



# Kinematic Calibration User Manual

Compatible robots: UR3e, UR5e, UR10e, UR16e

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# 1. Introduction

# 1.1. About this document

This document describes how to set up and do Dual Robot Calibration on Universal Robots e-Series robots with the e-Series Control Box. During Dual Robot Calibration, two robot arms are connected and perform coordinated movements to different positions to calibrate the robot kinematics.

This document also describes how to use key waypoints to correct programs automatically.

# 1.2. What's in the box

The box contains the following parts:

- The Dual Robot Calibration kit
  - Calibration Horse with alignment pins
  - · Calibration Tool Connector with alignment pins
  - Four M8-1.25x70 screws with washers
  - Eight M8-1.25x25 screws with washers
  - Eight M6-1.0x25 screws
  - Eight M6-1.0x25 screws
  - Go / NoGo tools
- This document

# 1.3. Terminology and abbreviations

In this document the following terms and corresponding abbreviations are used:

- Corresponding Tool Position (CTP)
- Tool Center Point (TCP)

## 1.4. Company Details

Universal Robots A/S Energivej 51, 5260 Odense S, Denmark +45 89 93 89 89

https://www.universal-robots.com

# 2. Safety

# 2.1. Safety Message Types

# 2.2. General safety precautions

For more information on safety, refer to the Safety section in the robot User Manual.



#### WARNING

Incorrect connection of the power source or ground wires can result in equipment damage or personnel injury.

Damage caused by invalid power source connection is not covered by warranty. Before starting the operation:

- · Ensure that the power source wiring is correct.
- Ensure that the grounding is correct.



#### NOTICE

This product includes the Universal Robots e-Series robot. General safety considerations that are valid for the Universal Robots e-Series robot are also valid for this product.

• For more information on safety, refer to the Safety section in the Universal Robots e-Series robot User Manual.

## 2.3. Dual Calibration safety precautions

This section contains safety precautions specific to Dual Robot Calibration and Program Correction.



#### WARNING

Obstructing the robots during the dual calibration process can result in equipment damage or personnel injury.

· Stay clear of the robots once the calibration starts.



#### NOTICE

Incorrect dual calibration can cause the robot to become inaccurate. Before saving the results:

• Pay attention to the generated statistics of the dual calibration.

# 3. Dual robot calibration: Preparation

This section describes how to mount two UR robot arms to a Calibration Horse and how to prepare them for dual calibration.

# 3.1. Required items

You need the following items to set up the robots for dual calibration:

- · Two Universal Robots e-Series robots of the same type and software version
- A Calibration Horse
- A 0.5 m stand for the Calibration Horse
- A network cable
- A Dual Robot Calibration kit (purchase number: 185500)

# i

#### NOTICE

Robot software versions 5.8 and later saves calibration results in the robot arm. Robots using older software versions save calibration results to the Control Box, so a calibrated robot arm and Contol Box must be used together.

# 3.2. The Calibration Horse

The Calibration Horse connects one robot arm to another via the base, as illustrated in the image below. Using the Calibration Horse allows you to attach the two tool flanges. The result is a closed robot arm circuit that makes coordinated movements, while performing a number of measurements.



## 3.3. How to mount robot arms to the Calibration Horse

This procedure requires the following criteria for success:

- Mount the robots at approximately 52.5°
- Use a custom installation before activating the robots.

#### To mount each robot arm

- 1. Use the screws to mount each robot to the Calibration Horse.
- 2. Turn on the control box, then leave the robot arm in the Idle state (Yellow indicator).

The screen, below shows the robot arm in the Idle state.



### To configure the mounting software

- 1. On PolyScope, in the Header, tap Installation.
- 2. Under General, select Mounting
- 3. Use arrow buttons to set the Tilt and the Rotate Robot Base Mounting, according to the values in the table below.

Robot size	Tilt	Rotate Robot Base Mounting
UR3e	52.5°	270°
UR5e	52.5°	90°
UR10e	52.5°	90°
UR16e	52.5°	90°

# 3.4. How to prepare robot safety settings

Configure the robot safety settings in PolyScope, as shown in the screen shot below.

