



USER MANUAL

HEX

Force Torque Sensor

For the KUKA KRC4

Edition E7

OnRobot FT KUKA Software Version 3.1.3

June 2018

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1 Preface

1.1 Target Audience

This document is intended for integrators who design and install complete robot applications. Personnel working with the sensor are expected to have the following expertise:

1. Basic knowledge of mechanical systems
2. Basic knowledge of electronic and electrical systems
3. Basic knowledge of the robot system

1.2 Intended Use

The sensor is designed for measuring forces and torques, installed on the end effector of a robot. The sensor can be used within the specified measurement range. Using the sensor outside of its range is considered misuse. OnRobot is not liable for any damage or injury resulting from misuse.

1.3 Important safety notice

The sensor is *partly completed machinery* and a risk assessment is required for each application the sensor is a part of. It is important that all safety instructions herein are followed. The safety instructions are limited to the sensor only and do not cover the safety precautions of a complete application.

The complete application must be designed and installed, in accordance with the safety requirements specified in the standards and regulations of the country where the application is installed.

1.4 Warning Symbols

**DANGER:**

This indicates a very dangerous situation which, if not avoided, could result in injury or death.

**WARNING:**

This indicates a potentially hazardous electrical situation which, if not avoided, could result in injury or damage to the equipment.

**WARNING:**

This indicates a potentially hazardous situation which, if not avoided, could result in injury or major damage to the equipment.

**CAUTION:**

This indicates a situation which, if not avoided, could result in damage to the equipment.

**NOTE:**

This indicates additional information such as tips or recommendations.

1.5 Typographic Conventions

The following typographic conventions are used in this document.

Table 1: Conventions

| | |
|---------------------------|--|
| <code>Courier Text</code> | File paths and file names, code, user input and computer output. |
| <i>Italicized text</i> | Citations and marking image callouts in text. |
| Bold text | UI elements, including text appearing on buttons and menu options. |
| Bold, blue text | External links, or internal cross-references. |
| <angle brackets> | Variable names that must be substituted by real values or strings. |
| 1. Numbered lists | Steps of a procedure. |
| A. Alphabetical lists | Image callout descriptions. |

2 Getting Started

2.1 Scope of Delivery

In the KUKA KRC4 OnRobot HEX Sensor Kit everything is provided that is required to connect the OnRobot force/torque sensor to your KUKA robot.

- OnRobot 6-axis force/torque sensor (variant HEX-E or HEX-H)
- OnRobot Compute Box
- OnRobot USB Drive
- Adapter-A, B, or C
- safety plug
- sensor cable (4 pin M8 - 4 pin M8, 5 m)
- Compute Box power cable (3 pin M8 – open ended)
- Compute Box power supply
- UTP cable (RJ45 - RJ45)
- USB cable (Mini-B – Type A)
- PG16 cable gland
- plastic bag, containing:
 - cable holder
 - M6x30 screws (2)
 - M6x8 screws (10)
 - M5x8 screws (9)
 - M4x8 screws (7)
 - M4x12 screws (2)
 - M4 washer (8)

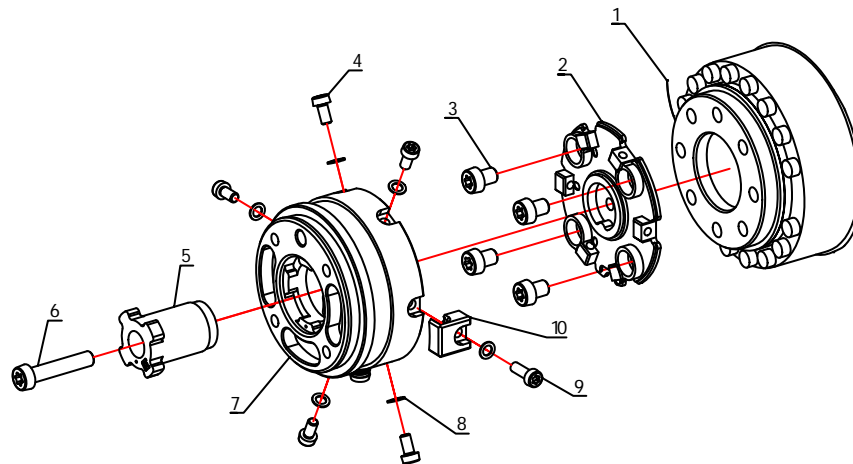
2.2 Mounting

Use only the screws provided with the sensor. Longer screws could damage the sensor or the robot.

2.2.1 ISO 9409-1-50-4-M6 Tool Flange

To mount the sensor to *ISO 9409-1-50-4-M6* tool flange, follow this process:

1. Fasten Adapter-A to the robot by four M6x8 screws. Use 6 Nm tightening torque.
2. Fasten the Sensor to the adapter by five M4x8 screws with M4 washers. Use 1,5 Nm tightening torque.
3. Fasten the cable to the Sensor with the Cable Holder by one M4x12 screw and M4 washer. Use 1,5 Nm tightening torque.
4. Fasten the Plug to the Sensor by one M6x30 Screw. Use 6 Nm tightening torque.

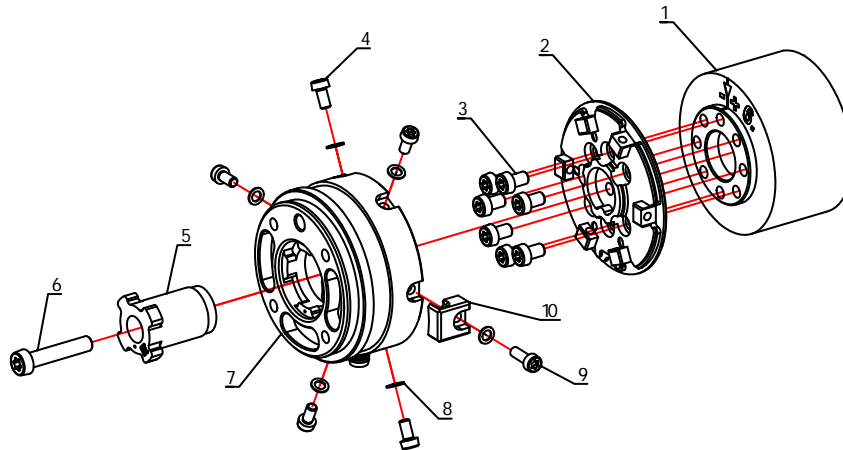


Legend: 1 – robot tool flange, 2 – Adapter-A, 3 - M6x8 screws, 4 – M4x8 screws, 5 – safety plug, 6 – M6x30 screw, 7 – sensor, 8 – M4 washer, 9 – M4x12 screw, 10 – cable holder

2.2.2 ISO 9409-1-31.5-7-M5 Tool Flange

To mount the sensor to *ISO 9409-1-31.5-7-M5* tool flange, follow this process:

4. Fasten Adapter-B to the Robot by seven M5x8 Screws. Use 4 Nm tightening torque.
5. Fasten the Sensor to the adapter by five M4x8 screws with M4 washers. Use 1,5 Nm tightening torque.
6. Fasten the cable to the Sensor with the Cable Holder by one M4x12 screw and M4 washer. Use 1,5 Nm tightening torque.
7. Fasten the Plug to the Sensor by one M6x30 Screw. Use 6 Nm tightening torque.

