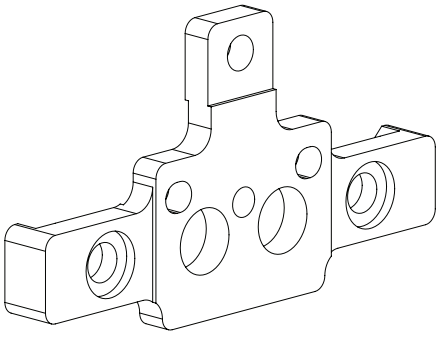
Required equipment - Pendulum Calibration

Using the Pendulum Calibration method requires specific calibration equipment. Below follows information about the equipment required, both general for all robot models and more specific adapters that are unique for different robot models.

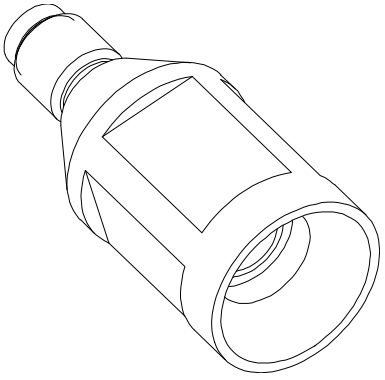
All robots - Calibration pendulum set

Equipment	Art. no.	Note
Calibration pendulum set	3HAC15716-1	The content is specified in the table *Contents of calibration pendulum set 3HAC15716-1 on page 37*. The set can only be rented from ABB, please contact the service department.
Isopropanol	11771012-208	For cleaning the sensor attachment points.

IRB 2600ID, IRB 1660ID - additional equipment

Equipment	Art. no.	Note
Turning disc adapter	3HAC038166-001	Includes all guide pins and attachment screws.  xx1200000017

IRB 760 - additional equipment

Equipment	Art. no.	Note
Turning disc adapter	3HAC038549-001	 xx1000001150

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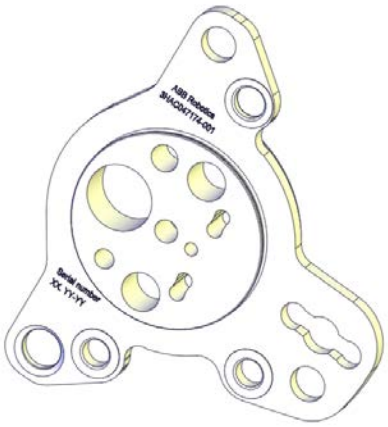
IRB 6650S, IRB 6660, IRB 6700, IRB 7600 - additional equipment

Note

For robots IRB 6650S, IRB 6660, IRB 6700, and IRB 7600, the turning disk adapter is required if there is a reference sensor calibration bracket on the base, see section *Reference position IRB6620, IRB6640 (with calibration bracket at base) on page 105*, *Reference position IRB6650S, IRB7600 (with calibration bracket at base) on page 106* and *Reference position IRB 6700 (with calibration bracket at base) on page 113*.

Always use the same method for Pendulum Calibration on each robot. That is, if the robot is calibrated with a bracket on the base and a turning disk adapter last time then continue using the bracket and adapter, otherwise the calibration values will be wrong.

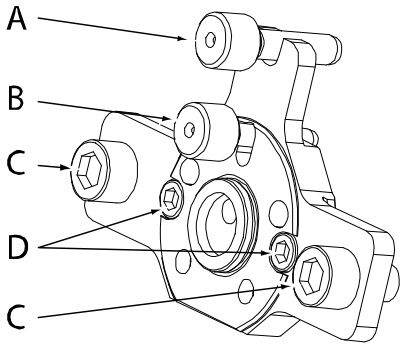
Equipment	Art. no.	Note
Reference sensor calibration bracket	3HAC048764-001	To be fitted to the calibration plate 3HAC020552-002, enclosed in the calibration pendulum set. Used for calibration of the sensor, fitted in vertical plane, if the sensor is fitted to a calibration bracket on the base when used as a reference sensor.
Turning disc adapter	3HAC048787-001	Includes all guide pins and attachment screws.  xx1400001433

IRB 1510ID, IRB 1520ID - additional equipment

Equipment	Art. no.	Note
Calibration tool set	3HAC041422-001	For calibration of axis 1. Includes calibration tool block, parallel pins and a protection screw.

Continues on next page

Contents of calibration pendulum set 3HAC15716-1

Quantity	Contents	Art. no.	Note
2	Inclinometer, Wyler Zerotronic	3HAC12837-7	
1	Cables Wyler		All required cables
1	USB to RS232 adapter cable	3HAC050406-001	Used on the IRC5 controller with main computer DSQC1000.
1	Leveltronic NT/41	3HAC15732-1	
1	Calibration pendulum	3HAC4540-1	Used as calibration sensor and reference sensor, depending on its function at the time.
1	Turning disc adapter	3HAC16423-1	Can be turned both ways to fit IRB 52, IRB140, IRB 1410, IRB 1600, IRB 1600ID, IRB 1520ID, IRB 2400, IRB 2600, IRB 4400, IRB 4450S, and IRB 4600. Includes all guide pins and attachment screws.  xx0200000276 A Guide pin 8 mm B Guide pin, 6 mm C Screw, M10 D Screw, M6
1	Sync plate	3HAC021287-001	
1	Calibration plate	3HAC020552-002	Required when calibrating the pendulum
4	Batteries		For battery supply of Leveltronic NT/41
1	Thread tap, M8		For repairing any damaged protective cover attachment holes.
5	Protective covers and attachment screws		For replacing any damaged protective covers.
1	Locating pin	3HAC14137-1	58 mm long For axis 1 calibration of IRB 660, IRB 6650S, and IRB 7600.

Continues on next page

1.6 Calibration equipment
Continued

Quantity	Contents	Art. no.	Note
1	Locating pin	3HAC14137-2	68 mm long For axis 1 calibration of IRB 52, IRB 140, IRB 260, IRB 460, IRB 760, IRB 1410, IRB 1600, IRB 2400, IRB 2600, IRB 4400, IRB 4450S, IRB 6620, IRB 6640, IRB 6660, IRB 6700.
1	Calibration bar	3HAC024702-001	For axis 6 calibration of IRB 260, IRB 460, IRB 660, and IRB 760.
1	User documentation	*3HAC16578-1*	*Operating manual - Calibration Pendulum*

Required equipment - Reference Calibration

Equipment	Art. no.	Note
Reference adapter	3HAC025397-001	Used as reference surface on the tool when calibrating the robot system with Reference Calibration.

1.7 Storage and warm up

Note

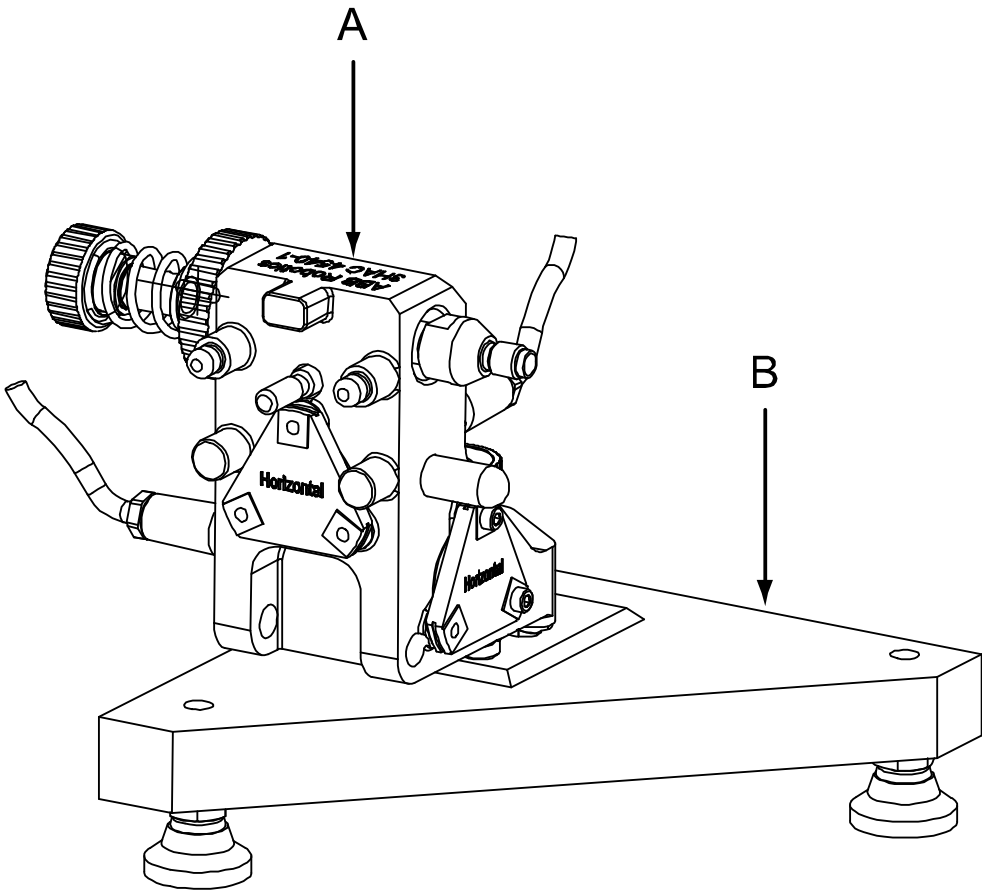
Always store the pendulum sensor in its carrying bag lying down or mounted on the calibration plate in a horizontal position.

Storage in a non horizontal position may cause long term drift and errors in the Wyler sensors.

Storage and warm up

After storage the pendulum tool must be mounted in a horizontal position and be warmed up (power on) for at least 5 minutes before use.

Storage position or warm up position is illustrated below.



xx0300000152

A	Calibration pendulum 3HAC4540-1
B	Calibration plate 3HAC020552-002

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2 Preparing the equipment

2.1 Introduction

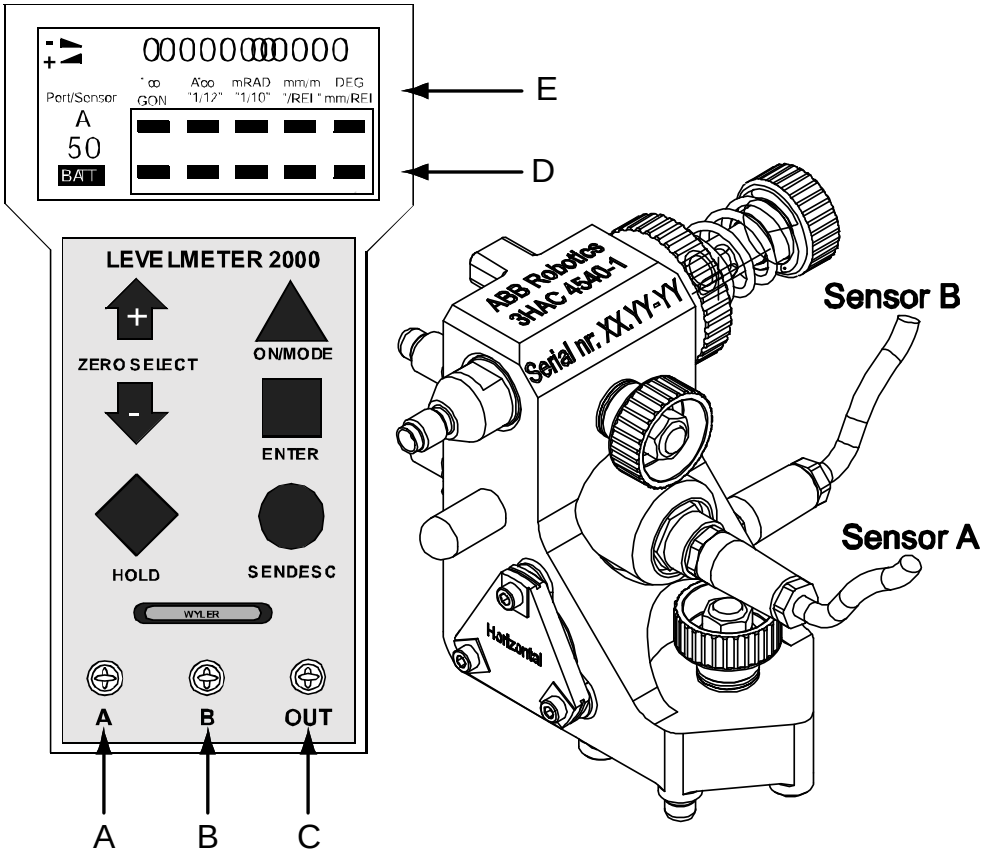
Introduction

This chapter describes the required preparations for the calibration equipment before calibrating the robot.

2.2 Start up of Levelmeter 2000

Layout and connection of Levelmeter 2000

The figure below shows the layout and connection of the Levelmeter 2000.



xx0200000126

A	Connection sensor A
B	Connection sensor B
C	Connection SIO 1
D	Selection pointer
E	Measuring unit

Preparations - setting of Levelmeter 2000

The procedure below details the initial preparations of the Levelmeter.

	Action
1	Warm up the Levelmeter 2000 for at least 5 minutes before use.
2	Set the measuring unit of the angle (DEG) to a sensibility of three decimals, e.g. 0.330º.

Continues on next page

Start up of Levelmeter

This is a simplified description of how to initialize the Levelmeter 2000. Detailed procedures are specified in the manual supplied by the manufacturer.

	Action	Note
1	Connect the measuring unit and sensor using the included cables.	
2	Turn on the power to the Levelmeter 2000.	Power sources are detailed in *Power sources of Levelmeter 2000 on page 44*.
3	Connect sensors A and B.	Detailed in *Identify sensors on page 44*.
4	Connect the Levelmeter 2000 to the controller. • IRC5 with main computer DSQC 639: the COM1 port on the control cabinet through the connector marked *OUT (connection SIO1)*. • IRC5 with main computer DSQC10xx: connect to the USB port on the controller with the USB/RS232-adapter, see *Connecting the Levelmeter through a USB port on page 43*. • OmniCore: connect to the USB port on the FlexPendant with the USB/RS232-adapter, see *Connecting the Levelmeter through a USB port on page 43*.	
5	Calibrate the robot.	

Connecting the Levelmeter through a USB port

On the IRC5 controller with main computer DSQC1000, and on OmniCore controller, the Levelmeter is connected to a USB port through a USB/RS232-adapter.

The correct USB/RS232-adapter is delivered with the Levelmeter, see *Calibration equipment on page 35*.

	Action	Note
1	Switch off the power to the controller.	**Note** If the USB/RS232-adapter is plugged in while the power to the controller is on then it will not be possible to continue the calibration. The adapter is only initiated when the controller starts.
2	• For IRC5: Insert the USB/RS232-adapter into a USB-port on the controller. • For OmniCore: Insert the USB/RS232-adapter into the USB-port on the FlexPendant.	
3	Power on the controller.	
4	Calibrate the robot.	

Continues on next page

	Action	Note
5	Switch off the power to the controller.	**Note** If the USB/RS232-adapter is removed while the power to the controller is on, then the system will hang. In that case, turn off the power and wait for 2-3 minutes until the backup energy bank has run out of power and all LEDS are out on the main computer. If the controller is powered on too early, the system will remain in the hang state.
6	Remove the USB/RS232-adapter from the USB-port.	
7	Power on the controller.	

Power sources of Levelmeter 2000

Two alternatives are available:

- Battery mode: turn on the Levelmeter by pressing **ON/MODE** until the display flashes. This will turn off battery saving mode. Do not forget to turn off after use.
- External power: connect the power cords (red/black) to 12-48 VDC, found either in the cabinet (connector XT31) or from an external power supply. See location of connectors in the IRC5 cabinet in the product manual for the controller.

Sensor address

	Action	Note
1	Make sure the sensors have different addresses. Any addresses will do, as long as they are entered as "Address1" and "Address2".	Detailed in the documentation supplied by sensor manufacturer, found in the calibration tool set.

Identify sensors

	Action	Note
1	Connect the sensor to the *sensor connection* points.	Marked *A* and *B*. See figure *Layout and connection of Levelmeter 2000 on page 42*.
2	Press **ON/MODE**.	To start the Levelmeter.
3	Press the button **ON/MODE** repeatedly until the text **SENSOR** is selected.	
4	Press **ENTER**.	
5	Press **ZERO/SELECT** arrows until **A B** is flashing.	
6	Press **ENTER**. Wait until **A** flashes.	
7	Press **ENTER**. Wait until **B** flashes.	
8	Press **ENTER**.	

Continues on next page

Result

The Levelmeter 2000 is now initialized and ready for use.

2.3 Start up of Bluemeter Sigma

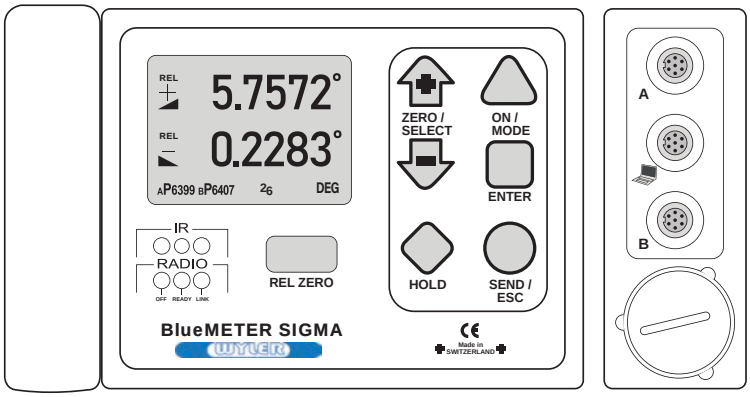
2.3.1 Introduction

Description

This section describes how to setup the Bluemeter Sigma unit, (from now on named BMS).

Layout and connection of Bluemeter Sigma

The figure below shows the layout and connection of the BMS.

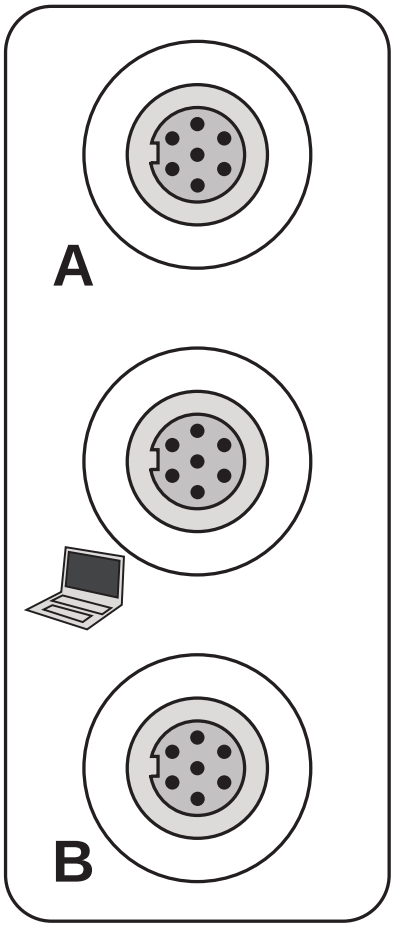


xx2100002795

2.3.2 Settings

Connections

The procedure below details the connections on the BMS.

	Action	Note
1	Insert batteries.	
2	Attach cables A sensor to A port. B sensor to B port. **Note** Note that the short adapter cable needs to be used if the BMS unit is to be connected to a robot controller or PC.	 xx2100002797
3	Start unit by pressing and hold button ON/MODE.	Wait for the unit to start

Set output mode

The procedure below details how to set output mode.

	Action	Note
1	Press ON/MODE button to display the menu.	
2	Step down to **Options** using + - button	
3	Press ENTER.	
4	Step down to **LM2000 Output-Mode**.	
5	Set **LM2000 Output-Mode** to **ON** using + - button, and press ENTER.	The output mode is now the same as for the older Levelmeter 2000.

Continues on next page

2.3.2 Settings
Continued

Set sensor Auto address to OFF

The procedure below details how to set sensor Auto address to OFF.

	Action	Note
1	Press ON/MODE button.	
2	Step down to **Options** using + - button	
3	Press ENTER.	
4	Step down to **Auto Address**, and press ENTER.	
5	Set the **Auto address** to **OFF**, and press ENTER	The sensor ID is printed on the physical sensor.

Assign sensor ID to port A and B

If a sensor is exchanged, the correct sensor ID must be connected to the correct port (A or B).

Note

The sensor ID is printed on the front of the sensor that is mounted on the pendulum.

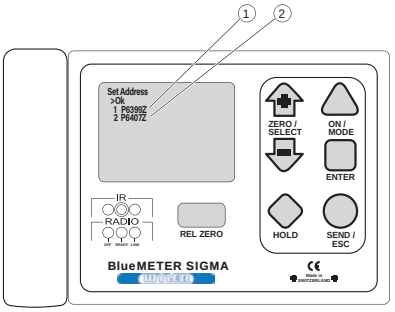
	Action	Note
1	Press ON/MODE button.	
2	Step down to **Sensor** using + - button	
3	Press ENTER.	
4	Press ENTER once more.	
5	Select the correct sensor ID for sensor port A using + - button , and press ENTER.	
6	Select the correct sensor ID for sensor port B using + - button , and press ENTER.	

Set sensor address

The procedure below details how to set sensor address.

	Action	Note
1	Press ON/MODE button.	
2	Step down to **Options** using + - button	
3	Press ENTER.	

Continues on next page

	Action	Note
4	Step down to **Set Address**, and press ENTER.	 xx2100002795 Wait for the unit to show sensor address and sensor ID.
5	Step down to the first sensor using + - button and press ENTER.	**Note** The sensor ID is printed on the physical sensor.
6	Use + - button and set address 1 for the sensor ID connected to the A port, and press ENTER.	
7	Use + - button and set address 1 for the sensor ID connected to the B port, and press ENTER.	
8	Use + - button and select **OK**, press ENTER.	**Note** The first sensor (A port) has now been assigned to address 1, and the second sensor (B port) has now been assigned to address 2.

Select what to show on the screen

The procedure below details how to Select what to show on the screen.

	Action	Note
1	Press ON/MODE button.	
2	Step down to **Display** using + - button	
3	Press ENTER.	
4	Use + - button and show the **option** to only display the value from the sensor.	Wait for the unit to show sensor address and sensor ID
5	Press ENTER.	**Note** Only values from sensors will be shown on the screen.

Continues on next page

2.3.2 Settings
Continued

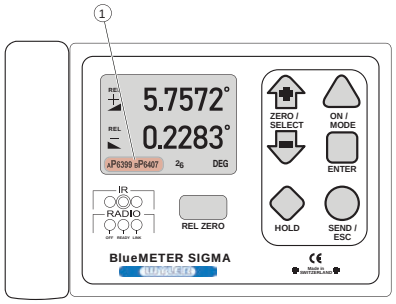
Select format/Unit for sensor values shown on the screen

The procedure below details how to select format/Unit for sensor values shown on the screen.

	Action	Note
1	Press ON/MODE button.	
2	Step down to **Unit** using + - button	
3	Press ENTER.	
4	Use + - button and select **DEG XX.XXXX**.	
5	Press ENTER.	

Select measuring mode

The procedure below details how to select format/Unit for sensor values shown on the screen.

	Action	Note
1	Press ON/MODE button.	
2	Step down to **Sensor** using + - button	
3	Press ENTER.	
4	Use + - button repeatably so that both sensor A and sensor B is shown.	
5	Press ENTER.	Measurement value both for sensor A and sensor B shall now be seen on the screen.  xx2100002795 1 Measurement values for sensor A and sensor B. **Note** There shall be no (-) sign before the B sensor ID

2.4 Calibrating sensors (calibration pendulum)

Purpose of calibrating sensors

The calibration pendulum is used as both a calibration and a reference sensor. The calibration of the sensors ensures that the same value but with opposite polarity (+/-) will be used if the pendulum is rotated 180 degrees.

When to calibrate the sensors

If the sensor has not been used for a while or if the pendulum has been transported, the sensor needs to be calibrated using the Levelmeter to give proper calibration result. The calibration of the sensors can be checked, see *Checking sensors on page 60*. If the difference is too large, a new calibration should be done.

The result of the sensor calibration will be stored in the Levelmeter. Therefor, the sensors need to be recalibrated if they are connected to a new Levelmeter.

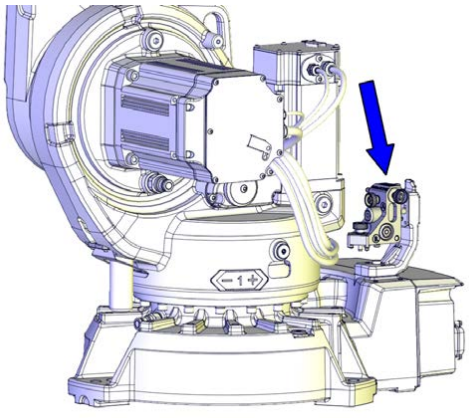
How to calibrate the sensors

The sensors are calibrated by first fitting them on a special calibration plate, included in the calibration pendulum set and then running a calibration procedure on the Levelmeter. See *Calibrating the sensor with Levelmeter 2000 on page 56* or *Calibrating the sensor with Bluemeter SIGMA on page 57*.

If the pendulum is fitted in a vertical plane to a calibration bracket when used as a reference sensor, then the sensor must also be fitted in vertical plane to the calibration plate. Verify if there is a calibration bracket at the base of the robot (not available for all robots). If there is a bracket, the sensor must be calibrated by fitted in vertical plane to the calibration plate.