General	! DANGER					
Safety	Use of Safety Configuration p			d by the risk as	sessment can result ir	n hazards that are not
Robot Limits	reasonably eliminated or risks	that are not sufficier	ntly reduced.			
Joint Limits						
Planes	Factory Presets			1	•	
Tool Position		Most Rest	ricted		Lea	ast Restricted
Tool Direction	O Custom					
I/O	Ŭ					
Hardware	Limit	Normal		Reduced		
Features	Power		300 W		200 W	
Fieldbus	Momentum		<b>25.0</b> kg m/s		<b>10.0</b> kg m/s	
	Stopping Time		<b>400</b> ms		<b>300</b> ms	
	Stopping Distance		<b>500</b> mm		<b>300</b> mm	
	Tool Speed		<b>1500</b> mm/s		<b>750</b> mm/s	
	Tool Force		150.0 N		<b>120.0</b> N	
	Elbow Speed		<b>1500</b> mm/s		<b>750</b> mm/s	
	Elbow Force		<b>150.0</b> N		120.0	
	S	afety password		Unlock	Lock	Арр

#### To configure the robot safety settings

- 1. Tap Safety and select Robot Limits.
- 2. Enter the password: lightbot and tap Unlock.
- 3. Tap Apply to unlock the Safety Configuration.
- 4. When the Safety Configuration dialog box appears, select Apply and restart.



# 3.5. How to prepare the robot network connection

Select a method, based on your connection type.

- Method 1 Manual: hen the robots are already connected to a local area network
- · Method 2 Master/Slave: for robots connected directly with single network cable

#### 3.5.1. Method 1: Manual connection

Use this method when the robots are already connected to a local area network.

#### NOTICE

Connecting the robots to a Local Area Network (LAN) can interfere with other devices sharing these IP addresses.

• Do not connect the robot to a LAN. Connect the two robots directly to eachother.

#### NOTICE

Connection between the two networks can break down, causing the calibration screen to change.

• Follow the on-screen instruction to resolve the network conflict and restart the calibration process.

#### Connecting the Manual network (Method 1)

Define the network connection types as listed in the following table:

Network connection type	Definition
Master	The main robot in the calibration process. Uses a single cable.
Slave	The subordinate robot in the calibration process.
Manual	A Master robot is selected and a Slave robot selected by a user supplied IP-address.

#### To connect the Manual network

- 1. In the Header, hold down Run to access Expert Mode.
- 2. Enter password and tap OK.
- 3. Under Kinematics calibration, select Dual Robot Calibration.



- 4. Choose the Master robot and the Slave robot:
  - a. On the Master robot, tap Master.
  - b. On the Slave robot, tap **Slave**.
- 5. On the Master robot tap the IP address field and enter the IP address or the host name of the Slave robot.
- 6. Tap **Connect network** to establish the network connection.

Run Program Installation Mov		PROGRAM <b><unname< b=""> INSTALLATION <b>default</b></unname<></b>	d>	Open Save	R+	Local	с с с с	$\equiv$
6	Enter the other robot's IP a	ddress						
File Editor	IP address or host name	9	1. Conne	ect the two robots	to a Ethernet netwo	rk		
Calibration	Connect	network		ect this robot with ress 'Connect netv	the other robot by e vork'	ntering th	ie IP add	ress
Joint Zeroing								
	Master ☑ Save calibration ☑ Correct home position	Slave						
	<b>Measurement status</b> Number saved State status	0 of 0						
	Main state	No state						
	This Robot	No state						
	Second Robot	No state						
					Back H	ome	Exit	:
O Idle	Speed	· 100	)%	000	)	Simu	ation	

### 3.5.2. Method 2: Master/Slave connection

Use this method only for robots connected directly with single network cable.

#### NOTICE

The network communication between the Master robot and the Slave robot can break down, causing the calibration to stop.

· Follow the on-screen prompt to resume the process

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#### NOTICE

The Master / Slave network connection uses self-assigned IP addresses, which can interfere with local area network devices.

#### Connecting the Master / Slave network (Method 2)

Network connection type	IP Address
Master	10.17.17.18
Slave	10.17.17.19

Define the network connection types as listed in the following table:

#### To connect the Master / Slave network

- 1. Use a network cable to connect the Ethernet ports of the two robot Control Boxes.
- 2. On PolyScope, in the Header, hold down Run to access Expert Mode.
- 3. Enter the password: lightbot and tap OK.



4. Under Kinematics calibration, select Dual Robot Calibration.



- 5. Choose the Master robot and the Slave robot:
  - a. On the Master robot, tap Master.
  - b. On the Slave robot, tap Slave.



