



ROBOTICS

# **Application manual**

Force control with software and hardware



Trace back information:  
Workspace Main version a450  
Checked in 2022-03-29  
Skribenta version 5.5.019

# **Application manual**

## **Force control with software and hardware**

**RobotWare 7.6**

**Document ID: 3HAC070206-001**

**Revision: C**

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# Overview of this manual

## About this manual

This manual contains information about the RobotWare option Force control Interface, for all robots using external force sensors. For GoFa robots, see *Application manual - Force control Standard for GoFa*.

## Usage

This manual can be used to find out what Force control is and how to use it. It provides information about system parameters and RAPID components related to Force control, and examples of how to use them.

## Who should read this manual?

This manual is mainly intended for robot programmers.

## Prerequisites

The reader should...

- be familiar with industrial robots and their terminology.
- be familiar with the RAPID programming language.
- be familiar with system parameters and how to configure them.

## References

| Reference  | Document ID    |
|--|----------------|
| <i>Product manual - OmniCore C30</i>   | 3HAC060860-001 |
| <i>Product manual - OmniCore C90XT</i>   | 3HAC073706-001 |
| <i>Product manual - OmniCore V250XT</i>  | 3HAC073447-001 |
| <i>Product specification - OmniCore C line</i>                                   | 3HAC065034-001 |
| <i>Product specification - OmniCore V line</i>                                   | 3HAC074671-001 |
| <i>Application manual - TuneMaster</i>   | 3HAC063590-001 |
| <i>Operating manual - OmniCore</i>   | 3HAC065036-001 |
| <i>Operating manual - RobotStudio</i>  | 3HAC032104-001 |
| <i>Technical reference manual - RAPID Overview</i>                               | 3HAC065040-001 |
| <i>Technical reference manual - RAPID Instructions, Functions and Data types</i> | 3HAC065038-001 |
| <i>Technical reference manual - System parameters</i>                            | 3HAC065041-001 |

## Revisions

| Revision | Description  |
|----------|--|
| A        | Released with RobotWare 7.0.   |
| B        | Released with RobotWare 7.2. <ul style="list-style-type: none"><li>• Information about IgnoreStandStillCheck added in <a href="#">FCCalib on page 66</a>.</li><li>• New instructions: <a href="#">FCSetMaxForceChangeTune on page 129</a> and <a href="#">FCResetMaxForceChangeTune on page 125</a>.</li></ul> |

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| Revision | Description  |
|----------|--|
| C        | Released with RobotWare 7.6. <ul style="list-style-type: none"><li>• Added instruction <a href="#">FCCondCombine on page 68</a>.</li><li>• The content specific for the GoFa robots is separated into another manual, <i>Application manual - Force control Standard for GoFa</i>.</li></ul> |

# 1 Introduction

## 1.1 About Force Control

---

### Purpose

The purpose of Force Control is to make the robot sensitive to contact forces. The result is that the robot can "feel" its surroundings. It can apply a constant force on a surface, even if the exact position of the surface is not known.

Here are some examples from powertrain assembly applications where force control is useful:

- Piston assembly
- Forward clutch hub assembly
- Torque converter assembly

Force Control can also be used for different kinds of material removal processes, surface finishing and surface processing. Where the robot can hold the tool and work on a fixed part or hold the part and work on a fixed tool.

Here are some examples of machining applications where force control is useful:

- Grinding
- Milling
- Polishing
- Deburring
- Deflashing
- etc.

---

### What is included

The option Force Control Interface gives access to:

- FC basic control and assembly, for more information see [About FC basic control and assembly on page 13](#).
- FC Pressure, for more information see [About FC Pressure on page 14](#).
- FC SpeedChange, for more information see [About FC SpeedChange on page 15](#).

---

### Limitations

- *Force Control Interface* is only available for 6-axis serial link robots.
- The total load, that is the sum of gravitational forces and external contact forces, must not exceed limits as specified in the load diagrams for a specific robot.

When the robot is force controlled, the following functionality is *not* accessible:

- *Collision Detection*
- *Conveyor tracking*
- *Independent axes*
- Joint soft servo (instruction `SoftAct`)

*Continues on next page*

# 1 Introduction

---

## 1.1 About Force Control

*Continued*

- *Path Offset*
- **RAPID instructions such as `FCAct`, `FCDeact`, `FCConditionWaitWhile`, and `FCRefStop` can only be called from normal level in a motion task.**
- *Sensor or Analog synchronization*
- *Sensor interface*
- *SoftMove*
- Tracking functionality
- Force controlled pressure applications (`FCPressL` etc) and Force controlled speed change applications (`FCSpdChgAct` etc) cannot be combined with EGM instructions.
- *World Zones*

### 1.2 About FC basic control and assembly

---

#### Purpose

The purpose of FC basic control and assembly is to make the robot sensitive to contact forces. The robot can "feel" its surroundings, react, and obtain a certain pressure against an object. This means that the robot will change its position in order to fulfil the commanded force instruction. This is useful in testing application, and all kinds of insertion applications.

---

#### What is included

FC basic control and assembly gives access to:

- instruction to set up gravity compensation and sensor offset calibration.
- instructions for activation and deactivation of Force Control.
- instructions for defining reference values (desired force, torque or movement).
- instructions for end conditions.
- instructions for supervision.
- functions returning information about load, detected forces, or process status.
- data types supporting the instructions and functions.

---

#### Basic approach

A RAPID program using Force Control basically follows these steps. For a more detailed example of how this is done, see [Code examples on page 40](#).

- 1 Identify the load and calibrate the system
- 2 Set up desired force and movement pattern.
- 3 Set up end condition.
- 4 Activate force control.
- 5 Activate force and movement pattern.
- 6 Wait for end condition to occur.
- 7 Deactivate force and movement patterns.
- 8 Deactivate force control.

# 1 Introduction

---

## 1.3 About FC Pressure

### 1.3 About FC Pressure

---

#### Purpose

The purpose of FC Pressure is to make the robot sensitive to contact forces. The robot can "feel" its surroundings and follow the surface of the processed part to obtain a certain pressure against an object. This means that the robot will change its position in order to apply a constant force/pressure on a surface, even if the exact position of the surface is not known.

Since pressure is obtained by moving the robot path, this function is suited for polishing, grinding, and cleaning, where a surface should be made even and smooth. The material that is removed and the changes of the surface topology/dimensions depends on the process parameters like tooling, applied pressure, robot speed etc.

Here are some examples from foundry and metal fabrication where FC Pressure is useful:

- Grinding of faucets
- Polishing of kitchen sinks
- Deflashing, grinding and cleaning of castings
- Deburring of castings
- etc

---

#### What is included

The function FC Pressure gives you access to:

- Instructions for programming FC Pressure start, movements and stop.

---

#### What is needed

FC Pressure requires a sensor input from the measured process forces to adjust the behavior of the robot. Depending of the application and required flexibility different force/torque sensors can be used.

For applications with the function FC Pressure, use

- 1 DOF (Degree Of Freedom), if the direction of the force is constant and the sensor can be integrated in the tooling.
- 6 DOF, for more flexible solutions.

---

#### Basic approach

- 1 Identify the load and calibrate the system.
- 2 Move to a point close to contact.
- 3 Set up desired force and start movement towards the surface.
- 4 Move linear or circular performing the process with contact.
- 5 Leave surface and deactivate force control.

---

**1.4 About FC SpeedChange**

---

**Purpose**

In processes where path accuracy is important and where the finished result shall comply with specific dimensions, FC SpeedChange is recommended. This function will be useful combined with force sensor or other input indicating excessive process forces, which can deteriorate the finished result. When FC SpeedChange is active and if machining forces exceed a certain value, then the path speed will automatically be reduced, thus decreasing forces, minimizing changed dimensions due to deflections of the robot arm and most probably avoid damaging the part/tool due to stress and heat. This will guarantee path accuracy even if much material shall be removed.

See below some examples from foundry and metal fabrication where FC SpeedChange is useful:

- Grinding unevenly distributed material on casted surfaces
- Milling along the edge of a work piece
- Deburring along contour of a work piece
- Deflashing unevenly distributed burr along a part line on castings
- Deburring of castings
- etc.

---

**What is included**

The function FC SpeedChange gives you access to

- Instructions for programming FC SpeedChange.
- Instructions for defining a recovery function for FC SpeedChange.

---

**What is needed**

FC SpeedChange requires a sensor input from the measured process forces to adjust the behavior of the robot. Depending of the application and required flexibility different sensors can be used.

For applications with the function FC SpeedChange, use:

- built in (analog, voltage) signal from the spindle representing the current or the torque of the motor. Spindle motors used for milling or grinding normally has a built in signal.
- 6 DOF force/torque, for more flexible solutions.

---

**Basic approach**

- 1 Configure the parameters for FC SpeedChange controller.
- 2 Identify the load and calibrate the sensor (if 6DOF sensor is used).
- 3 Define recovery function.
- 4 Activate FC SpeedChange.
- 5 Execute the machining task; move along the path performing the process.
- 6 Deactivate FC SpeedChange.

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## 2 Installation

### 2.1 Getting started with force control

#### Overview

This chapter describes the basic steps to get started with Force Control, from mounting the sensor to writing the first program. This manual only describes what is specific for a Force Control installation. For more information about installation and commissioning of the controller, see the product manual for the controller.

#### Hardware using a force sensor

The following hardware items are needed for Force Control:

- A Voltage measurement box, 3HAC034234-001 (delivered from ABB)
- B Cable between robot controller and voltage measurement box (delivered from ABB)
- C Cable between force sensor and voltage measurement box (delivered with sensor)
- D Robot mounted or room fixed force sensor

#### Additional axes

If additional axes are connected to a robot controller using Force Control, the serial measurement board for the additional axes should be connected to connector X2 on the voltage measurement box. See [Connector X2 on page 283](#).

The voltage measurement board will allocate node 4-7. The additional axes can only use node 1-3. When using an additional axis, the board position for the voltage measurement box needs to be set to 2. See [Measurement board number on page 232](#).

#### Force sensor and cable

The force sensor and the cable between force sensor and voltage measurement box are extra hardware needed for the Force Control option. These parts can be bought from any sensor supplier. ABB has integrated support for using the ABB force sensor, or force sensors from ATI Industrial Automation, which includes adapter plate and calibration parameter file for easy integration, but other sensor supplier can also be used. For further details see [About the Force Sensor interface on page 281](#).



#### Note

For recommended 6 DOF force sensor see the product specification for the robot controller.

#### UL approved

For an UL approved solution, it is required that:

- the force sensor must be UL marked

*Continues on next page*

## 2 Installation

### 2.1 Getting started with force control

*Continued*

- the signal cable between sensor and the voltage measurement box must be UL marked and rated VW-1.

#### Hardware using spindle signal for FC SpeedChange

The following hardware items are needed:

Voltage measurement box, 3HAC034234-001 (delivered from ABB)

Cable between robot controller and voltage measurement box (delivered from ABB)

Cable between Spindle motor and voltage measurement box (delivered with spindle)

Spindle with analog voltage signal output (delivered from external supplier)

#### Cable and spindle signal

The cable between spindle and voltage measurement box is extra hardware needed for the Force Control option FC SpeedChange.


The signal output (representing motor current or motor torque) must be integrated with the spindle used for machining.



#### Note

For recommended 6 DOF force sensor see the product specification for the robot controller, listed in [References on page 9](#).

#### Basic setup

|   | Action  | Note/illustration   |
|---|---|---|
| 1 | Mount the force sensor fixed in the room or on the robot's mounting flange. Sometimes adapter plates are needed between robot and sensor. | For non-ABB sensors, see the manual from the sensor supplier.<br><br> <b>Note</b><br>Make sure that the adapter and the sensor are tightly fixed, and that the orientation is correct. |
| 2 | Locate the signal output on the spindle motor   | Read the spindle supplier manual for more data. Make sure the signal amplitude is between 5V and 10V.   |
| 3 | Connect the cable from the Serial Measurement Link 2 on the robot controller to the voltage measurement box.                              | Use one of the cables: <ul style="list-style-type: none"><li>• 3HAC068917-001 (7 m)</li><li>• 3HAC068918-001 (15 m)</li><li>• 3HAC068919-001 (22 m)</li><li>• 3HAC068920-001 (30 m)</li></ul>   |

*Continues on next page*

|   | Action   | Note/illustration   |
|---|--|---|
| 4 | Connect the cable from the voltage measurement box to the sensor/spindle motor, or connect the cable from the voltage measurement box to the sensor.   | <ul style="list-style-type: none"> <li>Make sure to position the cable on the robot so that it is not damaged by the movements of the robot.</li> <li>If a 1DOF sensor is going to be used, make sure that the sensor signal is connected to correct channel in combination with the settings of the calibration matrix in order to activate Fx, Fy or Fz according to the reference settings in the program/application.</li> <li>If a spindle signal is used for Speed-Change a channel to connect the cable needs to be set. The channel is set by the parameter <a href="#">DAC channel on page 258</a>.</li> </ul> |
| 5 | Install RobotStudio and RobotWare on a PC.   | See <i>Operating manual - RobotStudio</i> .   |
| 6 | Create a new system in RobotStudio.  | See <i>Operating manual - RobotStudio</i>   |
| 7 | Configure the system using RobotStudio. Force Control parameters are set in the configuration topic <i>Motion</i> .  | Some of the Force Control parameters are already set. However, make sure they work for your application.  |
| 8 | For non-ABB sensor/signal configuration, sensor calibration data needs to be supplied by the manufacturer.<br>Right click the <i>Configuration</i> node in RobotStudio, select <b>Load Parameters</b> and then <b>Load parameters and replace duplicates</b> . | See also <a href="#">System parameters overview on page 21</a> and <a href="#">Configuration example on page 26</a> .   |
| 9 | Now that the system is configured the last step is to program the application. To get started more easily there are some basic code examples on how to use Force control. There is also a RAPID component overview for easy usage.                             | <a href="#">RAPID components on page 29</a><br><a href="#">Code examples on page 40</a>   |

#### General guidelines for Force Control

These guidelines can be useful even if you are an advanced programmer in Force Control and it is recommended to go through these steps from time to time.

- Force sensor calibration is required prior to any operation with force control enabled.
- Jogging the robot in force control is possible but all teaching and jogging in force control mode should be done with extreme caution.
- Avoid programming and jogging through singularities, see *Technical reference manual - RAPID Overview*, section *Singularities*.
- Always change damping parameters carefully and in small steps.
- Always change bandwidth of force filter carefully and in small steps.
- If you want to be sure to limit reference forces and movement speed, change the maximum parameters in the configuration to a desired value to avoid mistakes in the program.
- Use the supervision instructions to limit the movement of the robot.

*Continues on next page*

## 2 Installation

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### 2.1 Getting started with force control

*Continued*

- 8 Avoid deactivating Force Control while in contact. Remember that force control is deactivated when the program pointer is moved.
- 9 In case the program is interrupted, always start the program from the beginning.

---

#### Programming guidelines for Force Control

These guidelines can be useful even if you are an advanced programmer in Force Control and it is recommended to go through these steps from time to time.

- 1 Even if Force Control will change the path to obtain the contact reference, it's always best to have an initial programming of the path as close to the correct surface as possible.
- 2 Always try your new Force Control instructions with small reference without contact to any object to verify the movements.
- 3 Make sure that the Force Control start and end positions are not in contact with the work piece, but as close as possible.
- 4 Always use a lower speed and a smaller reference than intended when trying out the new movements.
- 5 Log the test signal for the spindle current/torque at normal operation in order to identify the correct, desirable signal level to be use in the SpeedChange controller.

## 3 Configuration

### 3.1 System parameters overview

#### About this section

This is an overview of the system parameters used in Force Control. For more information, see the respective parameter in section [System parameters on page 185](#).

#### Robot

These parameters belong to the type *Robot* in the topic *Motion*.

| Parameter      | Description                               |
|----------------|---|
| Use FC Master  | Specifies which <i>FC Master</i> to use.  |
| Use PMC Sensor | Specifies which <i>PMC Sensor</i> to use. |

#### FC Master

These parameters belong to the type *FC Master* in the topic *Motion*.

| Parameter           | Description                                    |
|---------------------|--|
| Name                | The name of the <i>FC Master</i> .             |
| Use FC Sensor       | Specifies which <i>FC Sensor</i> to use.       |
| Use FC Kinematics   | Specifies which <i>FC Kinematics</i> to use.   |
| Use FC Application  | Specifies which <i>FC Application</i> to use.  |
| Use FC Speed Change | Specifies which <i>FC Speed Change</i> to use. |

#### FC Sensor

These parameters belong to the type *FC Sensor* in the topic *Motion*.

| Parameter                    | Description   |
|------------------------------|---|
| Name                         | The name of the <i>FC Sensor</i> .  |
| Force Sensor Mount Unit Name | The name of the mechanical unit the sensor is mounted on. Most often ROB_1. If the sensor is room fixed the value should be empty.  |
| Force Sensor Type            | Specifies if the sensor should measure both force and torque or only force.   |
| Noise level                  | The highest noise level at which a force sensor calibration is allowed. Used to check that the robot is standing still.   |
| Force Sensor Frame x - z     | The origin of the sensor coordinate system, expressed in the tool0 coordinate system when the sensor is mounted on the robot, or expressed in the world coordinate system when the sensor is room fixed. The unit is meter. |
| Force Sensor Frame q1 - q4   | The orientation of the sensor coordinate system in relation to the tool0 coordinate system when the sensor is mounted on the robot, or to the world coordinate system when the sensor is room fixed.                        |

*Continues on next page*

## 3 Configuration

### 3.1 System parameters overview

*Continued*

#### FC Kinematics

These parameters belong to the type *FC Kinematics* in the topic *Motion*.

| Parameter   | Description   |
|---|---|
| Name  | The name of the <i>FC Kinematics</i> .  |
| Damping in Force x Direction<br>Damping in Force y Direction<br>Damping in Force z Direction    | Specifies how the robot speed depends on the contact force. A higher value makes the robot less sensitive to contact forces. Different damping can be used for different directions. The unit is Ns/m.                                      |
| Damping in Torque x Direction<br>Damping in Torque y Direction<br>Damping in Torque z Direction | Specifies how the tool reorientation speed depends on the torque induced by the environment. A higher value makes the robot less sensitive to contact torques. Different damping can be used for different directions. The unit is Nms/rad. |
| Bandwidth of force loop filter  | Specifies the behavior of the force control loop. A higher value makes the robot more compliant but can cause instability. The unit is Hz.  |
| Bandwidth of force frame filter   | The force measured in "force frame" will be low pass filtered with this bandwidth. The unit is Hz.  |

#### FC Application

These parameters belong to the type *FC Application* in the topic *Motion*.

| Parameter                       | Description   |
|---------------------------------|---|
| Name                            | The name of the <i>FC Application</i> .   |
| Max Ref Force                   | Maximum allowed reference force. The unit is N.   |
| Max Ref Force Change            | Maximum allowed change in reference force. The unit is N/s.   |
| Max Ref Torque                  | Maximum allowed reference torque. The unit is Nm.   |
| Max Ref Torque Change           | Maximum allowed change in reference torque. The unit is Nm/s.   |
| Max Ref TCP Speed               | Maximum allowed reference speed. The unit m/s.  |
| Max Ref Rot Speed               | Maximum allowed reference rotational speed. The unit is rad/s.  |
| Max Ref TCP Acc                 | Maximum allowed reference acceleration. The unit is m/s <sup>2</sup>                                      |
| Max Ref Rot Acc                 | Maximum allowed reference rotational acceleration. The unit is rad/s <sup>2</sup> .                       |
| Speed superv override           | Overrides the speed supervision with a factor.  |
| Largest measured contact force  | If measured contact force is larger than this value it is set to this value.                              |
| Lowest measured contact force   | A measured contact force lower than this value will be set to zero [dead band]. The unit is N.            |
| Largest measured contact torque | If measured contact torque is larger than this value it is set to this value.                             |
| Lowest measured contact torque  | A measured contact torque lower than this value will be set to zero [dead band]. The unit is Nm.          |
| Max Press TCP Speed             | Maximum linear speed in press movements. The unit is m/s.   |
| Max Press Rot Speed             | Maximum rotation speed in press movements. The unit is rad/s.   |
| Keep contact force at stop      | Defines whether the robot should be allowed to remain in contact when force control execution is stopped. |

*Continues on next page*

**Note**

The values of the *Max Ref xxx* parameters define the ramping step of the reference movement. If the parameter value is set too high, the ramping will produce jerks and trig the speed supervision.

**Note**

If the parameters *Lowest measured contact force* and *Lowest measured contact torque* are set too low, there is a risk that the robot will drift when in force control mode.