Robots for which a calibration bracket is available

A calibration bracket is available for the following robots:

Robot	Illustration
IRB 4600	 xx1400001051

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2.4 Calibrating sensors (calibration pendulum)

Continued

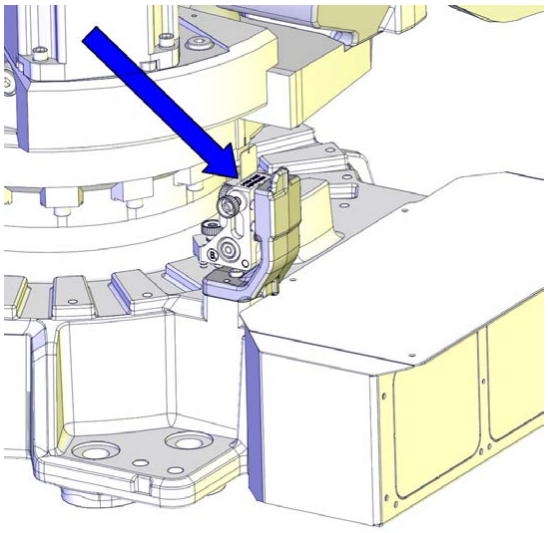
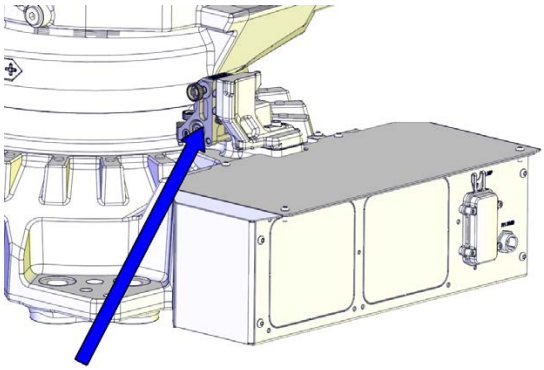
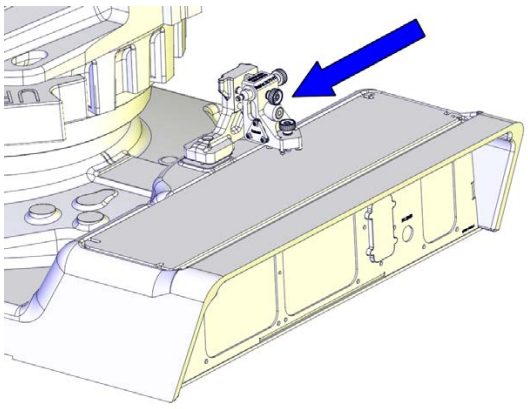
Robot	Illustration
IRB 6620 IRB 6640	 xx1400001052
IRB 6700	 xx1400001053
IRB 6650S IRB 7600	 xx1400001638

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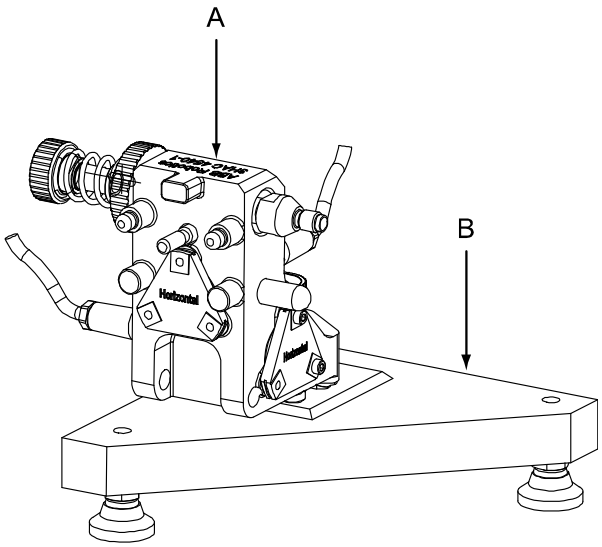
Illustration - fitting sensor to the calibration plate in a horizontal plane

The figure shows the calibration pendulum fitted in a horizontal plane to the calibration plate, used if the pendulum is fitted in a horizontal plane as a reference sensor.

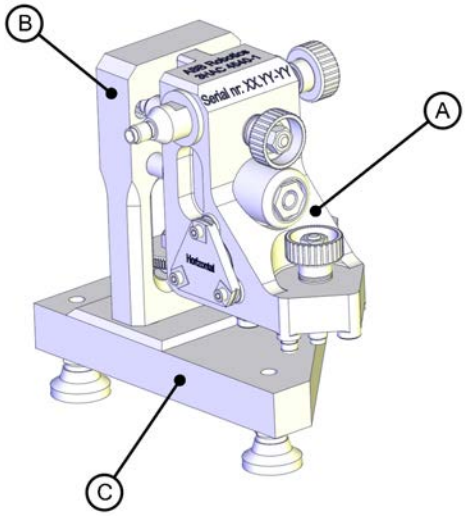


xx0300000152

A	Sensor (calibration pendulum, 3HAC4540-1)
B	Calibration plate (3HAC020552-002)

Illustration - fitting sensor to the calibration plate in a vertical plane

The figure shows the calibration pendulum fitted in a vertical plane to the calibration plate, used if the pendulum is fitted in a vertical plane as a reference sensor.



xx1400001624

A	Sensor (calibration pendulum, 3HAC4540-1)
B	Calibration bracket (3HAC048764-003)
C	Calibration plate (3HAC020552-002)

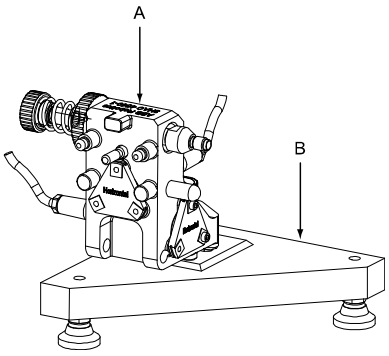
Continues on next page

Calibrating sensors

Use this procedure to calibrate the sensors.

Choose one of the preparation procedures, depending on if the sensor is fitted in a horizontal or a vertical plane.

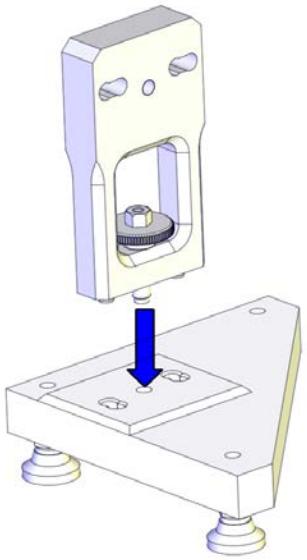
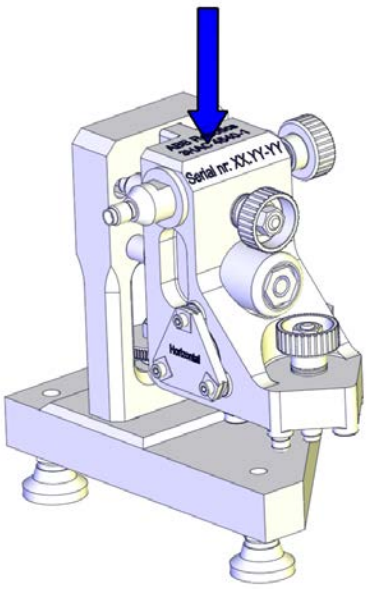
Preparing the calibration plate and fitting sensor in horizontal plane

	Action	Note/Illustration
1	Secure the calibration plate on a steady and flat foundation, for a example in a vise. **Note** It is important that the plate cannot move during the calibration of the sensor.	
2	Clean the calibration plate surface and the three contact surface points on the sensor holder with isopropanol.	
3	Fit the sensor in one of the two possible positions and tighten the screw.	 xx0300000152 A Sensor (calibration pendulum, 3HAC4540-1) B Calibration plate (3HAC020552-002)

Preparing the calibration plate and fitting sensor in vertical plane

	Action	Note/Illustration
1	Clean the calibration plate surface with isopropanol.	

Continues on next page

	Action	Note/Illustration
2	Fit the bracket to the calibration plate with the screw. **Note** Tighten the screw fully, the bracket must not move during calibration!	 xx1400001640
3	Secure the calibration plate on a steady and flat foundation, for a example in a vise. **Note** It is important that the plate cannot move during the calibration of the sensor.	
4	Clean the bracket surface and the three contact surface points on the sensor holder with isopropanol.	
5	Fit the sensor in one of the two possible positions by pressing it down gently with a thumb while tightening its fastening screw. Do not force the pendulum house sideways while tightening the screw.	 xx1400001641

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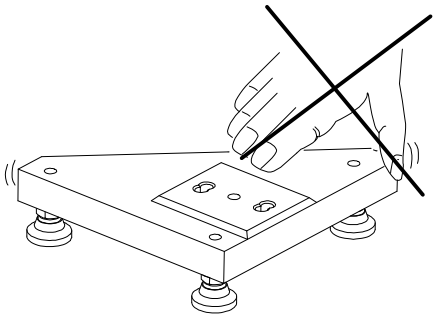
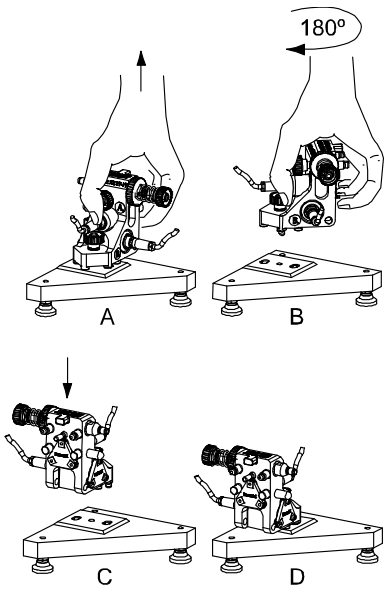
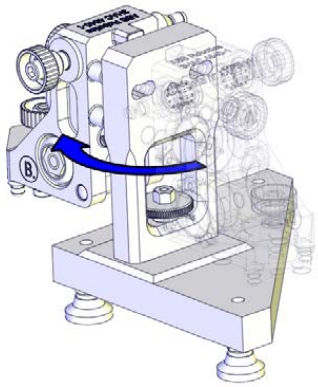
2.4 Calibrating sensors (calibration pendulum)
Continued

Calibrating the sensor with Levelmeter 2000

	Action	Note/Illustration
	Note Step *1*-*5* are for selecting which sensor to calibrate (A or B). Start with sensor A. Proceed with the calibration of sensor A as described in step *6*-*11*. When done, repeat step *1*-*11* for sensor B (marked with *).	
1	Press the **ON/MODE** button repeatedly until the text **SENSOR** is selected.	
2	Press **ENTER**.	
3	Press **ZERO/SELECT** repeatedly until **A*** flashes below **Port/Sensor**.	This selects sensor A for calibration. Select sensor B if sensor B is about to be calibrated.
4	Press **ENTER**. Wait until **A*** stops flashing and starts to flash again.	
5	Press **ENTER**.	
6	Press **ON/MODE** repeatedly until the text **ZERO** is selected.	
7	Press **ENTER**. The direction indicator (+/-) and the last zero offset will be displayed. Wait a couple of seconds for the sensor to stabilize.	**Note** Be careful not to change the position of the calibration plate from now on.
8	Press **HOLD**. Wait for the indicator below **ZERO** to flash.	

Continues on next page

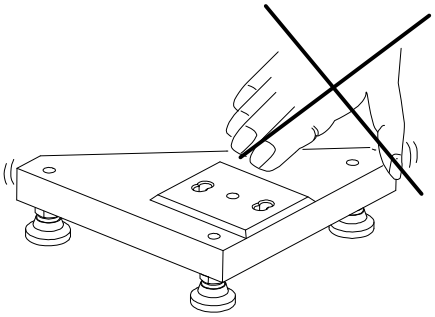
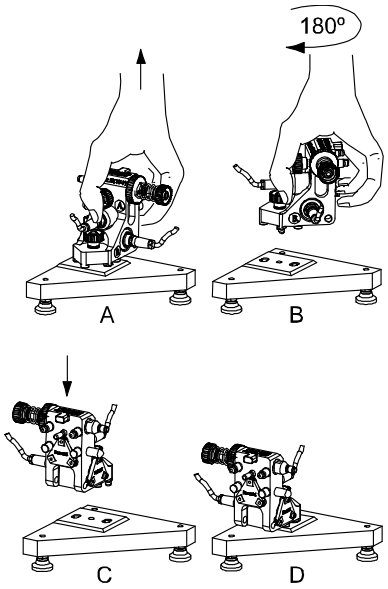
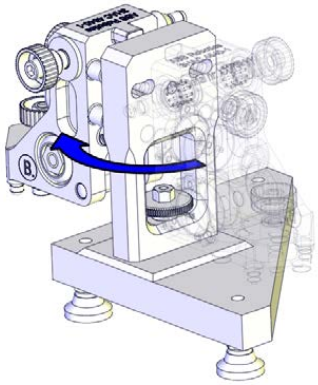
	Action	Note/Illustration
9	Remove the sensor carefully, turn it 180° and fit it on the calibration plate / bracket in the corresponding hole pattern. Make this slowly and with care, in order not to change the values of the sensor. Wait a couple of seconds for the sensor to stabilize. **Note** Be careful not to change the position of the calibration plate.  xx0300000207	Sensor fitted in horizontal plane:  xx0300000261 Sensor fitted in vertical plane:  xx1400001642
10	Press **HOLD**. Wait a couple of seconds for the new zero offset to be displayed.	
11	Press **ENTER**.	Sensor **A*** is now calibrated.
12	Repeat steps *1-5* but select sensor **B** instead of A. Then repeat steps *6-11*. to calibrate sensor B.	
13	When both sensors are calibrated: adjust the instrument as described in steps *1-5* so that **A B** is visible below **Port/Sensor** (not flashing).	**Note** (**A B**) should be visible, not (A-B).
14	Verify the result.	See *Checking sensors on page 60*.

Calibrating the sensor with Bluemeter SIGMA

	Action	Note/Illustration
1	Press the **ON/MODE**.	

Continues on next page

2.4 Calibrating sensors (calibration pendulum)
Continued

	Action	Note/Illustration
2	Step down to **Abs.Zero** using + - button.	
3	Press **ENTER** twice.	**Note** The display will show current measurements. (Values for both sensors will be stored for the 0 degrees mounting position after 15 seconds).
4	Wait until done.	
5	Carefully remove the sensor from the plate without moving the position of the plate. **Note** Be careful not to change the position of the calibration plate.  xx0300000207	Sensor fitted in horizontal plane:  xx0300000261 Sensor fitted in vertical plane:  xx1400001642
6	Mount the sensor in a 180 degrees position.	

Continues on next page

	Action	Note/Illustration
7	Press **ENTER**.	**Note** The display will show current measurements. (Values for both sensors will be stored for the 180 degrees mounting position after 15 seconds).
8	Wait until done.	The real zero value will be calculated and set by the instrument.
9	Verify the result.	See *Checking sensors on page 60*.

2.5 Checking sensors

Introduction

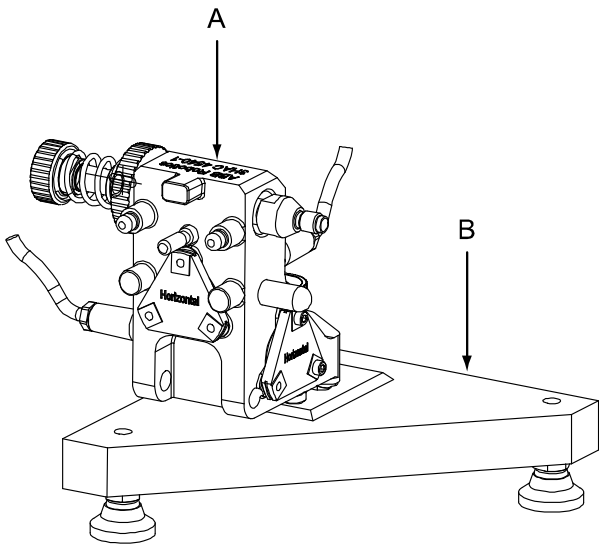
It is a good habit to check sensors before every new use to ensure that sensors has been correctly calibrated, see *Calibrating the sensor with Levelmeter 2000 on page 56* or *Calibrating the sensor with Bluemeter SIGMA on page 57*.

Sensor fitted to calibration plate

If the pendulum is fitted in a vertical plane to a calibration bracket when used as a reference sensor, then the sensor must also be fitted in vertical plane to the calibration plate. Verify if there is a calibration bracket at the base of the robot (not available for all robots). If there is a bracket, the sensor must be calibrated by fitted in vertical plane to the calibration plate.

Illustration - fitting sensor to the calibration plate in a horizontal plane

The figure shows the calibration pendulum fitted in a horizontal plane to the calibration plate, used if the pendulum is fitted in a horizontal plane as a reference sensor.



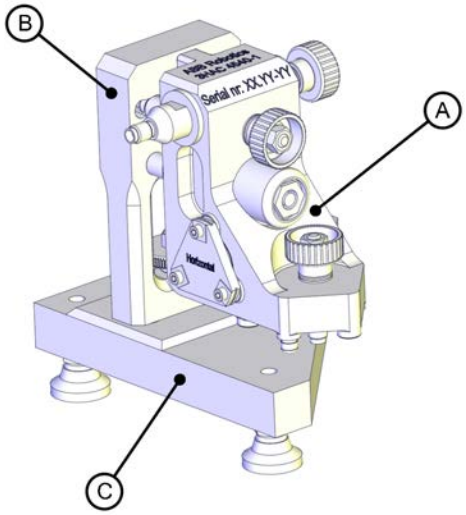
xx0300000152

A	Sensor (calibration pendulum, 3HAC4540-1)
B	Calibration plate (3HAC020552-002)

Continues on next page

Illustration - fitting sensor to the calibration plate in a vertical plane

The figure shows the calibration pendulum fitted in a vertical plane to the calibration plate, used if the pendulum is fitted in a vertical plane as a reference sensor.



xx1400001624

A	Sensor (calibration pendulum, 3HAC4540-1)
B	Calibration bracket (3HAC048764-003)
C	Calibration plate (3HAC020552-002)

Checking sensors

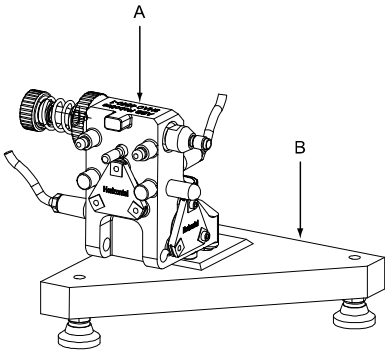
Use this procedure to check individual sensors with the Levelmeter 2000 or Bluemeter SIGMA.

Choose one of the preparation procedures, depending on if the sensor is fitted in a horizontal or a vertical plane.

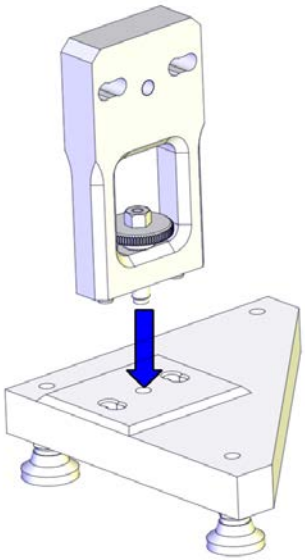
Preparing the calibration plate and fitting sensor in horizontal plane

	Action	Note/Illustration
1	Secure the calibration plate on a steady and flat foundation, for a example in a vise. **Note** It is important that the plate cannot move during the calibration of the sensor.	
2	Clean the calibration plate surface and the three contact surface points on the sensor holder with isopropanol.	

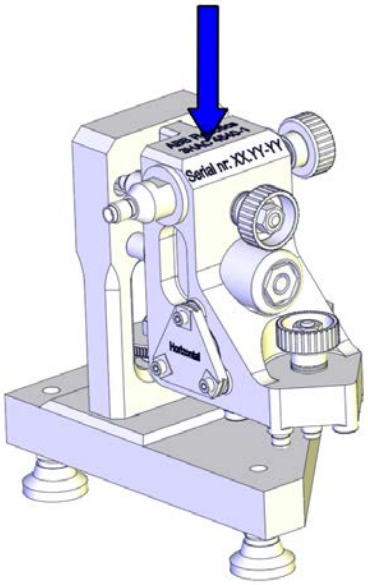
Continues on next page

	Action	Note/Illustration
3	Fit the sensor in one of the two possible positions and tighten the screw.	 xx0300000152 A Sensor (calibration pendulum, 3HAC4540-1) B Calibration plate (3HAC020552-002)

Preparing the calibration plate and fitting sensor in vertical plane

	Action	Note/Illustration
1	Clean the calibration plate surface with isopropanol.	
2	Fit the bracket to the calibration plate with the screw. **Note** Tighten the screw fully, the bracket must not move during calibration!	 xx1400001640
3	Secure the calibration plate on a steady and flat foundation, for a example in a vise. **Note** It is important that the plate cannot move during the calibration of the sensor.	
4	Clean the bracket surface and the three contact surface points on the sensor holder with isopropanol.	

Continues on next page

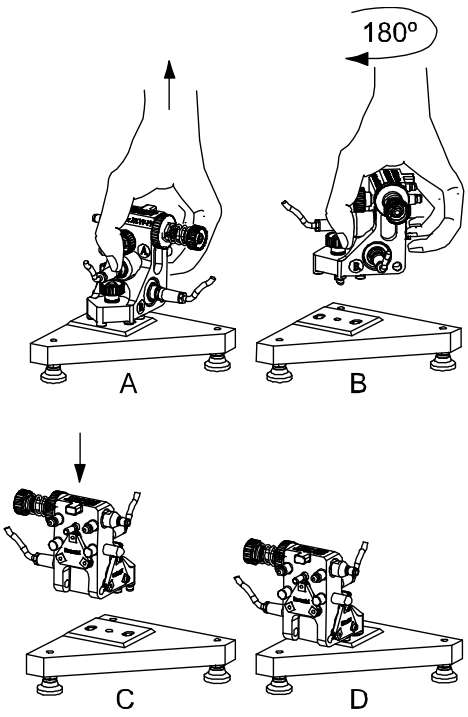
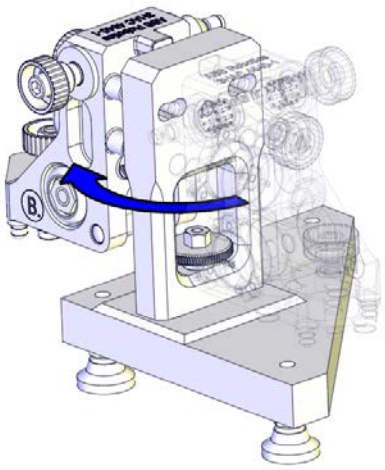
	Action	Note/Illustration
5	Fit the sensor in one of the two possible positions by pressing it down gently with a thumb while tightening its fastening screw. Do not force the pendulum house sideways while tightening the screw.	 xx1400001641

Checking the sensor

	Action	Note/Illustration
1	Adjust the instrument so that **A B** is visible below **Port**/**Sensor** (not flashing). **Note** (**A B**) should be visible, not (A-B).	If the instrument shows anything else, adjust it as described in steps *Calibrating the sensor with Levelmeter 2000 on page 56* or if using Bluemeter Sigma, see *Select measuring mode on page 50*.
2	Wait a couple of seconds for the sensors to stabilize, read the value shown by the instrument.	

Continues on next page

2.5 Checking sensors
Continued

	Action	Note/Illustration
3	Remove the sensor carefully, turn it 180° and fit it on the calibration plate / bracket in the corresponding hole pattern. Make this slowly and with care, in order not to change the values of the sensor. Wait a couple of seconds for the sensors to stabilize. **Note** Be careful not to change the position of the calibration plate.	Sensor fitted in horizontal plane:  xx0300000261 Sensor fitted in vertical plane:  xx1400001642
4	Read the values for A and B. Compare the reading to the reading done in step 2. If the reading for A or B differs more than 0.002 or if the polarity is the same, then the sensor must be recalibrated.	Recalibration is described in *Calibrating the sensor with Levelmeter 2000 on page 56* or *Calibrating the sensor with Bluemeter SIGMA on page 57*.

3 Calibrating

3.1 Functions in the calibration service routine

Types of calibration

The calibration service routine consists of two different parts:

- Calibration Pendulum II (robot home position, CalPend)
- Reference Calibration (RefCal)

Evolution overview

The table below shows when functions were introduced in the calibration service routine.

Function	Note
High performance calibration routine (called flip-flop) for IRB 7600	Eliminates calibration of axis 3/4 on the upper arm.
Automatic fine calibration	Switching windows and manual fine calibration no longer needed.
Reference calibration	Only valid for 6 axis robots.
Calibration of sensors only done in Levelmeter 2000 (not in RAPID program)	

3.2 Calibration Pendulum II

3.2.1 About Calibration Pendulum II

Using Calibration Pendulum II

Calibration Pendulum II is used in field, to restore the robot home position, for example after service activities. (Calibration Pendulum II is a function included in the service routine *Calibration Pendulum*.)

The principle of Calibration Pendulum II

In the calibration procedure the position of the sensor is first measured at the reference plane. Then the pendulum calibration sensor is placed on each axis and the robot is run to its calibration position, thus reducing the sensor difference to close to zero.

Peripheral equipment

The robot's upper arm must be free from any peripheral equipment during calibration. Fitted tools and similar *will* cause erroneous calibration positions.

Required tools

Required tools for performing Calibration Pendulum II are specified in *Calibration equipment on page 35*.

Prerequisites for best result

- Clean all contact surfaces on the robot with isopropanol.
- Clean all contact surfaces on the pendulum with isopropanol.
- Check that there is no grease or particles in the holes where the pendulum is mounted on the robot
- Do not to touch the sensors or the cables on the pendulum.
- Verify that the cables from the pendulum are hanging loose when mounted on the robot.
- Tighten the screw as hard as possible when mounting the pendulum on the flange (only applicable for large robots). It is important that the conical area on the screw is tight against the conical area on the flange.
- Check, and if needed calibrate, the sensors using the adjustment plate and the Levelmeter regularly, see *Checking sensors on page 60*, and *Calibrating sensors (calibration pendulum) on page 51*.

3.2.2 Preparing for calibration, CalPend

Preparing for calibration

Use this procedure to prepare for calibration with Calibration Pendulum II (CalPend).

	Action	Note
1	Verify that the mounting position of the robot allows it to be calibrated with Calibration Pendulum II.	See *Calibrating the robot at different mounting positions on page 12*
2	Make sure the robot is prepared for calibration. That is, all service or installation activities are completed and the robot is ready to run.	See the product manual for the robot.
3	Check that all required hardware is available for calibrating the robot.	Specified in section *Calibration equipment on page 35*.
4	Remove all peripheral equipment from the upper arm of the robot (for example tools and cables).	
5	Remove all the covers for the surfaces where to fit the calibration and reference sensors and clean them with isopropanol. **Note!** The same calibration pendulum is used as a calibration sensor and as a reference sensor depending on its function at the time. In the calibration procedure the pendulum will be called calibration sensor or reference sensor depending on its function at the time.	See mounting locations of reference and calibration sensors in *Calibration sensor mounting positions, CalPend on page 78*.
6	Clean the guide pin holes with isopropanol.	
7	Connect the calibration equipment to the robot controller and start the Levelmeter 2000.	Specified in *Start up of Levelmeter 2000 on page 42*.
8	Calibrate the robot.	See *Calibrating all axes, CalPend on page 68*.
9	Verify the calibration.	See *Verifying the calibration on page 128*.