6. On the Master robot, tap Connect network to establish the network connection.

File Editor	Enter the other robot's IP		1. Connect the	two robots to a Ethernet ne	twork
Calibration	Connec	t network		robot with the other robot k connect network'	by entering the IP address
Joint Zeroing			]		
	Master Save calibration Correct home position	Slave Save calibration Correct home position			
	Measurement status Number saved	0			
	<b>State status</b> Main state	Not connected			
	This Robot Second Robot	Not connected Not connected			
				Back	Home Exit

## 3.6. How to attach the Calibration Connector

The Calibration Connector attaches the two robot arms via the tool flanges.

#### To attach the Calibration Connector

- 1. Verify both robot arms are correctly attached to the Calibration Horse.
- 2. For each robot arm: On PolyScope, tap **Move** and select the **Home** button to return each robot arm to the Home position.

### UNIVERSAL ROBOTS

- 3. When the robots return to home position, attach the Calibration Connector to the designated Master robot.
- 4. Tap **Proceed** in the pop-up.
- 5. Tap Connect Robots.

File Editor	Conne	ct robots	Connect robots 1. Mount the robots tool flanges together.	
Calibration Joint Zeroing	🖬 Auto step		2. Press "Connect robots" to connect the tools. Caution: The Robots will begin to move.	
	Master ☑ ISave calibration ☑ Correct home position	Slave Save calibration Correct home position		
	<b>Measurement status</b> Number saved	0 of 0		
	<b>State status</b> Main state	Idle		
	This Robot	Idle		
	Second Robot	Idle		
			Back Home	Exit

As both robots move to bring the tool flanges close to each other, the Slave robot enters Freedrive.

- 6. Align the Slave robot's tool flange with the Calibration Connector.
- 7. Use the four screws and washers to attach the Slave robot's tool flange to the Calibration Connector.

The following illustrations show the Calibration Connector in use:



# 4. Dual robot calibration: Application

This section describes how to calibrate two robots of the same size.

# 4.1. How to calibrate the robots

Dual calibration is performed automatically, so you only need to start the process.

You can select the following options, for each robot before the calibration starts:

- Save calibration: The calculated kinematic calibration is applied and saved on the robot.
- **Correct home position**: Estimates and sets the Home Position using the calibration (define new joint offset angles).

#### To start the calibration

- 1. Ensure the Calibration Conector securely attaches both tool flanges.
- 2. If operator intervention is required during the calibration, you can disable the Auto step checkbox.
- 3. Tap Proceed and stand clear of the robots, as they start moving around.

Run Program Installation Mo		PROGRAM INSTALLATION	<unnamed></unnamed>		Save		сс сс	
File Editor Calibration Joint Zeroing	Connec	t robots	2. Press "Cor	nect robots"	anges together. to connect the to <b>will begin to m</b>			
		Slave ☑ Save calibration ☑ Correct home position						
	Measurement status Number saved State status Main state	0 of 0 Idle						
	This Robot Second Robot	Idle Idle						
0	Speed C	100%	O	00	Back	Home 11:24:3 June 22	Exit 39 2, 2018	(l)

## 4.2. Measuring positions and calibration statistics

Measurements are collected during dual calibration, as the robots continue to move around. A preliminary calibration is calculated, then replaced by the final calibration calculation.

	🕂 🙀 😡 🔤 PROSRAM KURNAMED 🔓 💼 🖬 🤤 C 🗧		Here Rockand Curranted>
File Editor	Start motion Colecting initial measurements	File Editor	Calculate Calculating the calibration
Calibration	Auto step	Calibration	Auto step
Joint Zeroing		Joint Zeroing	
	Slave         Slave <th< th=""><th></th><th>Master Binve Sieve cathration Sieve cathration Correct home position Correct home position</th></th<>		Master Binve Sieve cathration Sieve cathration Correct home position Correct home position
	Measurement status Number saved 3 of 337		Measurement status Number saved 337 of 337
	State status Main state Executing		State status Main state Executing
	This Robot Executing		This Robot Idle
	Second Robot Executing		Second Robot Idle
	Back Home Exit		Back Home Exit
0	Speed 100% U D 11.27.62	0	Speed 22,2018
1	Collecting the measurements	2 C	alculating the calibration

At the end of the dual calibration, a Calibration Results box provides a report on the success of the calibration. If the Calibration Results box appears as green text, then the calibration was successful. If the calibration Results box appears as red text, then the calibration was unsuccessful, and the procedure continues.