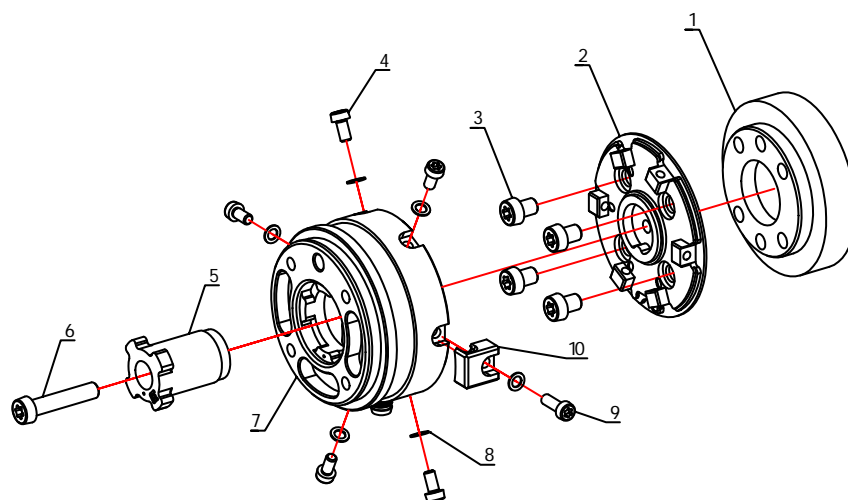


Legend: 1 – robot tool flange, 2 – Adapter-B, 3 – M5x8 screws, 4 – M4x8 screws, 5 – safety plug, 6 – M6x30 screw, 7 – sensor, 8 – M4 washer, 9 – M4x12 screw, 10 – cable holder

2.2.3 ISO 9409-1-40-4-M6 Tool Flange

To mount the sensor to *ISO 9409-1-40-4-M6* tool flange, follow this process:


1. Fasten Adapter-C to the Robot by four M6x8 Screws. Use 6 Nm tightening torque.
8. Fasten the Sensor to the adapter by five M4x8 screws with M4 washers. Use 1,5 Nm tightening torque.
9. Fasten the cable to the Sensor with the Cable Holder by one M4x12 screw and M4 washer. Use 1,5 Nm tightening torque.
10. Fasten the Plug to the Sensor by one M6x30 Screw. Use 6 Nm tightening torque.



Legend: 1 – robot tool flange, 2 – Adapter-C, 3 - M6x8 screws, 4 – M4x8 screws, 5 – safety plug, 6 – M6x30 screw, 7 – sensor, 8 – M4 washer, 9 – M4x12 screw, 10 – cable holder

2.3 Cable Connections

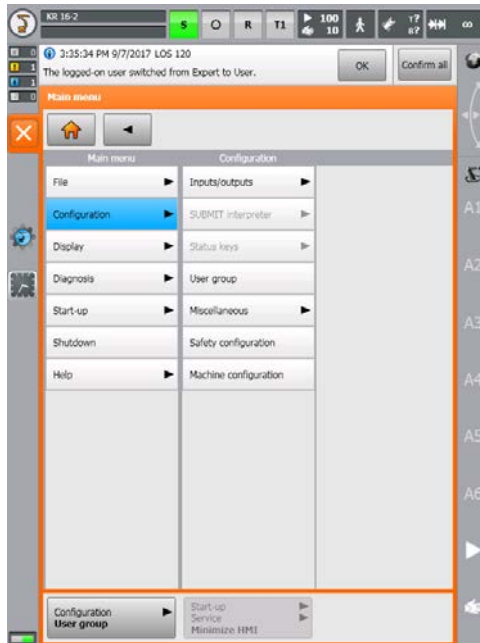
To connect the sensor, follow this process:

1. Connect the 4 pin M8 cable (5m long) to the sensor and secure it to the robot with cable ties.
 Make sure that enough extra cable length is available around the joints for bending.
2. Place the converter somewhere near the KUKA robot control cabinet and connect the 4 pin M8 sensor cable.
3. Connect the Compute Box's Ethernet interface with the KUKA controller's Ethernet interface (KLI) via the supplied UTP cable (yellow).
4. Use the Compute Box power supply to power the Compute Box, and the sensor from a wall socket.
5. Apply the correct network settings to both the Ethernet converter and the KUKA robot. The default Ethernet converter IP address is 192.168.1.1. If you need to change the IP address of the sensor, see [Changing the IP of the Sensor](#).

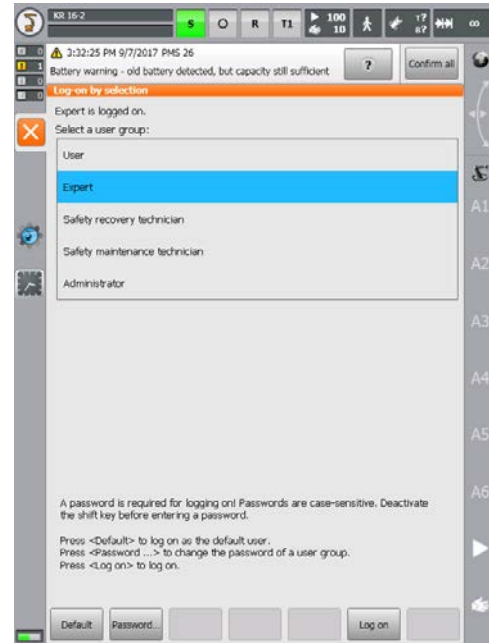
2.4 Software Installation

2.4.1 KUKA Line Interface Setup (Ethernet)

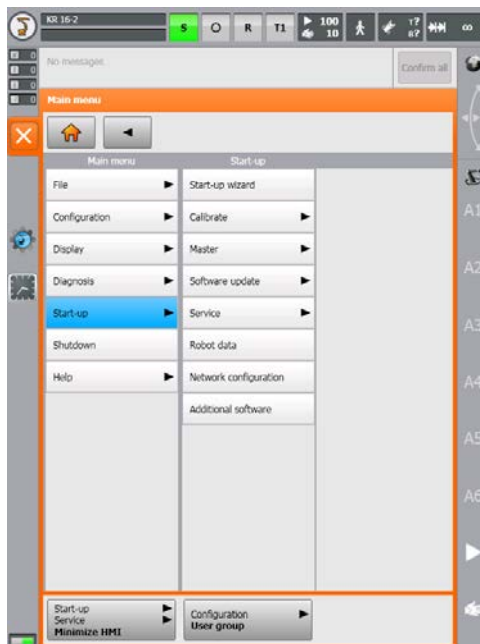
To change the IP settings of the KUKA robot controller, follow this process:



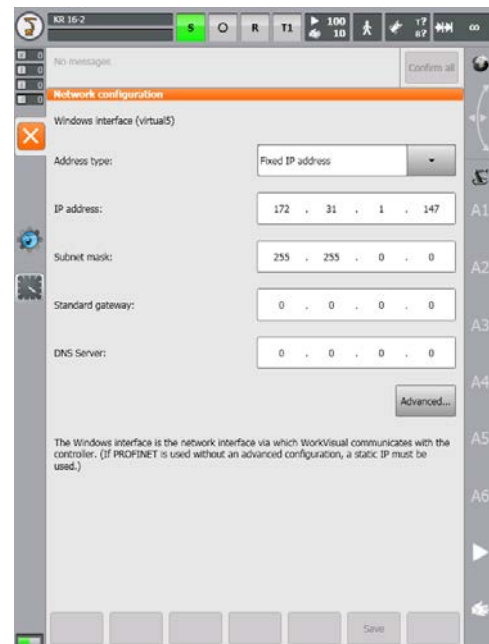
1. Go to 'Configuration' > 'User group'



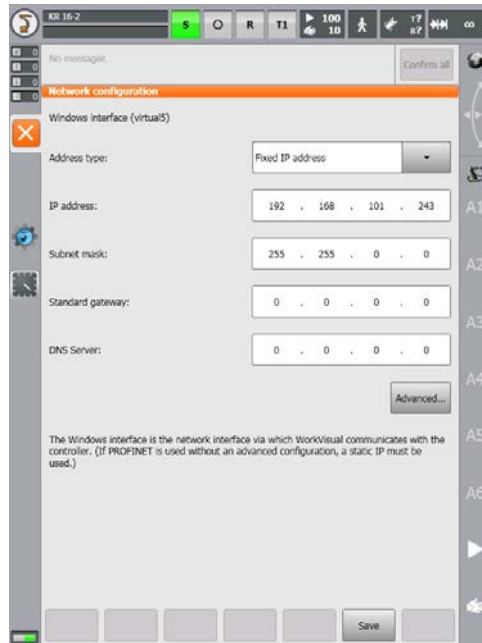
2. Select 'Expert' and type in your password