3.2.3 Calibrating all axes, CalPend

Introduction

This section describes how to perform the actual fine calibration of each axis using the calibration pendulum tools, specified in section *Calibration equipment on page 35*.

Sensor mounting positions

The positions where to fit the calibration pendulum (sensor) differ between different models and different axes. The positions are shown in *Calibration sensor mounting positions, CalPend on page 78*.

Calibration sequence

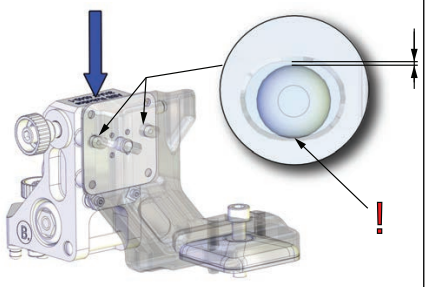
The axes must be calibrated in increasing sequence, that is, 1 - 2 - 3 - 4 - 5 - 6.

Calibration with calibration pendulum

The procedure below details how to fine calibrate the robot with calibration pendulum.

	Action	Note
1	Prepare the robot calibration, see *Preparing for calibration, CalPend on page 67*.	
2	Jog the robot axes to be calibrated to a position close to the correct calibration position.	See *Synchronization marks and synchronization position for axes on page 15*.
3	Update the revolution counters (a rough calibration).	See *Updating revolution counters on IRC5 robots on page 70*.
4	*Valid for axis 1 only!* Fit the *locating pin* to the robot base. **Note** Make sure the attachment surface is clean and free from any nicks or burrs.	See *Calibration sensor mounting positions, CalPend on page 78*.

Continues on next page

	Action	Note
5	Start the calibration service routine from the FlexPendant and follow the instructions, including fitting the calibration sensor when requested. **WARNING** After fitting the sensor on the robot, as specified on the FlexPendant, **clicking OK will start robot movement**! Make sure nobody is within the working range of the robot! **Note** When calibrating axis 1 for a suspended robot: press the pendulum against the locating pin and secure its position with for example a rubber band.	See *Calibration sensor mounting positions, CalPend on page 78*. Fitting the pendulum to the turning disk requires an adapter (included in the complete set). Article numbers are specified in section *Contents of calibration pendulum set 3HAC15716-1 on page 37*. How to handle the calibration program prior to the actual calibration of each axis is described in *Calibration Pendulum II procedure on FlexPendant on page 126*. **Note** Press down the pendulum gently while tightening its fastening screw, if fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.  xx1400001568
6	Tap **OK**. A number of information windows will flash by briefly on the FlexPendant, but no action is required until a specific action is displayed.	
7	Confirm the position of all calibrated axes when the calibration is completed.	See *Verifying the calibration on page 128*.
8	Disconnect all calibration equipment and refit all protective covers.	

3.2.4 Updating revolution counters

3.2.4.1 Updating revolution counters on IRC5 robots

Introduction

This section describes how to do a rough calibration of each manipulator axis by updating the revolution counter for each axis, using the FlexPendant.

Coupled axes

When updating the revolution counters for a coupled axis, also the axis it is coupled to needs to be at its synchronization position for the update to be correct; i.e. axis 4 needs to be in synchronization position when updating axis 5 and 6.

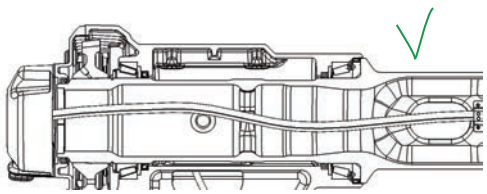
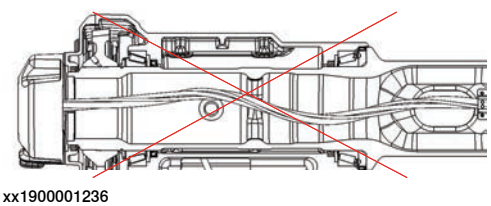
With reversed coupled joints, the relationship is the opposite, i.e. axis 4 needs to be in synchronization position to update axis 3.

Coupled axes	IRB 1410	IRB 1510	IRB 1520	IRB 1600	IRB 1600ID	IRB 1660ID	IRB 910 SC	IRB 2400	IRB 2600	IRB 2600ID	IRB 4400	IRB 4450S	IRB 4600
Axis 4, 5, 6				x				x	x		x	x	x
Axis 5, 6	x	x	x		x	x				x			
Axis 4, 3							x						

Mandatory check of cable harness prior to revolution counter update or calibration

Before updating the revolution counter or performing calibration, the status of the cable harness in the tubular shaft must be checked. There is a possibility that axis 4 has been rotated more than ±360° and therefor is positioned incorrectly (at wrong turn), causing the cable harness inside the tubular shaft to be twisted, which can damage the cabling.

Check the cable harness using a flashlight into the tubular shaft. Check that the cable harness is not twisted inside the tubular shaft.

Cabling is straight = axis 4 is positioned at correct turn	Cabling is twisted = axis 4 is positioned at wrong turn (rotated more than ±360°)
 xx1900001237	 xx1900001236

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Step 1 - Manually running the manipulator to the synchronization position

Use this procedure to manually run the manipulator to the synchronization position.

	Action	Note
1	Select axis-by-axis motion mode.	
2	Jog the manipulator to align the synchronization marks. IRB 140, 1400, 2400, 4400, 6600ID/6650ID, 6640ID: Axes 5 and 6 must be positioned together! **CAUTION** Check the position of axis 4 before continuing, see *Mandatory check of cable harness prior to revolution counter update or calibration on page 70*.	See *Synchronization marks and synchronization position for axes on page 15*.
3	When all axes are positioned, update the revolution counter.	*Step 2 - Updating the revolution counter with the FlexPendant on page 72*.

Correct calibration position of axis 4 and 6

When jogging the manipulator to synchronization position, it is extremely important to make sure that axes 4 and 6 of the following mentioned manipulators are positioned correctly. The axes can be calibrated at the wrong turn, resulting in an incorrect manipulator calibration.

Make sure the axes are positioned according to the correct calibration values, not only according to the synchronization marks. The correct values are found on a label, located either on the lower arm, underneath the flange plate on the base or on the frame.

At delivery the manipulator is in the correct position. Do NOT rotate axis 4 or 6 at power up before the revolution counters are updated.

If one of the following mentioned axes are rotated one or more turns from its calibration position before updating the revolution counter, the correct calibration position will be lost due to non-integer gear ratio. This affects the following manipulators:

Manipulator variant	Axis 4	Axis 6
IRB 52	Yes	Yes
IRB 460	No	No
IRB 660	-	No
IRB 760	-	Yes
IRB 1510	No	No
IRB 1520ID	No	No
IRB 1600	No	Yes
IRB 1600ID, IRB 1660ID	No	No
IRB 2400	No	No
IRB 2600	No	No

Continues on next page

3.2.4.1 Updating revolution counters on IRC5 robots

Continued

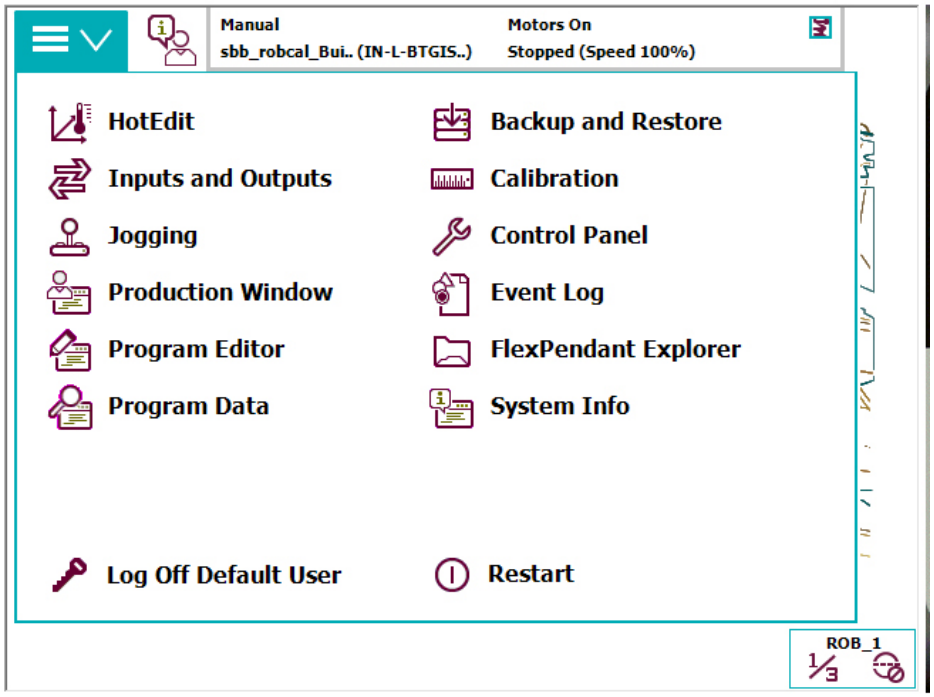
Manipulator variant	Axis 4	Axis 6
IRB 4400	No	No
IRB 4600	No	No
IRB 6650S	Yes	Yes
IRB 6620	Yes	No
IRB 6660	Yes	Yes
IRB 6700-235/2.65, -220/2.65 LID, -205/2.80, -200/2.80 LID, -175/3.05, -155/3.05 LID, -150/3.20, -145/3.20 LID, -200/2.60, -175/2.60 LID, -155/2.85, -140/2.85 LID	Yes	No
IRB 6700-300/2.70, -270/2.70 LID, -245/3.00, -220/3.00 LID	No	No
IRB 7600	Yes	Yes

If the synchronization marks seem to be wrong (even if the motor calibration data is correct), try to rotate the axis one turn, update the revolution counter and check the synchronization marks again (try both directions, if needed).

Step 2 - Updating the revolution counter with the FlexPendant

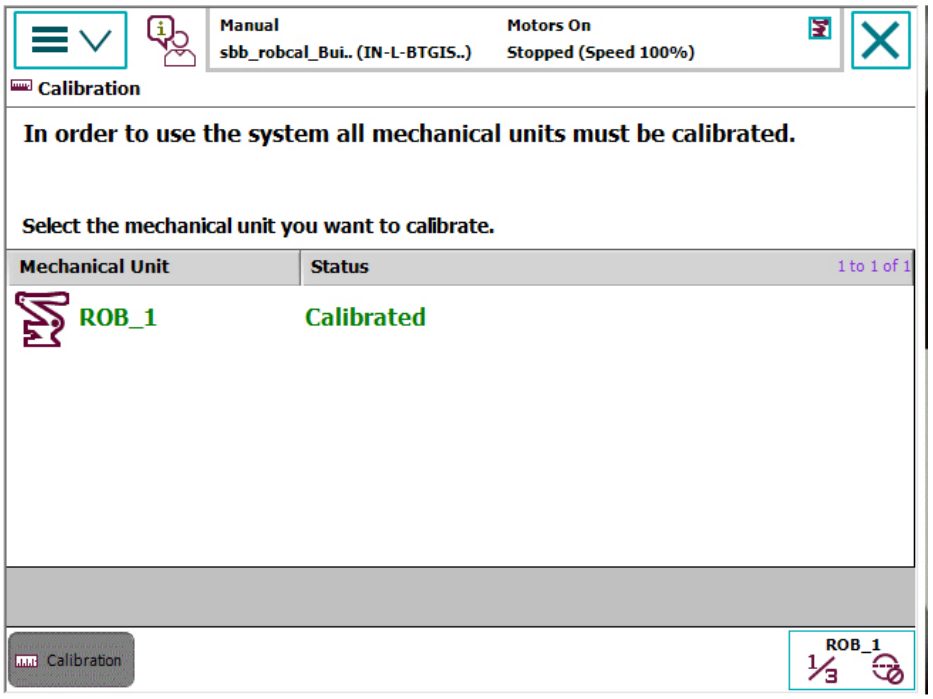
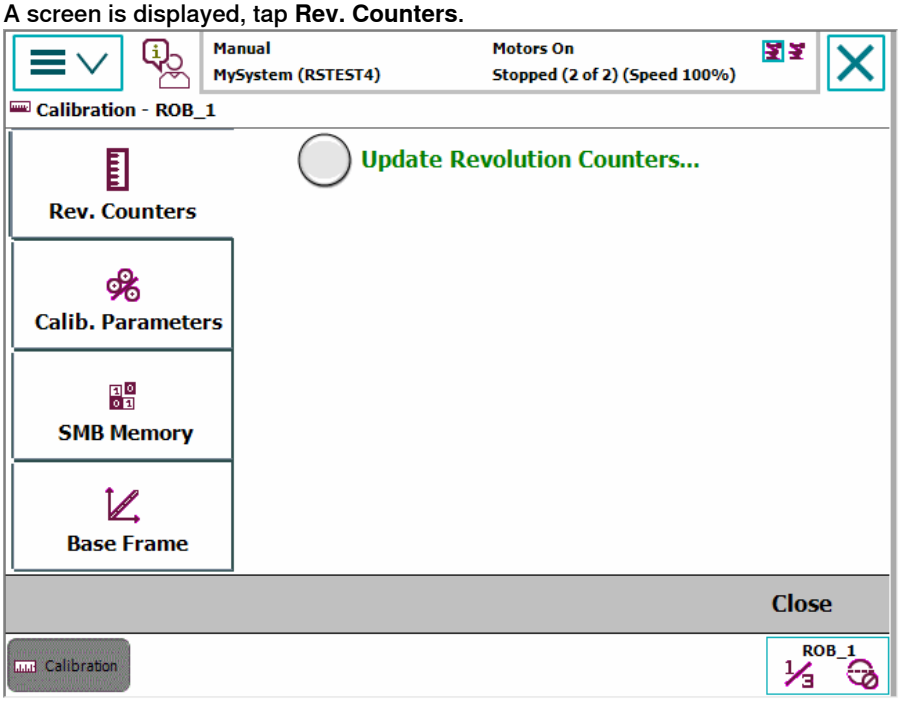
Use this procedure to update the revolution counter with the FlexPendant (IRC5).

	Action
1	On the **ABB** menu, tap **Calibration**.



xx1500000942

Continues on next page

	Action
2	All mechanical units connected to the system are shown with their calibration status. Tap the mechanical unit in question.  xx1500000943
3	A screen is displayed, tap **Rev. Counters**.  en0400000771

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3.2.4.1 Updating revolution counters on IRC5 robots

Continued

	Action
4	Tap **Update Revolution Counters...**. A dialog box is displayed, warning that updating the revolution counters may change programmed robot positions: • Tap **Yes** to update the revolution counters. • Tap **No** to cancel updating the revolution counters. Tapping **Yes** displays the axis selection window.
5	Select the axis to have its revolution counter updated by: • Ticking in the box to the left • Tapping **Select all** to update all axes. Then tap **Update**.
6	A dialog box is displayed, warning that the updating operation cannot be undone: • Tap **Update** to proceed with updating the revolution counters. • Tap **Cancel** to cancel updating the revolution counters. Tapping **Update** updates the selected revolution counters and removes the tick from the list of axes.
7	**CAUTION** If a revolution counter is incorrectly updated, it will cause incorrect manipulator positioning, which in turn may cause damage or injury! Check the synchronization position very carefully after each update. See *Checking the synchronization position on page 129*.

3.2.4.2 Updating revolution counters on OmniCore robots

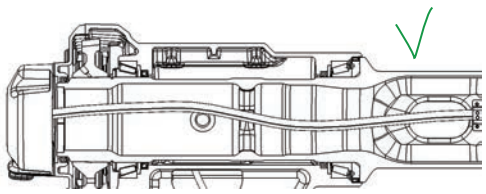
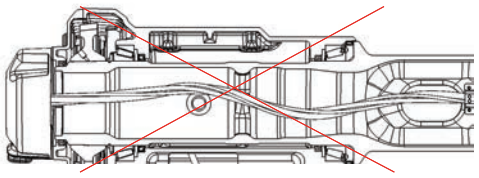
Introduction

This section describes how to do a rough calibration of each manipulator axis by updating the revolution counter for each axis, using the FlexPendant.

Mandatory check of cable harness prior to revolution counter update or calibration

Before updating the revolution counter or performing calibration, the status of the cable harness in the tubular shaft must be checked. There is a possibility that axis 4 has been rotated more than ±360° and therefor is positioned incorrectly (at wrong turn), causing the cable harness inside the tubular shaft to be twisted, which can damage the cabling.

Check the cable harness using a flashlight into the tubular shaft. Check that the cable harness is not twisted inside the tubular shaft.

Cabling is straight = axis 4 is positioned at correct turn	Cabling is twisted = axis 4 is positioned at wrong turn (rotated more than ±360°)
 xx1900001237	 xx1900001236

Step 1 - Manually running the manipulator to the synchronization position

Use this procedure to manually run the manipulator to the synchronization position.

	Action	Note
1	Select axis-by-axis motion mode.	
2	Jog the manipulator to align the synchronization marks.	See *Synchronization marks and synchronization position for axes on page 15*.
3	When all axes are positioned, update the revolution counter.	*Step 2 - Updating the revolution counter with the FlexPendant on page 76*.

Correct calibration position of axis 4 and 6

When jogging the manipulator to synchronization position, it is extremely important to make sure that axes 4 and 6 of the following mentioned manipulators are positioned correctly. The axes can be calibrated at the wrong turn, resulting in an incorrect manipulator calibration.

Make sure the axes are positioned according to the correct calibration values, not only according to the synchronization marks. The correct values are found on a label, located either on the lower arm, underneath the flange plate on the base or on the frame.

At delivery the manipulator is in the correct position. Do NOT rotate axis 4 or 6 at power up before the revolution counters are updated.

Continues on next page

3.2.4.2 Updating revolution counters on OmniCore robots
Continued

If one of the following mentioned axes are rotated one or more turns from its calibration position before updating the revolution counter, the correct calibration position will be lost due to non-integer gear ratio. This affects the following manipulators:

Manipulator variant	Axis 4	Axis 6
IRB 460	No	No
IRB 660	-	No
IRB 760	-	Yes
IRB 1510	No	No
IRB 1520ID	No	No
IRB 1600	No	Yes
IRB 1600ID, IRB 1660ID	No	No
IRB 2400	No	No
IRB 2600	No	No
IRB 4400	No	No
IRB 4600	No	No
IRB 6650S	Yes	Yes
IRB 6660	Yes	Yes
IRB 6700-235/2.65, -220/2.65 LID, -205/2.80, -200/2.80 LID, -175/3.05, -155/3.05 LID, -150/3.20, -145/3.20 LID, -200/2.60, -175/2.60 LID, -155/2.85, -140/2.85 LID	Yes	No
IRB 6700-300/2.70, -270/2.70 LID, -245/3.00, -220/3.00 LID	No	No
IRB 7600	Yes	Yes

If the synchronization marks seem to be wrong (even if the motor calibration data is correct), try to rotate the axis one turn, update the revolution counter and check the synchronization marks again (try both directions, if needed).

Step 2 - Updating the revolution counter with the FlexPendant

Use this procedure to update the revolution counter with the FlexPendant (OmniCore).

	Action
1	On the start screen, tap **Calibrate**. The calibration summary page for the mechanical unit is displayed.
2	In the **Calibration Methods** menu, select **Revolution Counters**.
3	In the **Selection** column select the axes for which revolution counters need to be updated.
4	Tap **Update**. A dialog box is displayed warning that the updating operation cannot be undone.
5	Tap **OK** to update the revolution counter.

Continues on next page

	Action
6	**CAUTION** If a revolution counter is incorrectly updated, it will cause incorrect manipulator positioning, which in turn may cause damage or injury! Check the synchronization position very carefully after each update. See *Checking the synchronization position on page 129*.

3.2.5 Calibration sensor mounting positions, CalPend

Introduction

This section specifies the mounting positions and directions of all calibration sensors on all robot systems using Calibration Pendulum II.

Removing equipment

Before fitting sensors to the robot:

- Make sure that there is no cabling that could affect the position of the sensor!
- Remove any position switches from axis 1. It is not possible to fit the sensor at the reference position otherwise!

Additional information on calibration, alternative calibration positions etc., can be found in the product manual for the robot.

Releasing the compressed spring

Release the compressed spring on the pendulum calibration tool after calibration of axis 1.

Also release the spring after calibration of axis 6 on IRB 260 and IRB 660.

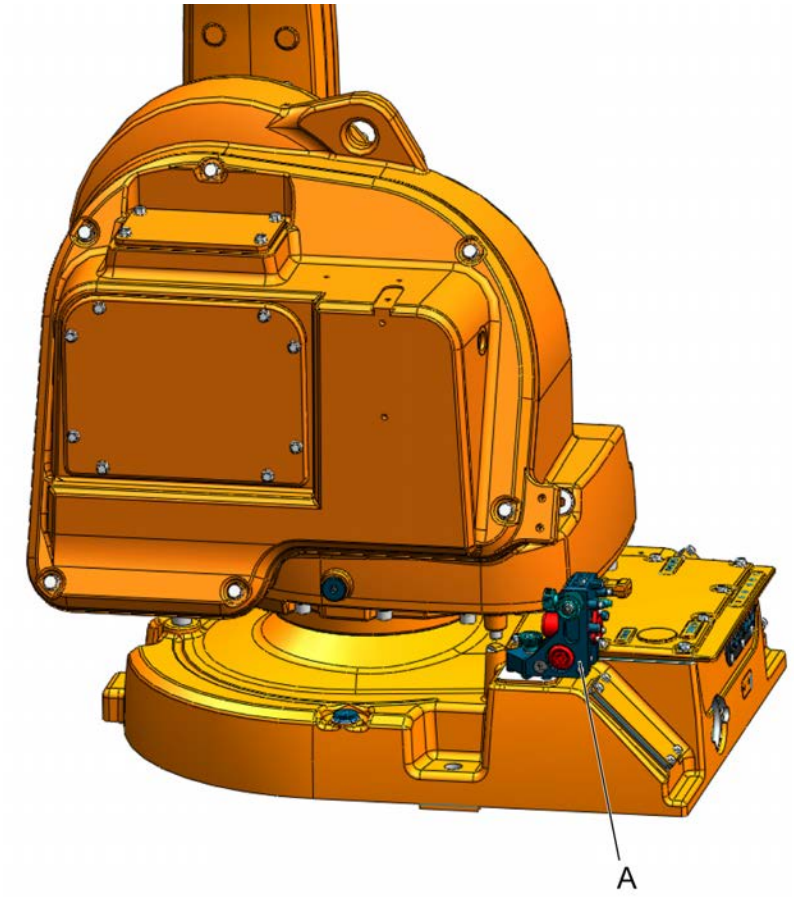
For instructions of how to compress/release the spring, see *Preparing for using the sensor on axes 1 and 6, CalPend on page 125*.

Continues on next page

IRB 52, IRB 140, IRB 1600, IRB 1520ID, IRB 2600, IRB 4600

The illustrations below show the mounting positions and directions for both the reference sensor and axis sensors on the robot. Notice that the pendulum is only fitted in one position at a time! Notice also that the direction of the sensor is always the same, on each axis!