**FC Speed Change**

These parameters belong to the type *FC Speed Change* in the topic *Motion*.

| Parameter                      | Description  |
|--------------------------------|--|
| Name                           | Defines the name of the <i>FC Speed Change</i> .   |
| Speed ratio min                | Specifies the minimum allowed speed ratio.   |
| No of speed levels             | Defines the number of speed levels.  |
| Speed ratio delta              | Limits acceleration/deceleration due to the SpeedChange functionality. A low value will give slower but smoother speed changes. Too high value of Speed_ratio_delta will result in jerky behavior. |
| Speed max update period        | Specifies the minimum time in seconds between speed changes.   |
| Feedback type                  | Defines the type of feedback to be used for speed change control.  |
| Feedback offset                | Specifies the offset to be subtracted from the measured feedback before the value is used in speed change control.   |
| Use Fdb LP filter              | Defines whether feedback low pass filter should be active.   |
| Fdb LP filter bandwidth        | Defines the bandwidth of the feedback low pass filter (Hz).  |
| Maximum TCP speed              | Defines the maximum original TCP speed for speed change. The unit is m/s.  |
| Recover rule fdb ratio         | A feedback to reference ratio larger than this while having reduced speed to lowest level will trig recover behavior or stop robot.  |
| Decrease rule safety fdb ratio | Defines the maximum feedback to reference ratio.   |
| Decrease rule safety fdb time  | Define the maximum time in seconds that the feedback to reference ratio can be continuously over <i>Decrease rule safety fdb ratio</i> before reducing robot speed.                                |
| Fdb trend step size            | Defines the minimum difference between two consecutive feedback values to count as a change in feedback.   |
| Decrease rule 1 fdb ratio      | For ABB internal use only.   |
| Decrease rule 1 fdb trend      | For ABB internal use only.   |
| Decrease rule 2 fdb ratio      | For ABB internal use only.   |
| Decrease rule 2 fdb trend      | For ABB internal use only.   |
| Increase rule 1 fdb ratio      | For ABB internal use only.   |

Continues on next page

## 3 Configuration

### 3.1 System parameters overview

*Continued*

| Parameter                 | Description                |
|---------------------------|----------------------------|
| Increase rule 1 fdb trend | For ABB internal use only. |
| Increase rule 2 fdb ratio | For ABB internal use only. |
| Increase rule 2 fdb trend | For ABB internal use only. |

#### PMC Sensor

These parameters belong to the type *PMC Sensor* in the topic *Motion*.

| Parameter            | Description                                     |
|----------------------|---|
| Name                 | The name of the <i>PMC Sensor</i> .             |
| Use PMC Sensor Setup | Specifies which <i>PMC Sensor Setup</i> to use. |



#### Note

*PMC SensorName* must be the same as *FC SensorName* when Force Control is used.

#### PMC Sensor Setup

These parameters belong to the type *PMC Sensor Setup* in the topic *Motion* and are supplied by the sensor manufacturer.

| Parameter                        | Description  |
|----------------------------------|--|
| Name                             | The name of the <i>PMC Sensor Setup</i> .  |
| fx 1 - fx 6                      | Specifies the contribution from each of the sensor's input voltages to the force measurement in the x direction.   |
| fy 1 - fy 6                      | Specifies the contribution from each of the sensor's input voltages to the force measurement in the y direction.   |
| fz 1 - fz 6                      | Specifies the contribution from each of the sensor's input voltages to the force measurement in the z direction.   |
| tx 1 - tx 6                      | Specifies the contribution from each of the sensor's input voltages to the torque measurement in the x direction.  |
| ty 1 - ty 6                      | Specifies the contribution from each of the sensor's input voltages to the torque measurement in the y direction.  |
| tz 1 - tz 6                      | Specifies the contribution from each of the sensor's input voltages to the torque measurement in the z direction.  |
| fx scale - tz scale              | Scaling factors to transform the values of the input voltages into force and torque values.  |
| fx max - tz max                  | The sensor's specified maximum force or torque in the respective direction.  |
| Max voltage for external AD card | The value should be set to the voltage working range of the A/D board. The range is assumed to be + - this value.  |
| Disable force sensor cable check | Some force sensors have a separate safety channel, which delivers a voltage above a certain level when the sensor is working, thus enabling system supervision. If the force sensor in use does not have a safety channel this supervision must be disabled. |
| Safety channel voltage           | Safety channel voltage level.  |
| Last node                        | Specifies the last node used on the PMC sensor.  |

*Continues on next page*





#### Note

It is very important that the *PMC Sensor Setup* values are correct, otherwise load identification and calibration will be incorrect. When running the function `FcLoadId`, the argument `LoadIdErr` will give a strong indication if the values are set correctly.



#### Note

The +/- sign of the calibration parameters needs to be chosen so that the resulting force and torque is the force/torque by which the surrounding effects the robot, not the other way round.

## 3 Configuration

### 3.2 Configuration example

### 3.2 Configuration example

#### Overview

This section shows a real configuration example, intended to facilitate the setup of the configuration parameters. Some parameters are sensor specific, but others can be copied, like maximum allowed values.

#### Robot

| Parameter      | Value      | Unit/Note |
|----------------|------------|-----------|
| Use FC Master  | fc_master1 | -         |
| Use PMC Sensor | fc_sensor1 | -         |

#### FC Master

| Parameter           | Value            | Unit/Note |
|---------------------|------------------|-----------|
| Name                | fc_master1       | -         |
| Use FC Sensor       | fc_sensor1       | -         |
| Use FC Kinematics   | fc_kinematics1   | -         |
| Use FC Application  | fc_application1  | -         |
| Use FC Speed Change | fc_speed_change1 | -         |

#### FC Sensor

| Parameter             | Value            | Unit/Note                 |
|-----------------------|------------------|---------------------------|
| Name                  | fc_sensor1       | -                         |
| Force Sensor Type     | Force and Torque | 6DOF                      |
| Mount Unit Name       | ROB_1            | Sensor mounted on robot 1 |
| Noise level           | 25               | -                         |
| Force Sensor Frame x  | 0                | m                         |
| Force Sensor Frame y  | 0                | m                         |
| Force Sensor Frame z  | 0.05             | m                         |
| Force Sensor Frame q1 | 1                | -                         |
| Force Sensor Frame q2 | 0                | -                         |
| Force Sensor Frame q3 | 0                | -                         |
| Force Sensor Frame q4 | 0                | -                         |

#### FC Kinematics

| Parameter                       | Value          | Unit/Note |
|---------------------------------|----------------|-----------|
| Name                            | fc_kinematics1 | -         |
| Bandwidth of force frame filter | 25             | Hz        |
| Bandwidth of force loop filter  | 3              | Hz        |

*Continues on next page*

| Parameter                     | Value | Unit/Note |
|-------------------------------|-------|-----------|
| Damping in Force x Direction  | 3000  | Ns/m      |
| Damping in Force y Direction  | 3000  | Ns/m      |
| Damping in Force z Direction  | 3000  | Ns/m      |
| Damping in Torque x Direction | 400   | Nms/rad   |
| Damping in Torque y Direction | 400   | Nms/rad   |
| Damping in Torque z Direction | 400   | Nms/rad   |

#### FC Application

| Parameter                       | Value           | Unit/Note          |
|---------------------------------|-----------------|--------------------|
| Name                            | fc_application1 | -                  |
| Max Ref Force                   | 1000            | N                  |
| Max Ref Force Change            | 1000            | N/s                |
| Max ref Torque                  | 400             | Nm                 |
| Max Ref Torque Change           | 200             | Nm/s               |
| Max Ref TCP Speed               | 5               | m/s                |
| Max Ref Rot Speed               | 5               | rad/s              |
| Max Ref TCP Acc                 | 1               | m/s <sup>2</sup>   |
| Max Ref Rot Acc                 | 1               | rad/s <sup>2</sup> |
| Speed Superv Override           | 3               | -                  |
| Largest measured contact force  | 1000            | N                  |
| Lowest measured contact force   | 3               | N                  |
| Largest measured contact torque | 400             | Nm                 |
| Lowest measured contact torque  | 1               | Nm                 |
| Max Press TCP Speed             | 5               | m/s                |
| Max Press Rot speed             | 5               | rad/s              |

#### FC Speed Change

| Parameter               | Value                                  | Unit/Note                        |
|-------------------------|--|----------------------------------|
| Name                    | fc_speed_change1                       | -                                |
| Speed ratio min         | 0.1                                    | -                                |
| No of speed levels      | 2                                      | -                                |
| Speed ratio delta       | 0.07                                   | -                                |
| Speed max update period | 0.08                                   | s                                |
| Feedback type           | Single DAC input<br>Calib. Force Magn. | Single dimension external sensor |
| Feedback offset         | 0                                      | -                                |
| Use Fdb LP filter       | Yes                                    | -                                |

*Continues on next page*

### 3 Configuration

#### 3.2 Configuration example

*Continued*

| Parameter                      | Value | Unit/Note |
|--------------------------------|-------|-----------|
| Fdb LP filter Bandwidth        | 30    | Hz        |
| Maximum TCP speed              | 0.3   | m/s       |
| Recover rule fdb ratio         | 1.3   | -         |
| Decrease rule safety fdb ratio | 1.5   | -         |
| Decrease rule safety fdb time  | 0.1   | s         |
| Fdb trend step size            | 8     | -         |
| Decrease rule1 fdb ration      | 0.7   | -         |
| ...                            | ...   | ...       |
| Increase rule 2 fdb trend      | 10    | -         |

#### PMC Sensor

| Parameter            | Value        | Unit / Note   |
|----------------------|--------------|---|
| Name                 | fc_sensor1   | -   |
| Use PMC Sensor Setup | ATI_ACROMAG1 | ATI_ACROMAG1 is used for robot 1 (ROB_1), ATI_ACROMAG2 is used for robot 2 (ROB_2) etc. |

#### PMC Sensor Setup

| Parameter | Value        | Unit / Note |
|-----------|--------------|-------------|
| Name      | ATI_ACROMAG1 | -           |
| fx 1      | 0.25479      | -           |
| fx 2      | 0.02958      | -           |
| ...       | ...          | ...         |
| ty max    | 400          | Nm          |
| tz max    | 400          | Nm          |



#### Note

The PMC Sensor Setup values are supplied by the sensor manufacturer.

## 4 Programming

### 4.1 RAPID components

#### 4.1.1 Force controlled pressure applications

##### Overview

These are the instructions used to start stop and run force controlled pressure applications.

Between the start and end instructions any combination and number of `FCPressL` and `FCPressC` can be used. The speed, force and zone may be changed for a new instruction allowing the process to be changed along with the properties of the application.

##### Pressure instructions

| Instruction                | Description   |
|----------------------------|---|
| <code>FCPressLStart</code> | Activates Force Control, starts movement and defines the data needed for the process below such as: <ul style="list-style-type: none"> <li>• Movement: <code>ToPoint</code>, Speed, <code>zonedata zone</code>, tool <code>Wobj</code></li> <li>• Force settings: direction of force, Force Threshold to start movement <code>ForceFrameRef</code> i.e <code>Wobj</code></li> </ul> |
| <code>FCPressL</code>      | Moves linear to <code>robtarget</code> with a force in the direction setup by <code>FCPressLStart</code> . Magnitude of the force can be changed for every <code>FCPressL</code> .  |
| <code>FCPressC</code>      | Moves circular to <code>robtarget</code> with a force in the direction setup by <code>FCPressLStart</code> . Magnitude of the force can be changed for every <code>FCPressC</code> .  |
| <code>FCPressEnd</code>    | Leaves surface and moves to <code>robtarget</code> .  |

##### Calibrate the sensor

| Instruction           | Description  |
|-----------------------|--|
| <code>FCLoadID</code> | Identifies the load measured by the force sensor. The identified load is used to calibrate the force sensor.   |
| <code>FCCalib</code>  | Calibrates the force sensor to remove sensor offset and compensate for gravity. Note that the calibration requires a precise definition of the load. Therefore, use the function <code>FCLoadID</code> before <code>FCCalib</code> . |

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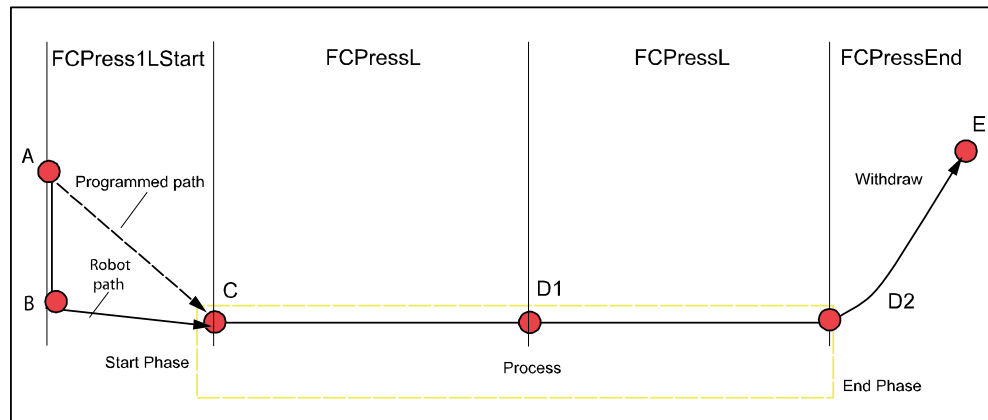
## 4 Programming

### 4.1.1 Force controlled pressure applications

*Continued*

#### The phases

The figure below describes the phases for the FC pressure application.



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- 1 During the start phase the robot will switch to force control mode and move in the direction of the reference force in order to search contact with the work piece (B). Once contact is achieved the robot will start the movement towards the programmed position (C).
- 2 During the process any number and combination of `FCPressL` and `FCPressC` may be used in order to run the application process (D1) (D2)...(Dx).
- 3 After the last process movement the robot will retract from the work piece in the opposite direction of the reference force until zero contact force is measured. At this time the robot will switch to position control and move to the end position (E).

## 4.1.2 Force controlled speed change applications

### Overview

The force controlled SpeedChange function will automatically slow down the robot speed based on the process force information (measured by force sensor, spindle motor current, etc.). The robot will slow down when the process force level raises above a defined threshold. After the process force reduces below a certain level, the robot will automatically regain its programmed speed. Between activation and deactivation any standard move instruction can be used.

### SpeedChange instructions

These are the instructions used to activate and deactivate force controlled SpeedChange:

| Instruction   | Description  |
|---------------|--|
| FCSpdChgAct   | Activates force controlled SpeedChange function with following parameters: <ul style="list-style-type: none"> <li>Reference (force, spindle motor current, etc.), reduce robot speed when the measured signal is greater than the reference.</li> <li>Recover function name (RAPID routine with the specified name will be called when certain condition satisfies.</li> <li>Different recover behaviors (e.g., MultipleRecover, NonStopAllTime).</li> </ul> |
| FCSpdChgDeact | Deactivates force controlled SpeedChange function.   |

These are instructions used to tune on-line configuration parameters for speed change function.

| Instruction      | Description   |
|------------------|---|
| FCSpdChgTunSet   | Change configuration parameter to a new value, with following input arguments <ul style="list-style-type: none"> <li>Configuration parameter type</li> <li>New valid value</li> </ul> |
| FCSpdChgTunReset | Restore configuration parameter to its original value that stored in configuration file <ul style="list-style-type: none"> <li>Configuration parameter type</li> </ul>                |

### Calibrate the sensor

This instruction is used to calculate the gravity and center of gravity for the current load. `FCLoadId` and `FCCalib` are required before the sensor can be used for Force Control.

| Instruction | Description  |
|-------------|--|
| FCCalib     | Calibrates the force sensor to remove sensor offset and compensate for gravity. Note that the calibration requires a precise definition of the load. Therefore, use the function <code>FCLoadID</code> before <code>FCCalib</code> . |



#### Note

`FCCalib` is only used for SpeedChange with force/torque sensor.

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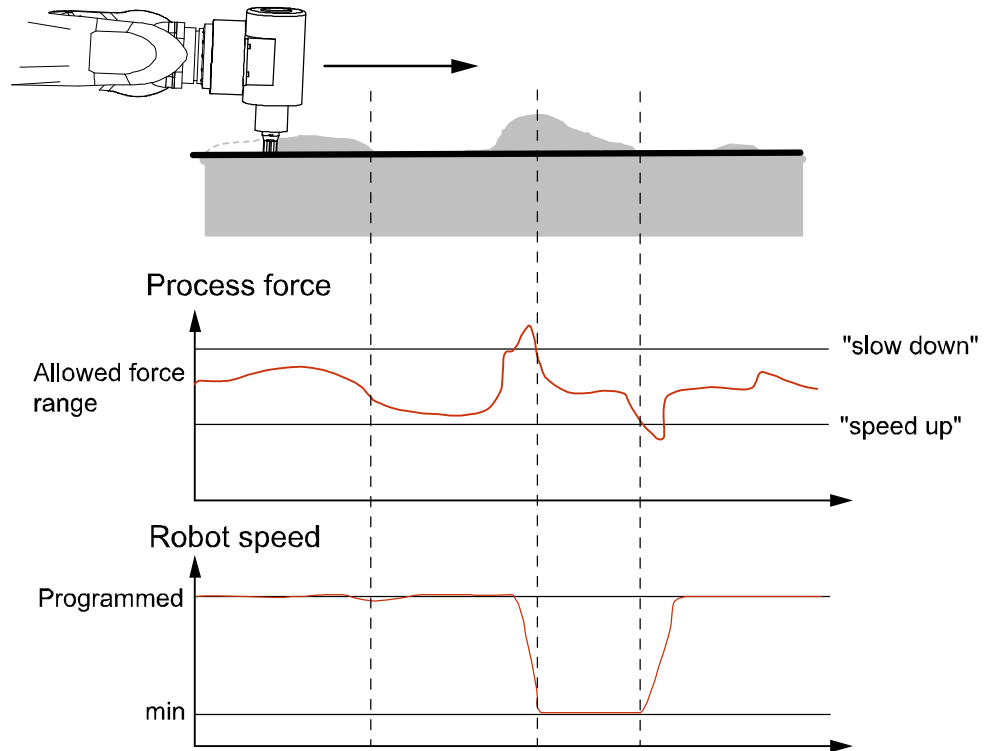
## 4 Programming

### 4.1.2 Force controlled speed change applications

*Continued*

#### Example

The figure below illustrates how the robot speed is adapting to keep the process force within allowed force range. For more information, see [How does it work? on page 33](#).



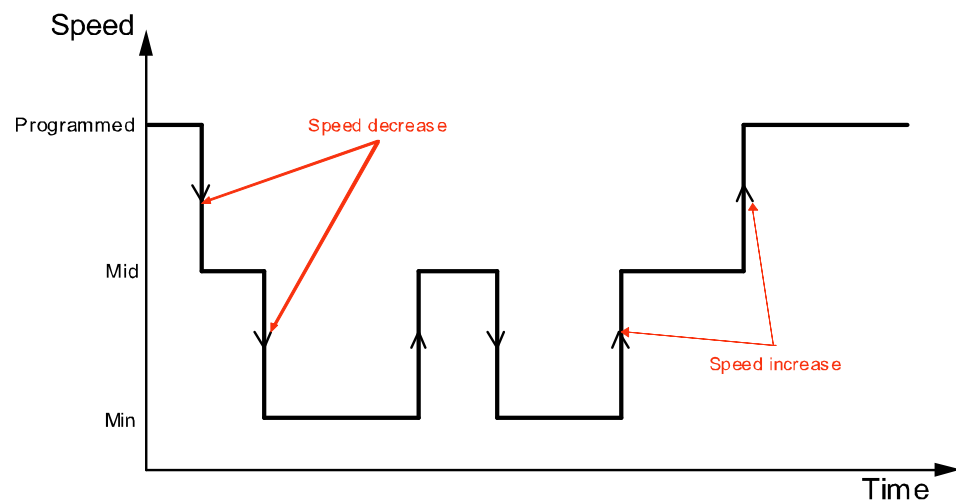
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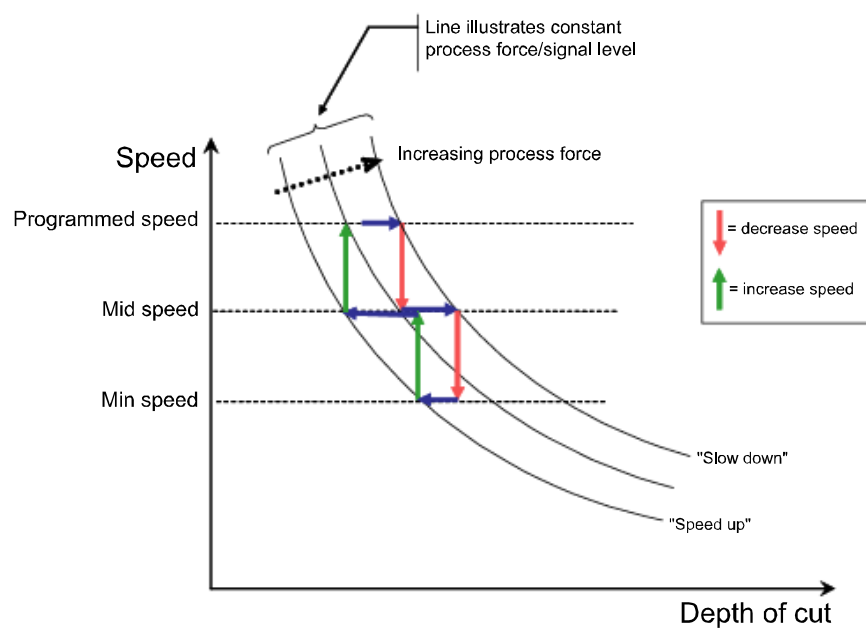
#### How does it work?

The control function for change the speed of the robot is "rule based" and include discrete speed levels in-between which the robot speed is changed. The number of speed levels can be defined using the parameter "No of speed levels". Below is an example showing a process using 3 speed levels. When the process forces increase the speed is reduced and vice a verse:



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The controller function is illustrated in the picture below:



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## 4 Programming

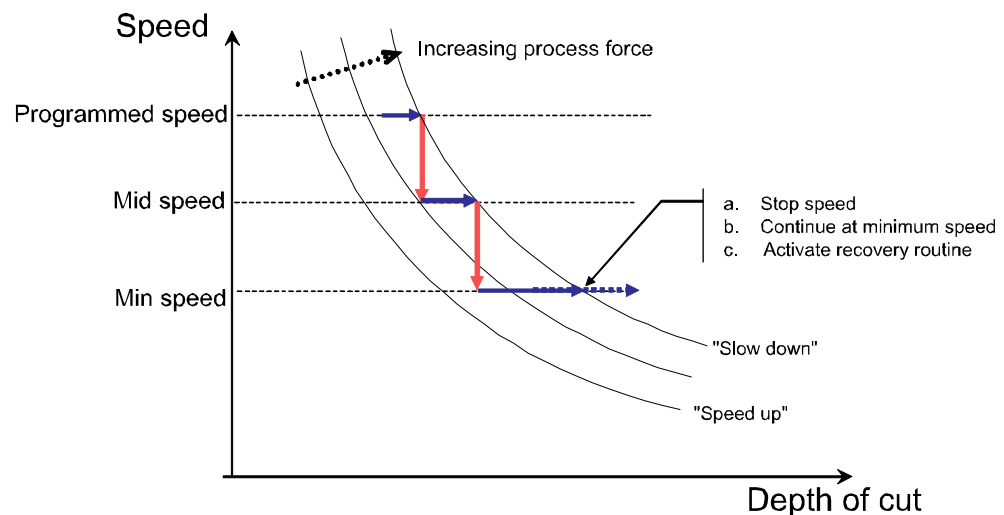
### 4.1.2 Force controlled speed change applications

*Continued*

If changes in process will appear suddenly and a short response time for SpeedChange is urgently required one shall consider to use a 2 speed level solution. This will result in the quickest speed reduction. Applications with slowly changing process forces will gain cycle time using a multiple speed level solution, but number of speed levels above 4 should be used with care.