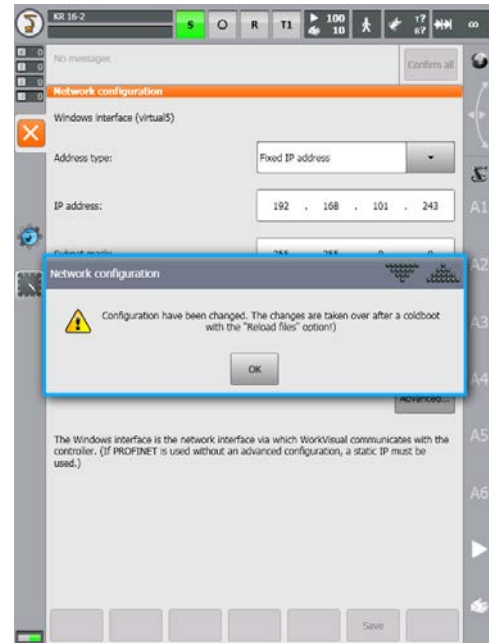
3. Go to 'Start-up' > 'Network configuration'



4. Set the IP address to be on the same subnet as the Compute Box

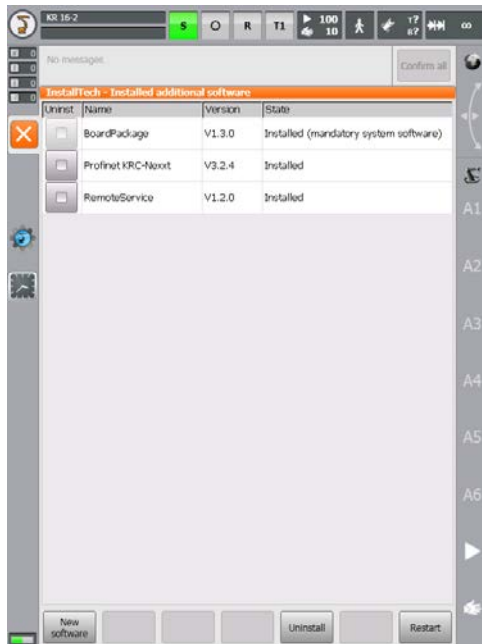


5. Click save

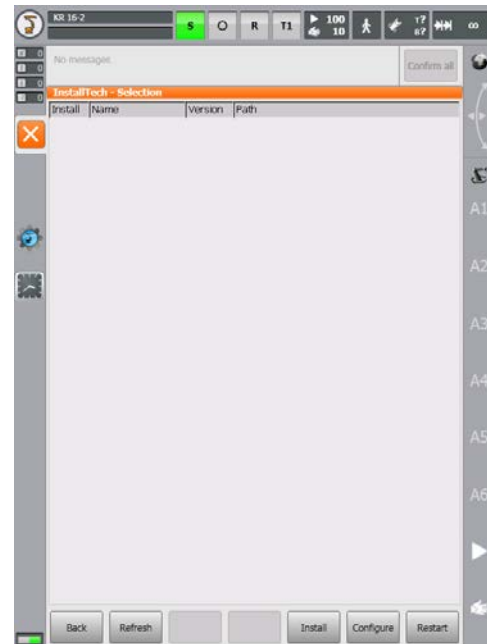


6. Accept the prompts and restart the robot controller

2.4.2 KUKA Robot Sensor Interface Package Installation



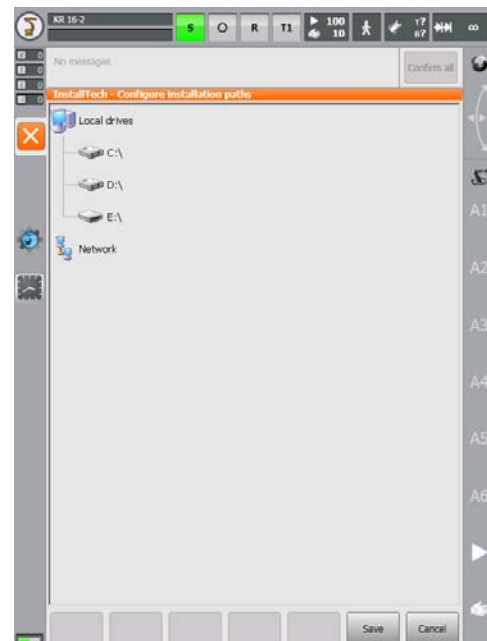
1. Go to 'Start-up' > 'Additional software', click on 'New software'



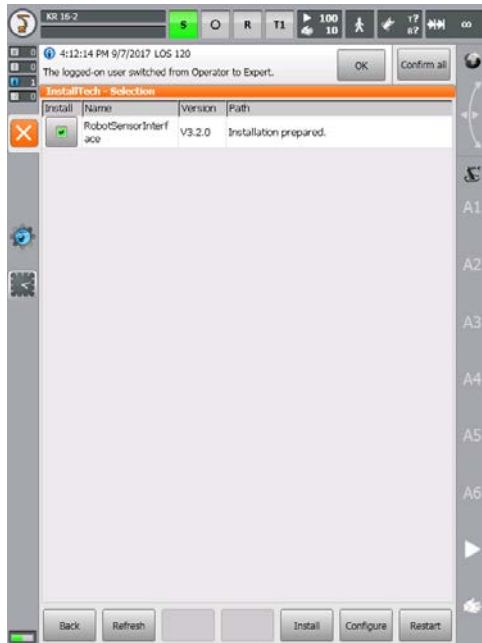
2. If no packages are listed click on 'Configure'.



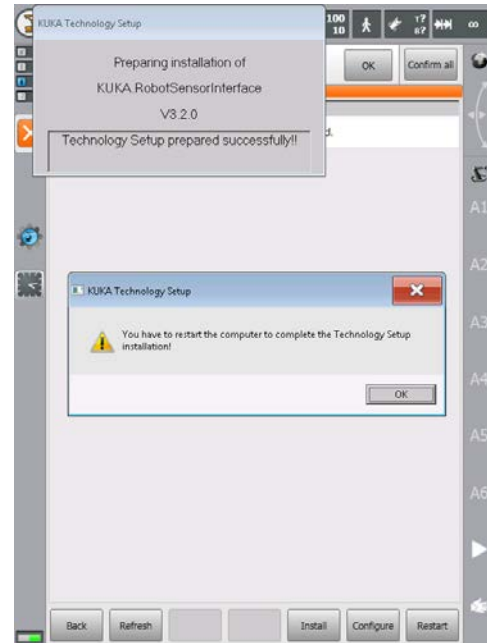
3. Click on an empty slot and click 'Path selection'



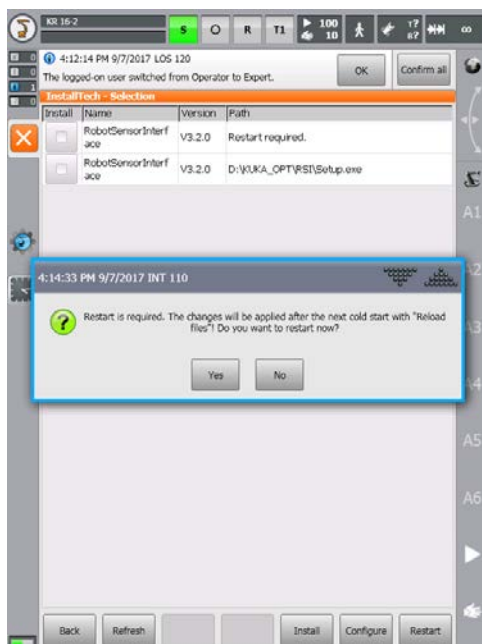
4. Browse for the installation folder of RSI, then click 'Save' twice