Reference position IRB 52



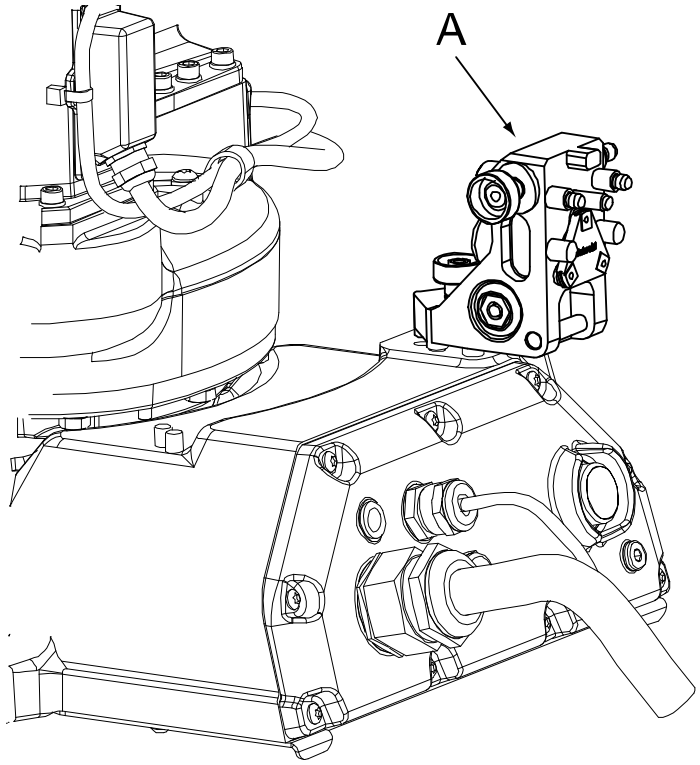
xx1200000107

A	Calibration pendulum as reference sensor in reference position at base

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

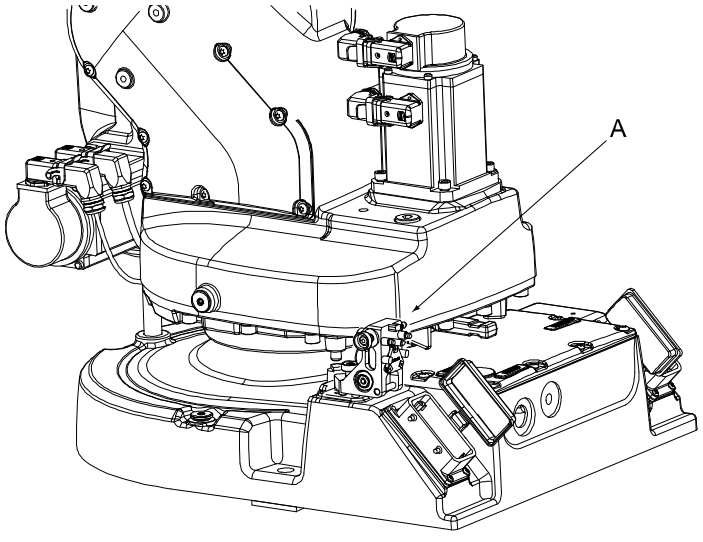
Reference position IRB 140



xx0200000244

A	Calibration pendulum as reference sensor in reference position at base

Reference position IRB 1600, IRB 2600, IRB 4600 (without calibration bracket at base)

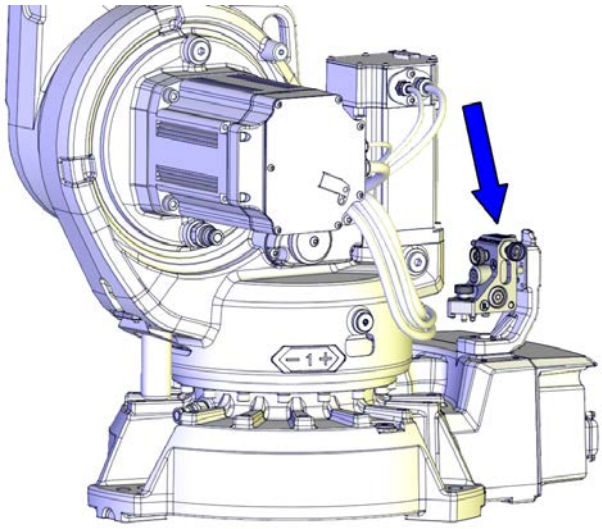


xx0500002490

A	Calibration pendulum as reference sensor in reference position at base

Continues on next page

Reference position IRB 4600 (with calibration bracket at base)



xx1400001051

A	Calibration pendulum as reference sensor in reference position at base, fitted to the calibration bracket (if available)

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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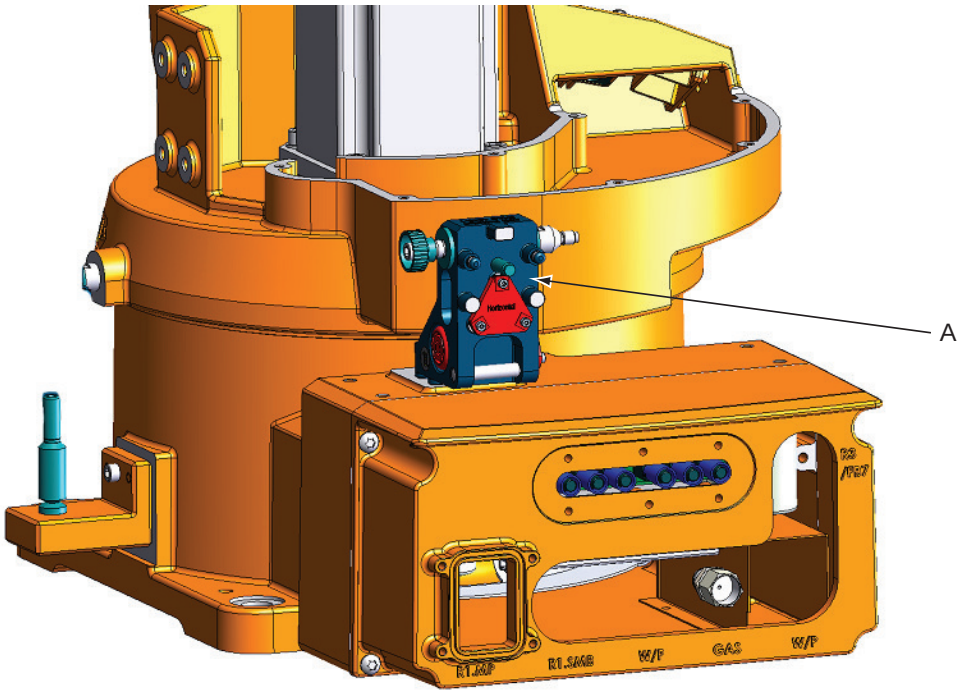
3.2.5 Calibration sensor mounting positions, CalPend
Continued

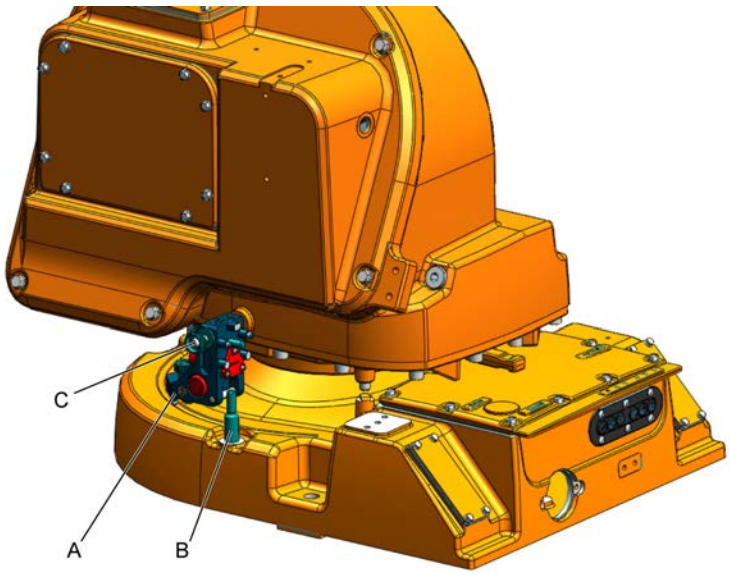
Reference position IRB 1520ID



xx1100000428

A	Calibration pendulum as reference sensor in reference position at base

Axis 1 IRB 52

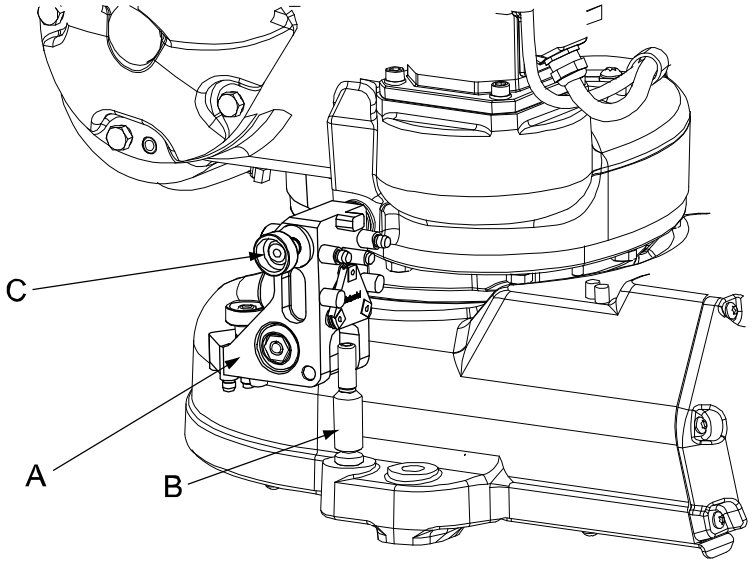


xx1200000109

A	Calibration pendulum as calibration sensor, axis 1
B	Locating pin, 68mm
C	Attachment screw

Continues on next page

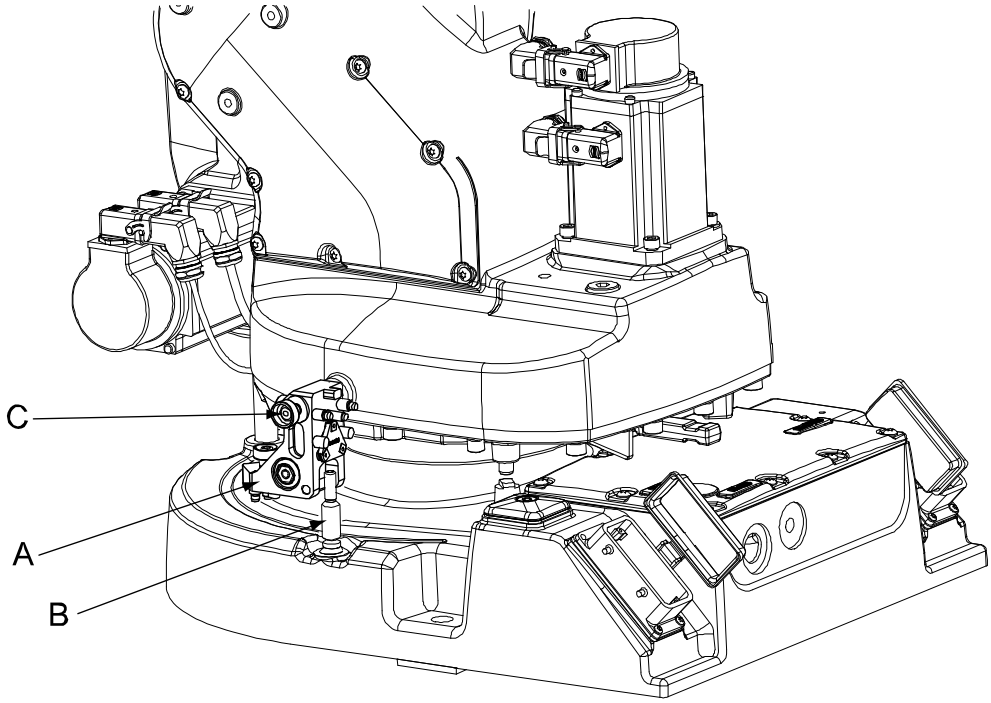
Axis 1 IRB 140



xx0200000245

A	Calibration pendulum as calibration sensor, axis1
B	Locating pin, 68mm
C	Calibration pendulum attachment screw

Axis 1 IRB 1600/1600ID, IRB 2600, IRB 4600



xx0500002491

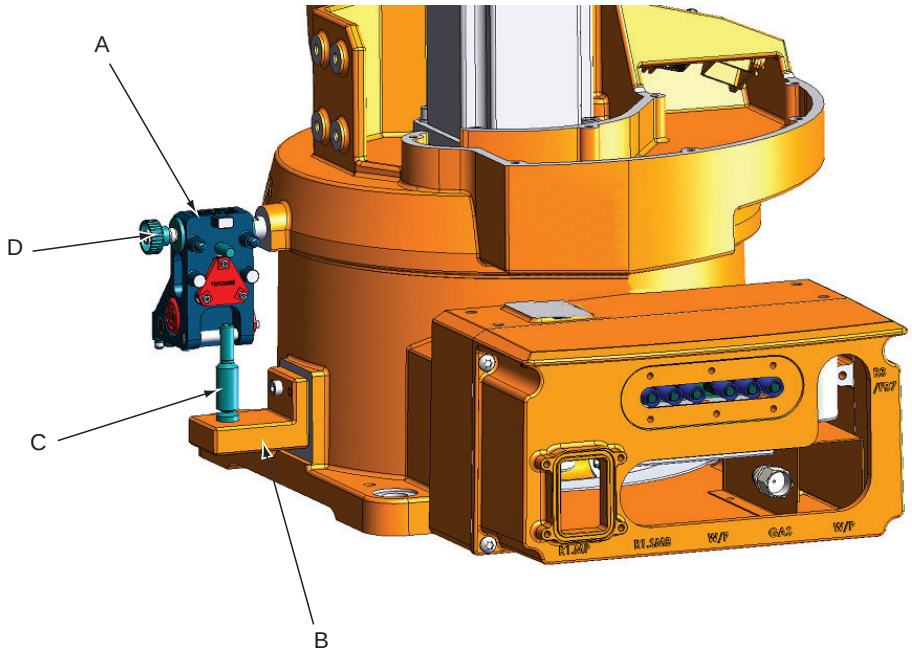
A	Calibration pendulum as calibration sensor, axis 1
B	Locating pin, 68mm
C	Attachment screw

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend

Continued

Axis 1 IRB 1520ID

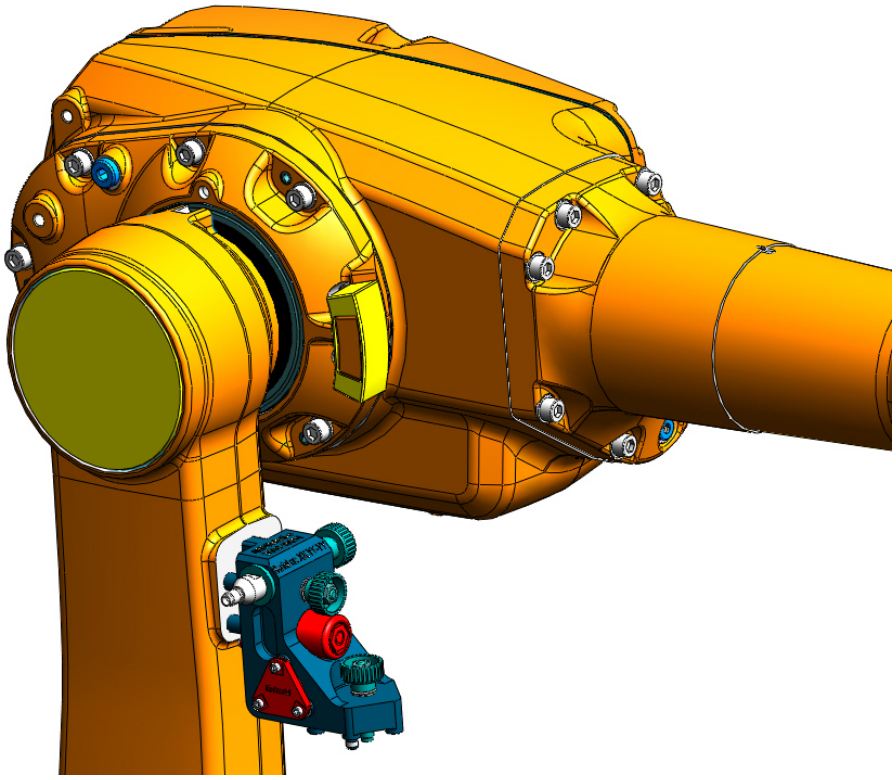


xx1100000430

A	Calibration pendulum as calibration sensor, axis 1
B	Calibration tool block
C	Locating pin
D	Calibration pendulum attachment screw

Continues on next page

Axis 2 IRB 52



xx1200000108

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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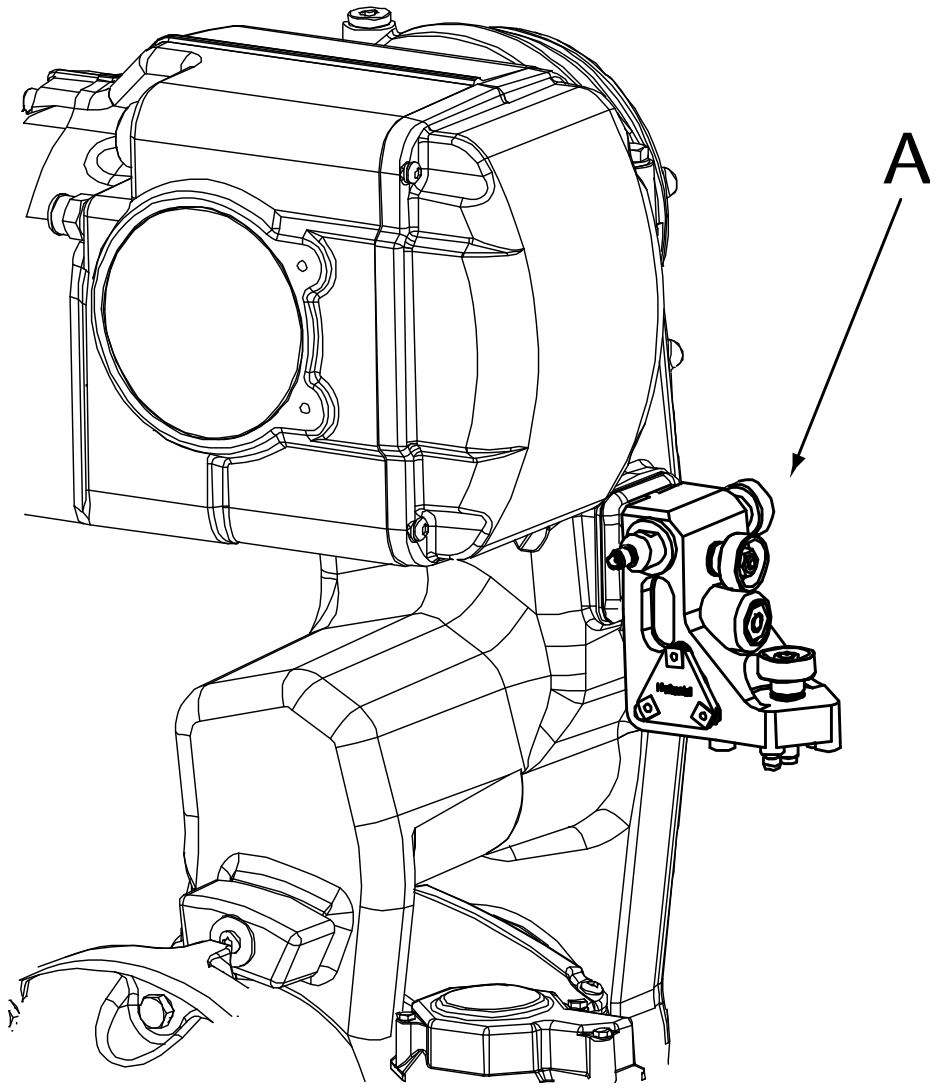
3.2.5 Calibration sensor mounting positions, CalPend

Continued

Axis 2 IRB 140



xx0200000246

A	Calibration pendulum as calibration sensor, axis 2

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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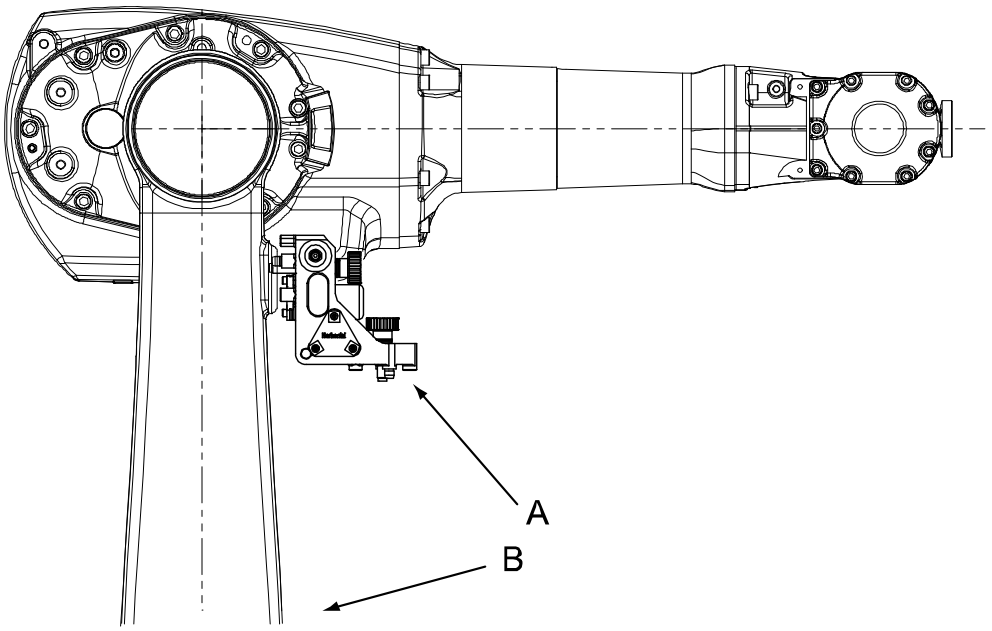
Axis 2 IRB 1600/1600 ID, IRB 1520ID, IRB 2600, IRB 4600



xx0500002492

A	Calibration pendulum as calibration sensor, axis 2, IRB 1600 and IRB 1520ID
B	Calibration pendulum as calibration sensor, axis 2, IRB 2600 and IRB 4600

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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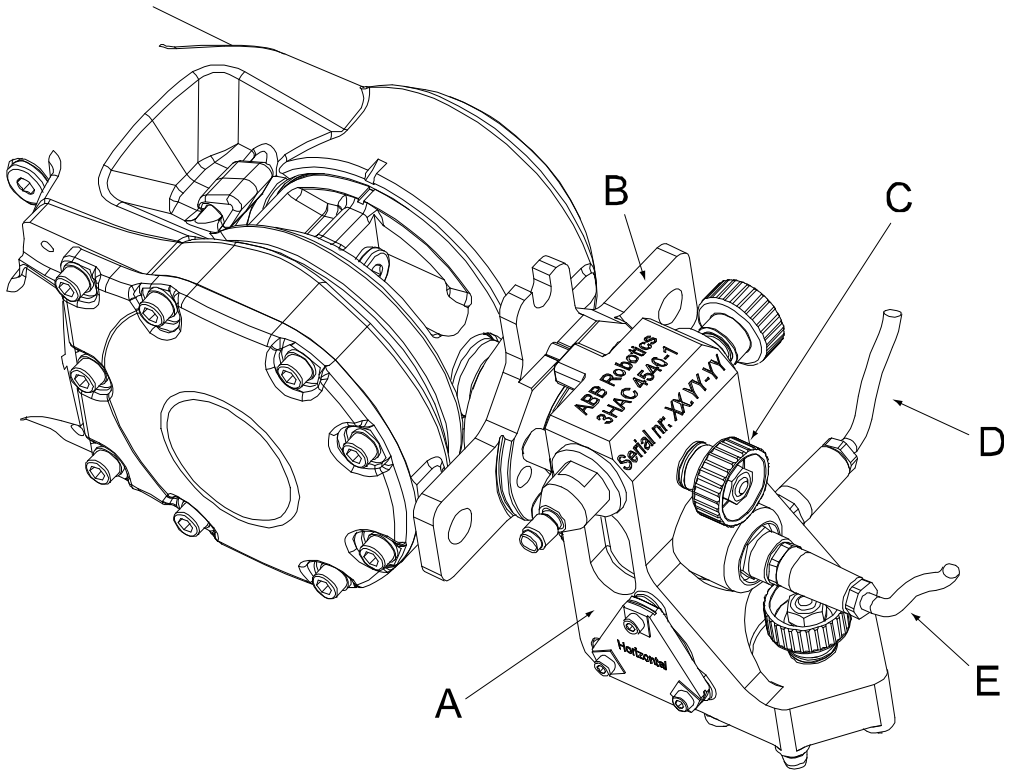
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 3, 4, 5 and 6 IRB 52, IRB 140, IRB 1600/1600ID, IRB 1520ID, IRB 2600, IRB 4600



xx0200000266

A	Calibration pendulum as calibration sensor, axis 3
B	Turning disk adapter
C	Sensor locking screw
D	Sensor cable, sensor B
E	Sensor cable, sensor A

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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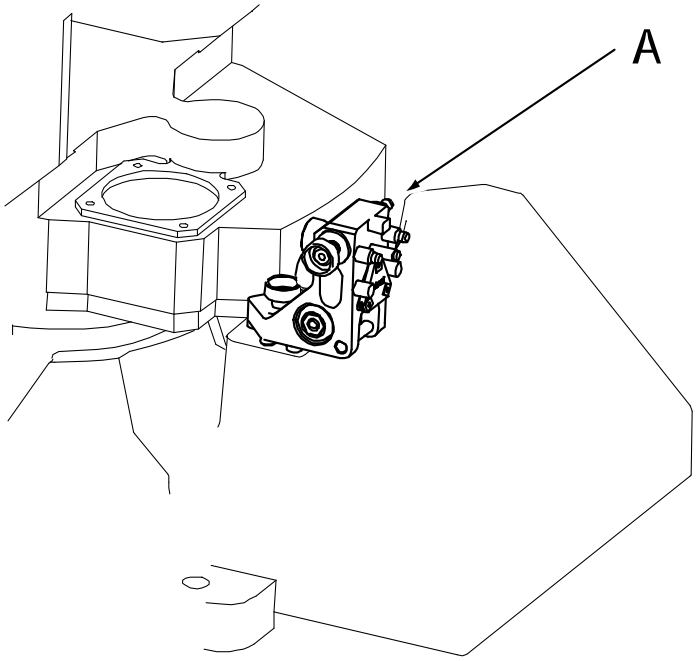
IRB 1410

The illustrations below show the mounting positions and directions for both the reference sensor and axis sensors on the robot. Notice that the pendulum is only fitted in one position at a time (the same pendulum is used as both a reference and a calibration sensor).