The Calibration Results provide statistics in millimeters (mm) and milliradians (mrad) which refer to the RMS deviation in Cartesian Space, as follows:

┌Calibration Results—		
Mean deviation	0.877 mrad	0.284 mm
Standard deviation	0.420 mrad	0.161 mm
Max deviation	2.540 mrad	0.907 mm

- Mean deviation: The average deviation in millimeters and in milliradians between the positions measured by the first and second robot.
- Standard deviation: The standard deviation calculated on the basis of the above.
- Max deviation: The maximal measured deviation.

### 4.2.1. Verifying a successful calibration

The calibration is successful if the criteria listed below are met.

- The mean deviation is less than 1 mm and 2 mrad.
- The standard deviation is less than 0.5 mmand 1 mrad.
- The difference between the Calibration Results and Control Results is no more than 50%.
- In the Scale Result, the Error value is less than the Limit value.



### 4.2.2. Troubleshooting a failed calibration

To find solution/s for a failed calibration, you can use one or more of the troubleshooting methods listed below.

- · Check security settings are set to least restricted.
- Remove the tool connector and unmount the robots from the Calibration Horse. Clean all surfaces on the robots, the Calibration Horse and the tool connector. Remount the robots while making sure that nothing is stuck between the parts.
- If one or more joints have been replaced, check that they are mounted correctly. For example, check the screw washers are on the correct side of the output flange.
- If one or more joints have been replaced, adjust the joint's zero position (see the Service Manual).

Start a new calibration when you finish the troubleshooting method/s.

### 4.3. Separating calibrated robots

This procedure has the following success criteria:

 Both robot tool flanges are disconnected from the Calibration Connector and completely free from screws and alignment pins etc.



#### CAUTION

Either robot can enter a Protective Stop while disconnecting.

- · Remove the Tool Connector and jog the robots to separate the robots manually.
- When the robots are separate and the Protective Stop is cleared, the disconnection dialog box reappears on PolyScope and you can retry the step.

### 4.3.1. To separate the calibrated robots

- 1.
- 2.

#### NOTICE

Tapping Proceed before removing all of the screws from the Tool Connector on the Slave robot, can lead to protective stops.

• Verify all screws are removed and clear the Protective Stop/s. Once this is done, try tapping Proceed again.

## 4.4. Validating calibration results

The results of the dual robot calibration are permanently saved after a successful validation.

#### To validate a calibration

1. When the Remove tool box appears, the validation is successful. Tap **Proceed** and remove the Calibration Connector.



- 2. Remove the Calibration Connector and all alignment pins and screws.
- 3. Use the Go / NoGo tool to verify the distance between the tool flanges are within a distance of 2.5 mm.

- Verify the 1.5 mm *Go* tool can pass between the robots tool flanges.
- Verify the 3.5 mm NoGo tool cannot pass between the two robots tool flanges.



- 4. When the Verify position dialog appears, tap **Proceed** to verify the robots home position.
- 5. Save the calibration and tap Exit.
- 6. In the Header under Run, tap the Exit icon to exit Expert Mode.

		PROGRAM INSTALLATION	<unnamed> default*</unnamed>	New Ope	n Save		с с с с
File Editor	Start	motion	Collecting 'init	tial' measure	ements		
Calibration	🗹 Auto step						
Joint Zeroing	Master Save calibration Correct home position	Slave Save calibration Correct home position					
	<b>Measurement status</b> Number saved <b>State status</b>	3 of 337					
	Main state	Executing					
	This Robot Second Robot	Executing Executing					
					Bacl	k Home	Exit
0	Speed 🦳	100%			0	11:27: June 22	

### 4.4.1. The Go/NoGo tools

The *Go* / *NoGo* tools are two pieces of cardboard, of different thicknesses, that verify the success of the calibration. The *Go* tool passes through the space between a pair of correctly calibrated tool flanges. The *NoGo* tool cannot pass between that space.



After calibration, when the Calibration Connector is removed and the tool flanges approach each other, use the *Go / NoGo* tools to verify the distance between the tool flanges.