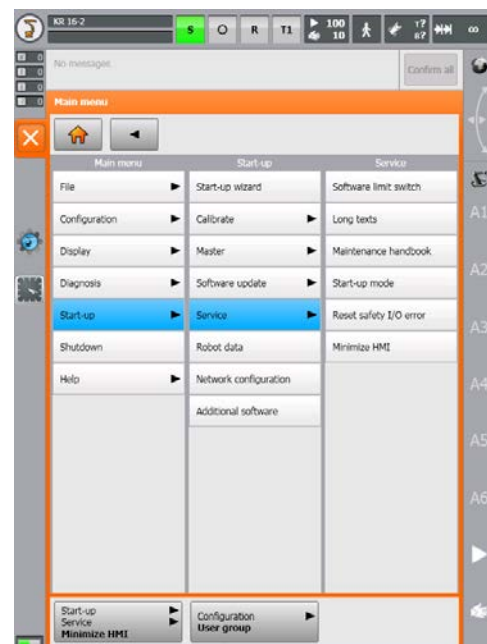
5. Mark the check box next to the RSI package name



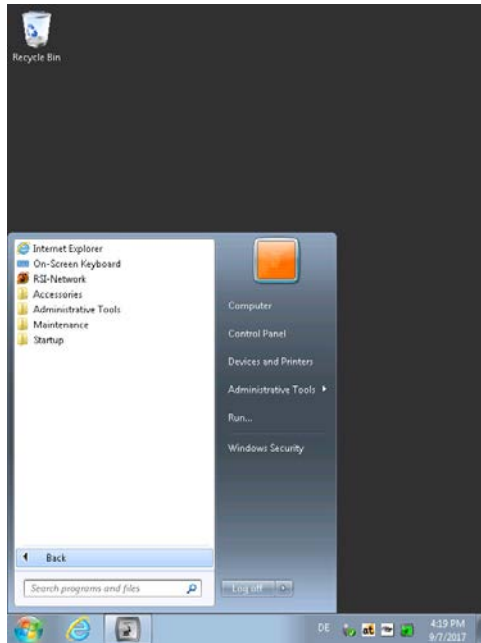
6. Wait for the installation, accept all prompts



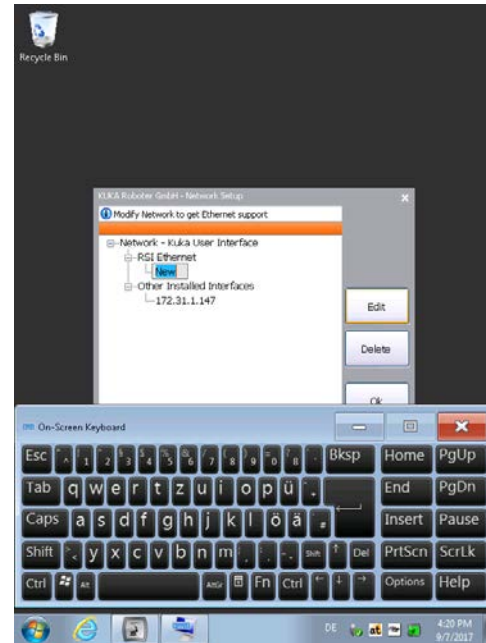
7. Click 'Yes' when asked to reboot the robot controller



8. After the reboot go to 'Start-up' > 'Service' > 'Minimize HMI'



9. Click on the Start menu and open the 'RSI-Network' application



10. Click on the 'New' field under 'RSI-Ethernet' and click 'Edit'. Enter an IP address with a different subnet than KLI

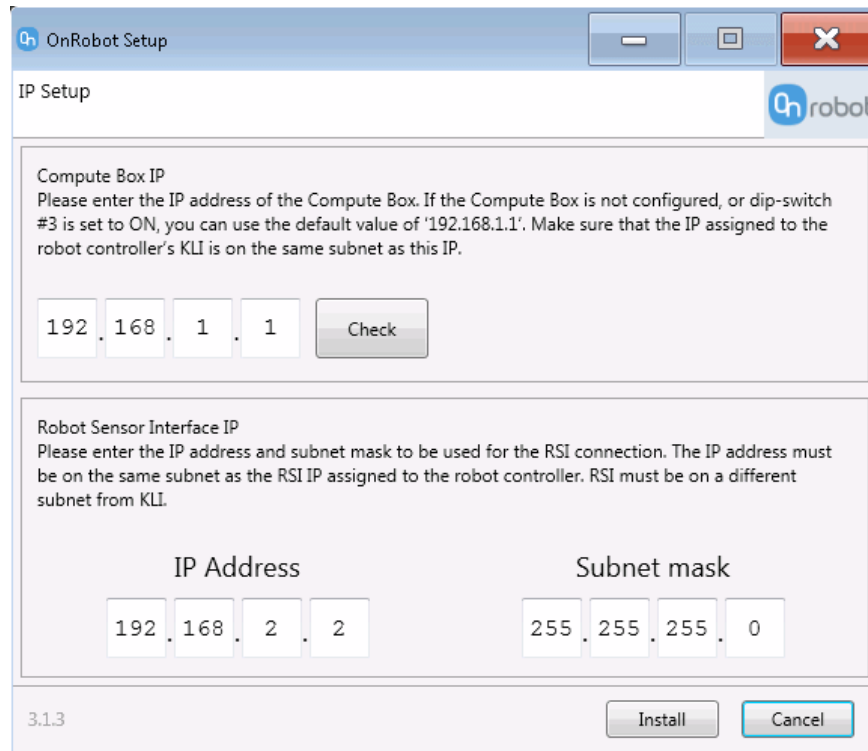
2.4.3 OnRobot KUKA Software Installation

11. Go to 'Main Menu'>'Configuration'>'User group' and select 'Expert' mode. Enter your password, then go to 'Start-up'>'Service'>'Minimize HMI'.
12. Plug the provided USB-drive into one of the control box's USB ports.
13. Browse for the OnRobot KUKA Setup program and launch it. This program has multiple purposes: You can use it for the initial installation of the OnRobot KUKA package, but also as a network configuration tool.
14. On the welcome screen click next.



15. On the next window you will find three input fields. The first is for defining the Compute Box to be used with your robot. The second and third one is for defining the RSI connection.
16. First enter the IP address of the compute box you want to use with the robot. The default address is 192.168.1.1, use this if your Compute Box has not been configured yet or if it is set to fixed IP mode.
17. After entering the IP address click on 'Check'. If the program successfully makes a connection to the Compute Box a green tick mark will appear along with the name of the sensor plugged into the box, and the version of the Compute Box software.
18. After successfully setting the Compute Box IP, continue by entering the IP and subnet mask for the RSI connection.

19. The IP you enter here must be on the same subnet as the one you defined during the RSI setup. (E.g.: if you set 192.168.173.1 for RSI on the robot controller set 192.168.173.X here. X can be any number between 2 and 255.) Make sure that you also use the same subnet mask as on the robot controller.



The image shows a screenshot of the 'OnRobot Setup' window, specifically the 'IP Setup' tab. The window has a title bar with the OnRobot logo and standard Windows window controls. The main content area is divided into two sections. The first section is titled 'Compute Box IP' and contains a text box with the instruction: 'Please enter the IP address of the Compute Box. If the Compute Box is not configured, or dip-switch #3 is set to ON, you can use the default value of '192.168.1.1'. Make sure that the IP assigned to the robot controller's KLI is on the same subnet as this IP.' Below this text box are four input fields containing the numbers 192, 168, 1, and 1, followed by a 'Check' button. The second section is titled 'Robot Sensor Interface IP' and contains a text box with the instruction: 'Please enter the IP address and subnet mask to be used for the RSI connection. The IP address must be on the same subnet as the RSI IP assigned to the robot controller. RSI must be on a different subnet from KLI.' Below this text box are two groups of input fields. The first group is labeled 'IP Address' and contains four fields with the values 192, 168, 2, and 2. The second group is labeled 'Subnet mask' and contains four fields with the values 255, 255, 255, and 0. At the bottom of the window, there is a version number '3.1.3' on the left and two buttons, 'Install' and 'Cancel', on the right.