Reference position IRB 1410



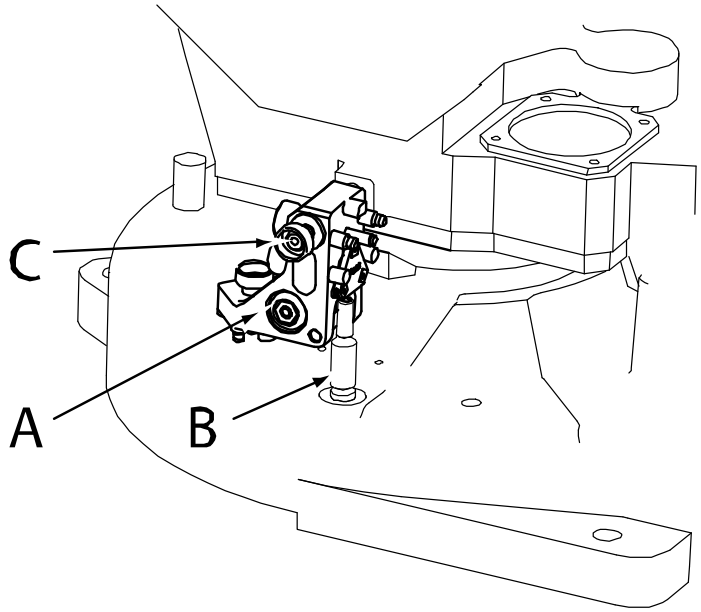
xx0200000248

A	Calibration pendulum in reference sensor position

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 1 IRB 1410

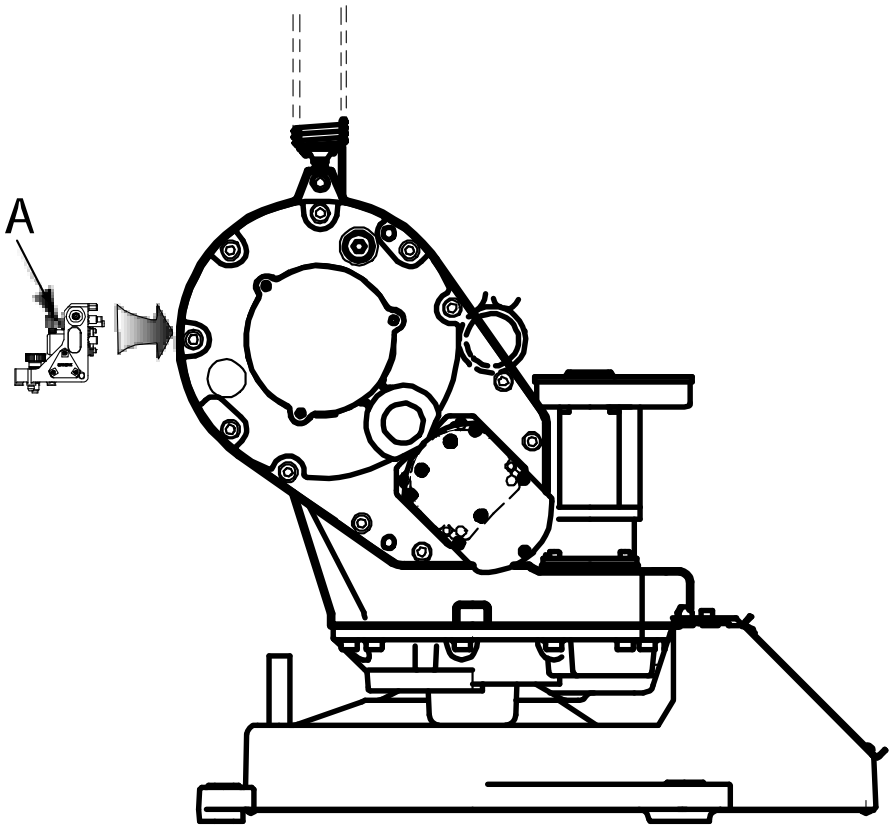


xx0200000249

A	Calibration sensor, axis 1
B	Locating pin, 68mm
C	Calibration pendulum attachment screw

Continues on next page

Axis 2 IRB 1410



xx0200000281

A	Calibration sensor, axis 2

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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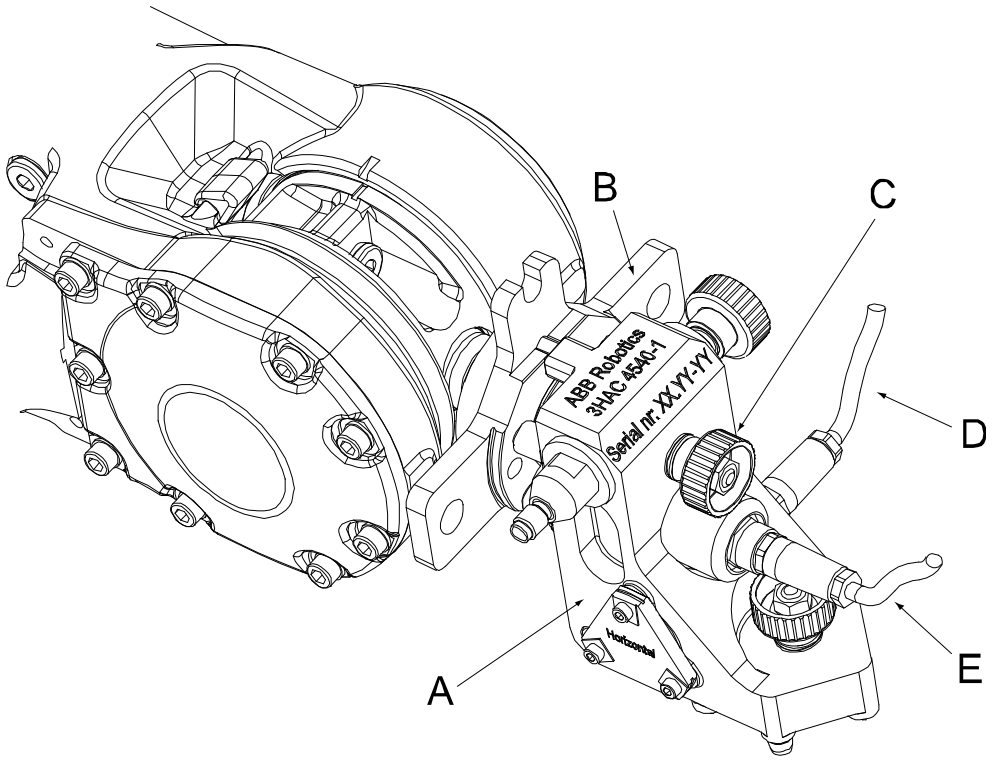
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 3, 4, 5 and 6 IRB 1410



xx0200000266

A	Calibration sensor
B	Turning disk adapter
C	Sensor locking screw
D	Sensor cable, sensor B
E	Sensor cable, sensor A

Note

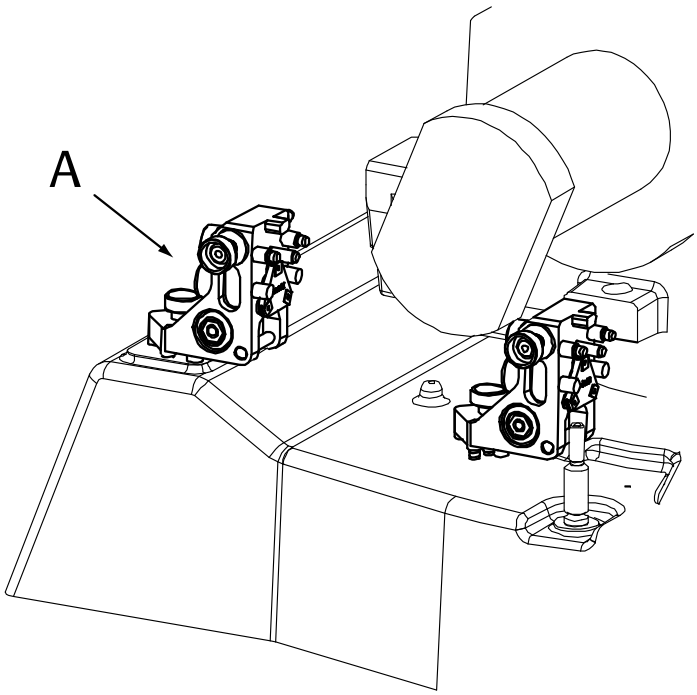
Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

Continues on next page

IRB 260, IRB 2400

The illustrations below show the mounting positions and directions for both the reference sensor and axis sensors on the robot. Notice that the pendulum is only fitted in one position at a time (the pendulum is used as both a reference and a calibration sensor)!

Reference position IRB 260 and IRB 2400



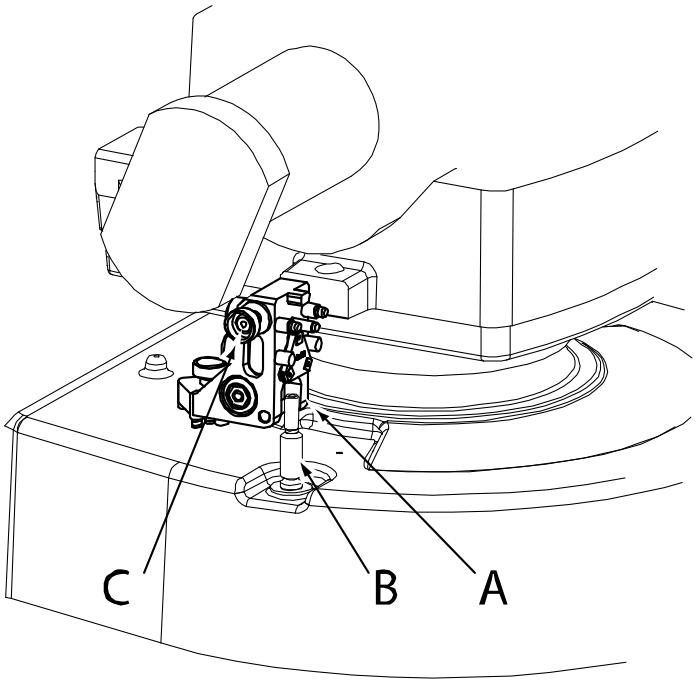
xx0200000250

A	Calibration pendulum in reference sensor position

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 1 IRB 260 and IRB 2400

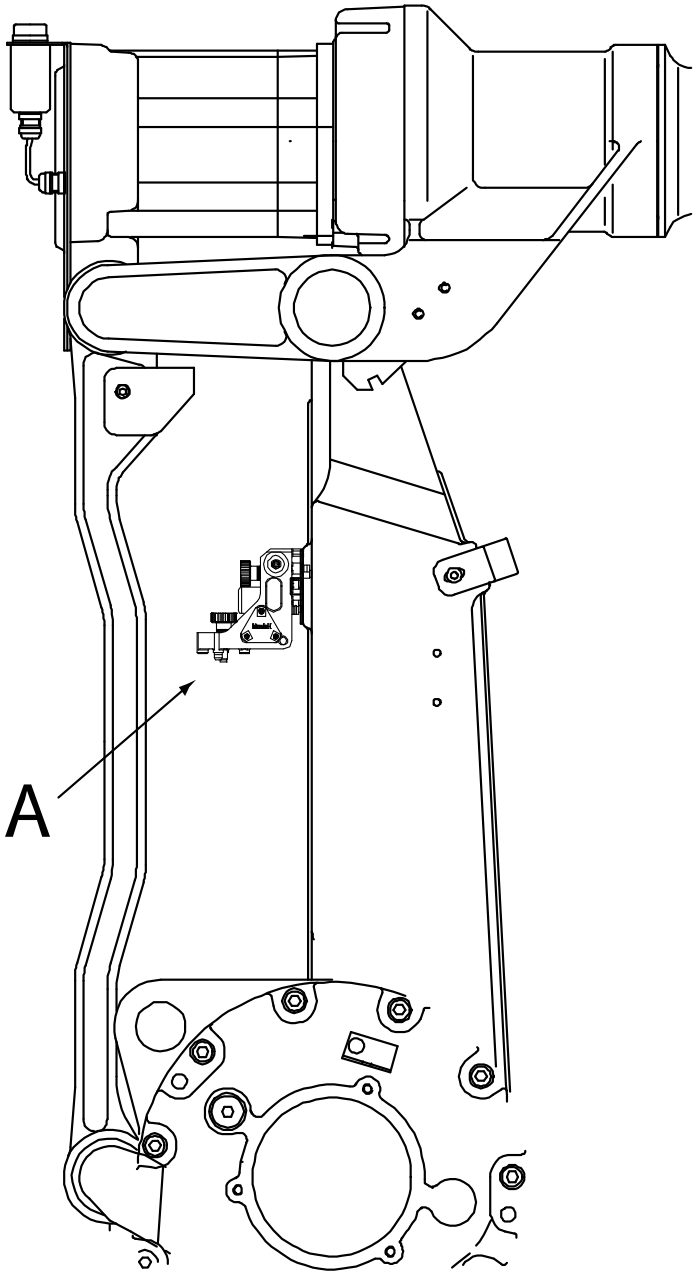


xx0200000251

A	Calibration sensor, axis 1
B	Locating pin, 68mm
C	Calibration pendulum attachment screw

Continues on next page

Axis 2 IRB 260 and IRB 2400



xx0200000280

A	Calibration sensor, axis 2

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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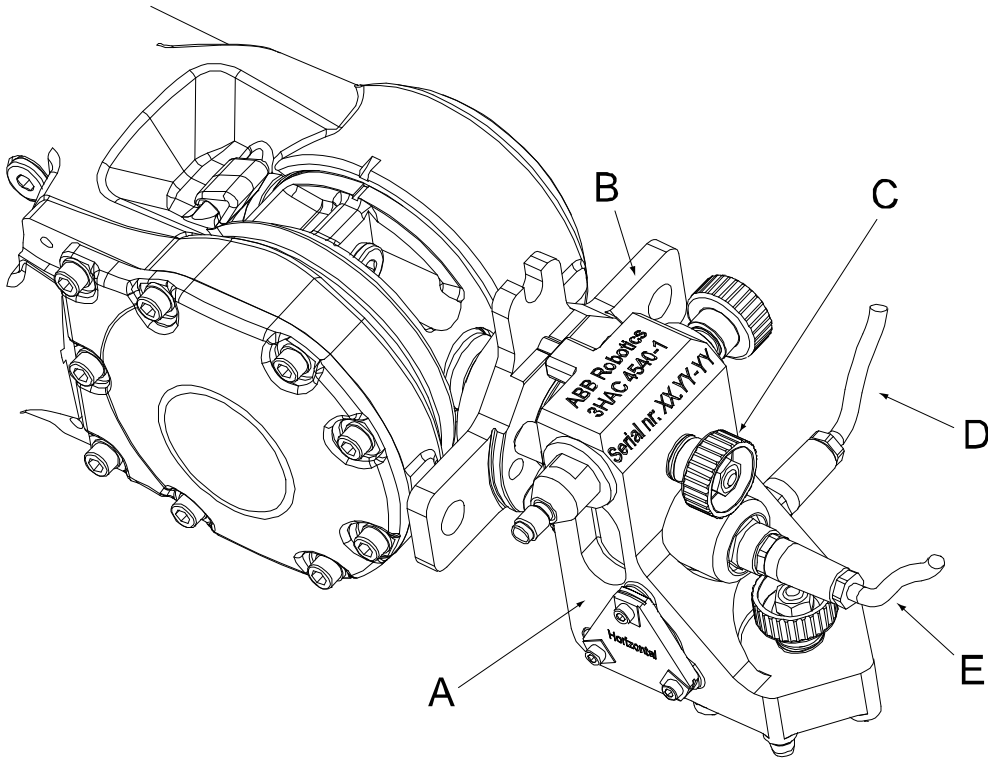
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 3, 4, 5 and 6 IRB 2400



xx0200000266

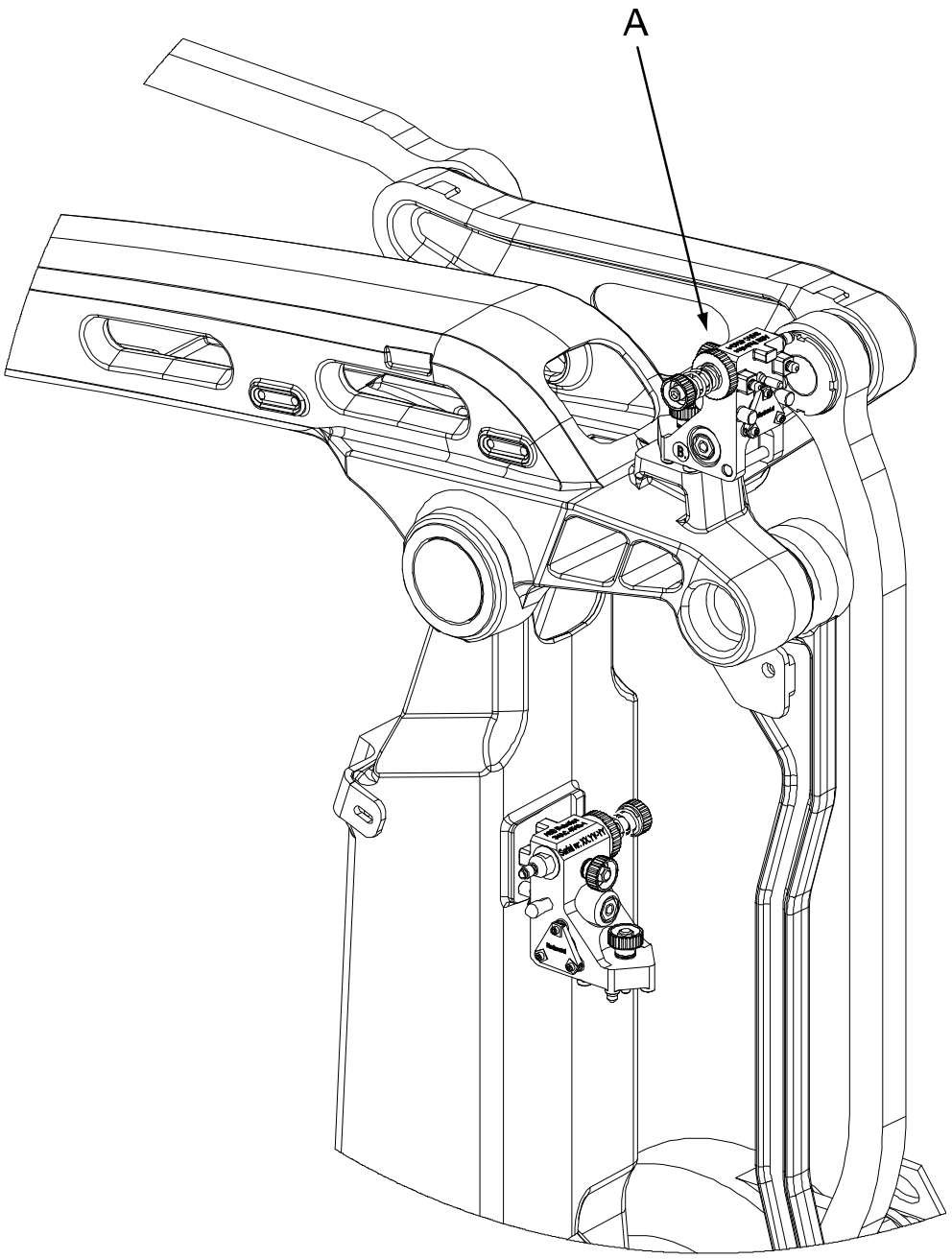
A	Calibration sensor
B	Turning disk adapter
C	Sensor locking screw
D	Sensor cable, sensor B
E	Sensor cable, sensor A

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

Continues on next page

Axis 3, IRB 260



xx0500002480

A	Calibration sensor, axis 3

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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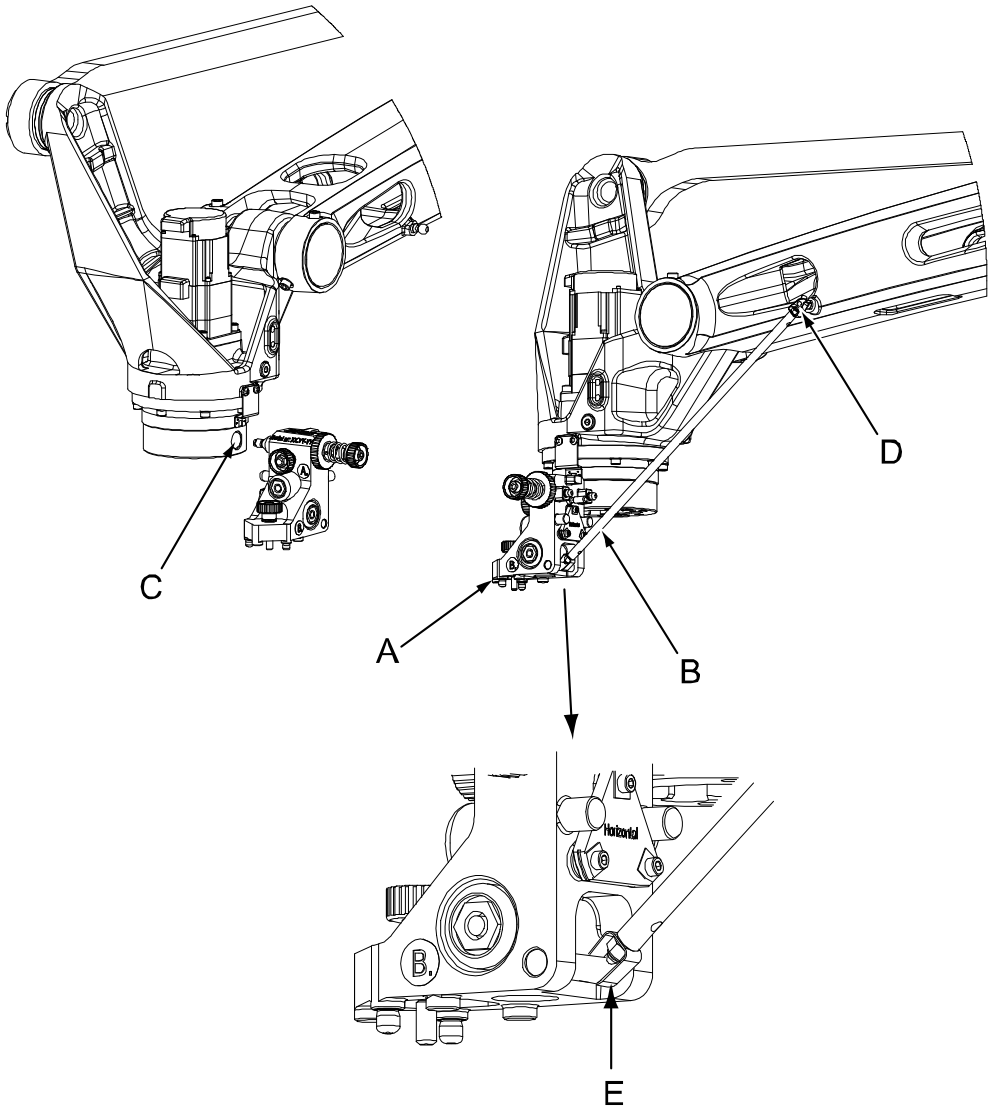
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 6, IRB 260



xx0500002481

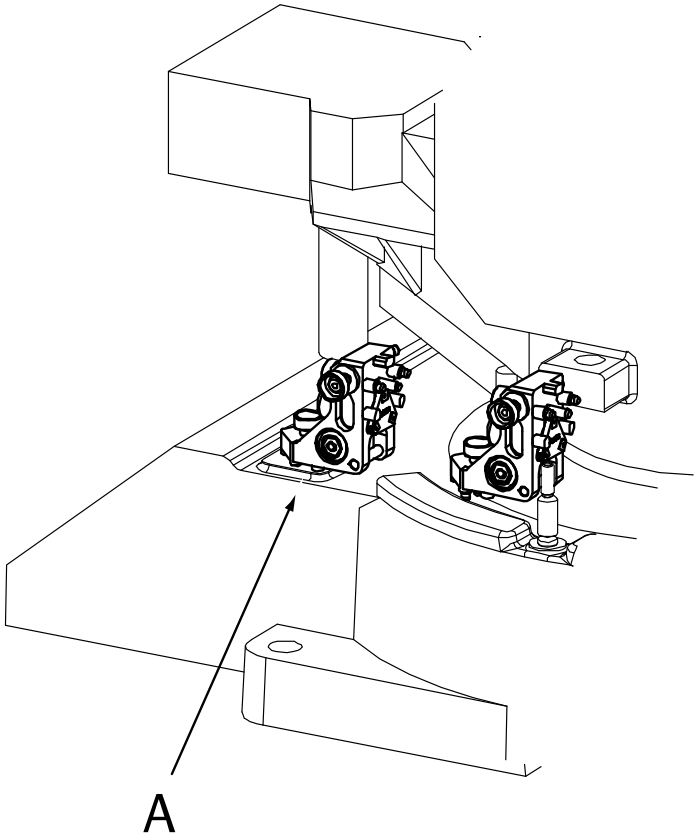
A	Calibration sensor, axis 6
B	Calibration bar, attached between the sensor and a ball plug on the robot
C	Tapered attachment hole on the turning disk
D	Ball plug where to attach the calibration bar
E	**Note!** Make sure to fit the calibration bar at the extreme right of the sensor pin.

Continues on next page

IRB 4400, IRB 4450S

The illustrations below show the mounting positions and directions for both the reference sensor and axis sensors on the robot. Notice that the pendulum is only fitted in one position at a time (the pendulum is used as both a reference and a calibration sensor)!