For situations where not even the minimum speed will reduce the process forces below the "slow down" level there are 3 optional behaviors to choose between.

- 1 When reaching the "slow down" level simply stop the robot speed.
- 2 When reaching the "slow down" level continue with minimum speed.
- 3 When reaching the "slow down" level activate a recovery routine. Recovery routine to be defined by the program designer and shall include a back up procedure to eliminate the cause of the exceeded process forces. After executing the recovery routine the robot will continue on the original path. If the "slow down" level is reached during the recovery routine the robot will stop.



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### 4.1.3 Force controlled assembly applications

#### About this section

This section presents an overview of the RAPID components, i.e. instructions, functions and data types, used in force controlled assembly applications. For more detailed information, such as the syntax, see [RAPID reference information on page 63](#).



#### Note

The RAPID instructions for Force Control can be found in the **MotionAdv.** pick list when programming using the FlexPendant or RobotStudio.

#### Instructions for sensor calibration

FCLoadID is used to estimate the mass and center of gravity of the current load as measured by the force sensor. FCCalib is used to calibrate the system, and is required before the sensor can be used for force control.

| Instruction | Description   |
|-------------|---|
| FCLoadID    | Identifies the load measured by the force sensor. The identified load is used to calibrate the force sensor.  |
| FCCalib     | Calibrates the force sensor to remove sensor offset and compensate for gravity. Note that the calibration requires a precise definition of the load. Therefore, FCLoadID should be used before FCCalib. |

#### Instructions for activation/deactivation of Force Control

These are the instructions used to activate and deactivate Force Control:

| Instruction | Description   |
|-------------|---|
| FCAct       | Activates Force Control.<br>FCAct activates Force Control and defines the parameters below: <ul style="list-style-type: none"> <li>force control coordinate system (used e.g. for damping of Force Control).</li> <li>damping (i.e. sensitivity to contact forces in different directions in the force control coordinate system).</li> </ul> |
| FCDeact     | Deactivates Force Control.  |

#### Instructions for force, torque and movement references

Force, torque and movement references are normally used to search for a fit.

When activating a force or a torque reference, the robot will attempt to maintain the specified force. When activating a movement reference, the robot will attempt to move according to the specified movement pattern.

*Continues on next page*

## 4 Programming

### 4.1.3 Force controlled assembly applications

*Continued*

These are the instructions used to handle force, torque and movement references:

| Instruction       | Description  |
|-------------------|--|
| FCRefMoveFrame    | <p>Sets up a reference movement coordinate system, i.e. a coordinate system in which reference movement can be defined. The origin of this coordinate system is always the tool center point, but the directions can be defined.</p> <p>If no reference movement coordinate system is specified, the directions of the work object coordinate system will be used. If no work object is used either, the directions of the world coordinate system will be used.</p> |
| FCRefForce        | <p>Specifies a reference force (size and direction) that the robot will try to maintain. The unit is N.</p> <p>The reference force is activated by FCRefStart.</p>   |
| FCRefTorque       | <p>Specifies a reference torque (size and direction) that the robot will try to maintain. The unit is Nm.</p> <p>The reference torque is activated by FCRefStart.</p>  |
| FCRefSprForceCart | <p>Specifies a position dependent reference force. The size of the force reference will increase with the distance from a specified position.</p>  |
| FCRefSpiral       | <p>Specifies a reference movement. The robot TCP tries to make a spiral movement with larger and larger circles (and then smaller and smaller).</p> <p>If a contact force affects the robot, e.g. something is blocking the path, the movement will deviate from the intended path.</p> <p>The reference movement is activated by FCRefStart.</p>  |
| FCRefCircle       | <p>Specifies a reference movement. The robot TCP tries to make a circle movement.</p> <p>If a contact force affects the robot, e.g. something is blocking the path, the movement will deviate from the intended path.</p> <p>The reference movement is activated by FCRefStart.</p>  |
| FCRefLine         | <p>Specifies a reference movement. The robot tries to move back and forth along a line.</p> <p>If a contact force affects the robot, e.g. something is blocking the path, the movement will deviate from the intended path.</p> <p>The reference movement is activated by FCRefStart.</p>  |
| FCRefRot          | <p>Specifies a reference movement. The robot tries to rotate back and forth.</p> <p>If a contact force affects the robot, e.g. something is blocking the path, the movement will deviate from the intended path.</p> <p>The reference movement is activated by FCRefStart.</p>   |
| FCRefStart        | <p>Activates reference force, torque and movement. The robot starts to move in order to achieve the specified reference values.</p>  |
| FCRefStop         | <p>Deactivates reference force, torque and movement.</p> <p>The reference values can also be deactivated by conditions (see <a href="#">Instructions for end conditions on page 37</a>).</p>   |

*Continues on next page*

**Instructions for end conditions**

Force, torque and movement references are normally used to search for a fit. End conditions are used to determine when such a search has succeeded. The search will continue with the specified reference values as long as the condition is true. When the condition turns false, the end condition is triggered and the search stops. All conditions have a time-out that allows execution to continue after a specified period of time, even if the criterion for ending the search was never fulfilled.

The reference values are by default active after an end condition has been triggered, but can be deactivated by the optional argument `ZeroRefAtEnd` in the `FCCondWaitWhile` instruction.

These are the instructions used to handle end conditions:

| Instruction                   | Description   |
|-------------------------------|---|
| <code>FCCondPos</code>        | Sets up a TCP position condition. The execution will wait while the condition is true and let the reference values affect the robot.<br>The condition is activated by <code>FCCondWaitWhile</code> .  |
| <code>FCCondOrient</code>     | Sets up a tool orientation condition. The execution will wait while the condition is true and let the reference values affect the robot.<br>The condition is activated by <code>FCCondWaitWhile</code> .  |
| <code>FCCondTCPSpeed</code>   | Sets up a TCP speed condition. The execution will wait while the condition is true and let the reference values affect the robot.<br>The condition is activated by <code>FCCondWaitWhile</code> .   |
| <code>FCCondReoriSpeed</code> | Sets up a tool reorientation speed condition. The execution will wait while the condition is true and let the reference values affect the robot.<br>The condition is activated by <code>FCCondWaitWhile</code> .  |
| <code>FCCondForce</code>      | Sets up a force condition. The execution will wait while the condition is true and let the reference values affect the robot.<br>The condition is activated by <code>FCCondWaitWhile</code> .   |
| <code>FCCondTorque</code>     | Sets up a torque condition. The execution will wait while the condition is true and let the reference values affect the robot.<br>The condition is activated by <code>FCCondWaitWhile</code> .  |
| <code>FCCondWaitWhile</code>  | Activates the specified condition.<br>By default, the reference values continue to be active after a condition is met. By setting the argument <code>ZeroRefAtEnd</code> , the reference values are deactivated when a condition is met.<br>Only the last specified condition is activated. |

**Instructions for supervision**

Instructions for supervision can be used as safety measurements, limiting robot speed, their work area etc. All supervision conditions must be true, otherwise an emergency stop will occur.

Supervision conditions must be set up before `FCAct`, as this is the activating instruction.

*Continues on next page*

## 4 Programming

### 4.1.3 Force controlled assembly applications


*Continued*

These are the instructions used to handle supervision:

| Instruction      | Description  |
|------------------|--|
| FCSupvPos        | Defines a volume that the TCP must stay within.<br>The supervision is activated by <code>FCAct</code> .<br>If no position supervision is set, a default position supervision is set up and activated by <code>FCAct</code> . The default supervision is a box stretching 500 mm in each direction from the point where the TCP is when <code>FCAct</code> is executed. |
| FCSupvOrient     | Defines orientation limits that the tool orientation must stay within.<br>The supervision is activated by <code>FCAct</code> .   |
| FCSupvTCPspeed   | Defines speed limits that the TCP speed must stay within.<br>The supervision is activated by <code>FCAct</code> and is by default 250 mm/s.  |
| FCSupvReoriSpeed | Defines reorientation speed limits that the tool orientation must stay within.<br>The supervision is activated by <code>FCAct</code> and is by default 50 deg/s.   |
| FCSupvForce      | Defines force limits that the contact force must stay within.<br>The supervision is activated by <code>FCAct</code> .  |
| FCSupvTorque     | Defines torque limits that the torque must stay within.<br>The supervision is activated by <code>FCAct</code> .  |

### Functions

These are the functions used for Force Control:

| Function         | Description  |
|------------------|--|
| FCLoadID         | Identifies the present load using the force sensor.<br> <b>Note</b><br>It is important to make a precise load identification and calibrate the sensor with this load before using Force Control.<br>Always use a Move instruction with fine position before a <code>FCLoadID</code> . |
| FCGetForce       | Retrieves the force sensor readings.   |
| FCGetProcessData | Returns information about the process.   |
| FCIsForceMode    | Returns true if the robot is in force mode, else false.  |

### Data types

These are the data types used in Force Control:

| Data type     | Description  |
|---------------|--|
| fcboxvol      | A box volume used by <code>FCCondPos</code> and <code>FCSupvPos</code> to define if the TCP should be inside or outside the box.           |
| fccylindervol | A cylinder volume used by <code>FCCondPos</code> and <code>FCSupvPos</code> to define if the TCP should be inside or outside the cylinder. |
| fcspherevol   | A sphere volume used by <code>FCCondPos</code> and <code>FCSupvPos</code> to define if the TCP should be inside or outside the sphere.     |
| fcprocessdata | Used by <code>FCGetProcessData</code> to return information about the Force Control process.   |

*Continues on next page*

| Data type                  | Description  |
|----------------------------|--|
| <code>fcframe</code>       | Used by <code>FCAct</code> and <code>FCRefMoveFrame</code> to define which coordinate system should be the reference for the force control coordinate system and the reference movement coordinate system. |
| <code>fcplane</code>       | Used by <code>FCRefCircle</code> and <code>FCRefSpiral</code> to define in which plane the robot should move.  |
| <code>fcforcevector</code> | Used by <code>FCGetForce</code> to return the detected forces in different directions.   |
| <code>fcdamping</code>     | Used by <code>FCAct</code> to define how fast the robot should move in a direction when it is exposed to a force or a torque in that direction.  |
| <code>fclindir</code>      | Used by <code>FCRefLine</code> to define in which direction the robot should move.   |
| <code>fcrotmdir</code>     | Used by <code>FCRefRot</code> to define in which direction the robot should rotate.  |
| <code>fccondstatus</code>  | Part of the data type <code>fcprocessdata</code> . Used to show which conditions are fulfilled.  |
| <code>fcspeedvector</code> | Defines 3 linear and 3 rotational speed components.  |
| <code>fcxyznum</code>      | Defines a numerical value in each of the directions x, y and z.  |

## 4 Programming

---

### 4.2.1 Force controlled pressure applications

## 4.2 Code examples

### 4.2.1 Force controlled pressure applications

---

#### Overview

This section provides examples on how to program the press instructions in Force Control for Machining. The basic approach for creating a RAPID program using force controlled press instruction is as follows:

- 1 Identify the load.
- 2 Move to a point close to contact but not in contact.
- 3 Calibrate.
- 4 Setup force control directions and start movement.
- 5 Move linear or circular with contact.
- 6 Leave surface.

---

#### Example

The following example uses force Z with a movement in x-direction.

```
PROC press1()  
  PERS loaddata TestLoad:=[0.001,[0,0,0.001],[1,0,0,0],0,0,0];  
  
  ! Identify the load using the sensor  
  TestLoad:=FCLoadID();  
  
  ! Move close to contact  
  MoveJ offs(B,0,0,2) , v100, fine, tool0; !! start 2mm above  
    contactpoint  
  
  ! Calibrate the force sensor  
  FCCalib TestLoad;  
  
  ! Approach surface and start move to robtarget C at 50% of 60 N  
    i.e 30 N  
  FCPressLStart C, v100, \Fz:=60, 50, z30, myTool;  
  
  ! Move Linear from C to D1 with a Force of 50 N in the z-direction  
  FCPressL D1,v100,50,z30,myTool;  
  
  ! Move Linear from D1 to D2 with a Force of 70 N in the  
    z-direction  
  FCPressL D2,v100,70,z30,myTool;  
  
  ! Leave surface and move to robtarget E, Force control is disabled  
    after this instruction  
  FCPressEnd E, v100,myTool;  
ENDPROC
```



## 4.2.2 Force controlled speed change applications

### Overview

This section provides examples on how to program the force controlled SpeedChange function. The basic approach for creating a RAPID program using force controlled SpeedChange is as follows:

- 1 Configure FC SpeedChange parameters such as, Feedback type, LP filter, etc.
- 2 If 6DOF force sensor is used for feedback, identify load and calibrate sensor. If an analogue signal is used from e.g. a spindle motor, define the nominal signal level in the parameter *Feedback offset*.
- 3 Active FC SpeedChange with reference and desired recover behavior.
- 4 Perform machining task.
- 5 Deactivate FC SpeedChange.



#### Note

Do not enable force control (`FCAct` in `Assembly FC`), when using force controlled SpeedChange function.

### Example with force sensor

This example shows how to use Force Controlled SpeedChange function with force sensor. Before running the RAPID program, make sure to choose "Calib Force Magn" option for FC SpeedChange system parameter "Feedback type".

```
PERS robtarget myHome := ...
VAR tooldata myTool := ...
VAR wobjdata myWobj := ...
PERS loaddata myLoad := ...

myLoad := FCLoadID();
FCCalib myLoad;

! move to home position
MoveL myHome, v200, fine, myTool\WObj:=myWobj;

! turn on spindle motor before machining
TurnOnMotor();

! activate SpeedChange with reference force = 200 (N)
FCSpdChgAct 200;

! conduct machining task along path
MoveL ...
...

! deactivate SpeedChange function
FCSpdChgDeact;
```

*Continues on next page*

## 4 Programming

---

### 4.2.2 Force controlled speed change applications

*Continued*

```
! turn off spindle motor after machining
TurnOffMotor();
```

---

#### Example with spindle motor current

This example shows how to use force controlled SpeedChange function with spindle motor current.

Before running the RAPID program:

- 1 Select *Single DAC Input* option for *Feedback type*.
- 2 Set up *Feedback offset* value, e.g., idle current of spindle motor.
- 3 If measurement is noisy, set up *Fdb LP filter bandwidth (Hz)* and select *Yes* for *Use Fdb LP filter*.

```
PERS robtargt myHome := ...
VAR tooldata myTool := ...
VAR wobjdata myWobj := ...

! move to home position
MoveL myHome, v200, fine, myTool\WObj:=myWobj;

! turn on spindle motor before machining
TurnOnMotor();

! activate SpeedChange with reference_motor_current = 2(A)
! use specified recover routine, "my_routine"
FCSpdChgAct 2 \RecoverFunName:="my_routine";

! conduct machining task along path
MoveL ...
...

! deactivate SpeedChange function
FCSpdChgDeact;

! turn off spindle motor after machining
TurnOffMotor();

! user specified recover routine
PROC my_routine()
VAR robtargt current_rbtrgt;

! get starting robot target
current_rbtrgt := CRobT(\Tool:=myTool \WObj:=myWobj);

! local cutting relative to current_rbtrgt
MoveL RelTool(current_rbtrgt,dx,dy,dz), v50, z0, myTool
    \WObj:=myWobj;

MoveL RelTool() ...;
...
```

*Continues on next page*

```
! move back to starting point and prepare for restoring  
! the original planned path  
MoveL current_rbtrgt, v50, z0, myTool\WObj:=myWobj;  
  
ENDPROC
```



#### Note

The parameter *Disable check of saturation* can be used if it is likely that the power output will reach saturation level.

### 4.2.3 Force controlled assembly applications

---

#### Overview

This section provides examples on how to program the robot. The basic approach for creating a RAPID program using Force Control Assembly is as follows:

- 1 Identify the load and calibrate the system.
- 2 Set up desired force and movement pattern.
- 3 Set up end condition.
- 4 Activate force control.
- 5 Activate force and movement pattern.
- 6 Wait for end condition to occur.
- 7 Deactivate force and movement patterns.
- 8 Deactivate force control.

---

#### Activating force control

This example shows the simplest way of achieving force control. Between the instructions `FCACT` and `FCDEACT` the robot will be sensitive to all forces affecting the sensor. The robot will move away from any contact forces, trying to maintain zero contact force on the sensor.

```
VAR tooldata tool1:=[TRUE,[[97.4,0,223],[1,0,0,0]], [5,[23,0,75],  
    [1,0,0,0],0,0,0]];  
PERS loaddata my_load:=[0.001,[0,0,0.001],[1,0,0,0],0,0,0];  
  
! Identify the load using the sensor  
my_load := FCLoadID();  
! Calibrate the force sensor  
FCCalib my_load;  
! Activate force control  
FCACT tool1;  
! Force control is active for 5 seconds  
WaitTime 5;  
! Deactivate force control  
FCDEACT;
```

---

#### Find object position

In this example, the robot will move in the z direction of the world frame. When it runs into an object, it will stop when the force is 10 N and wait there with a constant force. The position of the object can then be measured.

```
VAR tooldata tool1 := ...  
PERS loaddata my_load:=[0.001,[0,0,0.001],[1,0,0,0],0,0,0];  
VAR pos pos1;  
  
my_load := FCLoadID();  
FCCalib my_load;  
  
! Setup the force reference with 10N in Z-direction of the world  
    frame
```

*Continues on next page*

```

FCRefForce \Fz:=10;

! Activate Force Control
FCAct tool1;

! Start moving the robot to achieve the specified force
FCRefStart;

! Wait 10 sec, so the robot will reach the ordered force
WaitTime 10;

! Read robot position
pos1 := CPos(\Tool:=tool1);

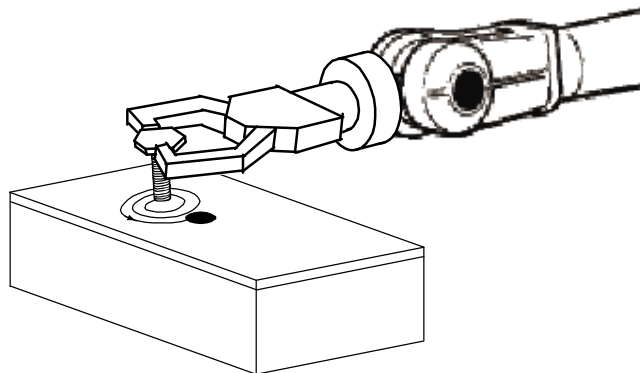
! Stop the reference values
FCRefStop;

! Deactivate force control
FCDeact;

```

#### Position search

In this example, the robot holds a bolt that should be inserted in a hole. The bolt is pressed towards a surface with a force of 10 N. It is moved in spirals along the surface until the hole is found. When the bolt is above the hole, the force will press it into the hole. When the bolt enters the hole, the z value of the TCP will become less than 550, the position search is finished and the program execution continues.



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```

VAR tooldata tool1 := ...
PERS loaddata my_load:=[0.001,[0,0,0.001],[1,0,0,0],0,0,0];
VAR fcboxvol my_box:= [-9e9, 9e9, -9e9, 9e9, 550, 9e9];
VAR fcprocessdata process_data;

my_load := FCLoadID();
FCCalib my_load;

! Setup the force reference with 10N in negative z direction
FCRefForce \Fz:= -10;

```

*Continues on next page*

## 4 Programming

---

### 4.2.3 Force controlled assembly applications

*Continued*

```
! Setup movement pattern
FCRefSpiral FCPlane_XY, 90, 50, 10;

! Setup end condition: while Z>550 and time<60
FCCondPos \Box:= my_box, 60;

! Activate Force Control
FCAct tool1;

! Activate force and movement pattern (the robot starts to move)
FCRefStart;

! Wait for end condition
FCCondWaitWhile;

! Check if the position condition or timeout triggered the condition
! Note that if a condition is FALSE it means it has triggered
process_data:=FcGetProcessData(DataAtTrigTime);
TPWrite "timecond = " \BOOL := process_data.conditionstatus.time;
TPWrite "positioncond = " \BOOL :=
    process_data.conditionstatus.position;
FcRefStop
FCDeact;
```

---

#### Supervision example

In this example, supervision is used. A position supervision limits the x coordinate to be between -200 and 1000, the y coordinate to be between -500 and 500 and the z coordinate to be between 300 and 1200. A force supervision in the force coordinate system limits the force in positive z direction to 1000 N.