OnRobot Setup

IP Setup

Compute Box IP

Please enter the IP address of the Compute Box. If the Compute Box is not configured, or dip-switch #3 is set to ON, you can use the default value of '192.168.1.1'. Make sure that the IP assigned to the robot controller's KLI is on the same subnet as this IP.

192 . 168 . 1 . 1 Check

Robot Sensor Interface IP

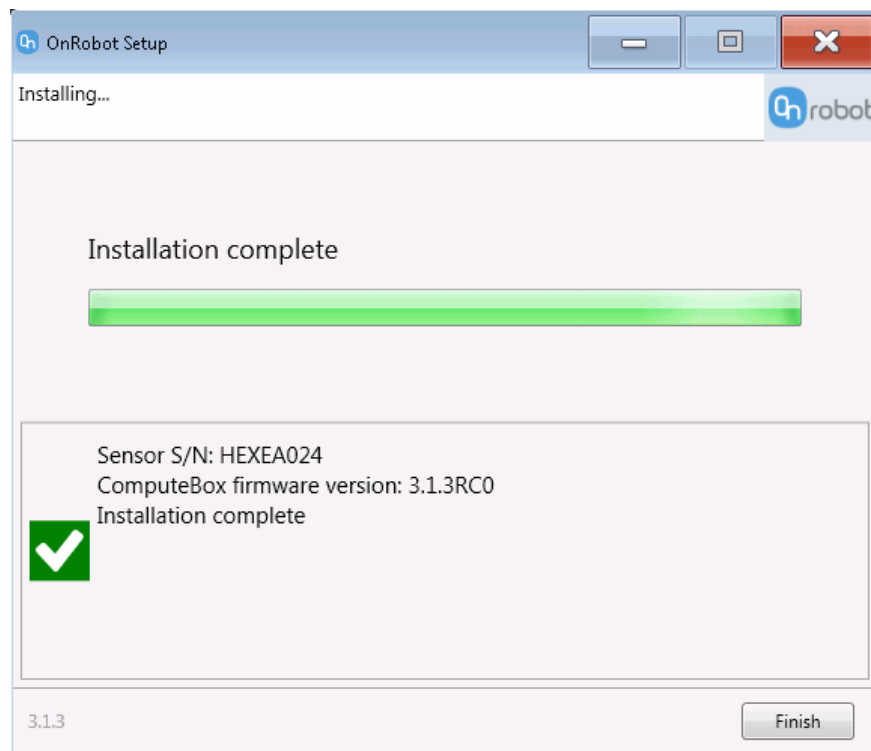
Please enter the IP address and subnet mask to be used for the RSI connection. The IP address must be on the same subnet as the RSI IP assigned to the robot controller. RSI must be on a different subnet from KLI.