Reference position IRB 4400 and IRB 4450S



xx0200000252

A	Calibration pendulum in reference sensor position

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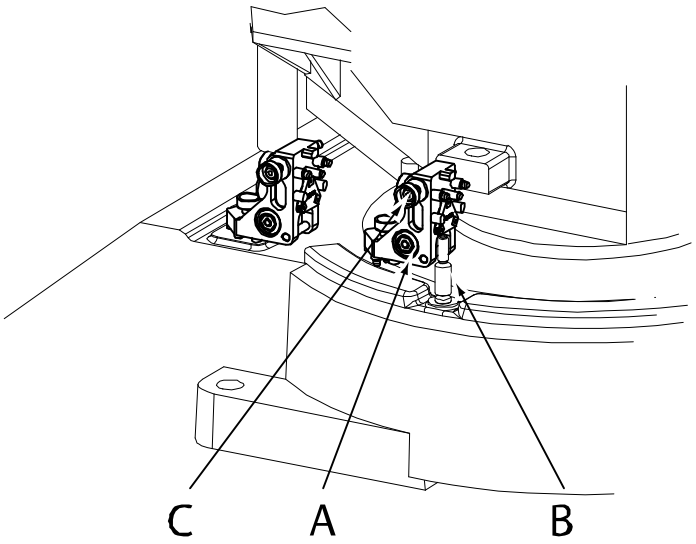
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 1 IRB 4400 and IRB 4450S



xx0200000253

A	Calibration sensor, axis 1
B	Locating pin, 68mm
C	Calibration pendulum attachment screw

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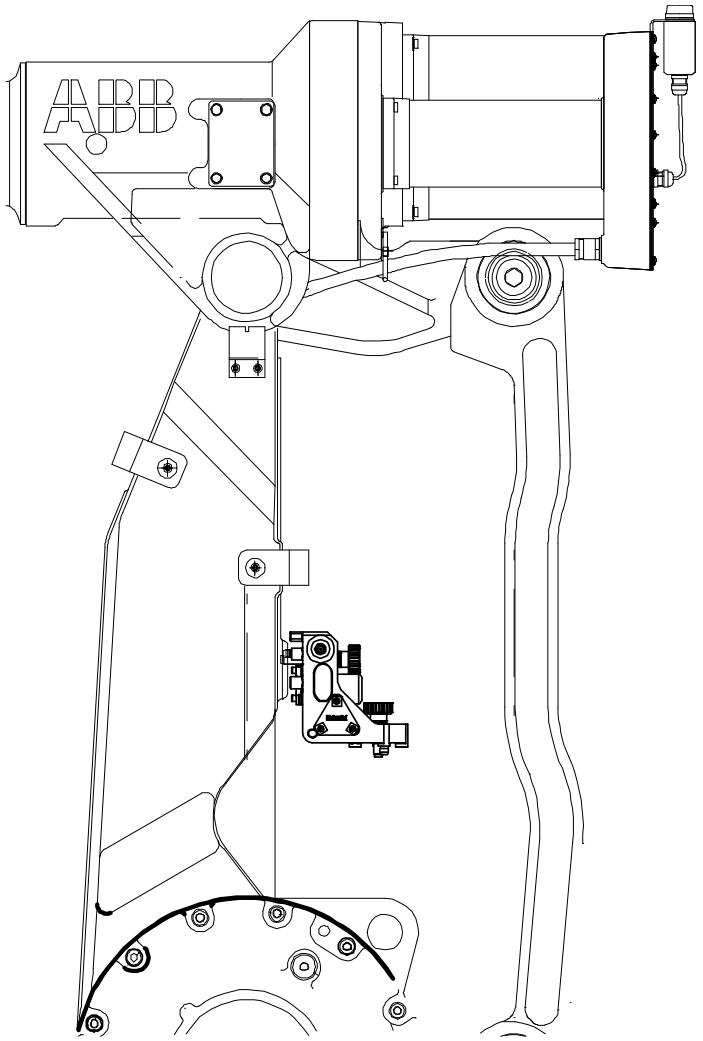
Axis 2 IRB 4400



xx0200000279

A	Calibration sensor, axis 2

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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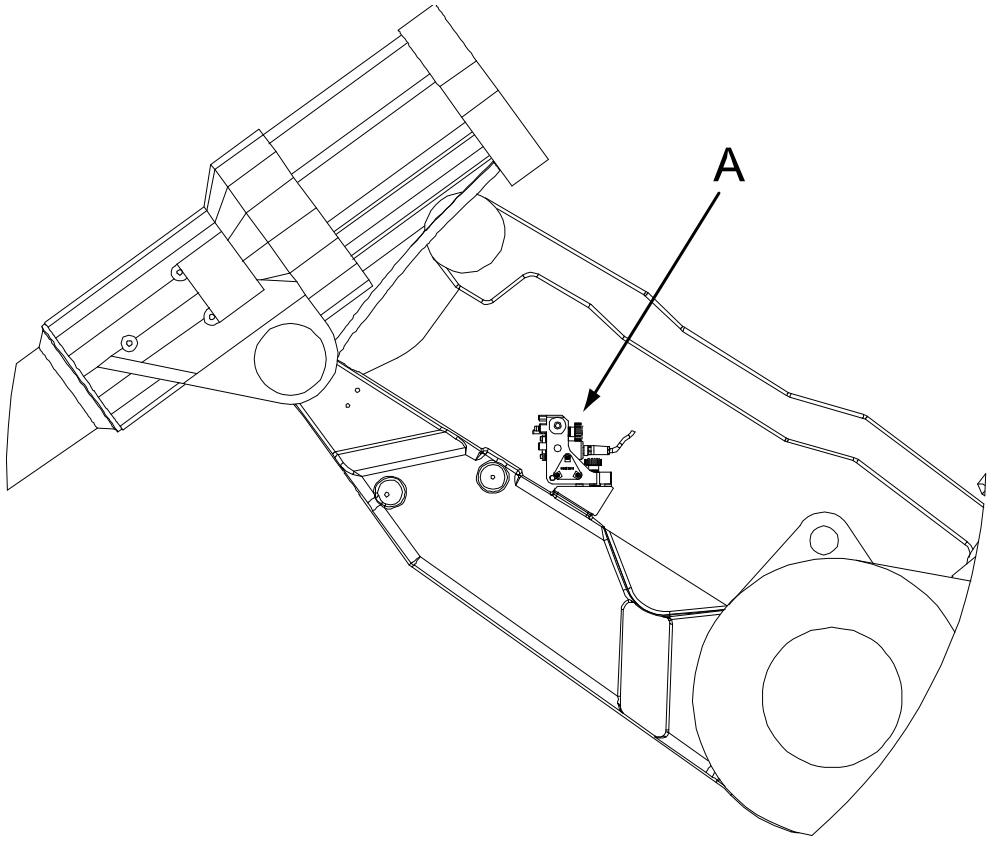
3.2.5 Calibration sensor mounting positions, CalPend

Continued

Axis 2, IRB 4450S



xx0500002488

A	Calibration sensor, axis 2

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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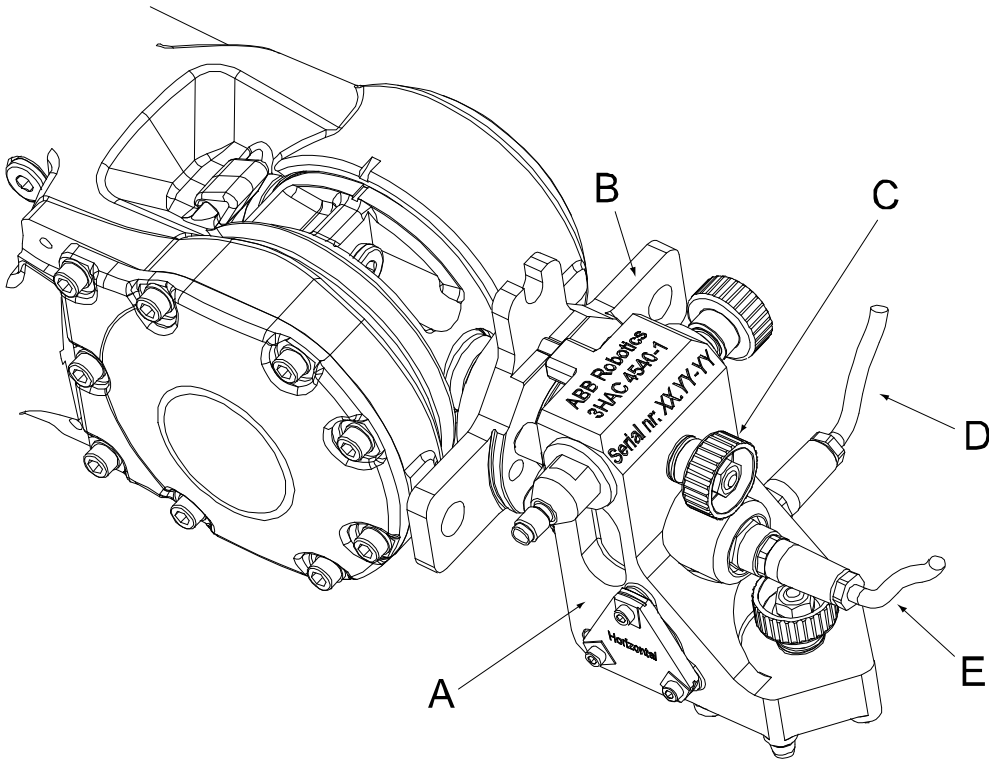
Axis 3, 4, 5 and 6 IRB 4400 and IRB 4450S



xx0200000266

A	Calibration sensor
B	Turning disk adapter
C	Locking screw
D	Sensor cable, sensor B
E	Sensor cable, sensor A

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

IRB 6600/6650, IRB 6650S, IRB 6620, IRB 6620LX, IRB 6640, IRB 6660, IRB 7600

The illustrations below show the mounting positions and directions for both the reference sensor and axis sensors on the robot. Note that IRB 6620LX cannot be calibrated on axis 1 (the linear axis).

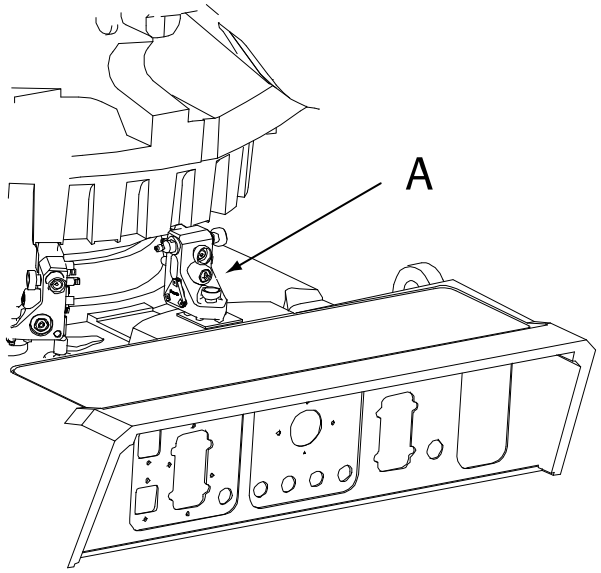
Reference position IRB 6620LX

The reference position for IRB6620LX is on the axis-2 frame.

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

Reference position IRB 6600/6650, IRB6650S, IRB6620, IRB6640, IRB6660, IRB7600 (without calibration bracket at base)



xx0200000183

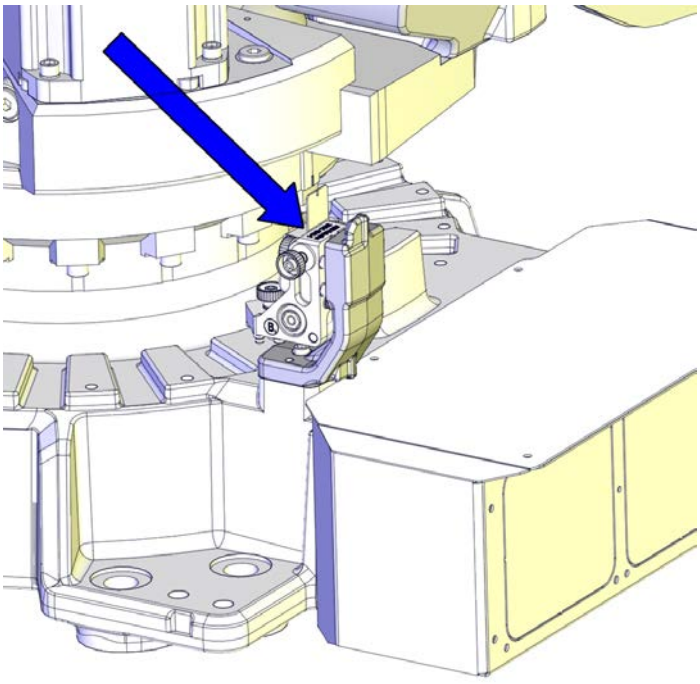
A	Calibration pendulum in reference sensor position. NOTE! The pendulum is only fitted in one position at a time!

Note

Always use the same method for Pendulum Calibration on each robot. That is, if the robot is calibrated with a bracket on the base and a turning disk adapter last time then continue using the bracket and adapter, otherwise the calibration values will be wrong.

Continues on next page

Reference position IRB6620, IRB6640 (with calibration bracket at base)

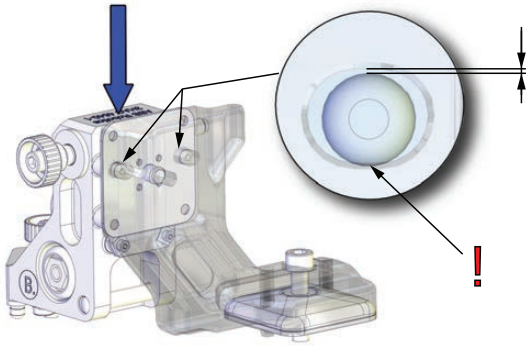


xx1400001052

-	Calibration pendulum as reference sensor in reference position at base, fitted to the calibration bracket (if available) NOTE! The pendulum is only fitted in one position at a time!

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.



xx1400001568

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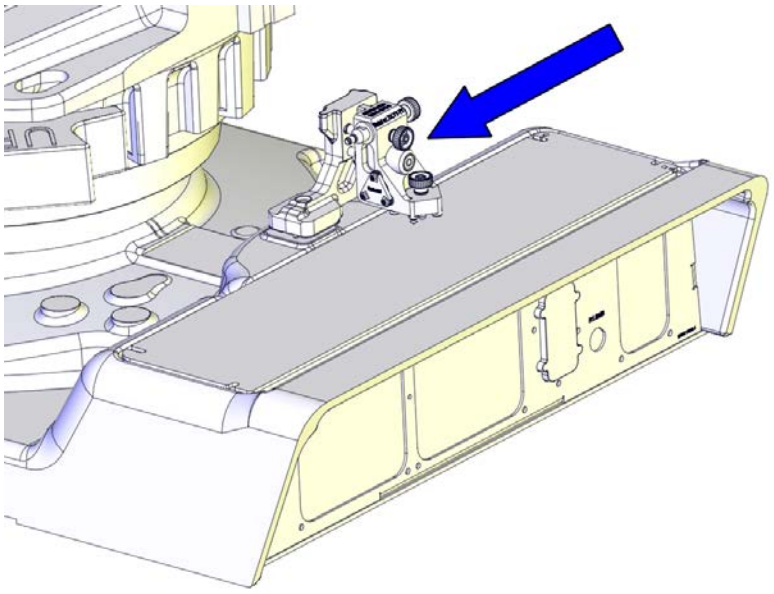
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Reference position IRB6650S, IRB7600 (with calibration bracket at base)

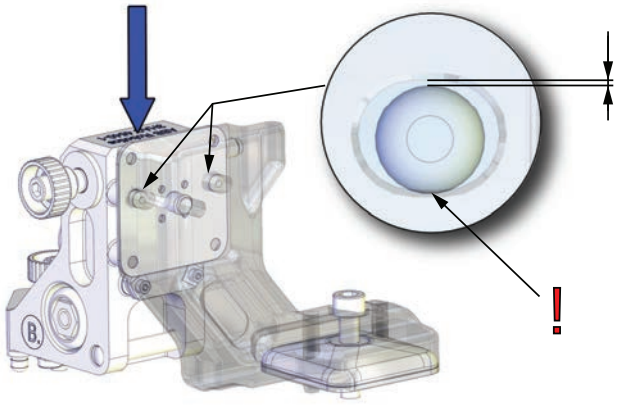


xx1400001638

-	Calibration pendulum as reference sensor in reference position at base, fitted to the calibration bracket (if available). NOTE! The pendulum is only fitted in one position at a time!

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.



xx1400001568

Axis 1 IRB6620LX

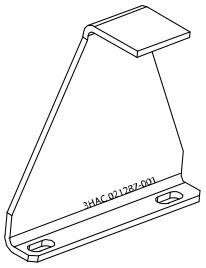
Calibration for axis 1 is described in *Product manual - IRB 6620LX*.

Continues on next page

Axis 1 IRB 6600/6650, IRB 6650S, IRB 6620, IRB 6640, IRB 6660, IRB 7600

Note

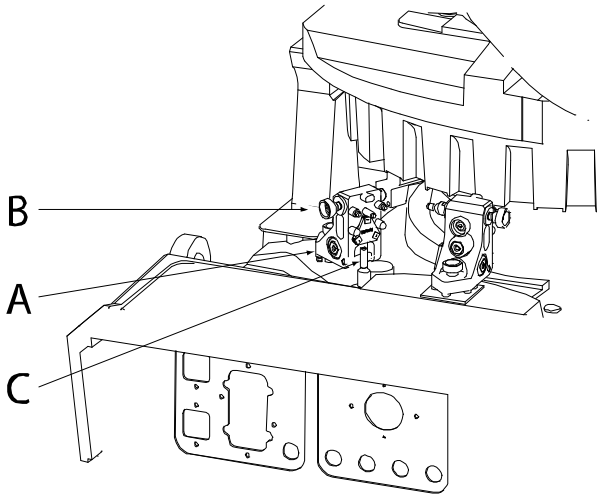
If an old calibration plate for axis 1 is fitted to the base, it is vital to change it to the new calibration plate 3HAC021287-001, or at least to remove it during calibration.



xx0400001107

Note

If position breaker(s) are fitted for axis 1, they must be removed before use of the calibration pendulum 3HAC4540-1 on axis 1.



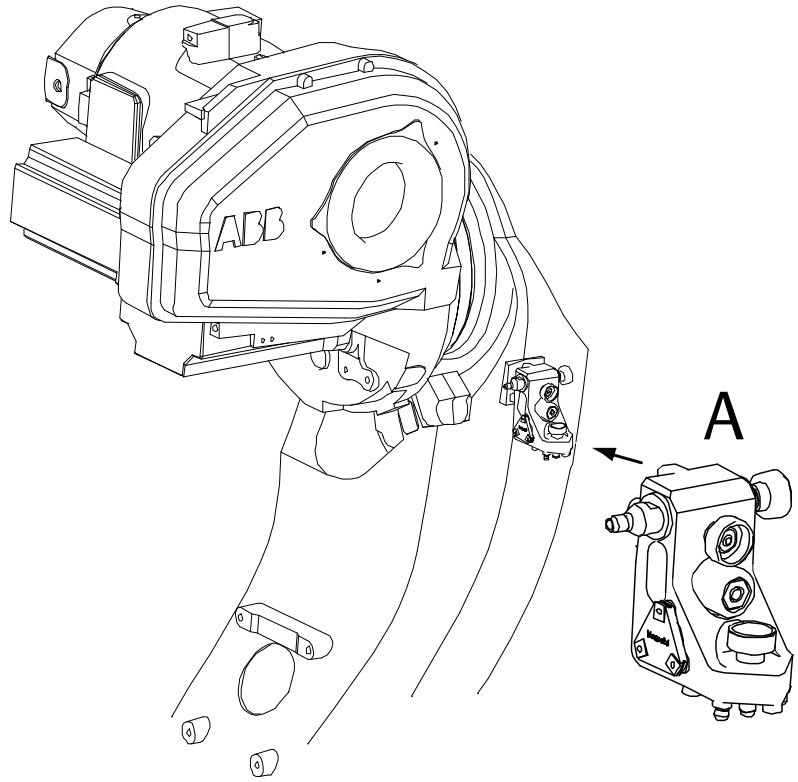
xx0200000177

A	Calibration pendulum. NOTE! The pendulum is only fitted in one position at a time!
B	Calibration pendulum attachment screw
C	Locating pin IRB 6600/6650, IRB 6650S, IRB 7600: 58 mm long IRB 6620, IRB 6640, IRB 6660: 68 mm long

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 2 IRB 6600/6650, IRB 6650S, IRB 6620, IRB 6620LX, IRB 6640, IRB 6660, IRB 7600



xx0200000178

A	Calibration pendulum, axis 2

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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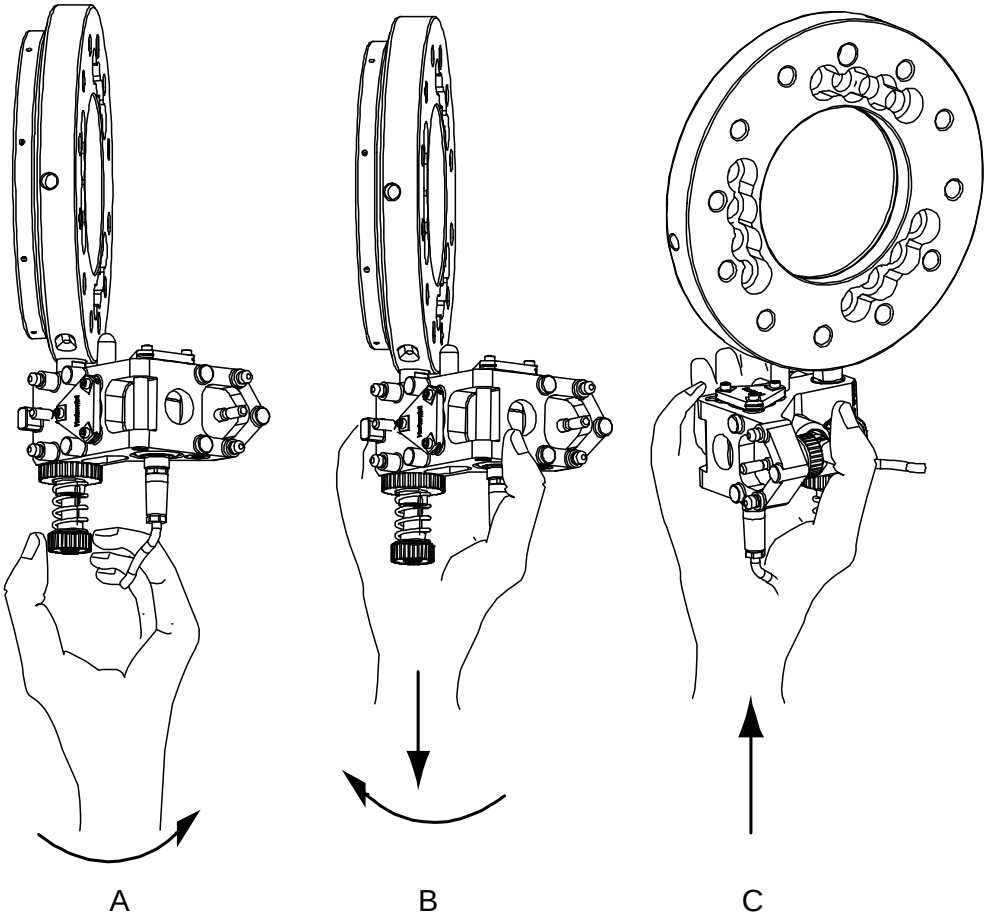
Axis 3-6 IRB 6600/6650, IRB 6650S, IRB 6620, IRB 6620LX, IRB 6640, IRB 6660, IRB 7600 without turning disk adapter



xx0300000274

A	Fit the calibration pendulum, screw home the attachment screw (by hand)
B	Compress the spring and rotate the calibration pendulum counter clockwise
C	At the end of the counter clockwise movement drop the calibration pendulum into its calibration position

Note

To ensure the result of the procedure to be accurate it is vital that it is performed identically each time.

Note

Always use the same method for Pendulum Calibration on each robot. That is, if the robot is calibrated with a bracket on the base and a turning disk adapter last time then continue using the bracket and adapter, otherwise the calibration values will be wrong.

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 3-6 IRB 6650S, IRB 6620, IRB 6620LX, IRB 6640, IRB 6660, IRB 7600 with turning disk adapter

Note

The robot has been pre-calibrated at the factory using the turning disk adapter if the robot is equipped with a calibration bracket at the base for fitting the reference sensor in a vertical plane.

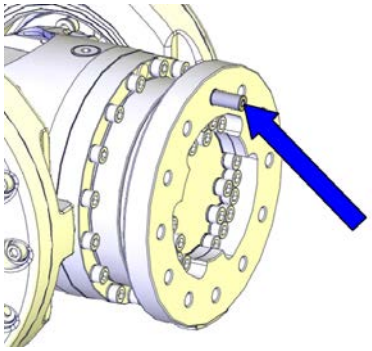
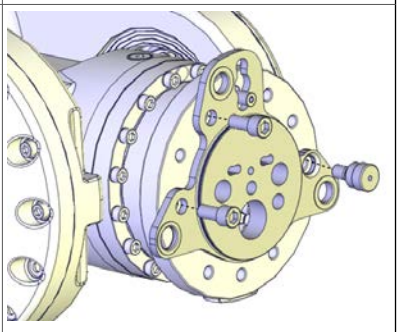
If the robot has been pre-calibrated with the turning disk adapter, the adapter should be used according to following recommendations:

- The adapter is required to be used for calibration of axis 3, 4 and 6. If the adapter is not used during calibration, there will be discrepancy in the calibration values for the axis.
- The adapter can be used also for calibration of axis 5, but it is not required. The calibration values are not affected.

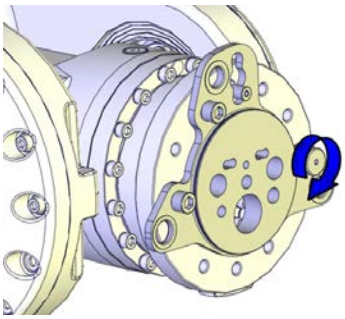
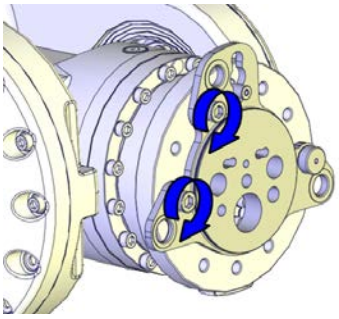
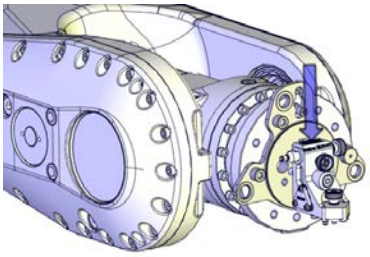
Note

To ensure the result of the procedure to be accurate it is vital that it is performed identically each time.

Fitting the sensor to the turning disk using a turning disk adapter

	Action	Note/Illustration
1	Clean the mounting surfaces of the turning disk and the turning disk adapter with isopropanol.	
2	Fit the guide pin to the turning disk. **Tip** If the guide pin does not fit the hole in the turning disk, rub down the part that enters the hole to make it fit. Avoid play! Use abrasive paper / emery cloth.	 xx1400001643
3	Fit the turning disk adapter with the conical screw and the two screws. Do not fasten them yet, the adapter must be movable for the next step. **Note** Turn the side of the turning disk adapter that fits into the turning disk cavity, inwards.	 xx1400001644

Continues on next page

	Action	Note/Illustration
4	Tighten the conical screw so that the adapter is forced to the right and fixed to the guide pin.	 xx1400001645
5	Then tighten the two screws that fastens the adapter.	 xx1400001646
6	Clean the adapter plate surface and the three contact surface points on the sensor holder with isopropanol.	
7	Fit the sensor to the adapter and tighten the screw. **Note** Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.	 xx1400001647

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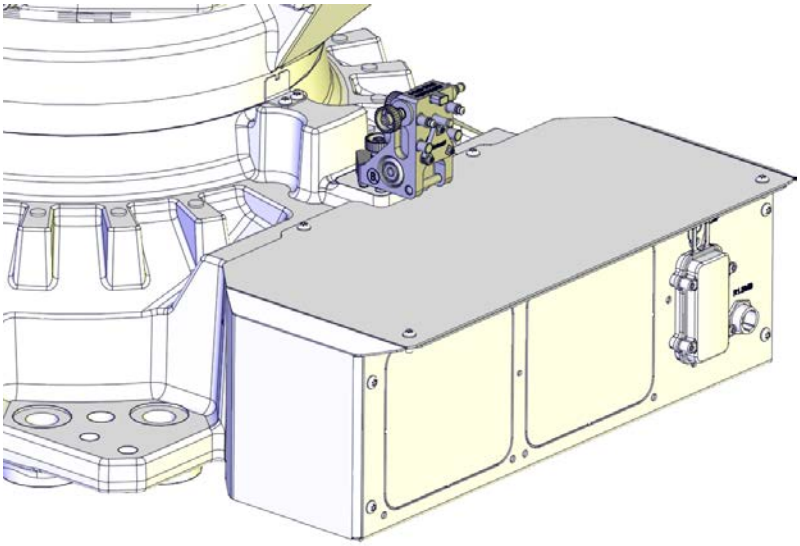
3.2.5 Calibration sensor mounting positions, CalPend
Continued

IRB 6700

The illustrations below show the mounting positions and directions for both the reference sensor and axis sensors on the robot.