```
VAR tooldata tool1 := ...
PERS loaddata my_load:=[0.001,[0,0,0.001],[1,0,0,0],0,0,0];
VAR fcboxvol my_supv_box:= [-200, 1000, -500, 500, 300, 1200];

my_load := FCLoadID();
FCCalib my_load;

! Set up position supervision
FCSupvPos \Box:= my_supv_box;

! Set up force supervision
FCSupvForce \Zmax:=1000;

! Activate Force Control and supervision
FCAct tool1;
...
FCDeact;
```

## 5 Execution behavior

### 5.1 Conflicting reference values

#### Only one reference in each direction

For each of the directions x, y and z, there can only be one reference movement.  
A new reference value overwrites the old value in the same direction.

#### Example 1

In this example, a force reference of 20 N will be activated by `FCRefStart`. The first `FCRefForce` will be overwritten, and therefore has no effect.

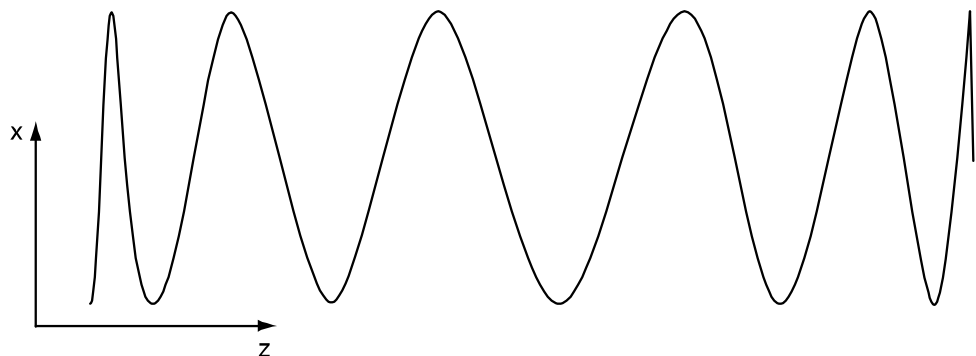
```
FCRefForce \Fx:=10;
FCRefForce \Fx:=20;
FCAct tool1;
FCRefStart;
```

#### Example 2

In this example, the reference movement in the x direction will be determined by the `FCRefCircle` instruction. The reference movement in the z direction is overwritten by the `FCRefLine` instruction.

```
FCRefCircle FCPLANE_XZ, 15, 300;
FCRefLine FC_LIN_Z, 300, 100;
FCAct tool1;
FCRefStart;
```

The resulting reference movement will be similar to the illustration below.



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#### Example 3

If you want a movement in the shape of a circle that drifts in one direction, you cannot use `FCRefCircle` and `FCRefLine` (see example above). Instead you can use `FCRefCircle` and `FCRefForce`, where the reference force results in a linear movement.

```
FCRefCircle FCPlane_XZ, 180, 100;
FCRefForce \Fz:=10;
FCAct tool1;
```

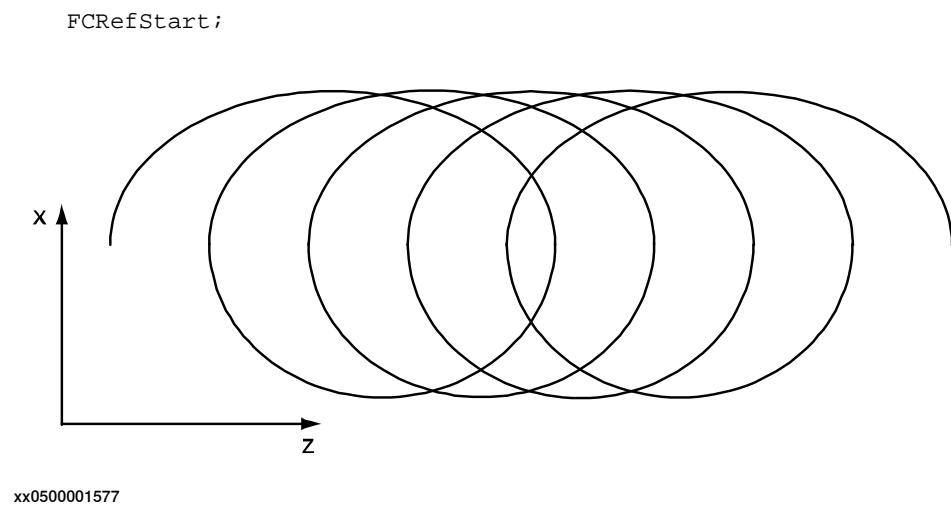
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## 5 Execution behavior

---

### 5.1 Conflicting reference values

*Continued*





## 5.2 Damping and LP-filter

### Damping

Damping is a definition of how large force is required for the robot to move at a certain speed. The damping parameters define how many Newtons are required to make the robot move at 1 m/s. The higher the value, the less responsive the robot gets.

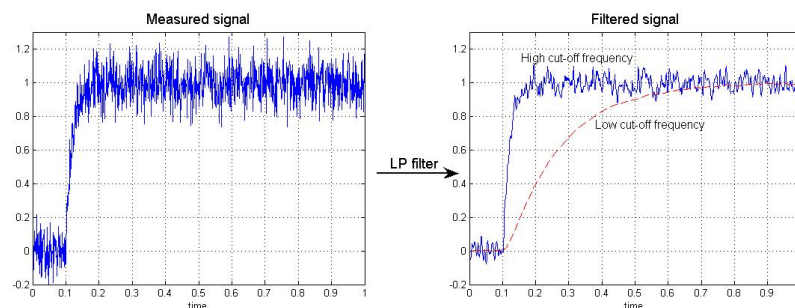
In Force Control, a contact force will make the TCP move with a speed proportional to the contact force. A contact torque will make the tool reorient with a speed proportional to the contact torque. The damping variable defines the proportions between a force and the resulting speed, and a torque and the resulting reorientation speed, in the direction x, y and z. The values are given as a percentage of the of the system parameter values defined in the type FC Kinematics, see [The FC Kinematics type on page 202](#).

### LP-filter

A Low-Pass filter lets the amplitude of low frequency signals pass through, and the amplitude of frequencies higher than the cut-off frequency are attenuated. If the signal is changing rapidly, a high cut-off frequency is needed. On the other hand, if the measured force is noisy, a low cut-off frequency may be required in order to remove the noise.

### Illustration

The figure illustrates an LP-filter.



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### Force controller structure and tuning

The picture shows a simplified picture of the force control loop.

In a force controlled direction the measured forces are subtracted from the corresponding reference forces.

This difference is divided by D (=Damping). Damping is a force to speed factor and thus a speed reference is generated. This speed reference is low pass filtered with a cut off frequency that should be chosen depending on your robot model and process etc.

Default it is set to 3Hz which is a suitable value when the contact is really stiff (metal to metal).

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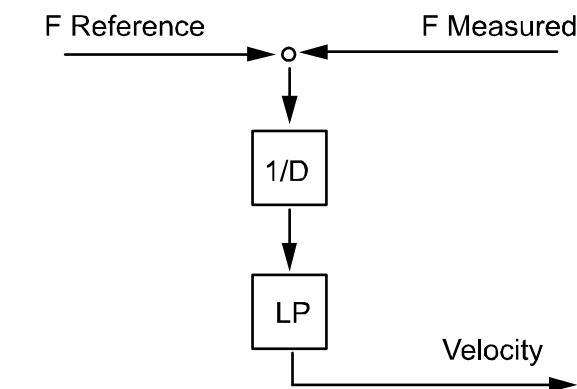
## 5 Execution behavior

### 5.2 Damping and LP-filter

*Continued*

For the large robot it is not possible to increase this value much but for a small robot with some compliance in the tool a filter frequency up to 25Hz can be used. Since tuning both damping and low pass filter depends on compliance of tool, robot model, robot configuration etc. there is a unique set of these parameters for each process.

Both the damping and the LP filter cut-off frequency strongly affect how quickly and accurately the system is able to control the pressure force. If the robot reacts slowly when the force changes, or loses contact with the workpiece for periods of one or several seconds also for accurately programmed paths and low speeds, it is often possible to improve performance by decreasing the damping and/or increasing the LP filter cut-off frequency. On the other hand, if the robot bounces or vibrates rapidly with constant or increasing amplitude when pressing against the surface, this indicates that the damping should be increased and/or the filter frequency should be decreased.



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#### Note

Changing the parameters of the damping or Low pass filter might make the robot unstable.

#### Damping

The damping can easily be changed by an argument in `FCPress1LStart`. The argument represent a percentage of the configured damping value. (down to 50%, no upper limit)

For bigger changes the damping value needs to be re configured under, Motion->FC Kinematics-> Damping in Force Z direction.

#### Low pass filter

Low Pass filter can be configured by the parameters in [Type FC Kinematics on page 202](#) or set by the RAPID instruction [FCSetLPFilterTune on page 128](#).

Default value for `FCSetLPFilterTune` is set by the system parameter *Bandwidth of force loop filter* in the type *FC Kinematics*.

The value set by this method is valid until the instruction `FCResetFilterTune` is used, a new value is set, or the controller is restarted.

## 5.3 Overcome friction

---

### Overview

The friction generated between the tool and the work object depends on the force applied by the robot. If the speed parameter in the `FCRefLine` instruction is too low the friction will keep the robot from moving.

---

### Example

```
...  
!Setup the force reference in the positive z direction  
FCRefForce \Fz:=300;  
FCRefLine FC_LIN_Y, 0.1, 100;  
FCAct tool1;  
FCRefStart;  
...
```

In this example the force against the work object is high and the speed is very low, so the robot might not move from its position.

To get the robot moving try one of the following:

- Reduce the force.
- Increase the speed.
- Add oscillation to the force.



#### Note

The amount of friction also depends on the materials of the tool and work object.

## 5 Execution behavior

---

### 5.4 Special cases

### 5.4 Special cases

---

#### Jog the robot in force control

The user is allowed to jog the robot in force control, the setup by `FCAct` is valid during jogging. To jog the robot in normal mode, use `FCDeact` or `PPmove` (see below).

#### Use PPmove

Moving the program pointer in the RAPID code is normally no problem. But if the program pointer is moved when the robot is in Force mode, the robot automatically switches from force mode to position mode.

#### Move the robot

Normal Move instructions are not allowed, and will be ignored if used, in force mode. This also applies to regain movements.

#### Start, stop and stepwise execution in manual mode

If you push the stop button force control references stop, but the force control mode is still active. When you push the start button force control references will start again.

During stepwise execution any force control references will start and stop, just as if you were pushing the start and stop buttons.

## 5.5 FC Press optimization

### 5.5.1 Use Spd FFW

#### Overview

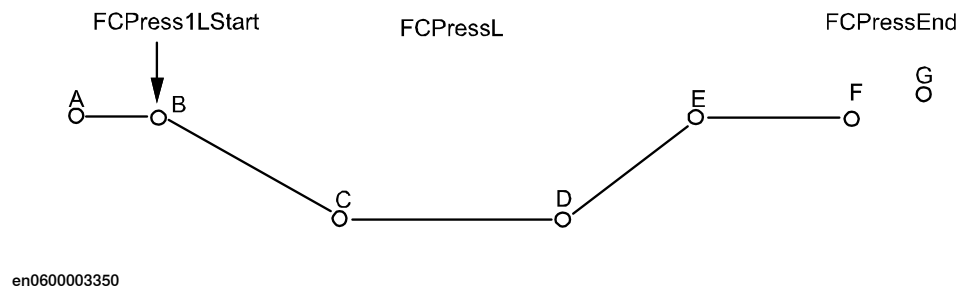
If the path is complex and the programmed path is accurate the performance is going to be enhanced by adding optional argument `UseSpdFFW` (use speed feed forward). `FCPressure` may be also used for temporary leaving the surface without deactivating.

#### Example 1

This example illustrates how to increase the performance.

```
FCPress1LStart;
```

The force in this example is directed down, see picture below. It would be possible to run directly from robtarget B to robtarget E but the performance will increase by adding robtarget C and D and using optional argument `\UseSpdFFW`.

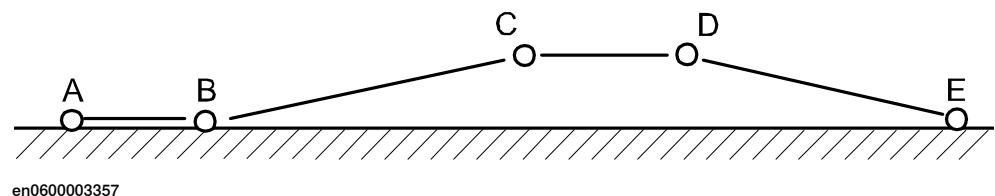


#### Example 2

This example illustrates how to leave the surface without deactivating.

```
FCPress1LStart B, v100, 70, z30 \UseSpdFFW, tool1;  
FCPressL C, v100, 0, z30, tool1;  
FCPressL D, v100, 0, z30, tool1;  
FCPressL E, v100, 70, z30, tool1;
```

The reference force is temporarily switched off (set to 0) together with the optional argument `UseSpdFFW`. The robot will leave the surface and follow the path to C and D. Note that the robot is still force controlled and will not behave 100% like position controlled robot. The robot will not reach exactly to position C or D.



*Continues on next page*

## 5 Execution behavior

---

### 5.5.1 Use Spd FFW

*Continued*



#### Note

Leaving the surface works best for tool coordinate system or work object coordinate system, i.e. argument `ForceFrameRef` in instruction `FCPress1LStart` set to `FC_REFFRAME_TOOL` (default) or `FC_REFFRAME_WOBJ`. If path coordinate system (`FC_REFFRAME_PATH`) is used, a jerky motion may occur. See [Programming in path coordinates on page 59](#).

## 5.6 FC SpeedChange control design

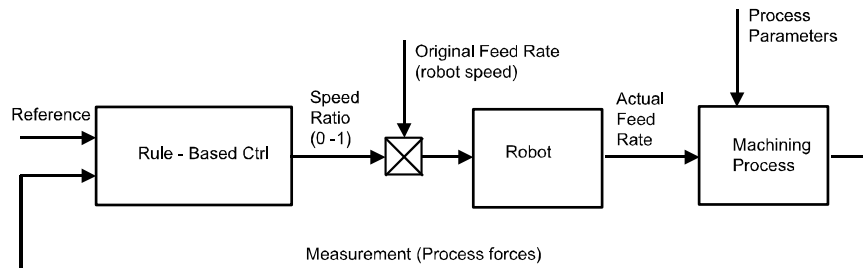
### 5.6.1 Controller scheme

#### Overview

The FC SpeedChange controller for reducing/increasing the robot speed is a rule-based logic controller. The design details are described in following sections.

#### Scheme

The force controlled speed control scheme is shown in the figure below. The maximum force is specified for the machining process, and the actual process force is monitored and controlled to be less than the maximum force by adjusting the machining feed rate (robot speed). The output of the rule-based logic control is the percentage (between 0% and 100%) of the original feed rate.



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*Continues on next page*

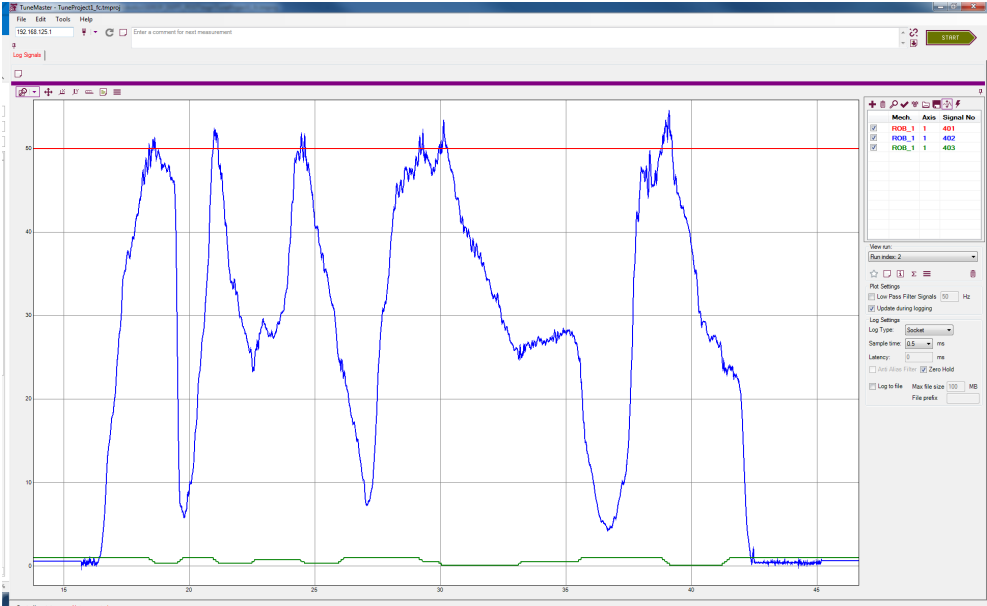
# 5 Execution behavior

## 5.6.1 Controller scheme

Continued

### Available test signals to tune the process

The following picture illustrates the three test signals that appear from a recording made with the TuneMaster. In this example the reference signal is set to value 50. When the difference between the reference signal (401) and the measurement signal (402) fulfills the criteria for speed decrease the speed ratio signal (403) drops, in this case to four levels.



xx1800000946

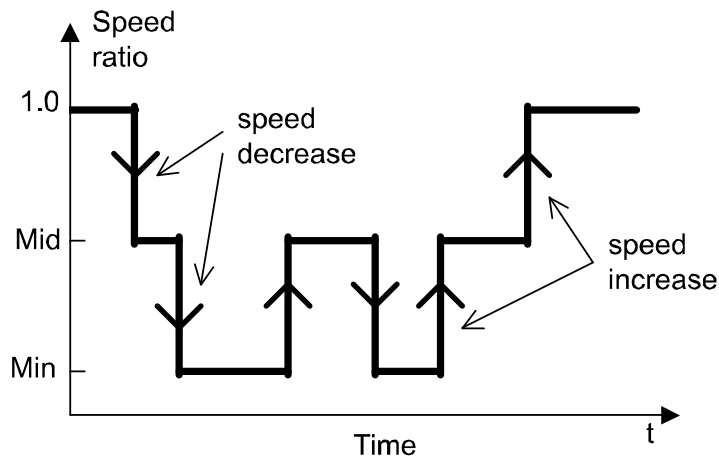
|                          |   |
|--------------------------|---|
| Signal 401 (red color)   | Reference test signal                   |
| Signal 402 (blue color)  | Measurement (Process force) test signal |
| Signal 403 (green color) | Speed ratio signal                      |



### 5.6.2 Rule based logical control

#### Increase/Decrease

The controller output, speed ratio, is generated by certain rules based on the measured process force information. A sample speed ratio output of 3-step rule-based logic controller is shown in the following figure.



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Instead of changing continuously as in normal PID control, speed ratio in rule-based logic control is divided into several discrete steps. The logic rules will decide when the speed will decrease or increase to the next stage or remain at current stage. The goal of SpeedChange is to keep process force below a pre-specified maximum force as fast as possible.

Although ideally more steps means more control accuracy, 3 steps would be enough for most applications. Too many steps will increase the response time when cutting large-size material and make speed reduction less responsive. 2-step speed control would be the most used control setup.

*Continues on next page*

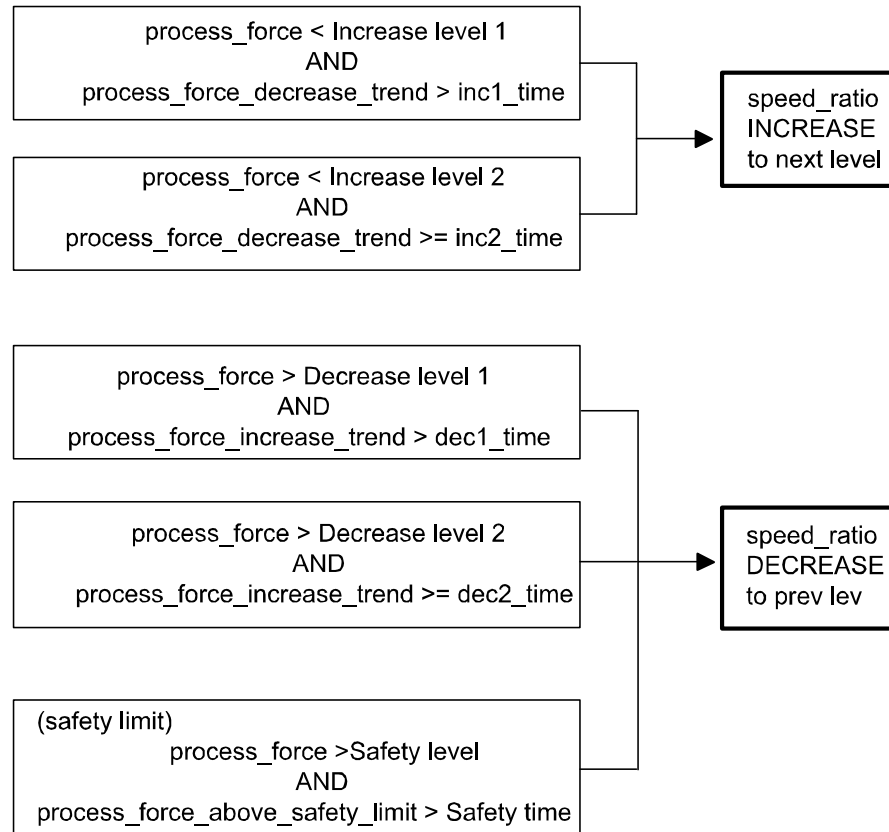
## 5 Execution behavior

### 5.6.2 Rule based logical control

*Continued*

#### Rules

The following rules decide when to increase or decrease the speed ratio. In all other conditions, controller maintains the previous speed ratio.



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#### 5.6.3 Programming in path coordinates

---

##### Overview

Defining the force control coordinate system relative to the path coordinate system gives the possibility to define the force control action relative to the programmed motion trajectories of the robot. This is particularly useful in situations where it is desired to apply a force against a surface with a varying normal direction, without reorienting the tool.

For a description of the path coordinate system see *Technical reference manual - RAPID Instructions, Functions and Data types*, instruction `CorrCon`.

---

##### Usage

It is important to note that all directions in path coordinates except the force control direction will be position-controlled. If the robot TCP position has drifted away from the programmed path and the path frame undergoes a quick rotation, this will cause the position reference to change quickly. This will introduce a very rapid corrective motion or "jerk" in the position-controlled directions. Built-in supervision is present in the system in order to stop the robot if the corrective motion becomes too fast. If this occurs, modify the program in one or several of the following ways:

- 1 Program the path closer to the surface.
- 2 Decrease the path speed, especially near sharp corners in the path.
- 3 Reprogram the path to avoid sharp path corners, for example, by increasing the size of the corner zones.

A rule of thumb is that the force control path deviation, the distance from the programmed TCP position to the true TCP position, should be shorter than the effective radius of curvature of the programmed path.

## 5 Execution behavior

---

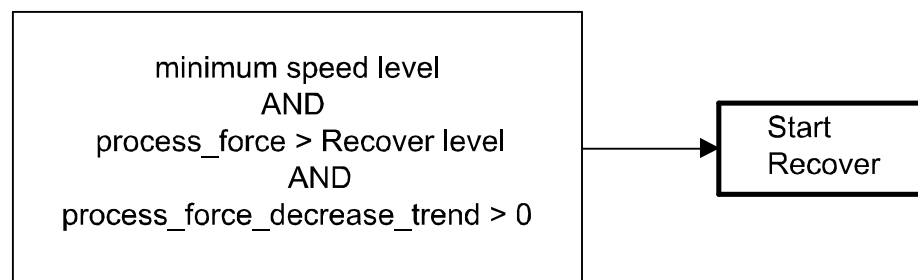
### 5.6.4 Recovery routine

#### 5.6.4 Recovery routine

---

##### Overview

If process force is still higher than the reference force when the feed rate is already at its lowest possible speed (usually this condition happens if larger volume of material than expected is encountered during machining process), a recovery process will start in order to avoid tool damage. The following diagram is the rule to enter the recovery process.



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The recovery process could simply stop the robot, or more a advanced solution would be to perform local cutting in layers to get rid of the large material, and then continue the original path after local cutting. The local cutting process needs to be implemented by user as a RAPID routine, no recovery routine is defined by default. A sample recovery routine is shown as below.

---

##### Recover example