IP Address Subnet mask

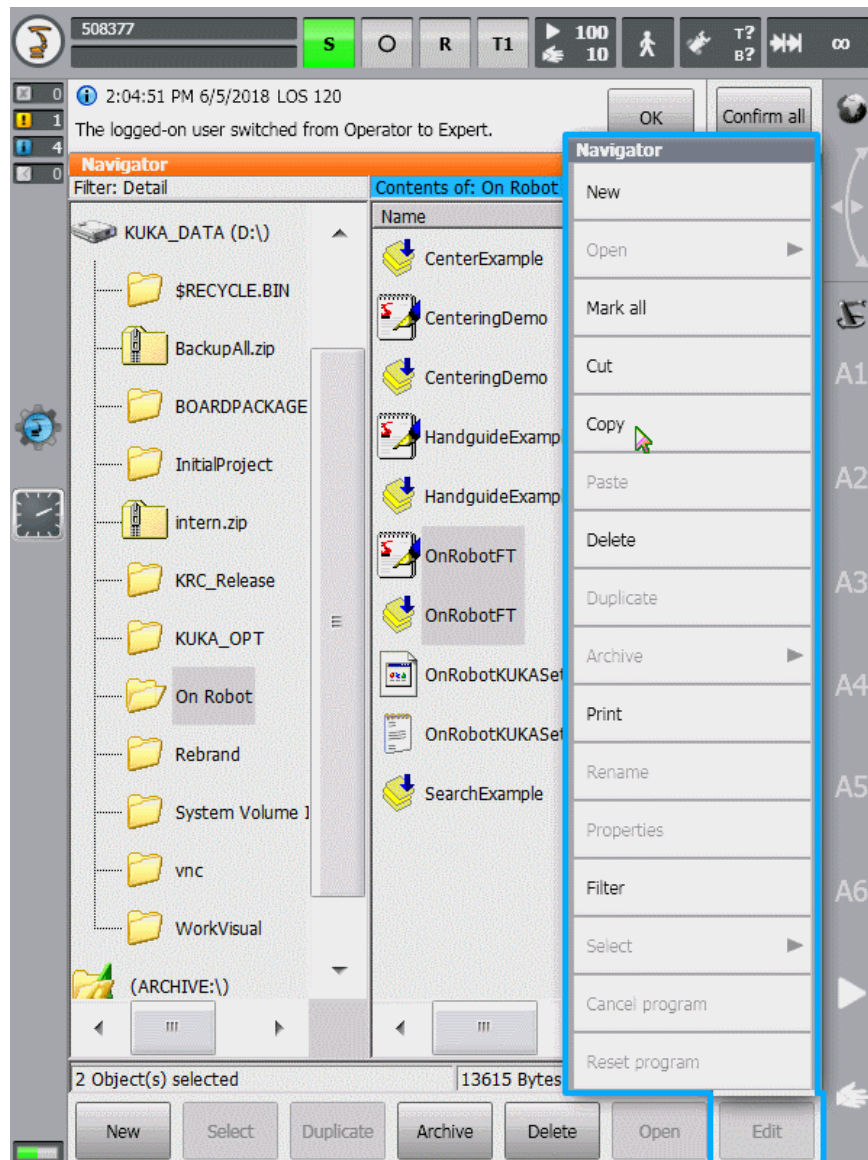
192 . 168 . 2 . 2 255 . 255 . 255 . 0

3.1.3 Install Cancel

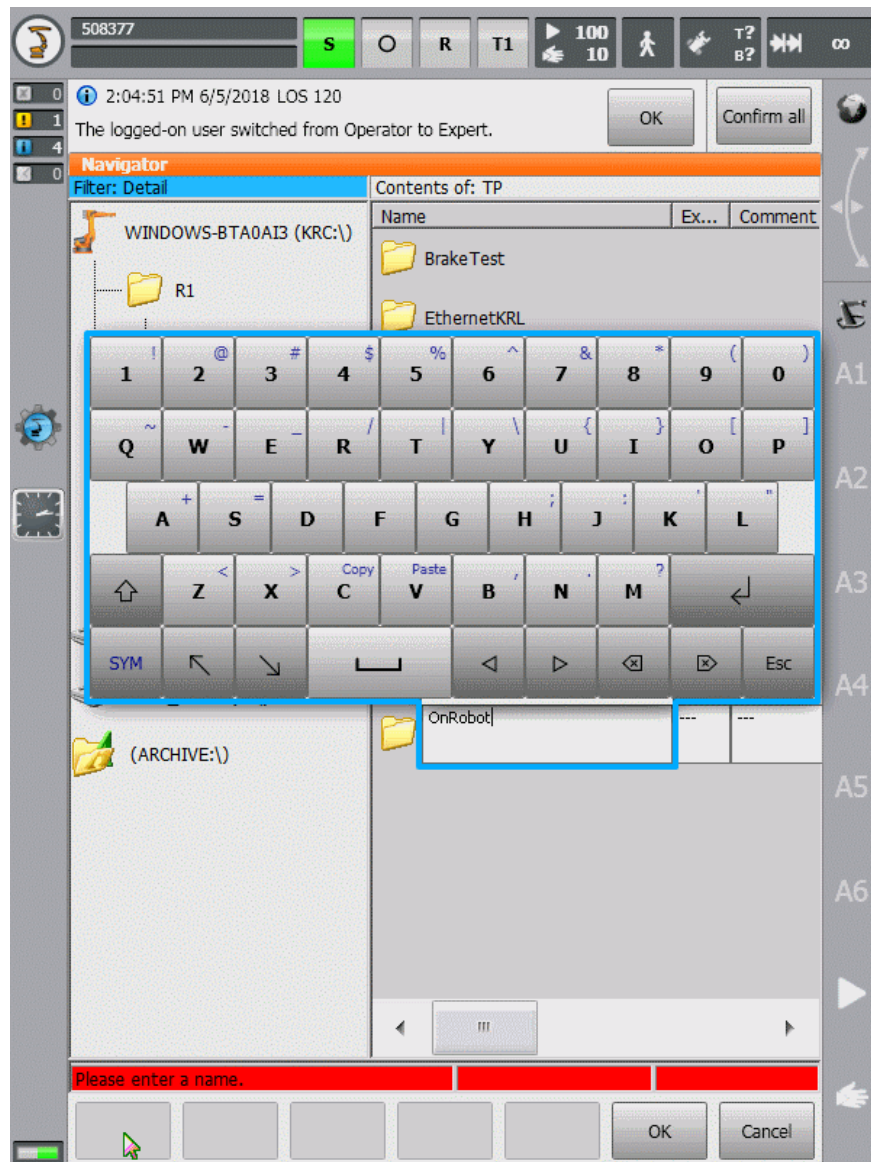
20. After filling in all the fields click on 'Install' to complete the installation/configuration. If the installation has been successful a green tick mark will appear. Installation failure can happen if there's a problem with the connection to the Compute Box or there's write protection on the robot controller's hard drive.



21. To complete the setup, go back to the Smart HMI and in the Navigator go to 'D:\OnRobot '. Select 'OnRobotFT.src' and 'OnRobotFT.dat', then in the 'Edit' menu press copy.



22. Go to 'KRC:\R1\TP' and create a folder with the following name: OnRobot.
Paste the two files into the new folder.



23. Restart the robot controller.

3 OnRobot Package Programming

3.1 Overview

3.1.1 KRL variables

POS (Native)

The native POS structure is used for giving either relative or absolute positions to the search and move functions.

OFFT

This is a structure that is used to define the force limits of a function. Its elements are:

REAL FX,FY,FZ,FX,TY,TZ ;Force and torque values in the sensor coordinate system

REAL F3D,T3D ;Force and torque vector magnitude

BOOL ABS ;This variable decides whether the sign of the F/T values are checked. If set to true, for example, then for a force limit of FX=10 the robot will stop for both a negative and positive F_X load that exceeds this value.

OFAXEN

Structure for enabling axes during hand-guiding.

BOOL X,Y,Z,A,B,C ;If true: movement along or around that axis is enabled.

3.1.2 KRL functions and subprograms

OF_HANDGUIDE()

OF_HANDGUIDE_AXEN()

OF_MOVE()

OF_MOVE_REL()

OF_SEARCH()

OF_SEARCH_REL()

OF_CENTER_REL()

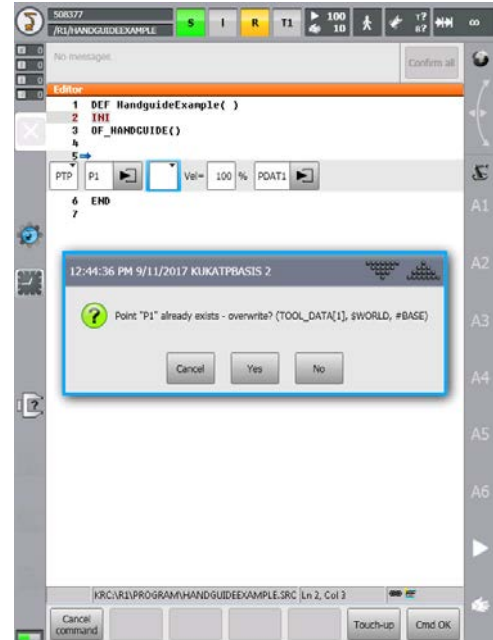
OF_ZERO()

3.2 Hand Guide

3.2.1 OF_HANDGUIDE()

This subprogram launches the sensor guided hand-guide on the robot. The program includes a BCO move to the actual position the program is launched at. In this mode all axes are enabled. **Do not touch the sensor or any attached tools upon starting the program.**

The subprogram can be inserted as the first line after the initializations and declarations to teach points for movement commands. After the robot is guided into the desired position, stop the current program, reset the interpreter back to the beginning of the program, and add a new movement command or use the 'Touch-up' button to modify an existing one. After the teaching, the hand-guide function can be disabled by either deleting the subprogram or commenting it out.



3.2.2 OF_HANDGUIDE_AXEN(...)

This version of the hand-guide subprogram lets the user select certain axes to be enabled during the hand-guide process. **Do not touch the sensor or any attached tools upon starting the program.**

Example:

```

DECL OFAXEN ENABLED_AXES
ENABLED_AXES={X TRUE, Y TRUE, Z FALSE, A FALSE, B FALSE, C
TRUE}
OF_HANDGUIDE_AXEN( ENABLED_AXES )
  
```

This starts the hand-guide process from the actual robot position, with movement enabled in the tool X-Y plane and rotation enabled around the C-axis (X-axis in the sensor coordinate system).

3.3 Collision Detection

3.3.1 OF_MOVE(...) and OF_MOVE_REL(...)

```
INT OF_MOVE(TARGET:IN, FTTARGET:IN, TRANSSPEED:IN,
ROTSPEED:IN)
```

```
INT OF_MOVE_REL(TARGET:IN, FTTARGET:IN, COORD[ ]:IN,
TRANSSPEED:IN, ROTSPEED:IN)
```

This function moves the robot from the actual to the desired position. If the sensor detects an obstacle the movement is stopped if the resulting force exceeds the defined threshold.

Arguments:

- **POS TARGET:** The target position, where the robot needs to move to. In the relative move function this is a distance relative to the starting position.
- **OFFT FTTARGET:** The force and the torque limits set to detect the collision (N, Nm).
- **CHAR COORD[]:** Coordinate system in which the movement will be carried out: "TOOL" or "BASE". Absolute move only works in "BASE", therefore this argument is only applicable for OF_MOVE_REL(...).
- **REAL TRANSSPEED:** Speed of the translation (mm/s).
- **REAL ROTSPEED:** Speed of the rotation (degrees/s).

Return value:

- **2:** Function exited due to a collision.
- **1:** Move completed without collision. (Normal exit state.)
- **0:** Movement did not begin due to the loading limit.

Example:

```
DECL POS P1
DECL OFFT FTLIMIT
DECL INT ret
P1={X 0,Y 0,Z 100,A 0,B 0,C 0}
FTLIMIT={FX 0, FY 0, FZ 0, TX 0, TY 0, TZ 0,F3D 2,T3D 0, ABS
TRUE}
OF_ZERO( )
ret=OF_MOVE_REL(P1,FTLIMIT,"TOOL",10,3)
```

The robot will move 100mm in the positive Z-direction in the TOOL coordinate system, but stops if a total force magnitude of 2 N is reached.