Reference position IRB 6700 (without calibration bracket at base)



xx1400002040

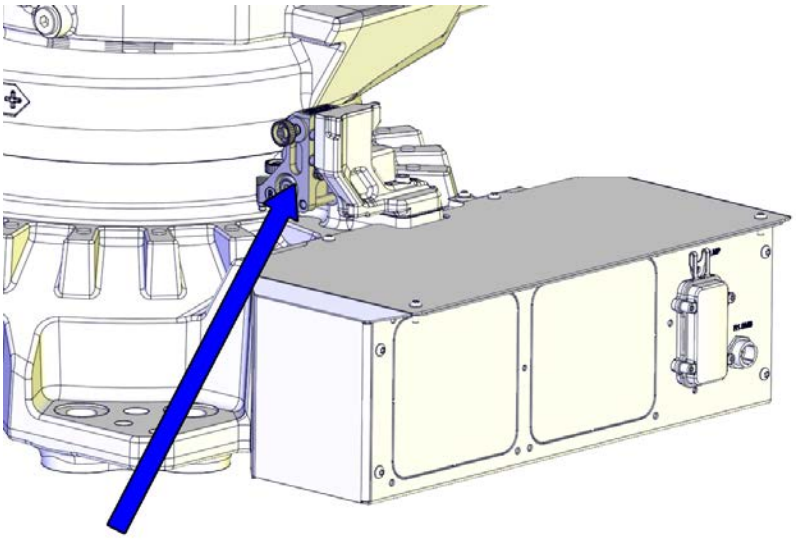
A	Calibration pendulum in reference sensor position. NOTE! The pendulum is only fitted in one position at a time!

Note

Always use the same method for Pendulum Calibration on each robot. That is, if the robot is calibrated with a bracket on the base and a turning disk adapter last time then continue using the bracket and adapter, otherwise the calibration values will be wrong.

Continues on next page

Reference position IRB 6700 (with calibration bracket at base)

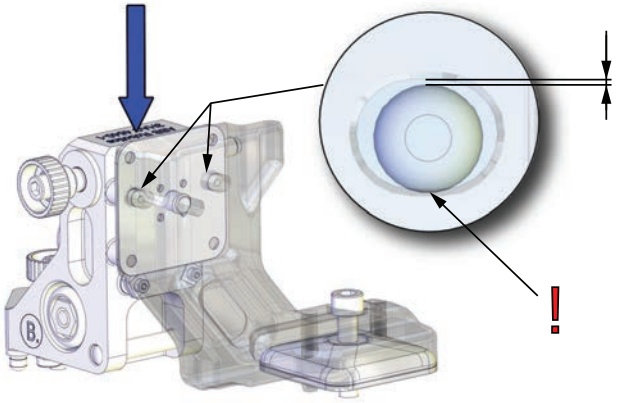


xx1400001053

-	Calibration pendulum as reference sensor in reference position at base, fitted to the calibration bracket (if available) NOTE! The pendulum is only fitted in one position at a time!

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.



xx1400001568

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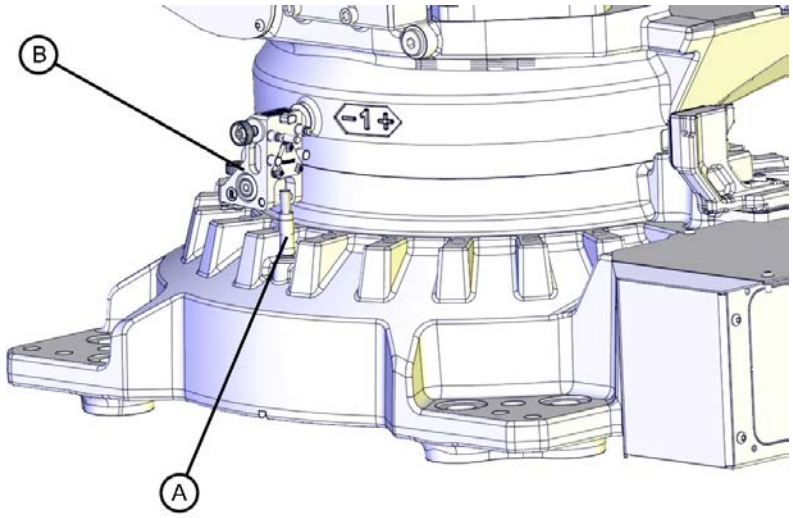
3.2.5 Calibration sensor mounting positions, CalPend
Continued

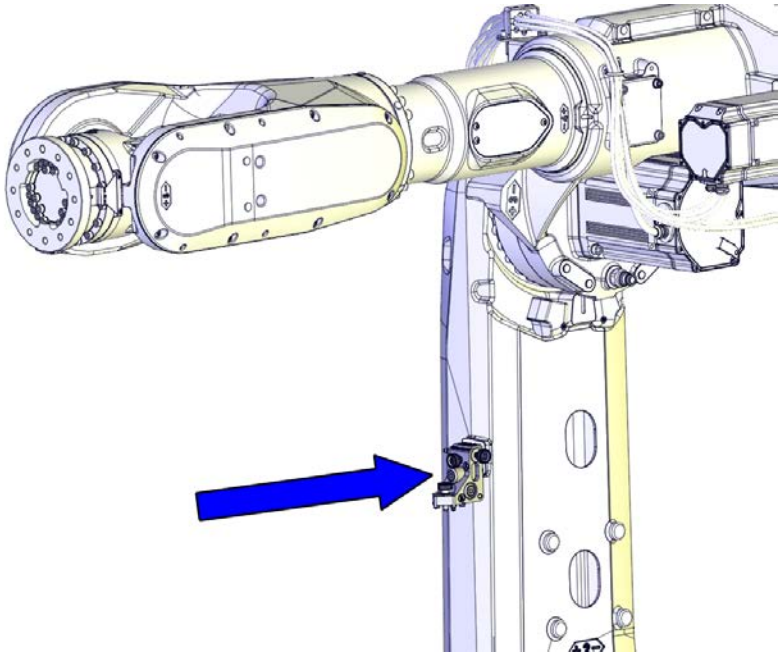
Axis 1 IRB 6700



xx1400001431

A	Locating pin
B	Calibration pendulum as calibration sensor, axis 1

Axis 2 IRB 6700



xx1400001432

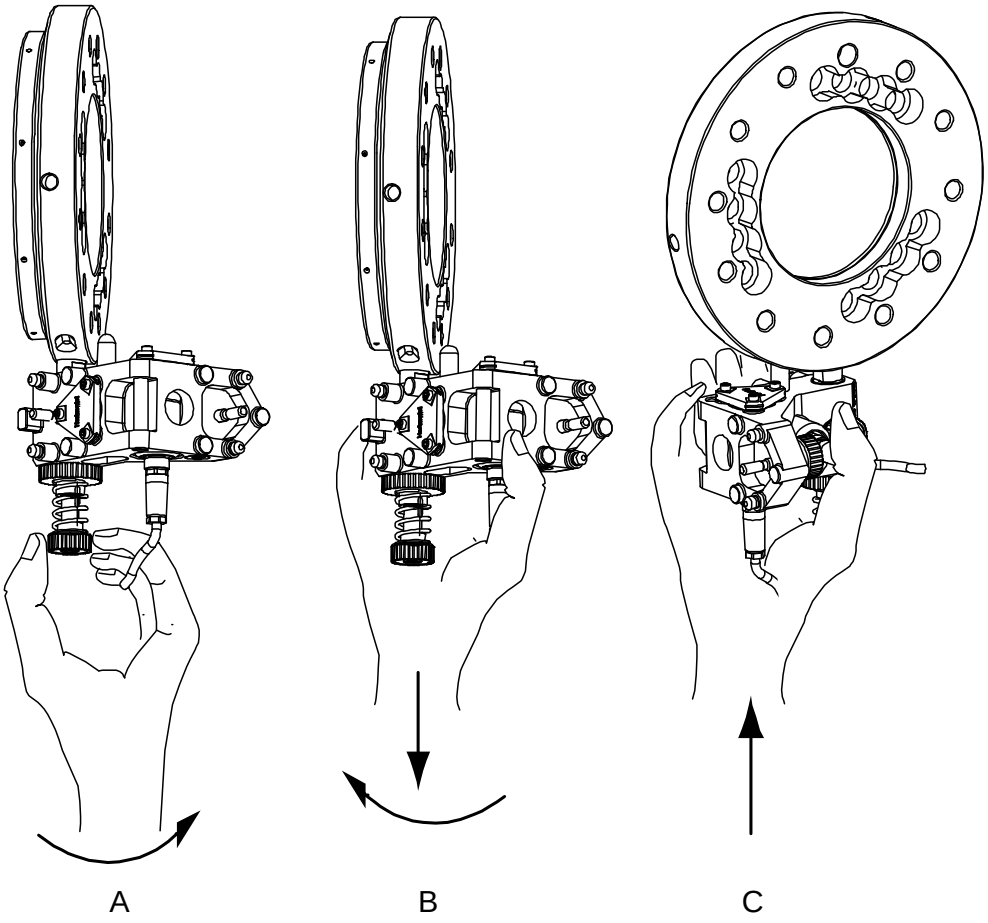
	Calibration pendulum as calibration sensor, axis 2

Continues on next page

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

Axis 3-6 IRB 6700 without turning disk adapter



xx0300000274

A	Fit the calibration pendulum, screw home the attachment screw (by hand)
B	Compress the spring and rotate the calibration pendulum counter clockwise
C	At the end of the counter clockwise movement drop the calibration pendulum into its calibration position

Note

To ensure the result of the procedure to be accurate it is vital that it is performed identically each time.

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

Note

Always use the same method for Pendulum Calibration on each robot. That is, if the robot is calibrated with a bracket on the base and a turning disk adapter last time then continue using the bracket and adapter, otherwise the calibration values will be wrong.

Axis 3-6 IRB 6700 with turning disk adapter

Note

The robot has been pre-calibrated at the factory using the turning disk adapter if the robot is equipped with a calibration bracket at the base for fitting the reference sensor in a vertical plane.

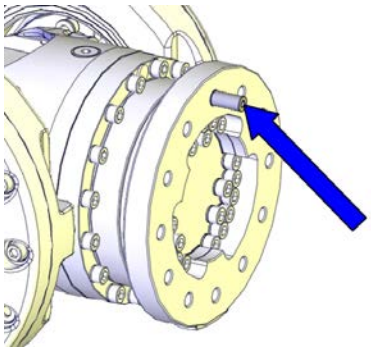
If the robot has been pre-calibrated with the turning disk adapter, the adapter should be used according to following recommendations:

- The adapter is required to be used for calibration of axis 3, 4 and 6. If the adapter is not used during calibration, there will be discrepancy in the calibration values for the axis.
- The adapter can be used also for calibration of axis 5, but it is not required. The calibration values are not affected.

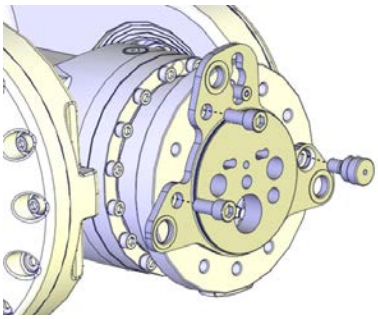
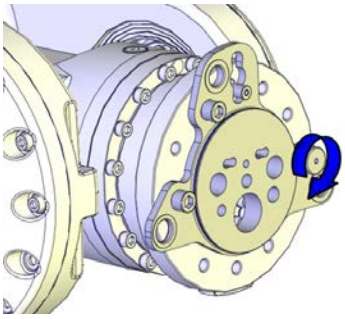
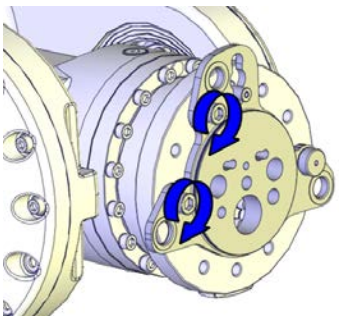
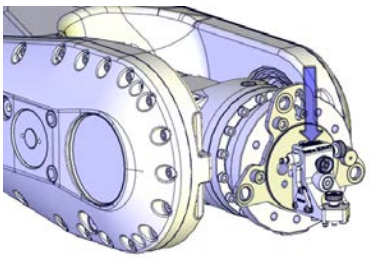
Note

To ensure the result of the procedure to be accurate it is vital that it is performed identically each time.

Fitting the sensor to the turning disk using a turning disk adapter

	Action	Note/Illustration
1	Clean the mounting surfaces of the turning disk and the turning disk adapter with isopropanol.	
2	Fit the guide pin to the turning disk. **Tip** If the guide pin does not fit the hole in the turning disk, rub down the part that enters the hole to make it fit. Avoid play! Use abrasive paper / emery cloth.	 xx1400001643

Continues on next page

	Action	Note/Illustration
3	Fit the turning disk adapter with the conical screw and the two screws. Do not fasten them yet, the adapter must be movable for the next step. **Note** Turn the side of the turning disk adapter that fits into the turning disk cavity, inwards.	 xx1400001644
4	Tighten the conical screw so that the adapter is forced to the right and fixed to the guide pin.	 xx1400001645
5	Then tighten the two screws that fastens the adapter.	 xx1400001646
6	Clean the adapter plate surface and the three contact surface points on the sensor holder with isopropanol.	
7	Fit the sensor to the adapter and tighten the screw. **Note** Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.	 xx1400001647

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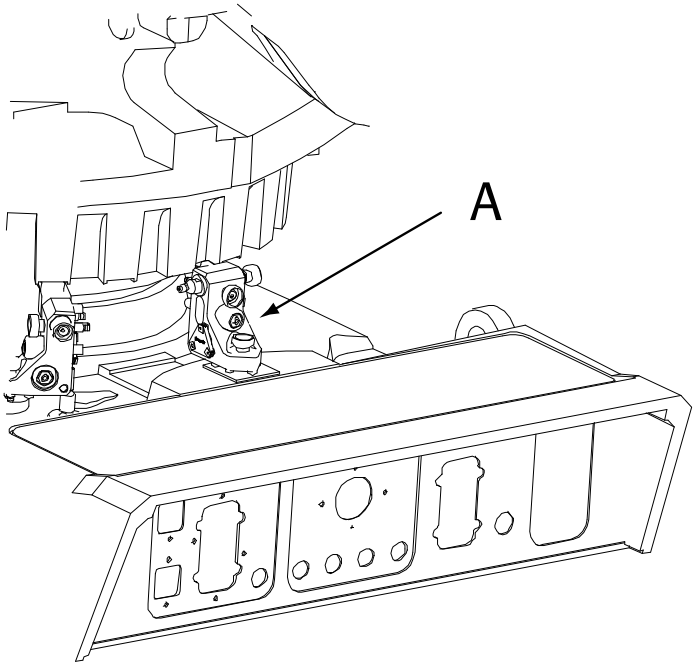
3.2.5 Calibration sensor mounting positions, CalPend
Continued

IRB 460, IRB 660, IRB 760

These illustrations show the mounting positions and directions for both the reference sensor and axis sensors on the robot. Notice that the pendulum is only fitted in one position at a time (the same pendulum is used as both a reference and a calibration sensor).

Reference position - IRB 660, IRB 760



xx0200000183

A	Calibration pendulum in reference sensor position. NOTE! The pendulum is only fitted in one position at a time!

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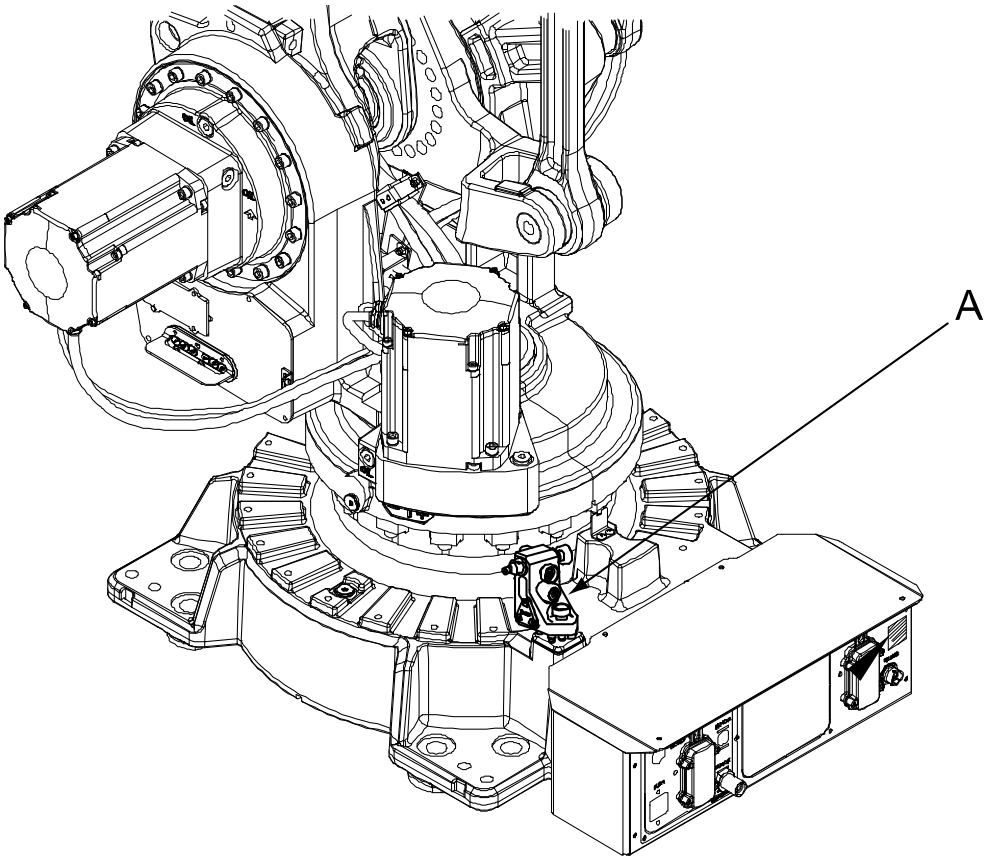
Reference position - IRB 460



xx1000001440

A	Calibration pendulum in reference sensor position. NOTE! The pendulum is only fitted in one position at a time!

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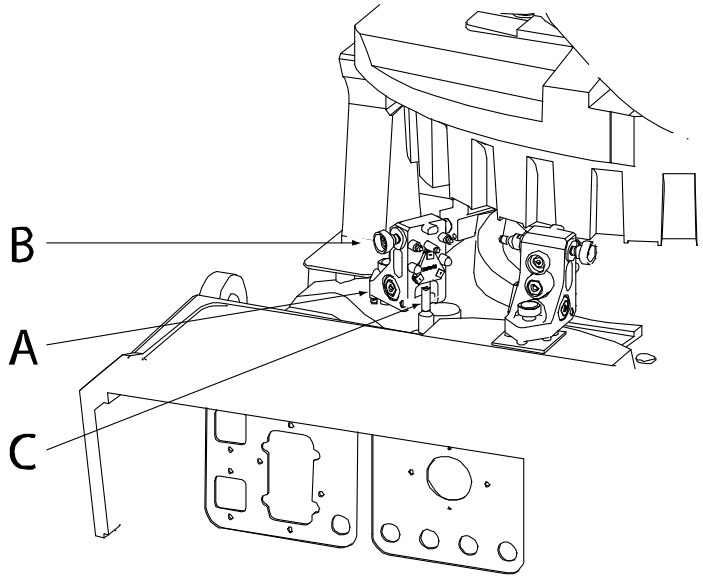
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 1 - IRB 460, IRB 660, IRB 760

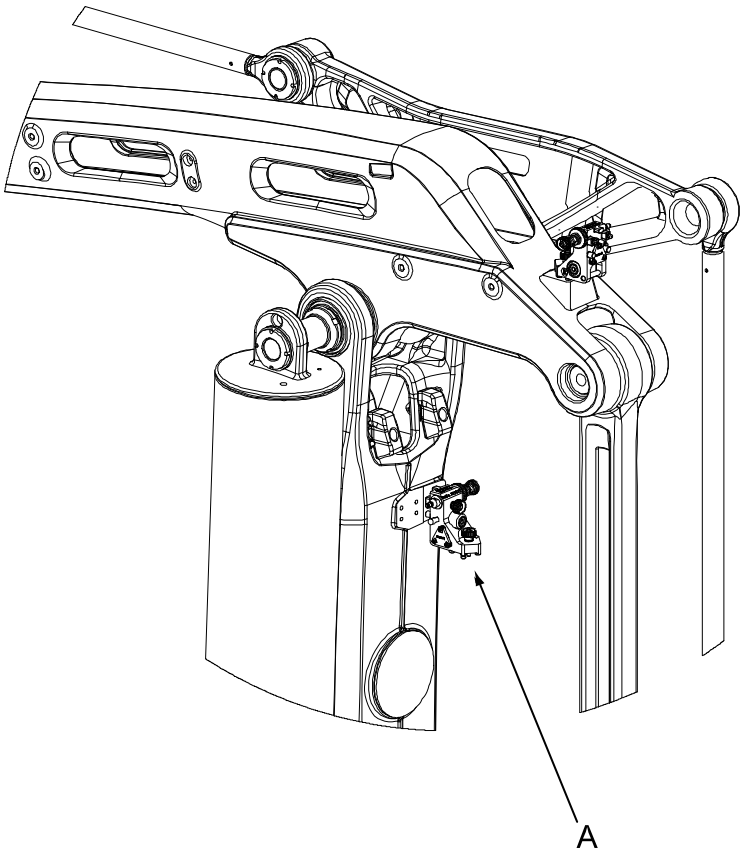


xx0200000177

A	Calibration pendulum. NOTE! The pendulum is only fitted in one position at a time!
B	Calibration pendulum attachment screw
C	Locating pin (58mm long for IRB 460, 68 mm long for IRB 660 and IRB 760)

Continues on next page

Axis 2 - IRB 460, IRB 660, IRB 760



xx0500002475

A	Calibration sensor, axis 2

Note

Press down the pendulum gently while tightening its fastening screw, when fitting the pendulum to a vertical plane. It is important that the two locating pins are centered and in contact with the lower hole edges in the bracket. There should be a small amount of play above and at the sides of the pin. Do not force the pendulum house sideways while tightening the pendulum screw.

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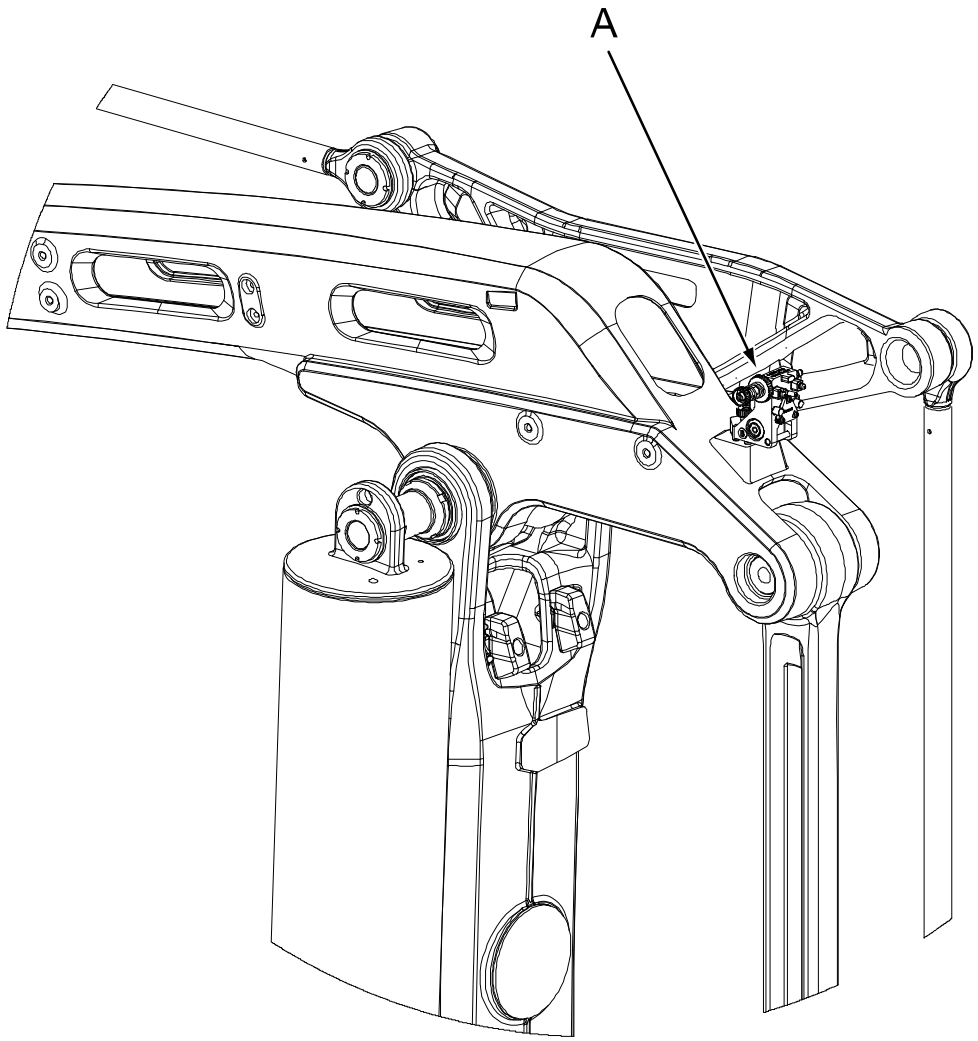
3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 3 - IRB 460, IRB 660, IRB 760