```
PROC user_recover_routine()  
VAR robtargt current_rbtrgt;  
! get starting robot target  
current_rbtrgt := CRobT(\Tool:=UserTool \WObj:=UserWobj);  
! local cutting relative to current_rbtrgt  
MoveL RelTool(current_rbtrgt,dx,dy,dz), v50, z0, UserTool  
  \WObj:=UserWobj;  
MoveL RelTool() ..... ;  
.....  
! move back to starting point  
MoveL current_rbtrgt, v50, z0, UserTool\WObj:=UserWobj;  
ENDPROC
```

The user-defined recover routine will be automatically called during recover process when specified.

## 6 Troubleshooting

### 6.1 What to do when...

#### Troubleshooting drifting robot

When the robot is in force control mode (after executing `FCAct`) and no external force except gravity are present, it should not move (as long as no reference force, torque or movement is applied). If the robot drifts away with a slow movement anyway, check the following:

| Step | Action   |
|------|--|
| 1    | The robot should be near its working position when calibrated with the instruction <code>FCCalib</code> .  |
| 2    | Verify that the load is identified with the instruction <code>FCLoadID</code> and that the <code>LoadIdErr</code> is smaller than 0.1 for an optimal load identification. If the movement of axes 5 and 6 are too limited during this load identification, the result may be poor. |
| 3    | Verify that the system parameters are correctly defined. E.g. too low damping in the type <i>FC Kinematics</i> may cause the robot to drift.   |
| 4    | Verify that the PMC Sensor setup matrix is correctly typed in.   |
| 5    | Verify the orientation of gravity with respect to the base frame. If necessary update the system parameter <i>Gravity Alpha</i> and <i>Gravity Beta</i> in the type <i>Robot</i> . For more information, see <i>Technical reference manual - System parameters</i> .               |

#### Troubleshooting that the robot stops with an emergency error

When the force control is activated by `FCAct` the speed and position is by default supervised. If the supervisions conditions are triggered the robot stops with an emergency error. These default conditions can be changed by specifying new conditions in the program.

##### Example 1

```
FCSupvPos \PosSupvFrame:=[current_pos.trans, [1,0,0,0]]
\Box:=[-1500,1500,-1500,1500,-1500,1500];
FCAct tool0 \ForceFrameRef:=FC_REFFRAME_WOBJ
\ForceFrameOrient:=[1,0,0,0]
\DampingTune:=[50,50,50,50,50,50];
```

Sets up a position supervision where the TCP must stay between -1500 mm and 1500 mm in all the three directions (i.e. x, y, z).

##### Example 2

```
FCSupvTCPspeed \Speed \Xmin:=-1000 \Xmax:= 1000 \Ymin:=-1000 \Ymax:=
1000 \Zmin:=-1000 \Zmax:= 1000;
FCAct tool0 \ForceFrameRef:=FC_REFFRAME_WOBJ
\ForceFrameOrient:=[1,0,0,0]
\DampingTune:=[50,50,50,50,50,50];
```

Sets up a linear speed supervision where the TCP speed must stay between -1000 mm/s and 1000 mm/s in all the three directions (i.e. x, y, z).

##### Example 3

```
FCSupvReoriSpeed \Speed \Xmin:=-100 \Xmax:= 100 \Ymin:=-100 \Ymax:=
100 \Zmin:=-100 \Zmax:= 100;
```

*Continues on next page*

## 6 Troubleshooting

---

### 6.1 What to do when...

*Continued*

```
FCAct tool0 \ForceFrameRef:=FC_REFFRAME_WOBJ  
           \ForceFrameOrient:=[1,0,0,0]  
           \DampingTune:=[50,50,50,50,50,50];
```

**Sets up a reorientation speed supervision where the reorientation speed must stay between -100 deg/s and 50 deg/s around all the three directions (i.e. x, y, z).**

## 7 RAPID reference information

### 7.1 Instructions

#### 7.1.1 FCAct

##### Usage

FCAct is used to activate Force Control. At the same time as Force Control is activated, FCAct is used to define the coordinate system for Force Control, and tune the force and torque damping. If a coordinate system is not specified in FCAct a default force control coordinate system is created with the same orientation as the work object coordinate system.

All Force Control supervision is activated by FCAct.

##### Basic example

```
VAR tooldata tool1:=[TRUE,[[97.4,0,223],[1,0,0,0]], [5,[23,0,75],
[1,0,0,0],0,0,0]];
FCAct tool1;
```

Activates Force Control with tool tool1.

The force control coordinate system has the same orientation as the world coordinate system. All dampings are set to 100% of the damping values in the system parameters.

Since the reference were not set in this example the robot will move away from any contact, trying to keep zero contact force.

See also [More examples on page 64](#).

##### Arguments

```
FCAct Tool [\WObj] [\ForceFrameRef] [\ForceFrameOrient]
[\DampingTune]
```

##### Tool

**Data type:** tooldata

The tool used during Force Control. The center point of this tool is the center of the force control coordinate system. Note that the dimensions of the sensor and any interface plates need to be included in the tool definition.

##### [\WObj]

*Work object*

**Data type:** wobjdata

Many of the Force Control definitions are based on the work object coordinate system. For example the orientation of the force control coordinate system and all the corresponding definitions are often given in relation to the work object coordinate system. Search patterns and end conditions are usually also defined in this coordinate system. If no work object is defined the default work object, with coordinate system equal to the world coordinate system, is used.

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.1 FCAct

#### Force Control

#### Continued

`[\ForceFrameRef]`

**Data type:** `fcframe`

`ForceFrameRef` here defines which coordinate system the force control coordinate system is related to. The parameter can be set to either the work object coordinate system or the tool coordinate system. The default value is the work object coordinate system.

`[\ForceFrameOrient]`

**Data type:** `orient`

This parameter specifies the orientation from the coordinate system selected in `ForceFrameRef`. The default value is `[1, 0, 0, 0]`. For information about how to calculate orientations, see the data type `orient` in *Technical reference manual - RAPID Instructions, Functions and Data types*.

`[\DampingTune]`

*Tuning of force and torque damping*

**Data type:** `fcdamping`

The `DampingTune` values can be used to modify the relation between the sensed force and the generated velocity in each direction. By default the values are 100% (of system parameter values) in all directions, but they can be between 50% and infinity. Smaller values means that the robot is more sensitive to external forces.

---

### Program execution

**Execution behavior:**

- `FCAct` activates Force Control, but does not activate reference values. Until `FCRefStart` is executed, the robot behavior is to move away from any sensed contact trying to keep zero contact force.
- All supervision conditions (e.g. `FCSupvPos`), set up prior to the `FCAct` instruction, are activated by `FCAct`. After activation, if any of these conditions are false, an emergency stop will occur.

---

### More examples

#### Example 1

```
VAR tooldata tool1:=[TRUE,[[97.4,0,223],[1,0,0,0]], [5,[23,0,75],
[1,0,0,0],0,0,0]];
FCAct tool1 \ForceFrameRef:=FC_REFFRAME_TOOL
\ForceFrameOrient:=[0,0,1,0];
```

Activates Force Control and defines a force control coordinate system. Based on the tool coordinate system, but rotated 180 degrees around the tools y axis.

#### Example 2

```
VAR tooldata tool1:=...
VAR wobjdata my_wobj := [FALSE,TRUE,"",[[0,0,0],[,0,0,0]],
[[0,0,0],[0.07071,0,0.7071,0]]];
FCAct tool1 \Wobj:=my_wobj;
```

Activates Force Control with:

- `tool tool1`

*Continues on next page*



- force control coordinate system orientation equal to the orientation of the work object `my_wobj`.

### Default supervision

When the force control is activated the speed and position is by default supervised. If the supervisions conditions are triggered, the robot stops with an emergency error.

These conditions are set as a default supervision:

- The position supervision is set so that the TCP must stay between -500mm and 500 mm in all directions (i.e. x, y, z) of the position supervision coordinate system.
- The linear speed supervision checks that the speed in all directions of the work object coordinate system is between -250 mm/s and 250 mm/s.
- The reorientation speed supervision checks that the reorientation speed in all directions of the work object coordinate system must be between -50 deg/s and 50 deg/s.

The default supervised conditions can be changed by specifying new conditions in the code, for more information see [Troubleshooting that the robot stops with an emergency error on page 61](#).

### Limitations

The Force Control will only behave correctly if the load is identified with `FCLoadID` and the sensor is calibrated with `FCCalib` before activating Force Control.

### Syntax

```
FCAct
[Tool':=' ] <persistent (PERS) of tooldata>
['\Wobj':=' <persistent (PERS) of wobjdata>]
['\ForceFrameRef':=' <expression (IN) of fcframe>]
['\ForceFrameOrient':=' <expression (IN) of orient>]
['\DampingTune':=' <expression (IN) of fcnumvector>'];'
```

### Related information

| For information about              | See                                  |
|------------------------------------|--------------------------------------|
| The data type <code>fcframe</code> | <a href="#">fcframe on page 172</a>  |
| Load identification                | <a href="#">FCLoadID on page 158</a> |
| Sensor calibration                 | <a href="#">FCCalib on page 66</a>   |
| Deactivating Force Control         | <a href="#">FCDeact on page 90</a>   |

## 7 RAPID reference information

---

### 7.1.2 FCCalib Force Control

### 7.1.2 FCCalib

---

#### Usage

FCCalib is used to calibrate the force sensor. Before this instruction is executed it is not possible to switch to force control. It is necessary to specify the data for the used load as an argument to this instruction. Load data can easily be retrieved by first performing a load identification using the function FCLoadID. By using the load data the system can do an internal calibration to compensate for sensor offset and prepare gravity force compensation. It is important to understand that the function FCCalib needs to be run every time the load is changed.



#### Tip

It is also recommended to do the calibration close to the position where the robot will be doing most work.



#### Note

The Calibration should always be done when no contact forces are present. The only exception is when using the optional parameter `Recovery` which might be used for example after an emergency stop.

#### Basic example

```
PERS loaddata my_load:=[0.001,[0,0,0.001],[1,0,0,0],0,0,0];  
my_load:= FCLoadID();  
FCCalib my_load;
```

The example above shows how to use FCCalib. It is very important for force control performance to have a good load definition. It is therefore strongly recommended to identify the load using the function FCLoadID.



#### Note

If sensor is room fixed, any load can be used as argument.

#### Arguments

```
FCCalib Load [\Recovery][\IgnoreStandStillCheck]
```

Load

Data type: loaddata

The load used to calibrate the sensor. Only mass and centre of gravity is presently used, so inertia does not have to be specified. Note that this load is the load the sensor feels. It is normal that this load is *not* zero even if only the sensor itself is mounted on the robot. Use the function FCLoadID to identify the load.

[\Recovery]

Data type: switch

*Continues on next page*

Specifies whether to use the previous calibration offset, which was read the last time `FCCalib` was called without this argument. Makes it possible to activate force control when in contact. The argument can be needed for example after an emergency stop.

[IgnoreStandStillCheck]

Data type: switch

Specifies if the process should check if vibrations from the previous movement should be ignored. If the process is stable and the robot is standing still, setting this argument can reduce the cycle time. This argument should not be set if the tool, such as the spindle, is vibrating.

#### Program execution

Before the sensor is calibrated with `FCCalib`, most other Force Control instructions are not allowed.

#### Syntax

```
FCCalib
  [Load':=' ] <expression (IN) of loaddata>
  ['\' Recovery']';'
  ['\' IgnoreStandStillCheck']';'
```

#### Related information

| For information about | See                                   |
|-----------------------|---------------------------------------|
| Load identification   | <a href="#">FCLoadID on page 158.</a> |

## 7 RAPID reference information

---

### 7.1.3 FCCondCombine

RobotWare - OS

### 7.1.3 FCCondCombine

---

#### Usage

FCCondCombine is used to combine more than one condition. The condition is later activated by calling the instruction FCCondWaitWhile, which will wait and hold the program execution while the specified condition is true.

Once activated with FCCondWaitWhile, the program execution will continue to wait while combined condition is within its specified limits.

---

#### Basic examples

The following example illustrates the instruction FCCondCombine.

```
FCCondCombine FC_POSITION_AND_FORCE_OR_TIME;
```

Enables a combination of a force and position condition.

---

#### Arguments

```
FCCondCombine fccombcond
```

fccombcond

Data type: string

The following values are allowed:

- FC\_POSITION\_OR\_TIME
- FC\_SPEED\_OR\_TIME
- FC\_FORCE\_OR\_TIME
- FC\_POSITION\_OR\_FORCE\_OR\_TIME
- FC\_POSITION\_AND\_FORCE\_AND\_TIME
- FC\_POSITION\_AND\_FORCE\_OR\_TIME

---

#### Limitations

The timeout used will be the one for the condition that was setup last.

Example if FCCondPos and FCCondForce is combined:

```
FCCondForce \Xmin:=-100 \XMax:=100, 60 ; ! 60s timeout
FCCondPos \Box:= my_box, 30; ! 30s timeout
FCCondCombine FC_POSITION_AND_FORCE_OR_TIME ;
```

---

#### Syntax

```
FCCondCombine < expression (IN) of string > ';' ;
```

---

#### Related information

| For information about | See  |
|-----------------------|--|
| FCCondWaitWhile       | <a href="#">FCCondWaitWhile on page 88</a> |

## 7.1.4 FCCondForce

### Usage

FCCondForce is used to set up an end condition based on measured force. The condition is later activated by calling the instruction FCCondWaitWhile, which will wait and hold the program execution while the specified condition is true. This allows the reference force, torque and movement to continue until the force is outside the specified limits.

A force condition is set up by defining minimum and maximum limits for the force in the directions of the force control coordinate system. Once activated with FCCondWaitWhile, the program execution will continue to wait while the measured force is within its specified limits.

It is possible to specify that the condition is fulfilled when the force is outside the specified limits instead. This is done by using the switch argument *Outside*.

The condition on force is specified in the force control coordinate system. This coordinate system is setup by the user in the instruction FCAct.

### Basic example

```
FCCondForce \Xmin:=-100 \XMax:=100, 60;
```

Defines a force condition that is true when the force in the x direction of the force control coordinate system is between -100 N and 100 N. No restriction is put on the force in other directions.

When this condition is activated the program execution will wait until the measured force is outside its limits, or until 60 seconds has passed.

See also [More examples on page 70](#).

### Arguments

```
FCCondForce [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]  
[\Outside] TimeOut
```

[\XMin]

*Minimum force in x direction*

**Data type:** num

Lower limit for force in the x direction of the force control coordinate system. A negative value limits the maximum force in the negative x direction.

The unit is Newton and the default value is negative infinity.

[\XMax]

*Maximum force in x direction*

**Data type:** num

Upper limit for force in the x direction of the force control coordinate system. A negative value limits the minimum force in negative x direction.

The unit is Newton and the default value is positive infinity.

[\YMin]

*Minimum force in y direction*

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.4 FCCondForce

#### Force Control

#### Continued

**Data type:** num

Lower limit for force in the y direction of the force control coordinate system. A negative value limits the maximum force in the negative y direction.

The unit is Newton and the default value is negative infinity.

[ \YMax ]

*Maximum force in y direction*

**Data type:** num

Upper limit for force in the y direction of the force control coordinate system. A negative value limits the minimum force in negative y direction.

The unit is Newton and the default value is positive infinity.

[ \ZMin ]

*Minimum force in z direction*

**Data type:** num

Lower limit for force in the z direction of the force control coordinate system. A negative value limits the maximum force in the negative z direction.

The unit is Newton and the default value is negative infinity.

[ \ZMax ]

*Maximum force in z direction*

**Data type:** num

Upper limit for force in the z direction of the force control coordinate system. A negative value limits the minimum force in negative z direction.

The unit is Newton and the default value is positive infinity.

[ \Outside ]

**Data type:** switch

Specify that the condition is fulfilled when the force is outside the specified limits.

TimeOut

**Data type:** num

This is the maximum time the condition is valid, in seconds. If the force condition has not turned false before this time, the wait is interrupted and the next RAPID instruction is executed.

---

### Program execution

Execution behavior:

- A time condition must be given (the argument `TimeOut`). The condition is considered true as long as the force condition AND the time condition is true.
- Use [FCGetProcessData on page 155](#), too see if the condition was met or timed out.

---

### More examples

#### Example 1

```
FCCondForce \XMin:=-100 \XMax:=100 \YMin:=-200 \YMax:=200, 60;
```

*Continues on next page*

Defines a force condition where the force in the x direction should be between -100 N and 100 N and in the y direction between -200 N and 200 N. The time condition is set to 60 seconds.

#### Example 2

```
FCCondForce \ZMin:=0 \ZMax:=100 \Outside, 60;
```

In this example the switch `Outside` is set, which means that the condition is fulfilled as long as the force is outside the specified limits. That is as long as the force in the Z direction is smaller than 0 N or larger than 100 N. The time-out is 60 seconds.

#### Example 3

```
FCCondForce \ZMax:=-10, 60;
```

This condition is true as long as the force in negative z direction is larger than 10 N. The time-out is 60 seconds.



#### Note

Sometimes the measured force is quite noisy. It is possible to filter the measured force by using the system parameter *Bandwidth of force frame filter*, under type *FC Kinematics*.

#### Limitations

The maximum reference force has different limit for different robot models, see the data sheet for Force Control.

#### Syntax

```
FCCondForce
[ '\XMin':=' <expression (IN) of num> ]
[ '\XMax':=' <expression (IN) of num> ]
[ '\YMin':=' <expression (IN) of num> ]
[ '\YMax':=' <expression (IN) of num> ]
[ '\ZMin':=' <expression (IN) of num> ]
[ '\ZMax':=' <expression (IN) of num> ]
[ '\Outside'],'
[TimeOut':=' ] <expression (IN) of num>;'
```

#### Related information

| For information about              | See   |
|------------------------------------|---|
| Setting up TCP position condition  | <a href="#">FCCondPos on page 76</a>        |
| Setting up reorientation condition | <a href="#">FCCondReoriSpeed on page 79</a> |
| Setting up TCP speed condition     | <a href="#">FCCondTCPSpeed on page 82</a>   |
| Setting up torque condition        | <a href="#">FCCondTorque on page 85</a>     |

## 7 RAPID reference information

---

### 7.1.5 FCCondOrient

#### Force Control

### 7.1.5 FCCondOrient

---

#### Usage

`FCCondOrient` is used to set up an end condition for the tool orientation. The condition is later activated by calling the instruction `FCCondWaitWhile`, which will wait and hold the program execution while the specified condition is true. This allows the reference force, torque and movement to continue until the orientation is outside the specified limits.

An orientation condition is set up by defining a maximum angle and a maximum rotation from a reference orientation. The reference orientation is either defined by the current z direction of the tool, or by specifying an orientation in relation to the z direction of the work object.

Once activated, the tool orientation must be within the limits (or outside, if the argument `Outside` is used).

#### Basic example

```
FCCondOrient \MaxAngle:= 15, 60;
```

In this example, no orientation condition coordinate system is specified. This means that the condition coordinate system is the same as the tool coordinate system at the time of execution of this instruction. When this condition is activated the program execution will wait until the tool's z axis deviates more than 15 degrees from the z axis of the condition coordinate system, or until 60 seconds has passed.

See also [More examples on page 74](#).

#### Arguments