3.3.2 OF_SEARCH(...) and OF_SEARCH_REL(...)

```
INT OF_SEARCH(TARGET:IN, FTTARGET:IN, TRANSSPEED:IN,
ROTSPEED:IN)
```

```
INT OF_SEARCH_REL(TARGET:IN, FTTARGET:IN, COORD[ ]:IN,
TRANSSPEED:IN, ROTSPEED:IN)
```

This function moves the robot from the actual to the desired pose during force control mode. The robot looks for collision and it stops if there was larger force or torque value than the given limit values. If the robot reaches the desired pose without collision, the search was unsuccessful.

This function can be used to search for a contact with a tool or reference point.

Arguments:

- **POS TARGET:** The target position, where the robot needs to move to. In the relative move function this is a distance relative to the starting position.
- **OFFT FTTARGET:** The force and the torque limits set to detect the collision (N, Nm).
- **CHAR COORD[]:** Coordinate system in which the movement will be carried out: "TOOL" or "BASE". Absolute move only works in "BASE" hence this argument is omitted.
- **REAL TRANSSPEED:** Speed of the translation (mm/s).
- **REAL ROTSPEED:** Speed of the rotation (degrees/s).

Return value:

- **2:** Function exited due to a collision. (Normal exit state.)
- **1:** Move completed without collision.
- **0:** Movement did not begin due to the loading limit.

Example:

```
DECL POS P1
DECL OFFT FTLIMIT
DECL INT ret
P1={X 445,Y 100,Z 810,A 180,B 0,C 180}
FTLIMIT={FX 0, FY -10, FZ 0, TX 0, TY 0, TZ 0,F3D 2,T3D 0,
ABS FALSE}
OF_ZERO( )
ret=OF_SEARCH(P1,FTLIMIT,10,3)
```

The robot will move to the given absolute position in the BASE coordinate system (regardless of starting position) and looks for a negative 10 N load. The function returns with a successful value if it finds this load.

3.3.3 OF_ZERO()

This subprogram will signal the Compute Box to record a bias value for the sensor. This biasing should be carried out before any move or search command if it was preceded by an orientation change (). Please make sure no external force is applied to the sensor during biasing, as this may lead to unpredictable program behaviour. Hand-guide subprograms always create a new bias value before start thus no need to call it explicitly.

3.4 Centerpointing

With the OF_CENTER function the center point along one of the six base axes can be found. The axis, the distance along it, and the collision forces need to be defined. The distances are always relative to the starting position of the robot.

3.4.1 OF_CENTER_REL(...)

```
POS OF_CENTER_REL(TARGET:IN, FTTARGET:IN, COORD[ ]:IN,
TRANSSPEED:IN, ROTSPPEED:IN)
```

The function moves the robot along the given axis until it finds an obstacle. After the collision, it moves to the opposite direction until another collision happens. After that the robot calculates the center of the two boundary points and moves to it.

Arguments:

- POS TARGET: The target position, where the robot needs to move to. This is a distance relative to the starting position.
- OFFT FTTARGET: The force and the torque limits set to detect the collision (N, Nm).
- CHAR COORD[]: Coordinate system in which the movement will be carried out: "TOOL" or "BASE".
- REAL TRANSSPEED: Speed of the translation (mm/s).
- REAL ROTSPPEED: Speed of the rotation (degrees/s).

Example:

```
DECL POS RELDIST,FINALPOS
DECL OFFT FTLIMIT
P1={X 200,Y 0,Z 0,A 0,B 0,C 0}
FTLIMIT={FX 2, FY 0, FZ 0, TX 0, TY 0, TZ 0,F3D 0,T3D 0, ABS
TRUE}
OF_ZERO( )
```

```
FINALPOS=OF_CENTER_REL(RELDIST,FTLIMIT,"TOOL",10,3)
```

The robot will start searching in the TOOL X-direction. If a wall is found it will go back to the starting point and search in the opposite direction. After the second collision the robot will move to the center of these two points.

4 Glossary of Terms

| Term | Description |
|----------------------------|---|
| Compute Box | A unit provided by OnRobot along with the sensor. It performs the calculations needed to use the commands and applications implemented by OnRobot. It needs to be connected to the sensor and the robot controller. |
| OnRobot Data Visualization | Data visualization software created by OnRobot, to visualize the data provided by the sensor. Can be installed on Windows operating system. |

5 List of Acronyms

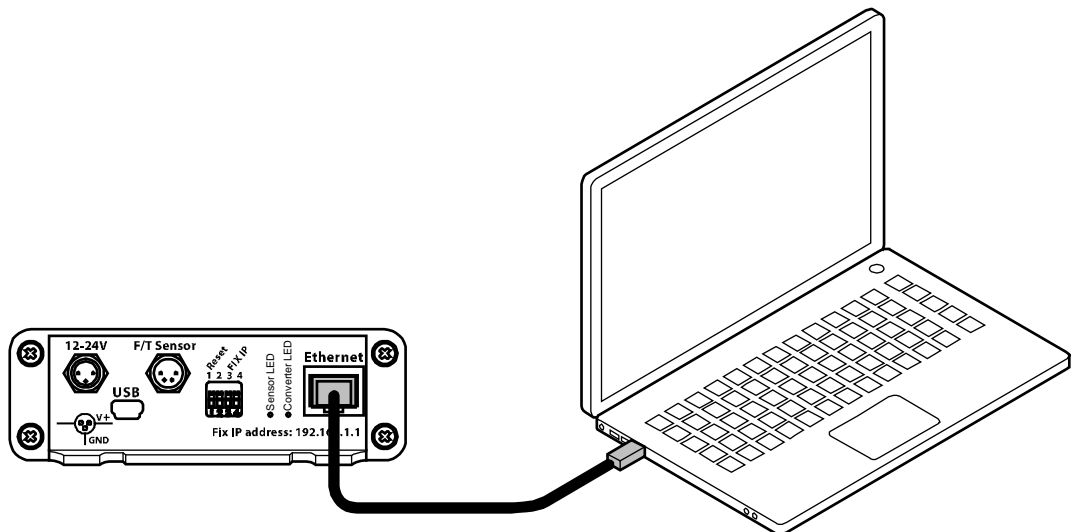
| Acronym | Expansion |
|---------|-------------------------------------|
| DHCP | Dynamic Host Configuration Protocol |
| DIP | dual in-line package |
| F/T | Force/Torque |
| ID | Identifier |
| IP | Internet Protocol |
| IT | Information technology |
| MAC | media access control |
| PC | Personal Computer |
| RPY | Roll-Pitch-Yaw |
| SP | Starting Position |
| SW | software |
| TCP | Tool Center Point |
| UTP | unshielded twisted pair |

6 Appendix

6.1 Changing the IP of the Compute Box

To change the IP address of the sensor, connect your laptop or an external PC to the OnRobot Compute Box.

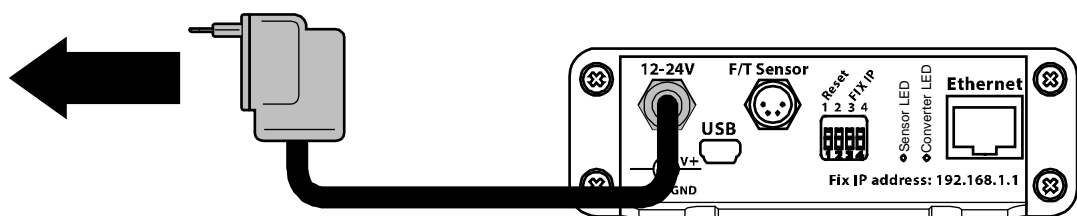
1. Make sure that the device is not powered. Connect the device and the computer with the provided Ethernet cable.