## 4.5. Resetting a calibration

You can manually reset or adjust a calibration by editing the following file:

root/.urcontrol/calibration.conf

Before editing the file, backup your original calibration file by saving it under a different name.

To reset the calibration

- 1. Set all numbers in delta arrays to zero and increase file\_save\_count by one.
- 2. Then reboot the robot to apply the changes.

The example below illustrates a case where all numbers in the delta arrays to zero.

```
[mounting]
  delta_theta = [ 0, 0, 0, 0, 0, 0]
2
  delta_a = [ 0, 0, 0, 0, 0, 0]
з
  delta_d = [ 0, 0, 0, 0, 0, 0]
4
  delta_alpha = [ 0, 0, 0, 0, 0, 0]
5
  joint_checksum = [ 0xb86d04a5, 0x8d29526e, 0x21a274b7, 0x5134a655, 0xc44d7e89,
6
      0x1be4dbeb]
  calibration_status = 2 # 0 == notInitialized / 1 == notLinearised / 2 == Linearised
7
  joint_raw_offset = [ 0.1, -.81973522672052201e-05, 3.81973522672052201e-05,
8
       .81973522672052201e-04, 0, 1.3]
  joint_selftest_data_crc = [ 0xfd8c0ed6, 0x9c3bef33, 0xfcca0113, 0x3ddc1b38, 0xad3f2781,
9
      0x848b8665]
  file_save_count = 2
10
```

# 5. Automatic program correction

This section describes how to correct a program automatically. Program correction uses key waypoints to allow a single program to work when moved from one uncalibrated robot to another.

Key waypoints make up a model that corrects the loaded program on a new robot. The model is specific to each installation file on the robot.

The quality of the model is detemined by the following:

- The number of key waypoints.
- The accuracy of the key waypoints.
- The distance betweeen each key waypoint.

You can also use program correction after a robot joint replacement.



#### NOTICE

Automatic program correction currently only supports fixed waypoints. Other waypoints types are not supported.



#### NOTICE

You can manually correct any unsupported program nodes when the automatic program correction is complete.

Automatic program correction currently does not support:

- · Move nodes with Use Joint Angles selected
- Palletizing

## 5.1. Accessing the Correction model

This section describes how to access the Correction model by enabling Program Correction.

#### NOTICE

A saved, corrected program cannot be edited or re-corrected.

• Backup and save your original program.

#### To access the Correction model

- 1. On PolyScope, in the Header, press and hold Run to access Expert Mode.
- 2. Enter the password: *lightbot* and tap **OK**.

Rame Program installation Move 10 Log	PROGRAM <b><unnamed></unnamed></b> INSTALLATION <b>default</b>	New Open	Save	сс <b>=</b>
	Enter passwor	°d		
[	ОК Са	ncel		
		licer		
Speed	100%		D	13:25:44 July 27, 2018

- 3. In the side menu, select **Calibration** and, under Joint/Robot replacement, tap **Program correction by key-waypoints**.
- 4. Tap the exit button under Run to exit Expert Mode.

Run Program Installation Mo		PROGRAM <unnamed> INSTALLATION default</unnamed>	New Open Save	° ° 💾
File Editor • Calibration Joint Zeroing	Joint/Robot replacement Program correction - by key-waypoints	<ol> <li>Exit Expert mode</li> <li>Select "Program Corr.</li> <li>Load program(s) with</li> <li>Select and redefine ke</li> <li>When programs are I</li> <li>Test the corrected pr</li> </ol>	ey-waypoints oaded they will be corrected	
	Kinematics calibration Dual Robot Calibration		s the relation between joint ang ne accuracy and linearity of the	
0	Speed C	∋ 100%	000	13:52:27 July 27, 2018

- 5. In the Header, tap the Hamburger Menu and select Program Correction.
- 6. Enter the password: *lightbot* again to access the Correction model node on the **Program Correction** screen.

# 5.2. Redefining key waypoints

This subsection illustrates an example of a simple Pick and Place program, to describe how to redefine a key waypoint.



#### To redefine a key waypoint

- 1. Tap Load Program and select a program to load into the Correction Model, to create a correction model program tree.
- 2. In the new correction model program tree, select one of the key waypoints.

The waypoints in the Correction Model tree that are not re-taught are displayed in italics with the undefined waypoint icon.