```
FCCondOrient [\OrientCondFrame] [\MaxAngle] [\MaxRot] [\Outside]  
            TimeOut
```

`[\OrientCondFrame]`

***Orient condition coordinate system***

**Data type:** `orient`

`OrientCondFrame` is used to set the coordinate system in which the tool orientation condition is defined. The coordinate system is set by an `orient` in relation to the work object coordinate system. If `OrientCondFrame` is omitted, the tool coordinate system at the time of execution is used as orientation condition coordinate system.

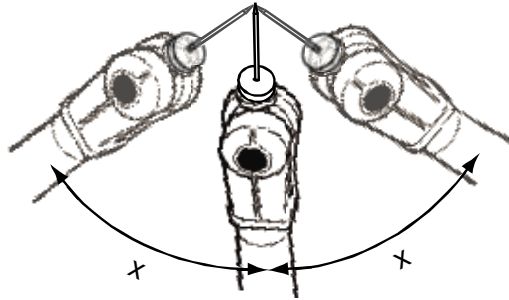
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[ \MaxAngle ]

**Data type:** num

The maximum allowed angle between the z direction of the tool and the z direction of the orientation condition coordinate system. The unit is degrees.



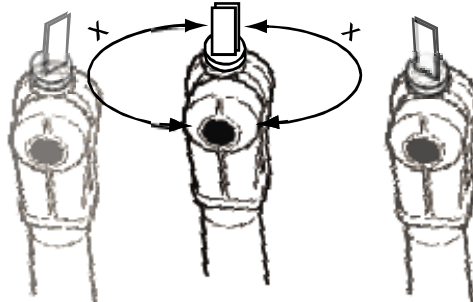
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|   |          |
|---|----------|
| x | MaxAngle |
|---|----------|

[ \MaxRot ]

**Data type:** num

The maximum tool rotation around the z axis, compared to the orientation condition coordinate system. The unit is in degrees.



xx0500001912

|   |        |
|---|--------|
| x | MaxRot |
|---|--------|

[ \Outside ]

**Data type:** switch

Makes the condition true when the tool orientation is outside the specified angles.

TimeOut

**Data type:** num

This is the maximum time the condition is valid, in seconds. If the orientation condition has not turned false before this time, the wait is interrupted and the next RAPID instruction is executed.

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.5 FCCondOrient

#### Force Control

#### Continued

---

#### Program execution

Execution behavior:

- A time condition must be given (the argument `TimeOut`). The condition is considered true as long as the orientation condition AND the time condition is true.
- Use [FCGetProcessData on page 155](#), too see if the condition was met or timed out

---

#### More examples

##### Example 1

```
FCCondOrient \MaxRot:= 45, 60;
```

In this example, the orientation condition coordinate system is set to the same as the tool coordinate system at the time of execution of this instruction. When this condition is activated the program execution will wait until the tool's rotation around the z axis deviates more than 45 degrees from the condition coordinate system, or until 60 seconds has passed.

##### Example 2

```
VAR orient my_orient:=[0,0,1,0];  
FCCondOrient \OrientCondFrame:=my_orient \MaxAngle:= 30, 60;
```

In this example, the z direction of the orientation condition coordinate system is in negative z direction of the work object coordinate system. When this condition is activated the program execution will wait until the tool's z direction deviates more than 30 degrees from the z direction of the condition coordinate system. If this does not happen within 60 seconds there is a time-out.

##### Example 3

```
VAR orient my_orient:=[0,0,1,0];  
FCCondOrient \OrientCondFrame:=my_orient \MaxAngle:=15  
           \MaxRot:=45, 60;
```

In this example, the z direction of the orientation condition coordinate system is in negative z direction of the work object coordinate system.

When this condition is activated the program execution will wait until the first of the following occurs:

- The tool's z direction deviates more than 30 degrees from the z direction of the orientation condition coordinate system.
- The tool's rotation around the z axis deviates more than 45 degrees from the orientation condition coordinate system.
- 60 seconds has passed.

---

#### Syntax

```
FCCondOrient  
  ['\OrientCondFrame':=' <expression (IN) of orient>]  
  ['\MaxAngle':=' <expression (IN) of num>]  
  ['\MaxRot':=' <expression (IN) of num>]  
  ['\Outside'],'  
  [TimeOut':='] <expression (IN) of num>';'
```

*Continues on next page*

---

### Related information

| For information about                    | See   |
|--|---|
| Setting up position condition            | <a href="#">FCCondPos on page 76</a>        |
| Setting up TCP speed condition           | <a href="#">FCCondTCPSpeed on page 82</a>   |
| Setting up reorientation speed condition | <a href="#">FCCondReoriSpeed on page 79</a> |
| Setting up force condition               | <a href="#">FCCondForce on page 69</a>      |
| Setting up torque condition              | <a href="#">FCCondTorque on page 85</a>     |
| Activating previous conditions           | <a href="#">FCCondWaitWhile on page 88</a>  |

## 7 RAPID reference information

---

### 7.1.6 FCCondPos

#### Force Control

### 7.1.6 FCCondPos

---

#### Usage

**FCCondPos** is used to set up an end condition for the TCP position. The condition is later activated by calling the instruction **FCCondWaitWhile**, which will wait and hold the program execution while the specified condition is true. This allows the reference force, torque and movement to continue until the specified position is outside the specified limits.

A position condition is set up by defining a volume in space for the TCP position. Once activated the measured TCP position has to be within the specified volume (or outside, if the argument **Outside** is used).

---

#### Basic example

```
VAR fcboxvol my_box:= [-100, 100, -200, 200, -300, 300];  
FCCondPos \Box:= my_box, 60;
```

When this condition is activated the program execution will wait until the robot TCP is outside the defined box or until 60 seconds has passed.

See also [More examples on page 77](#).

---

#### Arguments

```
FCCondPos [\PosCondFrame] [\Box] | [\Cylinder] | [\Sphere]  
[\Outside] TimeOut
```

**[\PosCondFrame]**

**Position condition coordinate system**

**Data type:** pose

**PosCondFrame** is used to set the coordinate system in which the TCP position condition is defined. The coordinate system is set by a pose in relation to the work object coordinate system. The default value is [(0,0,0),(1,0,0,0)], meaning that if the parameter is omitted the position TCP condition is defined in the work object coordinate system.

**[\Box]**

**Data type:** fcboxvol

Defines a box-shaped volume. The position condition is by default true when the TCP is inside the box. If the argument **Outside** is set, the condition is true when the TCP is outside the box.

One, and only one, of the arguments **Box**, **Cylinder** and **Sphere** must be used.

**[\Cylinder]**

**Data type:** fccylindervol

Defines a cylinder-shaped volume. The position condition is by default true when the TCP is inside the cylinder. If the argument **Outside** is set, the condition is true when the TCP is outside the cylinder.

One, and only one, of the arguments **Box**, **Cylinder** and **Sphere** must be used.

*Continues on next page*

[\Sphere]

Data type: `fcspherevol`

Defines a sphere-shaped volume. The position condition is by default true when the TCP is inside the sphere. If the argument `Outside` is set, the condition is true when the TCP is outside the sphere.

One, and only one, of the arguments `Box`, `Cylinder` and `Sphere` must be used.

[\Outside]

Data type: `switch`

Makes the condition true when the TCP is outside the specified volume.

TimeOut

Data type: `num`

This is the maximum time the condition is valid, in seconds. If the position condition has not turned false before this time, the wait is interrupted and the next RAPID instruction is executed.

## Program execution

Execution behavior:

- A time condition must be given (the argument `TimeOut`). The condition is considered true as long as the position condition AND the time condition is true.
- Use [FCGetProcessData on page 155](#), too see if the condition was met or timed out

## More examples

```
VAR fccylindervol my_cyl:= [300, 0, -200, 500, 250];
VAR pose my_cs := [[0,0,600],[0.7071,0,0.7071,0]];
FCCondPos \PosCondFrame := my_cs \Cylinder:=my_cyl, 60;
```

In this example the cylinder is not directly specified in the work object coordinate system but in a new coordinate system defined in relation to the work object coordinate system.

## Syntax

```
FCCondPos
[ '\PosCondFrame' := <expression (IN) of datatype pose> ]
[ '\Box' := <expression (IN) of datatype fcbboxvol> ]
[ '\Cylinder' := <expression (IN) of datatype fccylindervol> ]
[ '\Sphere' := <expression (IN) of datatype fcspherevol> ]
[ '\Outside' := ]', '
[ TimeOut := ] <expression (IN) of num>';'
```

## Related information

| For information about                    | See                                       |
|--|---|
| The data type <code>fcbboxvol</code>     | <a href="#">fcbboxvol on page 162</a>     |
| The data type <code>fccylindervol</code> | <a href="#">fccylindervol on page 166</a> |

Continues on next page

## 7 RAPID reference information

---

### 7.1.6 FCCondPos

#### Force Control

#### Continued

| For information about                    | See   |
|--|---|
| The data type fcspherevol                | <a href="#">fcspherevol on page 180</a>     |
| Setting up orientation condition         | <a href="#">FCCondOrient on page 72</a>     |
| Setting up TCP speed condition           | <a href="#">FCCondTCPSpeed on page 82</a>   |
| Setting up force condition               | <a href="#">FCCondForce on page 69</a>      |
| Setting up reorientation speed condition | <a href="#">FCCondReoriSpeed on page 79</a> |
| Activating previous conditions           | <a href="#">FCCondWaitWhile on page 88</a>  |

## 7.1.7 FCCondReoriSpeed

### Usage

`FCCondReoriSpeed` is used to setup an end condition for the reorientation speed. The condition is later activated by calling the instruction `FCCondWaitWhile`, which will wait and hold the program execution while the specified condition is true. This allows the reference force, torque and movement to continue until the reorientation speed is outside the specified limits.

A reorientation speed condition is setup up by defining minimum and maximum limits for the TCP reorientation speed in all directions of the work object. Once activated with `FCCondWaitWhile`, the program execution will wait while the measured reorientation speed is within its specified limits. If the argument `Outside` is set, the execution will wait while the reorientation speed is outside the limits.

The condition on the reorientation speed is specified in the work object coordinate system.

### Basic example

```
FCCondReoriSpeed \XMin:=-50 \XMax:=50, 60;
```

Defines a reorientation speed limit condition that is fulfilled if the reorientation speed around work object's x direction is between -50 degrees per seconds and 50 degrees per second. No restriction is put on the reorientation speed in other directions.

When this condition is activated the program execution will wait until the measured speed is outside its specified limits or until 60 seconds has passed.

### Arguments

```
FCCondReoriSpeed [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]  
[\Outside] TimeOut
```

`[\XMin]`

*Minimum reorientation speed around the x direction*

**Data type:** num

Lower reorientation speed limit around the work object's x direction. A negative value limits the maximum reorientation speed in the negative x direction. The unit is degrees per second and the default value is negative infinity.

`[\XMax]`

*Maximum reorientation speed around the x direction*

**Data type:** num

Upper reorientation speed limit around the work object's x direction. A negative value limits the minimum reorientation speed in the negative x direction. The unit is degrees per second and the default value is positive infinity.

`[\YMin]`

*Minimum reorientation speed around the y direction*

**Data type:** num

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.7 FCCondReoriSpeed

#### Force Control

#### Continued

Lower reorientation speed limit around the work object's y direction. A negative value limits the maximum reorientation speed in the negative y direction. The unit is degrees per second and the default value is negative infinity.

[ \YMax ]

*Maximum reorientation speed around the y direction*

Data type: num

Upper reorientation speed limit around the work object's y direction. A negative value limits the minimum reorientation speed in the negative y direction. The unit is degrees per second and the default value is positive infinity.

[ \ZMin ]

*Minimum reorientation speed around the z direction*

Data type: num

Lower reorientation speed limit around the work object's z direction. A negative value limits the maximum reorientation speed in the negative z direction. The unit is degrees per second and the default value is negative infinity.

[ \ZMax ]

*Maximum reorientation speed around the z direction*

Data type: num

Upper reorientation speed limit around the work object's z direction. A negative value limits the minimum reorientation speed in the negative z direction. The unit is degrees per second and the default value is positive infinity.

[ \Outside ]

Data type: switch

Specify that the condition is fulfilled when the speed is outside the specified limits.

TimeOut

Data type: num

This is the maximum time the condition is valid, in seconds. If the force condition has not turned false before this time, the wait is interrupted and the next RAPID instruction is executed.

---

### Program execution

Execution behavior:

- A time condition must be given (the argument TimeOut). The condition is considered true as long as the force condition AND the time condition is true.
- Use [FCGetProcessData on page 155](#), too see if the condition was met or timed out

---

### Syntax

```
FCCondReoriSpeed
[ '\XMin' := <expression (IN) of num> ]
[ '\XMax' := <expression (IN) of num> ]
[ '\YMin' := <expression (IN) of num> ]
[ '\YMax' := <expression (IN) of num> ]
```

*Continues on next page*



```
['\'ZMin':=' <expression (IN) of num>]  
['\'ZMax':=' <expression (IN) of num>]  
['\'Outside'],''  
[TimeOut':='] <expression (IN) of num>';'
```

---

#### Related information

| For information about            | See  |
|----------------------------------|--|
| Setting up orientation condition | <a href="#">FCCondOrient on page 72</a>    |
| Setting up TCP speed condition   | <a href="#">FCCondTCPSpeed on page 82</a>  |
| Setting up force condition       | <a href="#">FCCondForce on page 69</a>     |
| Setting up torque condition      | <a href="#">FCCondTorque on page 85</a>    |
| Activating previous condition    | <a href="#">FCCondWaitWhile on page 88</a> |

## 7 RAPID reference information

---

### 7.1.8 FCCondTCPSpeed

#### Force Control

### 7.1.8 FCCondTCPSpeed

---

#### Usage

FCCondTCPSpeed is used to setup an end condition for the TCP speed. The condition is later activated by calling the instruction FCCondWaitWhile, which will wait and hold the program execution while the specified condition is true. This allows the reference force, torque and movement to continue until the speed is outside the specified limits.

A TCP speed condition is setup up by defining minimum and maximum limits for the TCP speed in all directions of the work object. Once activated with FCCondWaitWhile, the program execution will continue to wait while the measured speed is within its specified limits.

It is possible to specify that the condition is fulfilled when the speed is outside the specified limits instead. This is done by using the switch argument *Outside*. The condition on TCP speed is specified in the work object coordinate system.

---

#### Basic example

```
FCCondTCPSpeed \Xmin:=100 \Xmax:=100, 60;
```

Defines a speed limit condition that is true if the speed in work object's x direction is between -100 and 100 mm/s. No restriction is put on the speed in other directions. When this condition is activated the program execution will wait until the measured speed in the x direction is outside its specified limits, or until 60 seconds has passed.

See also [More examples on page 84](#).

---

#### Arguments

```
FCCondTCPSpeed [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]  
[\Outside] TimeOut
```

[\XMin]

*Minimum speed in the x direction*

Data type: num

Lower limit for TCP speed in the x direction of the work object coordinate system. A negative value limits the maximum speed in the negative x direction.

The unit is mm/s and the default value is negative infinity.

[\XMax]

*Maximum speed in the x direction*

Data type: num

Upper limit for TCP speed in the x direction of the work object coordinate system. A negative value limits the minimum speed in negative x direction.

The unit is Newton and the default value is positive infinity.

[\YMin]

*Minimum speed in the y direction*

Data type: num

*Continues on next page*

Lower limit for TCP speed in the y direction of the work object coordinate system.  
A negative value limits the maximum speed in the negative y direction.

The unit is mm/s and the default value is negative infinity.

[ \YMax ]

*Maximum speed in the y direction*

Data type: num

Upper limit for TCP speed in the y direction of the work object coordinate system.  
A negative value limits the minimum speed in negative y direction.

The unit is Newton and the default value is positive infinity.

[ \ZMin ]

*Minimum speed in the z direction*

Data type: num

Lower limit for TCP speed in the z direction of the work object coordinate system.  
A negative value limits the maximum speed in the negative z direction.

The unit is mm/s and the default value is negative infinity.

[ \ZMax ]

*Maximum speed in the z direction*

Data type: num

Upper limit for TCP speed in the z direction of the work object coordinate system.  
A negative value limits the minimum speed in negative z direction.

The unit is Newton and the default value is positive infinity.

[ \Outside ]

Data type: switch

Specify that the condition is fulfilled when the speed is outside the specified limits.

TimeOut

Data type: num

This is the maximum time the condition is valid, in seconds. If the speed condition has not turned false before this time, the wait is interrupted and the next RAPID instruction is executed.

---

### Program execution

Execution behavior:

- A time condition must be given (the argument `TimeOut`). The condition is considered true as long as the TCP speed condition AND the time condition is true.
- Use [FCGetProcessData on page 155](#), too see if the condition was met or timed out

*Continues on next page*

## 7 RAPID reference information

### 7.1.8 FCondTCPSpeed

#### Force Control

#### Continued

#### More examples

##### Example 1

```
FCondTCPSpeed \Xmin:=-50 \Xmax:=50 \Ymin:=-50 \Ymax:=50 \Zmin:=-50
\Zmax:=50 \Outside, 60;
```

In this example limits for the speed are specified, but by setting the switch `Outside` the condition is fulfilled when the speed is outside the specified limits. That is, the speed needs to be larger than 50 mm/s or smaller than -50 mm/s for one of the specified directions.

When this condition is activated the program execution will wait until the measured speed is between -50 and 50 mm/s in all directions, or until 60 seconds has passed.

#### Syntax

```
FCondTCPSpeed
[ '\ ' XMin ':' < expression (IN) of num > ]
[ '\ ' XMax ':' < expression (IN) of num > ]
[ '\ ' YMin ':' < expression (IN) of num > ]
[ '\ ' YMax ':' < expression (IN) of num > ]
[ '\ ' ZMin ':' < expression (IN) of num > ]
[ '\ ' ZMax ':' < expression (IN) of num > ]
[ '\ ' Outside ] ','
[ TimeOut ':' < expression (IN) of num > ';' ]
```

#### Related information

| For information about                    | See  |
|--|--|
| Setting up position condition            | <a href="#">FCondPos on page 76</a>        |
| Setting up orientation condition         | <a href="#">FCondOrient on page 72</a>     |
| Setting up reorientation speed condition | <a href="#">FCondReoriSpeed on page 79</a> |
| Setting up force condition               | <a href="#">FCondForce on page 69</a>      |
| Setting up torque condition              | <a href="#">FCondTorque on page 85</a>     |
| Activating previous set condition        | <a href="#">FCondWaitWhile on page 88</a>  |

## 7.1.9 FCCondTorque

### Usage

`FCCondTorque` is used to set up an end condition for torque. The condition is later activated by calling the instruction `FCCondWaitWhile`, which will wait and hold the program execution while the specified condition is true. This allows the reference force, torque and movement to continue until the torque is outside the specified limits.

A torque condition is setup up by defining minimum and maximum limits for the torque in the directions of the force control coordinate system. Once activated with `FCCondWaitWhile`, the program execution will continue to wait while the measured torque is within its specified limits.

It is possible to instead specify that the condition is fulfilled when the torque is outside the specified limits. This is done by using the switch argument `Outside`.

The condition on torque is specified in the force control coordinate system. This coordinate system is setup by the user in the instruction `FCAct`.

### Basic example

```
FCCondTorque \XMin:=-100 \XMax:=100, 60;
```

Defines a torque condition that is true when the torque in the x direction of the force control coordinate system is between -100 Nm and 100 Nm. No restriction is put on the torque in other directions.

When this condition is activated the program execution will wait until the measured torque is outside its limits, or until 60 seconds has passed.

See also [More examples on page 87](#).

### Arguments

```
FCCondTorque [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]  
[\Outside] TimeOut
```

`[\XMin]`

*Minimum torque in x direction*

Data type: num

Lower limit for torque in the x direction of the force control coordinate system. A negative value limits the maximum torque in the negative x direction.

The unit is Nm and the default value is negative infinity.

`[\XMax]`

*Maximum torque in x direction*

Data type: num

Upper limit for torque in the x direction of the force control coordinate system. A negative value limits the minimum torque in negative x direction.

The unit is Nm and the default value is positive infinity.

`[\YMin]`

*Minimum torque in y direction*

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.9 FCCondTorque

#### Force Control

#### Continued

**Data type:** `num`

Lower limit for torque in the y direction of the force control coordinate system. A negative value limits the maximum torque in the negative y direction.

The unit is Nm and the default value is negative infinity.

[`\YMax`]

*Maximum torque in y direction*

**Data type:** `num`

Upper limit for torque in the y direction of the force control coordinate system. A negative value limits the minimum torque in negative y direction.

The unit is Nm and the default value is positive infinity.

[`\ZMin`]

*Minimum torque in z direction*

**Data type:** `num`

Lower limit for torque in the z direction of the force control coordinate system. A negative value limits the maximum torque in the negative z direction.

The unit is Nm and the default value is negative infinity.

[`\ZMax`]

*Maximum torque in z direction*

**Data type:** `num`

Upper limit for torque in the z direction of the force control coordinate system. A negative value limits the minimum torque in negative z direction.

The unit is Nm and the default value is positive infinity.

[`\Outside`]

**Data type:** `switch`

Specify that the condition is fulfilled when the torque is outside the specified limits.

`TimeOut`

**Data type:** `num`

This is the maximum time the condition is valid, in seconds. If the torque condition has not turned false before this time, the wait is interrupted and the next RAPID instruction is executed.

---

### Program execution

Execution behavior:

- A time condition must be given (the argument `TimeOut`). The condition is considered true as long as the torque condition AND the time condition is true.
- Use [FCGetProcessData on page 155](#), too see if the condition was met or timed out

*Continues on next page*

**More examples****Example 1**

```
FCondTorque \XMin:=-10 \XMax:=10 \YMin:=-10 \YMax:=10 \ZMin:=-10
           \ZMax:=10 \Outside, 60;
```

In this example, torque limits in all directions of the force control coordinate system are specified. The switch **Outside** set, which means that the condition is fulfilled as long as the torque is outside the specified limits. That is, the torque needs to be larger than 10 Nm or smaller than -10 Nm for one of the specified directions.

When this condition is activated the program execution will wait until the measured torque is between -10 and 10 Nm in all directions, or until 60 seconds has passed.

**Syntax**