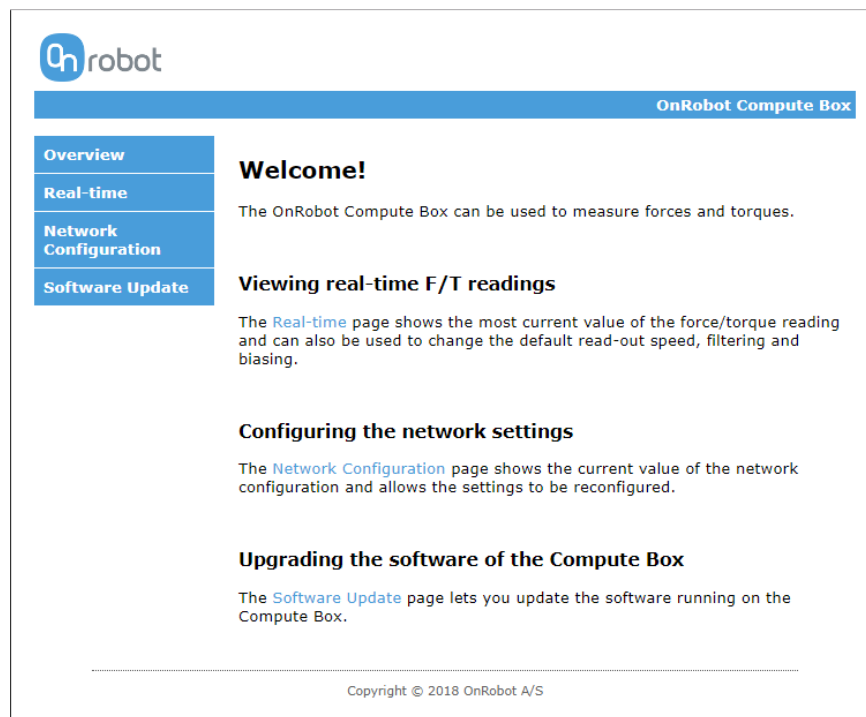
2. If your device is in the factory default settings, proceed to step 3. Otherwise, make sure to switch the DIP switch 3 to the ON position (up) and the DIP switch 4 to the OFF position (down).



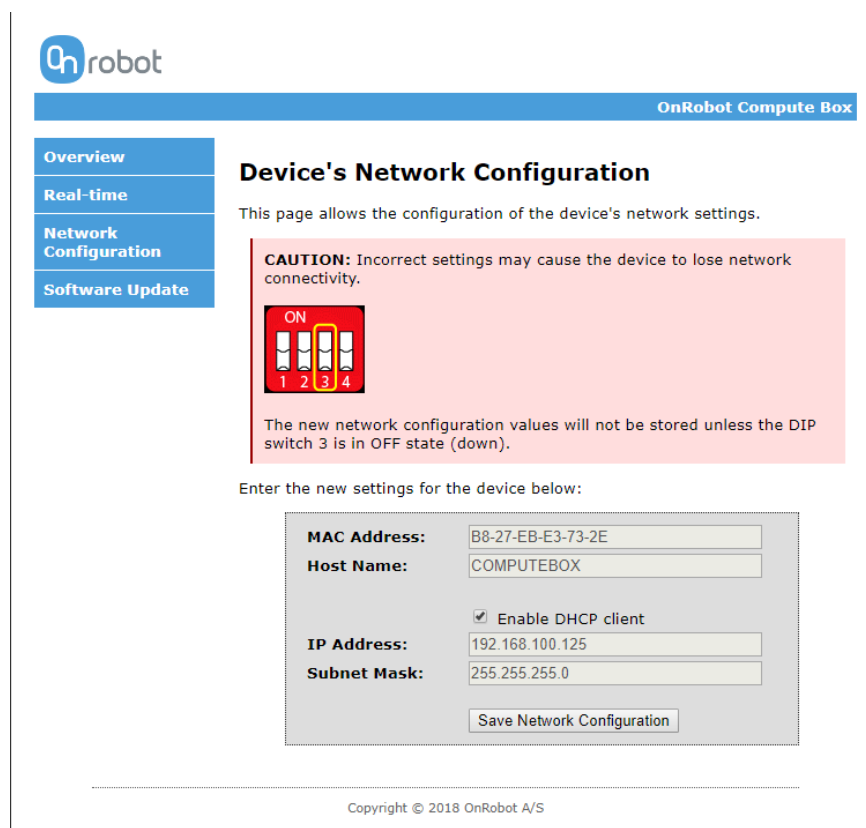
3. Power the device from the provided power supply and wait 30 seconds for the device to boot up.



4. Open a web browser (Internet Explorer is recommended) and navigate to <http://192.168.1.1>. The welcome screen displays real-time sensor data.



- Click on **Network Configuration** in the left-side menu. The following screen is displayed:



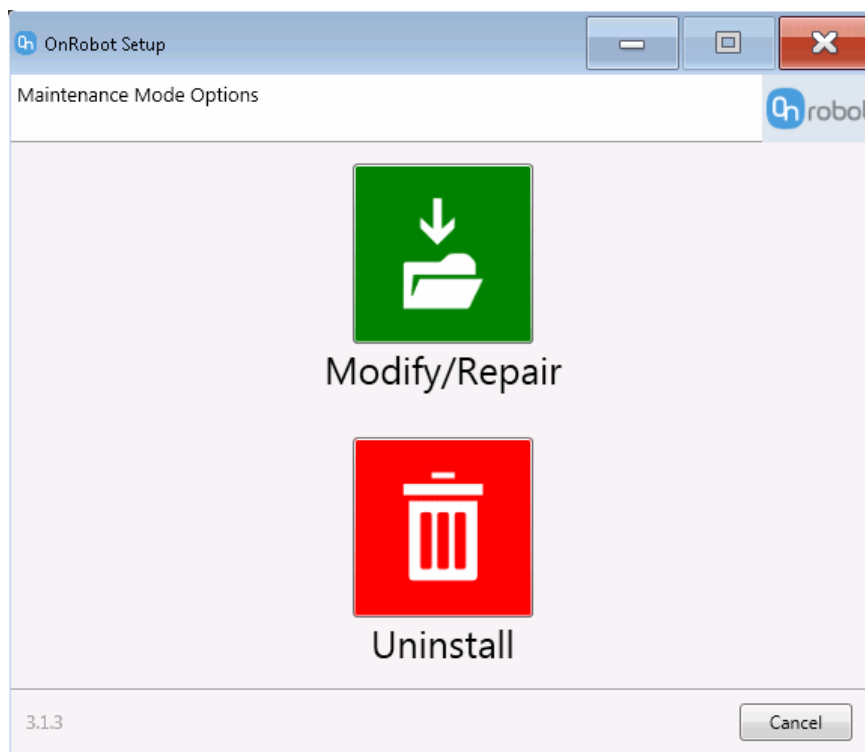
- Uncheck the Enable DHCP client checkbox, if it is checked.
- Edit the IP Address.

8. Set DIP switch 3 to off position.
9. Click the Save Network Configuration button
10. Open a web browser (Internet Explorer is recommended) and navigate to the IP Address set in step 7.

6.2 Software Uninstallation

The following steps will uninstall the OnRobot package from your robot controller:

1. Enter 'Expert' mode by going to the Main Menu then 'Configuration'>'User group'.
2. Minimize the user interface with 'Start-up'>'Service'>'Minimize HMI'.
3. Open the file explorer and go to 'D:\OnRobot'.
4. Launch the OnRobot Setup executable file.
5. Click on 'Uninstall' and accept the prompts.



6. Restart the robot controller.

6.3 Troubleshooting

N/A

6.4 Editions

| Edition | Comment |
|-----------|--|
| Edition 2 | Document restructured. Glossary of Terms added. List of Acronyms added. Appendix added. Target audience added. Intended use added. Copyright, Trademark, contact information, original language information added. |
| Edition 3 | Editorial changes. |
| Edition 4 | Editorial changes. |
| Edition 5 | Editorial changes. |
| Edition 6 | Editorial changes. |
| Edition 7 | New Look&Feel. |