Co Program C	Reagram		Have	Ś	2				RAM <unnamed: ION default</unnamed: 	Naw	Open	Save			с с с с	=
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- 3. Tap Change this waypoint to redefine the configuration for the selected waypoint.
- 4. When the Move Tab is activated, teach the robot a new position and tap OK.

Correction model P:PickPlace	Waypoint: pick			
			Move to old position Old joint angles [-88.84 -105.16 -143.28 -22.96 91.46 1. Change this waypoint	09]。
			Reset	

### 5.2.1. Using the Corresponding Tool Position (CTP)

The CTP is the endpoint of the robot with, or without, picked objects. The CTP improves the accuracy of the correction by redefining the waypoint and defining individual key waypoints.

Typical CTP locations include: The Tool Center Point (TCP) where the object is picked and the end point where the object is placed.

Program C Program Installation 40 Nove 10	Log	PROGRAM <unnamed></unnamed>	
▼ correction model         ♥ [P:PickPlace         ♥ ∰ Movel         □ @ To_Pick         ♥ ∰ Movel         □ @ Dolk         ■ Set DO[0]=On         ● Movel         □ @ To_Pick         ♥ Movel         □ @ To_Piace         ● Movel         □ @ To_Piace         ● Movel         □ @ To_Piace         ● Movel         □ @ To_Piace	Setting the Correspondent Setting the Correspondence of the Corr	ending Tool Position	OK
Speed			13:47:29 July 27, 2018

#### To use the CTP

- 1. Tap Change CTP to specify the CTP location.
- 2. Change the CTP coordinates and tap OK to redefine the "pick" key waypoints.
- 3. Continue to redefine waypoints until all key waypoint are redefined.

### 5.2.2. Using waypoints from multiple programs

Add key waypoints from multiple programs, if the key waypoints are distributed over multiple programs.



### To use waypoints from multiple programs

1. Select the root node of the Correction Model tree and tap Load Program.

### 5.2.3. Using key waypoint groups

The key waypoints are grouped according to the source robot's relationship to new robot's installation. Each key waypoint is named and refers to the source source program.



- You can expand the Correction Model node for an overview in the Correction Model tree.
- You can select a waypoint, or a group of waypoints, and tap **Delete** to remove selected key waypoints from the **Correction Model** tree.

# 5.3. Correcting a program

#### NOTICE

Saving an untested program overwrites any previous programs.

· Test and correct the unsaved program before saving it.

#### To correct a program

- In the Program Correction screen, tap Load Program and select the program to correct. The robot controller software detects if a correction is applicable.
- 2. Once the Correct Program Waypoint pop-up appears, select **Correct Waypoints**. Another pop-up indicates when the correction is done.

- If the correction failed, verify and improve the key waypoints.
- If better accuracy is required, you can add additional key waypoints to the Correction Model and start the program correction again.
- 3. Once the program is successfully corrected, tap the play button and allow the robot to move through the waypoints. You can also select individual waypoints and use the **Move Robot Here** functionality.
- 4. Save the corrected program under a new name.

	PROGRAM <unnamed></unnamed>	сс <b>—</b>
▼       Correction model         ▼       ▼         ↓       ⊕	+ Load Program         Overview of saved key-waypoints         SN: 200020004 robot to this robot <ul> <li>Installation: default</li> <li>PickPlace, pick</li> <li>PickPlace, Place</li> </ul>	This Robot Information: Serial Number: 20155512345 Checksum: 0x5769ffa0 Old Robot: Serial Number: 2000200004 Checksum: 0x35461a80 Corresponding Tool Position: [0.0, 0.0, 0.0] mm
Speed Speed		13:47:29 July 27, 2018

# 6. Tool drawings

# 6.1. Calibration Horse

The UR3e and the UR10e robot arms are mounted in different positions.



6.2. Calibration Connector



# 7. Copyright and disclaimers

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# 7.1. Calibration and programming of robots patent

The Dual Robot Calibration method is covered by one, or more, of the following patents:

- CN103889663 B
- CN104991518 B
- EP2760642 B1

- EP2796249 B1
- JP6182143 B2
- MX343142 B

- RU2605393 C2
- US9248573 BB
- US9833897 BB

The Dual Robot Calibration method is also covered by one, or more, of the following patent applications:

- BR112014007077 A2
- SG10201502615Q A1
- SG11201400923Q A1
- TH141798 A

Software Name: PolyScope 5 Software Version: 5.21 Document Version: 10.11.72