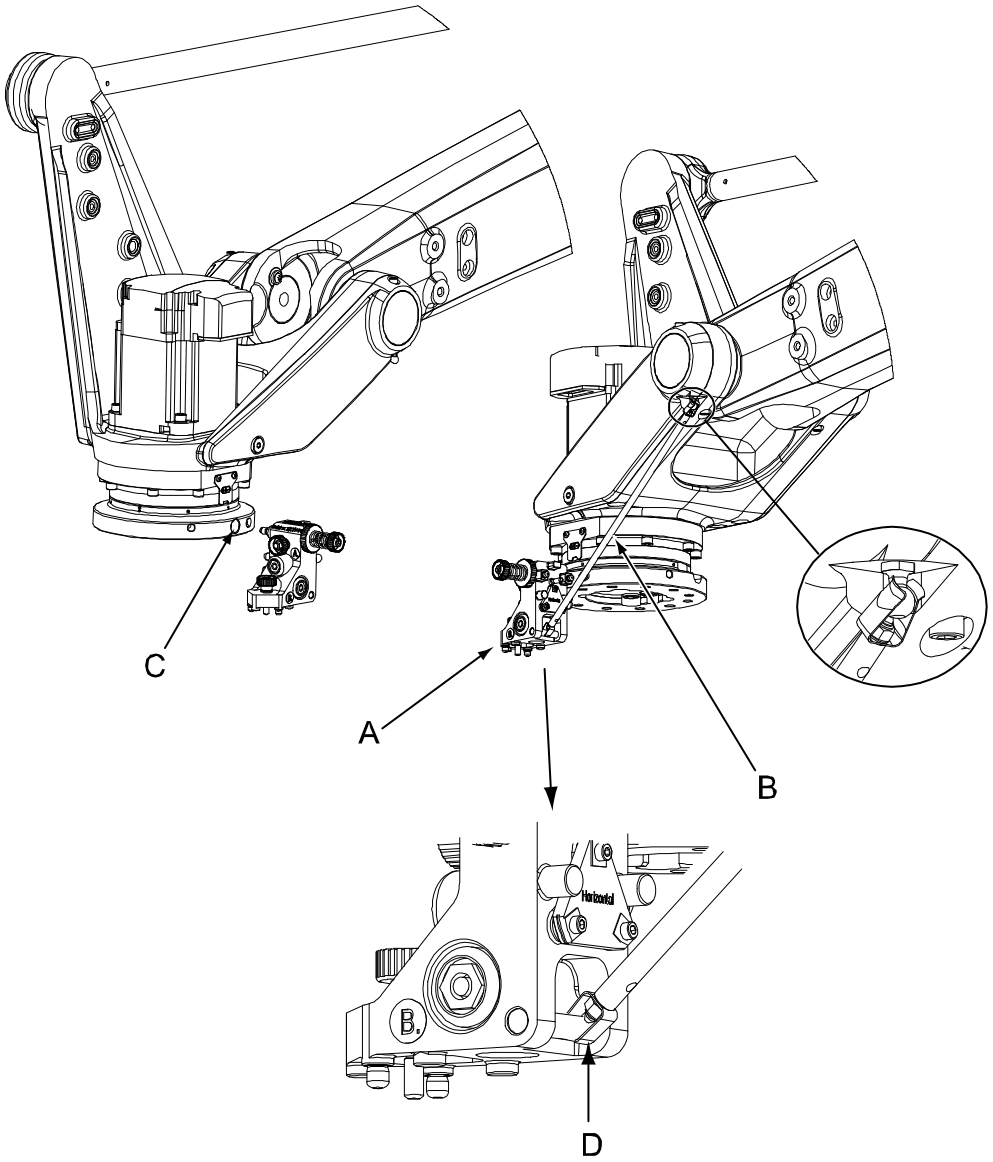


xx0500002473

A	Calibration sensor, axis 3

Continues on next page

Axis 6 - IRB 460, IRB 660



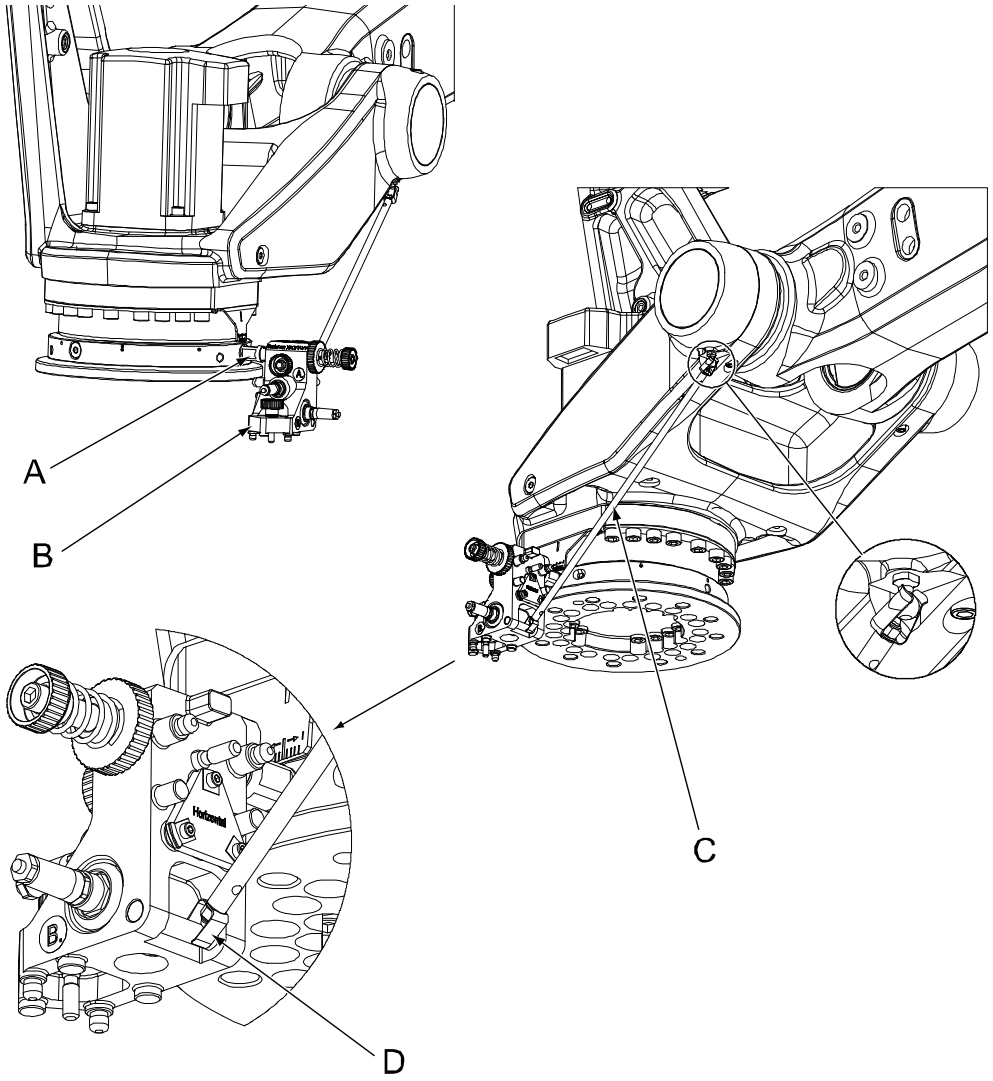
xx0500002474

A	Calibration sensor, axis 6
B	Calibration bar, attached between the sensor and a ball plug on the robot
C	Tapered attachment hole on the turning disk
D	**Note!** Make sure to fit the calibration bar at the extreme right of the sensor pin.

Continues on next page

3.2.5 Calibration sensor mounting positions, CalPend
Continued

Axis 6 - IRB 760



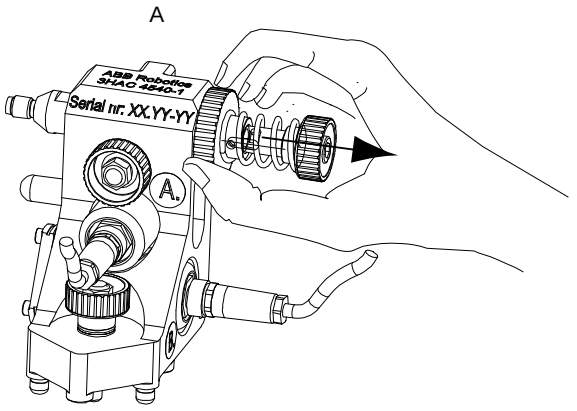
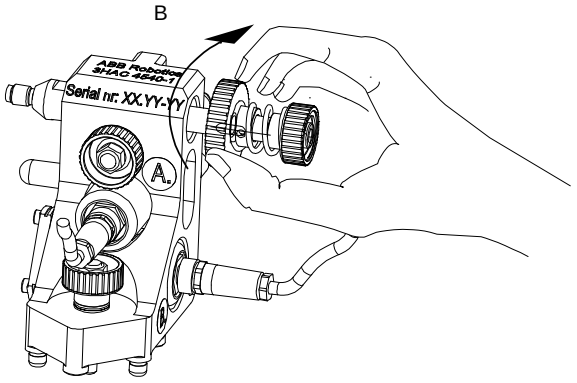
xx1000001208

A	Turning disk adapter
B	Calibration sensor, axis 6
C	Calibration bar, attached between the sensor and a ball plug on the robot
D	**Note!** Make sure to fit the calibration bar at the extreme right of the sensor pin.

3.2.6 Preparing for using the sensor on axes 1 and 6, CalPend

Preparing for calibration pendulum

Use this procedure to prepare the calibration pendulum before calibration of axes 1 and 6 on IRB260, IRB460, IRB660 and IRB760, and axis 1 on all other robots.

	Action	Illustration
1	Compress the spring by moving the inner hand wheel (axial movement)	 xx0400001101
2	Rotate the inner hand wheel clockwise on the shaft to lock the spring in compressed position.	 xx0400001102
3	After calibration of axis 1 (or axis 6 on IRB260, IRB 460, IRB660 and IRB 760), release the compressed spring.	

3.2.7 Calibration Pendulum II procedure on FlexPendant

Calibration Pendulum II procedure for IRC5

Use this procedure to calibrate the robot with the calibration pendulum method using the FlexPendant.

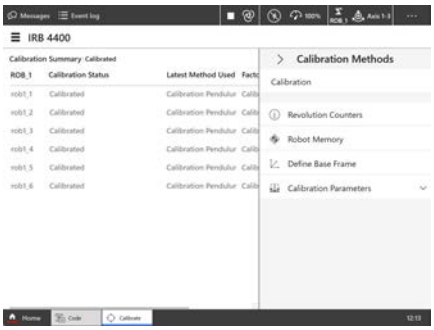
	Action	Note
1	On the ABB menu tap **Program Editor**.	
2	Tap **Test** and then **Call Routine**.	
3	Select the **CalPendulum** routine and tap **Go to**.	
4	Start the program by pressing the start button.	
5	If you want to calibrate axes 1-2 with axes 3-6 in alternative position, select alternative positions for axes 3-6.	
6	Follow the instructions on the FlexPendant.	Proceed to calibrate the individual robot axes, see *Calibrating all axes, CalPend on page 68*.

Calibration Pendulum II procedure for OmniCore

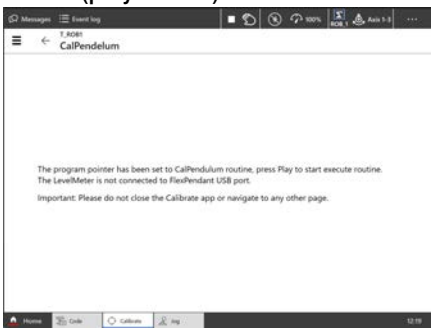
Use this procedure to calibrate the robot with the calibration pendulum method using the FlexPendant.

Note

The *Calibration Pendulum* service routine requires FlexPendant OS version 2.0.

	Action	Note
1	Open the **Calibrate** app.	
2	In the **Calibration Methods** menu, tap **Calibration**.  xx2400000409	The program pointer is set to the *CalPendulum* routine. The connection status of the LevelMeter is shown.

Continues on next page

	Action	Note
3	Start the program by pressing the start button (play button).  xx2400000410	**Note** The **Calibrate** app must be open on the FlexPendant. If the app is closed, then the communication with the Levelmeter is lost.
4	If you want to calibrate axes 1-2 with axes 3-6 in alternative position, select alternative positions for axes 3-6.	
5	Follow the instructions on the FlexPendant.	Proceed to calibrate the individual robot axes, see *Calibrating all axes, CalPend on page 68*.

Interrupting the routine

If you want to terminate the execution of the routine, select **Cancel Call Routine** to set the program pointer back to the program line where it was before selecting **Call Routine**.

3.2.8 Verifying the calibration

Introduction

Always verify the results after calibrating *any* robot axis to verify that all calibration positions are correct.

Verifying the calibration

Use this procedure to verify the calibration result.

	Action	Note
1	Run the calibration home position program twice. Do not change the position of the robot axes after running the program!	See *Checking the synchronization position on page 129*.
2	Adjust the *synchronization marks* when the calibration is done, if necessary.	This is detailed in section *Synchronization marks and synchronization position for axes on page 15*.
3	Write down the values on a new label and stick it on top of the calibration label. **IRB 52:** The label is located on the inside wall of the upper arm housing cover. **IRB 2600, IRB 4600, IRB 460, IRB 660, IRB 6650S, IRB 6700, IRB 760, IRB 7600:** The label is located on the lower arm. **IRB 1410, IRB 2400, IRB 4400:** The label is located underneath the flange plate on the base. **IRB 1510ID, IRB 1520ID:** The label is located on the housing of the axis-2 gearbox.	
4	Remove any calibration equipment from the robot.	

3.2.9 Checking the synchronization position

Introduction

Check the synchronization position of the robot before beginning any programming of the robot system. This may be done:

- Using a `MoveAbsJ` instruction with argument zero on all axes.
- Using the **Jogging** window on the FlexPendant.Using the **Jog** window on the FlexPendant.

Continues on next page

3.2.9.1 Checking the synchronization position on IRC5 robots

Using a MoveAbsJ instruction

Use this procedure to create a program that runs all the robot axes to their synchronization position.

	Action	Note
1	On ABB menu tap **Program editor**.	
2	Create a new program.	
3	Use **MoveAbsJ** in the **Motion&Proc** menu.	

4	Create the following program:
	`MoveAbsJ [[0,0,0,0,0,0],`
	`[9E9,9E9,9E9,9E9,9E9,9E9]]`
	`\NoEOffs, v1000, fine, tool0`	

5	Run the program in manual mode.	
6	Check that the synchronization marks for the axes align correctly. If they do not, update the revolution counters.	See *Synchronization marks and synchronization position for axes on page 15* and *Updating revolution counters on page 70*.

Using the jogging window

Use this procedure to jog the robot to the synchronization position of all axes.

	Action	Note
1	On the **ABB** menu, tap **Jogging**.	
2	Tap **Motion mode** to select group of axes to jog.	
3	Tap to select the axis to jog, axis 1, 2, or 3.	
4	Manually run the robots axes to a position where the axis position value read on the FlexPendant, is equal to zero.	
5	Check that the synchronization marks for the axes align correctly. If they do not, update the revolution counters.	See *Synchronization marks and synchronization position for axes on page 15* and *Updating revolution counters on page 70*.

3.2.9.2 Checking the synchronization position on OmniCore robots

Using a MoveAbsJ instruction

Use this procedure to create a program that runs all the robot axes to their synchronization position.

	Action	Note
1	Tap **Code**.	
2	Create a new program.	
3	Use **MoveAbsJ** in the **Add Instruction** menu.	

4	Create the following program:
	`MoveAbsJ [[0,0,0,0,0,0],`
	`[9E9,9E9,9E9,9E9,9E9,9E9]]`
	`\NoEOffs, v1000, fine, tool0`	

5	Run the program in manual mode.	
6	Check that the synchronization marks for the axes align correctly. If they do not, update the revolution counters.	See *Synchronization marks and synchronization position for axes on page 15* and *Updating revolution counters on page 70*.

Using the jogging window

Use this procedure to jog the robot to the synchronization position of all axes.

	Action	Note
1	Tap **Jog**.	
2	From the **Mechanical unit** list select a mechanical unit.	
3	From the **Motion mode** section, select an axis-set that need to be jogged. For example, to jog axis 2, select the axis set **Axis 1-3**.	
4	Follow the screen instruction on joystick movements to understand the direction of the axis that you want to move and move the joystick.	
5	Manually run the robots axes to a position where the axis position value read on the FlexPendant, is equal to zero.	
6	Check that the synchronization marks for the axes align correctly. If they do not, update the revolution counters.	See *Synchronization marks and synchronization position for axes on page 15* and *Updating revolution counters on page 70*.

3.3 Reference Calibration

3.3.1 About Reference Calibration

Usage

The routine Reference Calibration is used in field, to restore the robot home position, for example after service activities. (Reference Calibration is a function included in the service routine Calibration Pendulum.)

Principle

The calibration procedure is based on reference values that are defined once and then used each time the robot needs to be recalibrated. The values are stored on the controller, with a file name equal to the serial number of the robot.

The reference values must be defined before required use of robot recalibration.

Peripheral equipment and robot position

Tools and process cabling are allowed on the robot.

Reference Calibration can be used for both floor mounted and hanging robots.

As for the robot position, the axes 2-6 are set to 0º, while the position of axis 1 has no significance but can instead be set to whatever suits best for the installation.

Limitations

The Reference Calibration has the following limitations:

- Calibration of axis 1 must be performed with Calibration Pendulum II.
- The axes of a serial link robot (bending backwards robot) are divided into two groups: axes 2, 3, 5 and axes 4, 6. Parallel rod robots have their own calibration reference for axis 2 on the lower arm, which results in the grouping 2 and 3, 5 and 4, 6 instead. Reference Calibration can only be used for one axis from each group at the same occasion. Calibration is consequently not possible for several axes within the same group. If service activities are performed for several axes within the same group, the service must be divided into sessions with calibration in between.

Which robot systems can be calibrated with Reference Calibration?

The integrated software for Reference Calibration is developed for RobotWare 5.07 and later. For BaseWare 4.0 and earlier releases of RobotWare 5, standalone versions are available with manual operation, detailed in separate documentation enclosed with the release.

Required tools

See *Calibration equipment on page 35*.

3.3.2 Preparing the reference surface for the tool

Introduction

To perform Reference Calibration the robot needs to be prepared with a reference surface (adapter) for fitting the calibration pendulum housing on the tool.

This section describes how to prepare the reference surface.

Reference adapter should stay fitted permanently

The reference adapter should be permanently fitted and never removed after obtaining the reference values. If the reference surface is temporary, it is critical to be able to refit the adapter with high accuracy once its going to be used for calibration after service. The inaccurancy of refitting the adapter will have negative impact on the calibration procedure.

Hanging robots

Prepare the reference surface in the same way for hanging robots as for floor mounted. The reference sensor will be upside down and all the measurements are taken upside down.

Required equipment

Equipment	Art. no.
Reference adapter	3HAC025397-001

Preparing the reference surface

Use this procedure to prepare the reference surface for the reference sensor.

	Action	Note
1	**Note** To achieve high accuracy, the reference surface should be fitted permanently to the robot. Removing and refitting once the reference values are defined increases inaccuracy and has a negative impact on the calibration performance!	
2	Select an appropriate location for the reference surface on the tool.	The mounting location must be: • horizontal ± 5º, when robot is standing in calibration position. • perpendicular to the tool flange surface ± 5º (to be mounted in one of four directions, in steps of 90º).
3	Use the *reference adapter* as a drilling pattern and mark where to drill the four holes on the selected mounting location.	
4	Drill the two holes matching the M8 screws to a depth of 10 mm. Cut the thread M8.	

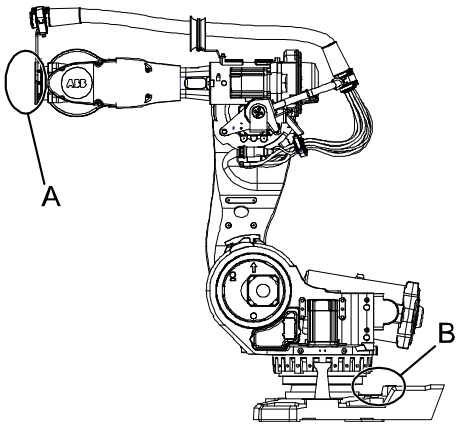
Continues on next page

3.3.2 Preparing the reference surface for the tool
Continued

	Action	Note
5	Drill the two remaining holes (Ø 6 mm) to a depth of minimum 5 mm.	
6	Fit the reference adapter using the two M8 screws and the two guiding pins included with the adapter.	

Reference surfaces

Reference surfaces for serial link robots



xx0500002470

Note

For large robots (IRB 6640, IRB 6620, IRB 6700, and IRB 7600) with RobotWare 5.15.03/5.60 or later, there is one reference surface available on the tube shaft (axis 4) and one on the tool (axis 6). Robots with earlier versions of RobotWare only have the axis-6 reference surface.

The name of the text file for the reference contains the robot serial number. For robots calibrated on the tube shaft, the filename ends with `_tubeshaft.txt`.

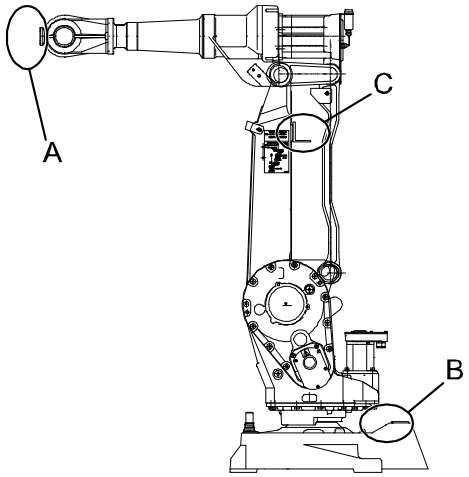
The same service routine is used for all reference surfaces.

A Reference surface at the tool. See *Preparing the reference surface for the tool on page 133*.

B Reference surface at base.

Continues on next page

Reference surfaces for parallel rod robots



xx0500002471

A Reference surface at the tool. See *Preparing the reference surface for the tool on page 133*.

B Reference surface at base.

C Reference surface of axis 2.

3.3.3 Defining reference values for calibration of axes 2-6

Introduction

To perform Reference Calibration, reference values must first be defined and stored to the robot system. This must be done before recalibration is required.

This section describes how to define these reference values for the robot system. The values are then used each time the robot needs to be recalibrated.

Defining reference values

The definition of reference values is made once and the values are then stored to the robot system.

The procedure of defining the reference values differs some between serial link and parallel rod robots. Differences are pointed out in the procedure.

	Action	Note
1	Make sure the robot is prepared for the procedure, that is, all service or installation activities are completed and the robot is ready to run.	
2	Check that all required hardware is available for calibrating the robot.	See *Calibration equipment on page 35*.
3	Remove any mechanical equipment that might stop the calibration movements, for example mechanical stops on axis 1.	
4	Prepare the reference surface on the tool.	See *Preparing the reference surface for the tool on page 133*.
5	Run the robot to the desired position regarding axis 1. Move axes 2-6 close to zero degrees.	**Note!** The position set for axis 1 at this point determines also the future position of the axis at each occasion of recalibration.
6	Prepare and clean the reference surfaces to be used with isopropanol.	See *Reference surfaces on page 134*.
7	Run the service routine **CalPendulum** from the FlexPendant and select **Reference Calibration**. If there are no reference values set for the robot, the program senses it and requires to define these. **Warning!** The robot will automatically move to the calibration position, keeping the manually set axis 1 position and setting axes 2-6 to zero.	The program will guide through the complete procedure, giving information of each step to perform. How to run a service routine from the FlexPendant is described in *Operating manual - IRC5 with FlexPendant* or *Operating manual - OmniCore*.

Continues on next page

	Action	Note
8	Make notes or take pictures that shows the following conditions under which the reference values were taken: • position and alignment of the calibration pendulum housing at the reference surface on the tool (allowed to be fitted in one of four directions, in steps of 90º) • position of axis 1 • tools and/or dresspack mounted on the robot. The information is valuable at future service occasions to get highest accuracy possible from the recalibration.	
9	Remove the calibration tools from the robot and refit the covers to the reference surfaces.	
10	Restore the robot for production.	

Storing the reference values

The reference values are automatically stored on the controller, as a file named equally to the serial number of the robot. The file is stored in the *Home* folder.

3.3.4 Preparing for calibration, RefCal

Introduction

This section describes all required preparations for performing Reference Calibration (RefCal).

Preparing for calibration

The procedure below details how to prepare the calibration procedure.

	Action	Note
1	**Note** Before doing Reference Calibration, reference values must be defined and stored in the robot system. If no values are available, the robot must be calibrated with Pendulum Calibration II instead.	
2	Make sure the robot is prepared for calibration. That is, all service or installation activities are completed and the robot is ready to run.	
3	Make sure that all required hardware is available for calibrating the robot.	See *Calibration equipment on page 35*.
4	Connect the calibration equipment to the robot controller and start up the Levelmeter 2000.	See *Start up of Levelmeter 2000 on page 42*.
5	The reference adapter should be permanently fitted to the tool when defining the reference values, to achieve accurate values during calibration. If the adapter is missing anyhow, it must be fitted as detailed in section *Preparing the reference surface for the tool on page 133*.	See *Preparing the reference surface for the tool on page 133*.
6	Remove any mechanical equipment that might stop the calibration movements, for example mechanical stops on axis 1.	
7	Remove all the covers from the reference surfaces and clean them with isopropanol.	See *Reference surfaces on page 134*.
8	Calibrate the robot.	See *Calibrating axes 2-6 using predefined reference values on page 139*.

3.3.5 Calibrating axes 2-6 using predefined reference values

Prerequisites

The calibration procedure requires previously defined reference values. If there are no reference values stored in the robot system, Reference Calibration is not possible. Calibrate the robot using Calibration Pendulum II instead.

Reference Calibration can only be used for one axis from each of the groups 2, 3, 5 and 4, 6.

Calibration sequence

The program will ask for what axis to calibrate. The program will automatically run the correct sequence to get the correct accuracy. Axis 4 will always be run four times and axis 5 will always be run three times.

If two axes are selected, these will be run in a double sequence, for example 5, 6, 5, 6.

We recommend using automatic fine calibration instead of manual.

Calibrating axes 2-6 with Reference Calibration

Use this procedure to calibrate the robot with Reference Calibration.

	Action	Note
1	Read the limitations for Reference Calibration.	See *Limitations on page 132*.
2	Prepare the calibration, see *Preparing for calibration, RefCal on page 138*.	
3	Perform a fine calibration of the axis that has been serviced.	
4	Jog the robot close to the defined position regarding axis 1. Data about the position is stored in the file that contains the reference values and will be used later on in the calibration procedure, but the axis should be moved as close as possible to the defined position to prevent large movement of the axis later on.	There should be notes or pictures taken during definition of the reference values that shows the position of axis 1.
5	Jog axes 2-6 close to zero degrees.	
6	Run the service routine **CalPendulum** from the FlexPendant and select **Reference Calibration**. **Warning!** The robot will move automatically to the calibration position and will use the values for axis 1 positioning from the reference file.	The program will guide the operator through the complete procedure, giving information of each step to perform. Follow the steps in the program carefully. How to run a service routine from the FlexPendant is described in *Operating manual - IRC5 with FlexPendant* or *Operating manual - OmniCore*.
7	After ending the program, remove all the calibration tools and refit the covers to the reference surfaces.	
8	Restore the robot for production.	

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