```
FCondTorque
[ '\ ' XMin ':' < expression (IN) of num > ]
[ '\ ' XMax ':' < expression (IN) of num > ]
[ '\ ' YMin ':' < expression (IN) of num > ]
[ '\ ' YMax ':' < expression (IN) of num > ]
[ '\ ' ZMin ':' < expression (IN) of num > ]
[ '\ ' ZMax ':' < expression (IN) of num > ]
[ '\ ' Outside ] ','
[ TimeOut ':' < expression (IN) of num > ';' ]
```

**Related information**

| For information about                    | See  |
|--|--|
| Setting up position condition            | <a href="#">FCondPos on page 76</a>        |
| Setting up orientation condition         | <a href="#">FCondOrient on page 72</a>     |
| Setting up TCP speed condition           | <a href="#">FCondTCPSpeed on page 82</a>   |
| Setting up reorientation speed condition | <a href="#">FCondReoriSpeed on page 79</a> |
| Setting up force condition               | <a href="#">FCondForce on page 69</a>      |
| Activating previous set condition        | <a href="#">FCondWaitWhile on page 88</a>  |

## 7 RAPID reference information

---

### 7.1.10 FCCondWaitWhile

#### Force Control

### 7.1.10 FCCondWaitWhile

---

#### Usage

**FCCondWaitWhile** is used to activate previously set up conditions. This instruction will wait and hold the program execution while the specified condition is true. This allows the reference force, torque and movement to continue until a specified condition limit is reached.

#### Basic example

```
FRefLine FC_LIN_X, 500, 100;  
FCCondForce \Zmax:=10, 60;  
FCAct;  
FRefStart;  
FCCondWaitWhile;
```

In this example, **FCCondWaitWhile** activates the force condition. The execution will wait and the reference movement will continue until the force in positive z direction is above 10 N, or until 60 seconds has passed.

See also [More examples on page 88](#).

#### Arguments

```
FCCondWaitWhile [\ZeroRefAtEnd]
```

[\ZeroRefAtEnd]

**Zero reference at end**

**Data type:** switch

If this argument is used all references will be switched off once the condition turns false and the wait is over.

#### More examples

##### Example 1

```
FRefLine FC_LIN_X, 500, 100;  
FCCondForce \Zmin:=10, 60;  
FCAct;  
FRefStart;  
FCCondWaitWhile \ZeroRefAtEnd;
```

Same as the basic example except here the system will immediately turn off the reference movement once the wait is over.

#### Syntax

```
FCCondWaitWhile  
[ '\ ZeroRefAtEnd ] ';' 
```

#### Related information

| For information about            | See                                     |
|----------------------------------|---|
| Setting up position condition    | <a href="#">FCCondPos on page 76</a>    |
| Setting up orientation condition | <a href="#">FCCondOrient on page 72</a> |

*Continues on next page*



| For information about                    | See   |
|--|---|
| Setting up TCP speed condition           | <a href="#">FCCondTCPSpeed on page 82</a>   |
| Setting up reorientation speed condition | <a href="#">FCCondReoriSpeed on page 79</a> |
| Setting up force condition               | <a href="#">FCCondForce on page 69</a>      |
| Setting up torque condition              | <a href="#">FCCondTorque on page 85</a>     |

## 7 RAPID reference information

---

### 7.1.11 FCDeact

#### Force Control

### 7.1.11 FCDeact

---

#### Usage

`FCDeact` is used to deactivate Force Control. After a successful deactivation the robot is back in position control.

---

#### Basic example

```
FCDeact ;  
Deactivates Force Control.
```

---

#### Arguments

```
FCDeact  
There are no arguments to the instruction FCDeact.
```

---

#### Program execution

When running the instruction `FCDeact` the robot goes from being force controlled to being position controlled.

---

#### Limitations

- The force control can only be deactivated if:
- The reference values are deactivated by `FCRefStop` , or if the `cfg` parameter *Keep contact force at stop* in FC Application is set.
  - There are no robot movements.

---

#### Syntax

```
FCDeact ' ; '
```

---

#### Related information

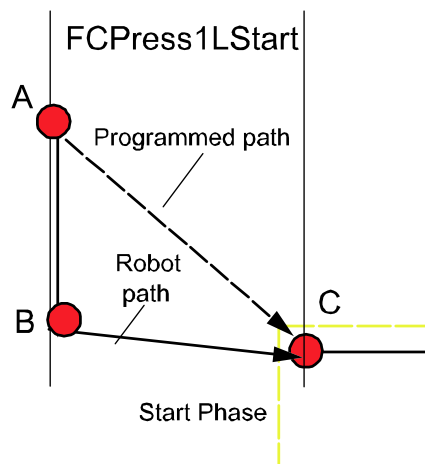
| For information about    | See                              |
|--------------------------|----------------------------------|
| Activating force control | <a href="#">FCAct on page 63</a> |

## 7.1.12 FCPress1LStart

## Usage

FCPress1LStart is used to make contact to a surface and move the tool centre point (TCP) linearly to a first given destination. The following contact movement should be done with the FCPressL instruction. Instruction starts a sequence for regulation in one direction on force. If you want to follow a corner or otherwise follow in more than one dimension this instruction should not be used.

Move close to the contact point (NOT IN CONTACT) The point ToPoint is where the first move in contact from the contact point will go. ForceThreshold is the parameter that will have to be tuned for best result.



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(A) is the point close to contact. The force reference will move us to point (B) which is a point when we have contact. The movement to point C (ToPoint) will start when the force has reached a certain level defined by the parameter ForceThreshold (in % of ordered force)

Instruction sets up some data that is true for a sequence. The force is set in each coordinate direction, this will result in one force in one direction calculated from these settings. This direction of force definition is true for all following FCPress-move instructions and will be until FCPressEnd. All parameters in FCPress1LStart except ToPoint, Speed, Force and Zone is true until FCPressEnd.

**Note**

The distance B to C must be more than 100 ms, or else C will become a fine point.

## Basic example

Basic example of the instruction FCPress1LStart is illustrated below.

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.12 FCPress1LStart

#### Force Control

#### Continued

See also [FCPress1LStart on page 91](#).

#### Example

```
FCPress1LStart p10, v100 \Fz:=200, 57, z30, tool1
```

Move in positive force direction (= z) until 57% (= 114N) of force is reached and then start toward p10 while force builds up to 100% (=200N).

---

#### Arguments

```
FCPress1LStart ToPoint [\ToNextPoint] Speed [\Fx] [\Fy] [\Fz]  
ForceThreshold [\ForceFrameRef] [\ForceChange] [\DampingTune]  
[\TimeOut] [\UseSpdFFW] [\PosSupvDist] Zone Tool [\WObj]
```

ToPoint

**Data type:** robtarget

The destination point of the robot and external axes. It is defined as a named position or stored directly in the instruction (marked with an \* in the instruction).

[\ToNextPoint]

**Data type:** robtarget

The destination point of the robot and external axes. It is defined as a named position or stored directly in the instruction (marked with an \* in the instruction). This should only be used if the robtarget in the first FCPressL is to close and therefore becomes a corner path failure.

Speed

**Data type:** speeddata

The speed data that applies to movements. Speed data defines the velocity for the tool centre point, the tool reorientation and external axes.

[\Fx]

*Reference force in x direction*

**Data type:** num

Defines the constant reference force in the x direction of the force control coordinate system. If this argument is omitted there will be zero contact force in the x direction.

[\Fy]

*Reference force in y direction*

**Data type:** num

Defines the constant reference force in the y direction of the force control coordinate system. If this argument is omitted there will be zero contact force in the y direction.

[\Fz]

*Reference force in z direction*

**Data type:** num

Defines the constant reference force in the z direction of the force control coordinate system. If this argument is omitted there will be zero contact force in the z direction.

ForceThreshold

**Data type:** num

*Continues on next page*

Percentage of the contact force that should be reached before move toward the robtarget starts. TCP moves in force direction until this percentage is reached. When percentage of force is reached, the movement toward target starts.

[ \ForceFrameRef ]

**Data type:** fcframe

ForceFrameRef here defines which coordinate system the force control coordinate system is related to. The parameter can be set to either the work object coordinate system, the tool coordinate system or the path coordinate system described in section [Programming in path coordinates on page 59](#).

FC\_REFFRAME\_WOBJ, FC\_REFFRAME\_TOOL or FC\_REFFRAME\_PATH.

The default value is the tool coordinate system.

[ \ForceChange ]

**Data type:** num

Tuning parameter to ramp up force. Unit is [N/s]. This argument overrides configured value.

[ \DampingTune ]

**Data type:** num

DampingTune is the relation value between the measured force and the applied resulting force. By default the value are 100% (of system parameter values), but it can be between 50% and infinity. Smaller values than 100% means that the robot is more sensitive to external force

[ \TimeOut ]

**Data type:** num

If force hasn't build up before this time is reached then continue with next instruction. Unit is [s].

[ \UseSpdFFW ]

**Data type:** switch

If this argument is used then feed forward regulation is used. If argument isn't used then regulation in force direction is done only with force control without help from programmed path. Use this argument if path is complex and programmed path is close to actual path.

[ \PosSupvDist ]

**Data type:** num

The robot will stop if it has moved more than the distance PosSupvDist away from the programmed path. Default value is 20mm. Unit is [mm].

Zone

**Data type:** zonedata

Zone data for the movement. Zone data describes the size of the generated corner path.

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.12 FCPress1LStart

#### Force Control

#### Continued

Tool

**Data type:** tooldata

The tool used during Force Control. It is the center point of this tool that is used for all calculations. Note that the dimensions of the sensor and any interface plates need to be included in the tool definition. To change tool force control has to be deactivated.

[ \wobj ]

**Data type:** wobjdata

The work object (coordinate system) to which the robot position in the instruction is related. This argument can be omitted, and if it is, the position is related to the world coordinate system. If, on the other hand, a stationary TCP or coordinated external axes are used, this argument must be specified. To change work object force control has to be deactivated.



#### Note

The coordinate systems mentioned in the arguments list are described in [The coordinate systems on page 278](#).

---

### Program execution

**Execution behavior:**

- FCPress1LStart **activates Force Control**.

---

### More examples

More examples of how to use the instruction FCPress1LStart are illustrated below.

#### Example 1

```
VAR tooldata tool1:=[TRUE,[[97.4,0,223],[1,0,0,0]],  
  [5,[23,0,75],[1,0,0,0],0,0,0]];  
FCPress1LStart p10, v100 \Fy:=-100, 57  
  \ForceFrameRef:=FC_REFFRAME_TOOL, z30, tool1;
```

**Activates Force Control and defines a force control coordinate system based on the tool1 coordinate system with force on negative y axis.**

#### Example 2

```
VAR tooldata tool1:=...  
VAR wobjdata my_wobj :=  
  [FALSE,TRUE,"",[[0,0,0],[0,0,0]],[[0,0,0],[0.07071,0,0.7071,0]]];  
FCPress1LStart p10, v100 \Fz:=200, 57,  
  \ForceFrameRef:=FC_REFFRAME_WOBJ \ForceChange:=200, z30, tool1  
  \Wobj:=my_wobj;
```

**Activates Force Control with:**

- tool tool1
- force control coordinate system orientation equal to the orientation of the work object my\_wobj.
- maximum force change to 200 Newton per second

*Continues on next page*

## Example 3

```

VAR tooldata tool1:=...

VAR wobjdata my_wobj :=
[FALSE,TRUE,"",[[0,0,0],[,0,0,0]],[[0,0,0],[0.07071,0,0.707 1,0]]];

FCPress1LStart p10, v100 \Fz:=200, 57,
    \ForceFrameRef:=FC_REFFRAME_WOBJ \ForceChange:=200
    \PosSupvDist:=100 , z30, tool1 \WObj:=my_wobj;

```

This example will behave like example 2 unless the robot would deviate from the programmed path. In example 2 the robot will stop if it deviates more than 20 mm, and in this example the robot may drift 100 mm before it stops.

## Limitations

The Force Control will only behave correctly if the load is identified with `FCLoadID` and the sensor is calibrated with `FCCalib` before activating Force Control with `FCPress1LStart`. **FCPress1-move instructions can only be used between `FCPress1LStart` and `FCPressEnd`.**

## Syntax

```

FCPress1LStart
[ ToPoint ':= ' ] < expression (IN) of robtarget >
[ '\ ToNextPoint ':= ' < expression (IN) of robtarget > ] ', '
[ Speed ':= ' ] < expression (IN) of speeddata >
[ '\ Fx ':= ' < expression (IN) of num > ]
[ '\ Fy ':= ' < expression (IN) of num > ]
[ '\ Fz ':= ' < expression (IN) of num > ] ', '
[ ForceThreshold ':= ' ] < expression (IN) of num >
[ '\ ForceFrameRef ':= ' < expression (IN) of fcframe > ]
[ '\ ForceChange ':= ' < expression (IN) of num > ]
[ '\ DampingTune ':= ' < expression (IN) of num > ]
[ '\ TimeOut ':= ' < expression (IN) of num > ]
[ '\ UseSpdFFW ] ', '
[ '\ PosSupvDist ':= ' < expression (IN) of num > ]
[ Zone ':= ' ] < expression (IN) of zonedata > ', '
[ Tool ':= ' ] < persistent (PERS) of tooldata >
[ '\ WObj ':= ' < persistent (PERS) of wobjdata > ] ';

```

## Related information

| For information about                      | See                                   |
|--|---------------------------------------|
| Linear one dimensional press instruction   | <a href="#">FCPressL on page 101</a>  |
| Circular one dimensional press instruction | <a href="#">FCPressC on page 96</a>   |
| End the press instruction                  | <a href="#">FCPressEnd on page 98</a> |

## 7 RAPID reference information

---

### 7.1.13 FCPressC

#### Force Control

### 7.1.13 FCPressC

---

#### Usage

FCPressC is used to move the tool centre point (TCP) circular to a given destination and during this movement a contact force can be maintained to a surface

---

#### Basic examples

##### Example

```
VAR num Force=60;  
FCPressC p10, p20, v100, Force, z30, tool0;
```

Move circularly to point p20 with speed v100 and a contact force of 60 N in the direction decided by the FCPress1LStart instruction. The Circle is defined by the start position, the circle point p10 and the destination point p20.

---

#### Arguments

FCPressC CirPoint ToPoint Speed Force Zone Tool [\Wobj]

##### CirPoint

*Circle point*

**Data type:** robtarget

The circle point of the robot and external axes. It is defined as a named position or stored directly in the instruction (marked with an \* in the instruction).

##### ToPoint

*Destination point*

**Data type:** robtarget

The destination point of the robot and external axes. It is defined as a named position or stored directly in the instruction (marked with an \* in the instruction).

##### Speed

*The speed of the TCP*

**Data type:** speeddata

The speed data that applies to movements. Speed data defines the velocity for the tool centre point, the tool reorientation and external axes.

##### Force

**Data type:** num

The force size in the direction defined in the coordinate system chosen in FCPress1LStart.

##### Zone

**Data type:** zonedata

Zone data for the movement. Zone data describes the size of the generated corner path.

##### Tool

**Data type:** tooldata

*Continues on next page*



The tool is used during Force Control. Note that this must be the same tool that is used in the `FCPress1LStart` instruction.

This argument is only present due to offline programming purposes.

[`\Wobj`]

**Data type:** `wobjdata`

The work object (coordinate system) to which the robot position in the instruction is related to. Note that this must be the same work object that is used in the `FCPress1LStart` instruction.

This argument is only present due to offline programming purposes.

### Program execution

Execution behavior:

- `FCPressC` moves toward target in contact with surface at the specified force. Movement will follow the surface and as a result the path will not be completely circular.

### Limitations

Instruction can only be used between a `FCPress1LStart` and a `FCPressEnd`. Tool and `WObj` cannot be changed while force control is active. Tool and work object are set in `FCPress1LStart` and cannot be changed until after `FCPressEnd` and a new `FCPress1LStart`.

### Syntax

```
FCPressC
[ CirPoint':=' ] < expression (IN) of robtarg> ', '
[ ToPoint':=' ] < expression (IN) of robtarg> ', '
[ Speed ':=' ] < expression (IN) of speeddata > ', '
[ Force':=' ] < expression (IN) of num > ', '
[ Zone ':=' ] < expression (IN) of zonedata > ', '
[ Tool ':=' ] < persistent (PERS) of tooldata >
[ '\ ' Wobj ':=' < persistent (PERS) of wobjdata > ] ';'

```

### Related information

| For information about                     | See                                       |
|---|---|
| Start press instruction.                  | <a href="#">FCPress1LStart on page 91</a> |
| Linear one dimensional press instruction. | <a href="#">FCPressL on page 101</a>      |
| End press instruction.                    | <a href="#">FCPressEnd on page 98</a>     |

## 7 RAPID reference information

### 7.1.14 FCPressEnd

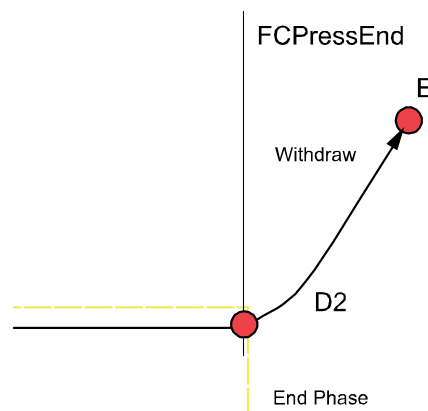
#### Force Control

### 7.1.14 FCPressEnd

#### Usage

FCPressEnd is used to release the contact from the FCPressLLStart and FCPressL

When calling this function the position is D2 which is a point where a contact force is present. The user specifies a point E which should be close to contact but NOT IN contact



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The same force reference as was used in FCPressLLStart (but with different sign) will start to reduce the contact force giving an upward movement. At the same time the move instruction to point E will give a horizontal movement

When the horizontal movement is finished, force control is switch off and position control will move to point E.



#### Note

The horizontal (orthogonal to force direction) distance between point (D2) and (E) should be short.

#### Basic examples

Basic example of the instruction FCPressEnd is illustrated below.

See also [More examples on page 99](#).

#### Example

```
FCPressEnd p10, v100, tool0;
```

Move to p10 with 100mm/s and on the way when force is zero turn off force control.

#### Arguments

```
FCPressEnd ToPoint Speed [\ForceChange] [\ZeroContactValue |  
DeactOnly] Tool [\Wobj]
```

ToPoint

Data type: robtarget

*Continues on next page*

The destination point of the robot and external axes. It is defined as a named position or stored directly in the instruction (marked with an \* in the instruction).

Speed

**Data type:** speeddata

The speed data that applies to movements. Speed data defines the velocity for the tool centre point, the tool reorientation and external axes.

[ \ForceChange ]

**Data type:** num

Tuning parameter to ramp up force. Value in argument is given in [N/s].

[ \ZeroContactValue | DeactOnly ]

**Data type:** num | switch

Two options are available to deactivate force control. The first is to specify a force limit and if the force is less than the argument `ZeroContactValue`, then force control is deactivated.

The second option, `DeactOnly`, deactivates force control when the reference force is less than zero force. This option can be useful when experiencing a lot of disturbances from a vibrating tool when measuring the force. This option can also be used when having problems due to roughly calibrated work objects.

If the arguments are not used, a default value defined in the system parameters will be used.

Tool

**Data type:** tooldata

The tool is used during Force Control. Note that this must be the same tool that is used in the `FCPress1LStart` instruction.

This argument is only present due to offline programming purposes.

[ \Wobj ]

**Data type:** wobjdata

The work object (coordinate system) to which the robot position in the instruction is related to. Note that this must be the same work object that is used in the `FCPress1LStart` instruction.

This argument is only present due to offline programming purposes.

---

## Program execution

Execution behavior:

- `FCPressEnd` deactivates force control and switch to position control when force becomes less than `ZeroContactValue`.

---

## More examples

More examples of how to use the instruction `FCPressEnd` are illustrated below.

### Example 1

```
FCPressEnd p10, v100 \ForceChange:=100;
```

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.14 FCPressEnd

#### Force Control

#### Continued

Set max release speed of force to 100N/s and then deactivate Force Control.

#### Example 2

```
FCPressEnd p10, v100 \ZeroContactValue:=2.5;
```

When force is less than 2.5N then deactivate force control and continue move to p10.

#### Example 3

```
FCPressEnd p10, v100 \DeactOnly;
```

When the reference force is deactivated, the force control is also deactivated and the tool will leave the surface.

---

### Limitations

Tool and work object are set in `FCPress1LStart` and cannot be changed until after `FCPressEnd` in a new `FCPress1LStart`.

---

### Syntax

```
FCPressEnd
  [ToPoint ':='] <expression (IN) of robtarg>','
  [Speed ':='] <expression (IN) of speeddata>
  ['\' ForceChange ':='] <expression (IN) of num>
  ['\' ZeroContactValue ':='] <expression (IN) of num>','
  [['\' DeactOnly ':='] <expression (IN) of num>','
  [Tool ':='] <persistent (PERS) of tooldata>
  ['\' Wobj ':='] <persistent (PERS) of wobjdata>]';'
```

---

### Related information

| For information about       | See                                       |
|-----------------------------|---|
| Start the press instruction | <a href="#">FCPress1LStart on page 91</a> |

## 7.1.15 FCPressL

### Usage

FCPressL is used to move the tool centre point (TCP) linearly to a given destination and during this movement a contact force can be maintained to a surface.

### Basic examples

Basic examples of the instruction FCPressL are illustrated below.

### Example

```
VAR num Force=60;
FCPressL p10, v100, Force, z30, tool0;
```

Move to point p10 with speed v100 and a contact force of 60 N in the direction decided by the FCPressLStart instruction.

### Arguments

```
FCPressL ToPoint Speed Force Zone Tool [\Wobj]
```

#### ToPoint

**Data type:** robtarget

The destination point of the robot and external axes. It is defined as a named position or stored directly in the instruction (marked with an \* in the instruction).

#### Speed

**Data type:** speeddata

The speed data that applies to movements. Speed data defines the velocity for the tool centre point, the tool reorientation and external axes.

#### Force

**Data type:** num

The force size in the direction defined in the coordinate system chosen in FCPressLStart.

#### Zone

**Data type:** zonedata

Zone data for the movement. Zone data describes the size of the generated corner path.

#### Tool

**Data type:** tooldata

The tool is used during Force Control. Note that this must be the same tool that is used in the FCPressLStart instruction.

This argument is only present due to offline programming purposes.

#### [\Wobj]

**Data type:** wobjdata

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.15 FCPressL

#### Force Control

#### Continued

The work object (coordinate system) to which the robot position in the instruction is related to. Note that this must be the same work object that is used in the `FCPress1LStart` instruction.

This argument is only present due to offline programming purposes.

---

#### Program execution

##### Execution behavior:

- `FCPressL` moves toward target in contact with surface at the specified force. Movement will follow the surface and as a result the path will not be completely linear

---

#### Limitations

Instruction can only be used between a `FCPress1LStart` and a `FCPressEnd`.

Tool and WObj cannot be changed while force control is active. Tool and work object are set in `FCPress1LStart` and cannot be changed until after `FCPressEnd` and a new `FCPress1LStart`.

---

#### Syntax

##### Instruction

```
[ ToPoint' := ' ] < expression (IN) of robtarget > ', '
[ Speed ' := ' ] < expression (IN) of speeddata > ', '
[ Force ' := ' ] < expression (IN) of num > ', '
[ Zone ' := ' ] < expression (IN) of zonedata > ', '
[ Tool ' := ' ] < persistent (PERS) of tooldata >
[ '\ ' Wobj ' := ' < persistent (PERS) of wobjdata > ] ';'

```

---

#### Related information

| For information about                       | See                                       |
|---|---|
| Start press instruction                     | <a href="#">FCPress1LStart on page 91</a> |
| Circular one dimensional press instruction. | <a href="#">FCPressC on page 96</a>       |
| End press instruction.                      | <a href="#">FCPressEnd on page 98</a>     |

## 7.1.16 FCRRefCircle

### Usage

`FCRRefCircle` is used to specify a reference movement for Force Control. The purpose of a reference movement is usually to search through an area to try to find a fit. The instruction is only used to set up the reference movement, not to activate it. Activation is done with the instruction `FCRRefStart`. Once activated, the robot will try to move according to the references (i.e. in a circle). This reference will not be enforced; if a contact force affects the robot the movement pattern will be hard to predict.

The circle is specified in the reference movement coordinate system. The coordinate system origin is the tool center point. Its orientation is normally the same as that of the work object coordinate system but can be changed by using the instruction `FCRRefMoveFrame`.

### Basic example

```
FCRRefCircle FCPLANE_XY, 30, 100;
```

Sets up, but does not activate, a circular shaped reference movement in the XY plane. The speed is 30 degrees per second and the radius 100 mm.

### Arguments

```
FCRRefCircle Plane Speed Radius
```

Plane

**Data type:** `fcplane`

Specifies which plane the circle is defined in (`FCPLANE_XY`, `FCPLANE_XZ` or `FCPLANE_YZ`)

Speed

**Data type:** `num`

The speed of the circle movement. The unit is degrees per second

Radius

**Data type:** `num`

The radius of the circle. The unit is in mm.

### Program execution

**Execution behavior:**

- The reference movement must be set up before activating the references with `FCRRefStart`.
- The circular path starts in the middle of the circle, moves to the circle boundary and then moves counter clockwise.

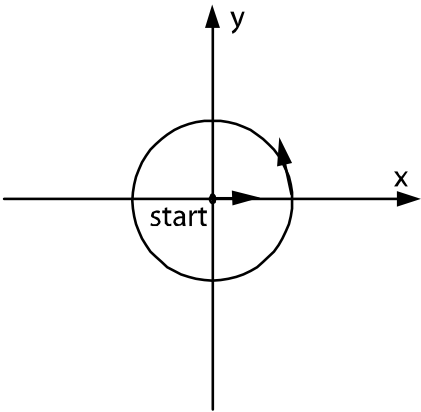
*Continues on next page*

# 7 RAPID reference information

## 7.1.16 FCRefCircle

Force Control

Continued



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### Syntax

```
FCRefCircle
[ Plane ':'= ' ] < expression (IN) of fcplane > ','
[ Speed ':'= ' ] < expression (IN) of num > ','
[ Radius ':'= ' ] < expression (IN) of num > ';'

```

### Related information

| For information about                | See                                     |
|--------------------------------------|---|
| The data type plane                  | <a href="#">fcplane on page 176</a>     |
| Setting up linear reference movement | <a href="#">FCRefLine on page 107</a>   |
| Setting up spiral reference movement | <a href="#">FCRefSpiral on page 113</a> |
| Activating reference values          | <a href="#">FCRefStart on page 118</a>  |
| Deactivating reference values        | <a href="#">FCRefStop on page 120</a>   |



## 7.1.17 FRefForce

## Usage

FRefForce is used to specify a reference force for Force Control. This instruction is only used to set up the reference force, not to activate it. Activation is done with the instruction FRefStart.

Once activated the robot will start to move in order to achieve the reference force. The reference force is usually set up by using a constant force, but it is possible to use an oscillating reference force.

## Basic example

```
FRefForce \Fz:=10;
```

Sets up a constant reference force of 10 N in the positive z direction of the force control coordinate system.

See also [More examples on page 106](#).

## Arguments

```
FRefForce [\Fx] [\Fy] [\Fz] [\Amp] [\Period]
```

[\Fx]

*Reference force in x direction*

**Data type:** num

Defines the constant reference force in the x direction of the force control coordinate system.

If this argument is omitted there will be zero contact force in the x direction

[\Fy]

*Reference force in y direction*

**Data type:** num

Defines the constant reference force in the y direction of the force control coordinate system.

If this argument is omitted there will be zero contact force in the y direction

[\Fz]

*Reference force in z direction*

**Data type:** num

Defines the constant reference force in the z direction of the force control coordinate system.

If this argument is omitted there will be zero contact force in the z direction

[\Amp]

*Amplitude of force oscillation*

**Data type:** fcxyznum

The magnitude of the optional oscillating part of the force reference, in the unit Newtons.

If Amp is used, Period should also be used.

*Continues on next page*

## 7 RAPID reference information

### 7.1.17 FCRefForce

#### Force Control

#### Continued

[ \Period ]

*Period of force oscillation*

**Data type:** fcxyznum

The period time for the optional oscillating part of the reference torque, in the unit seconds. If Period is used, Amp should also be used.

#### Program execution

Execution behavior:

- The reference force is specified in the force control coordinate system.
- The reference force must be set up before activating the references with FCRefStart.

#### More examples

##### Example 1

```
FCRefForce \Fy:=20 \Fz:=10;
```

Sets up a constant references force that has a 20 N component in the x direction and a 10N component in the z direction.

##### Example 2

```
VAR fcxyznum myAmp:=[0,0,10];  
VAR fcxyznum myPeriod:=[0,0,1];  
FCRefForce \Fz:=10 \Amp:=myAmp \Period:=myPeriod;
```

Sets up an oscillating reference force between 0 and 20 Newton in the positive z direction of the force control system.

#### Syntax

```
FCRefForce  
[ '\ Fx ' := < expression (IN) of num > ]  
[ '\ Fy ' := < expression (IN) of num > ]  
[ '\ Fz ' := < expression (IN) of num > ]  
[ '\ Amp ' := < expression (IN) of fcxyznum > ]  
[ '\ Period ' := < expression (IN) of fcxyznum > ] ';' 
```

#### Related information

| For information about         | See                                     |
|-------------------------------|---|
| Setting up torque reference   | <a href="#">FCRefTorque on page 121</a> |
| Activating reference values   | <a href="#">FCRefStart on page 118</a>  |
| Deactivating reference values | <a href="#">FCRefStop on page 120</a>   |
| The data type fcxyznum        | <a href="#">fcxyznum on page 182</a>    |

## 7.1.18 FCRefLine

### Usage

`FCRefLine` is used to specify a reference movement for Force Control. This instruction is only used to set up the reference movement, not to activate it. Activation is done with the instruction `FCRefStart`.

Once activated with `FCRefStart`, the robot will try to move according to the references (i.e. back and forth along a linear path). This reference will not be enforced, if a contact force affects a robot the movement pattern will be hard to predict.

The purpose of a reference movement is usually to search through an area to try to find a fit.

The line is specified in the reference movement coordinate system. This coordinate system's origin is the tool center point. Its orientation is normally the same as the orientation of the work object coordinate system but can be changed by using the instruction `FCRefMoveFrame`.

### Basic example

```
FCRefLine FC_LIN_X, 500, 100;
```

Sets up, but does not activate, a linear shaped reference movement in the x-direction. The maximum speed is 500 mm/s and the distance peak to peak is 100 mm [amplitude +/-50 mm].

### Arguments

```
FCRefLine Direction MaxSpeed Distance [\OneSideOfStartPos]
```

Direction

**Data type:** `fclindir`

Specifies which direction the reference is set in (`FC_LIN_X`, `FC_LIN_Y`, `FC_LIN_Z`).

MaxSpeed

**Data type:** `num`

The maximum speed of the linear movement. The unit is millimeters per second.

Distance

**Data type:** `num`

The amplitude of the movement. The TCP is oscillating between positive and negative value of the parameter `Distance / 2`. The unit is millimeters.

`[\OneSideOfStartPos]`

**Data type:** `switch`

This argument limits the movement to only one side of the start position. The side depends on the sign of the `MaxSpeed` argument.

*Continues on next page*

## 7 RAPID reference information

### 7.1.18 FCRefLine

#### Force Control

#### Continued

#### Program execution

##### Execution behavior:

- The reference movement must be set up before activating the references with `FCRefStart`
- A line in any of the linear directions is oscillating between the positive and the negative value of the parameter `Distance / 2` (i.e. the movement from one turning point to the other is `Distance`).

#### Syntax

```
FCRefLine
[ Direction ':= ' ] < expression (IN) of fclindir > ', '
[ Speed ':= ' ] < expression (IN) of num > ', '
[ Distance ':= ' ] < expression (IN) of num > ', '
['\OneSideOfStartPos] ';' ;
```

#### Related information

| For information about                             | See  |
|---|--|
| Setting up a reference movement coordinate system | <a href="#">FCRefMoveFrame on page 109</a> |
| Setting up circular reference movement            | <a href="#">FCRefCircle on page 103</a>    |
| Setting up rotational reference movement          | <a href="#">FCRefRot on page 111</a>       |
| Activating reference values                       | <a href="#">FCRefStart on page 118</a>     |
| Deactivating reference values                     | <a href="#">FCRefStop on page 120</a>      |

## 7.1.19 FCRefMoveFrame

### Usage

`FCRefMoveFrame` is used to set up a coordinate system, in which reference movements can be defined. It is called the reference movement coordinate system. The origin of this coordinate system is always the tool center point, but the user can specify orientation by using `FCRefMoveFrame`. The orientation is specified in relation to the orientation of the work object coordinate system or the tool coordinate system.

If no coordinate system is defined (i.e. `FCRefMoveFrame` not used) the reference movement coordinate system has the same orientation as the work object coordinate system.

### Basic example

```
VAR orient myOrient:= [0.924,0,0,0.383];
FCRefMoveFrame myOrient;
FCRefLine FC_LIN_X, 500, 100;
```

Without the coordinate system definition there would be a linear movement in the x direction of the work object. With the definition shown in this example there will be a linear movement in the xy direction of the work object. The x and y axes are moved clockwise 45 degrees around the z axis.

### Arguments

```
FCRefMoveFrame [\RefMoveFrameRef][\RefMoveFrameOri]
```

`[\RefMoveFrameRef]`

**Data type:** `fcframe`

`RefMoveFrameRef` defines which coordinate system the reference coordinate system is related to. The parameter can be set to either the work object coordinate system or the tool coordinate system. The default value is the work object coordinate system.

`[\RefMoveFrameOri]`

**Data type:** `orient`

This parameter specifies the orientation from the coordinate system selected in `RefMoveFrameRef`. The default value is `[1,0,0,0]`. For information about how to calculate orientations, see the data type `orient` in *Technical reference manual - RAPID Instructions, Functions and Data types*.

### More examples

These scenarios illustrate a reference movement coordinate system related to the tool frame versus the work object frame.

#### Example 1 - Tool coord

```
FCRefMoveFrame \RefMoveFrameRef:=FC_REFFRAME_TOOL;
```

#### Example 2 - Work object coord

```
FCRefMoveFrame \RefMoveFrameRef:=FC_REFFRAME_WOBJ;
```

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.19 FRefMoveFrame

#### Force Control

#### Continued

##### Scenario 1

The tool frame and work object frame share the same orientation, the z -axis pointing upwards. If a rotation around the z-axis is started the result will be the same for Example 1 and Example 2.

##### Scenario 2

If the orientation of the tool is changed, however, the result will no longer be the same. In Example 1 the tool will still rotate around the z axis of the tool. In Example 2, however, the tool will rotate in a cone shaped pattern.

---

### Syntax

```
FRefMoveFrame
[ '\ ' RefMoveFrameRef ':' = ' < expression (IN) of fcfame > ]
[ '\ ' RefMoveFrameOri ':' = ' < expression (IN) of orient > ] ';' 
```

---

### Related information

| For information about                  | See                                     |
|--|---|
| The data type fcfame                   | <a href="#">fcfame on page 172.</a>     |
| Setting up spiral reference movement   | <a href="#">FRefSpiral on page 113.</a> |
| Setting up circular reference movement | <a href="#">FRefCircle on page 103.</a> |
| Setting up linear reference movement   | <a href="#">FRefLine on page 107.</a>   |
| Activating reference values            | <a href="#">FRefStart on page 118.</a>  |
| Deactivating reference values          | <a href="#">FRefStop on page 120.</a>   |

## 7.1.20 FCRefRot

### Usage

FCRefRot is used to specify a reference movement for Force Control. This instruction is only used to set up the reference movement, not to activate it. Activation is done with the instruction FCRefStart.

Once activated with FCRefStart, the robot will try to move according to the references (i.e. rotate around a chosen axis in a coordinate system). This reference will not be enforced, if a contact force affects a robot the movement pattern will be hard to predict.

The purpose of a reference movement is usually to search through an area to try to find a fit.

The rotation is specified in the reference movement coordinate system. The coordinate system origin is the tool center point. Its orientation is normally the same as the orientation of the work object coordinate system but can be changed by using the instruction FCRefMoveFrame.

### Basic example

```
FCRefRot FC_ROT_Z, 5, 10;
```

Sets up a rotation around the work object z direction. When activated the TCP will rotate back and forth around the z-axis with a distance (peak to peak) of 10 degrees [amplitude +/- 5 degrees]. The maximum speed will be 5 degrees per second.

### Arguments

```
FCRefRot Direction MaxSpeed Distance [\OneSideOfStartPos]
```

Direction

**Data type:** fcrotmdir

Specifies the direction of the rotation (FC\_ROT\_X, FC\_ROT\_Y, FC\_ROT\_Z).

MaxSpeed

**Data type:** num

The maximum speed of the rotational movement. The unit is degrees per second.

Distance

**Data type:** num

The amplitude of the movement. The TCP is oscillating between positive and negative value of the parameter Distance / 2. The unit is in degrees.

[\OneSideOfStartPos]

**Data type:** switch

This argument limits the movement to only one side of the start position. The side depends on the sign of the MaxSpeed argument.

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.20 FCRefRot

#### Force Control

#### Continued

---

#### Program execution

##### Execution behavior:

- The reference movement must be set up before activating the references with FCRefStart.
- The rotation angle describes a sine function of the time with an amplitude  $\text{Distance} / 2$  (i.e. the movement from one turning point to the other is Distance).

---

#### Syntax

```
FCRefRot
[ Direction ':= ' ] < expression (IN) of fcrotmdir > ', '
[ Speed ':= ' ] < expression (IN) of num > ', '
[ Distance ':= ' ] < expression (IN) of num > ] ', '
[ '\OneSideOfStartPos' ] ';' ;
```

---

#### Related information

| For information about                  | See                                     |
|--|---|
| The data type fcrotmdir                | <a href="#">fcrotmdir on page 177</a>   |
| Setting up spiral reference movement   | <a href="#">FCRefSpiral on page 113</a> |
| Setting up circular reference movement | <a href="#">FCRefCircle on page 103</a> |
| Setting up linear reference movement   | <a href="#">FCRefLine on page 107</a>   |
| Activating reference values            | <a href="#">FCRefStart on page 118</a>  |
| Deactivating reference values          | <a href="#">FCRefStop on page 120</a>   |



## 7.1.21 FCRRefSpiral

### Usage

FCRRefSpiral is used to specify a reference movement for Force Control. This instruction is only used to set up the reference movement, not to activate it. Activation is done with the instruction FCRRefStart.

Once activated with FCRRefStart, the robot will try to move according to the references (i.e. in a spiral). This reference will not be enforced, if a contact force affects a robot the movement pattern will be hard to predict.

The purpose of a reference movement is usually to search through an area to try to find a fit.

The spiral is specified in the reference movement coordinate system. This coordinate system's origin is the tool center point. Its orientation is normally the same as the orientation of the work object coordinate system but can be changed by using the instruction FCRRefMoveFrame.

### Basic example

```
FCRRefSpiral FCPLANE_XY, 50, 100, 10
```

Sets up, but does not activate, a spiral shaped reference movement in the XY plane. The speed is 50 degrees per second and the largest radius 100 mm. After expanding the radius for 10 turns the radius will decrease for another 10 turns. After this the movement will be repeated in opposite direction.

### Arguments

```
FCRRefSpiral Plane Speed Radius Turns
```

Plane

**Data type:** fcplane

Specifies which plane the spiral is defined in (FCPLANE\_XY, FCPLANE\_XZ or FCPLANE\_YZ).

Speed

**Data type:** num

The speed of the spiral movement. The unit is degrees per second.

Radius

**Data type:** num

The radius of the spiral. The unit is in mm.

Turns

**Data type:** num

The number of turns expanding the spiral.

### Program execution

Execution behavior:

- The reference movement must be set up before activating the references with FCRRefStart.

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.21 FCRefSpiral

#### Force Control

#### Continued

---

#### Syntax

```
FCRefSpiral
[ Plane ':=' ] < expression (IN) of fcplane > ','
[ Speed ':=' ] < expression (IN) of num > ','
[ Radius ':=' ] < expression (IN) of num > ','
[ Turns ':=' ] < expression (IN) of num > ';'

```

---

#### Related information

| For information about                     | See  |
|---|--|
| The data type fcplane                     | <a href="#">fcplane on page 176</a>        |
| Setting up linear reference movement      | <a href="#">FCRefLine on page 107</a>      |
| Setting up circular reference movement    | <a href="#">FCRefCircle on page 103</a>    |
| Setting up rotational reference movements | <a href="#">FCRefMoveFrame on page 109</a> |
| Activating reference values               | <a href="#">FCRefStart on page 118</a>     |
| Deactivating reference values             | <a href="#">FCRefStop on page 120</a>      |

## 7.1.22 FCRRefSprForceCart

## Usage

FCRRefSprForceCart is used to set up a position dependent force reference. This force reference works like a virtual mechanical spring. The further away the robot TCP is from a defined attractor point, the larger the reference force trying to pull the robot towards the attractor. The attractor point is defined in the work object coordinate system. It is possible to define different stiffness in different directions.

## Basic example

```
FCRRefSprForceCart \stiffnessX:=100 \MaxForceX:=1000;
```

Sets up a reference spring force, with a stiffness of 100 N/m and a maximum force of 1000 N. The attractor position is not set and therefore implicitly set to the current TCP position. The spring is only active in the x direction of the work object.

See also [More examples on page 116](#).

## Arguments

```
FCRRefSprForceCart [\StiffnessX] [\StiffnessY] [\StiffnessZ]
                  [MaxForceX] [MaxForceY] [MaxForceZ][\PosAttractor]
```

[\StiffnessX]

**Data type:** num

This argument defines the spring stiffness in the x direction of the work object. This factor multiplied with the distance between TCP and attractor point gives the force reference in the x direction.

[\StiffnessY]

**Data type:** num

This argument defines the spring stiffness in the y direction of the work object. This factor multiplied with the distance between TCP and attractor point gives the force reference in the y direction

[\StiffnessZ]

**Data type:** num

This argument defines the spring stiffness in the z direction of the work object. This factor multiplied with the distance between TCP and attractor point gives the force reference in the z direction

[\MaxForceX]

**Data type:** num

This argument defines the maximum allowed force in x direction of the work object when the robot is in spring mode. Even if the distance between TCP and attractor point keeps increasing the force in x-direction never gets larger than MaxForceX.

[\MaxForceY]

**Data type:** num

*Continues on next page*

## 7 RAPID reference information

### 7.1.22 FCRefSprForceCart

#### Force Control

#### Continued

This argument defines the maximum allowed force in y direction of the work object when the robot is in spring mode. Even if the distance between TCP and attractor point keeps increasing the force in y-direction never gets larger than `MaxForceY`.

`[\MaxForceZ]`

Data type: `num`

This argument defines the maximum allowed force in z direction of the work object when the robot is in spring mode. Even if the distance between TCP and attractor point keeps increasing the force in z-direction never gets larger than `MaxForceZ`.

`[\PosAttractor]`

Attractor position

Data type: `pos`

The attractor position is the position the robot TCP tries to reach. This position is set in the work object coordinate system. If omitted, the TCP at the time of execution of this instruction is used.

#### Program execution

Execution behavior:

- The reference spring force must be set up before activating the references with `FCRefStart`.

#### More examples

##### Example 1

```
VAR pos myPos := [100,200,300];
FCRefSprForceCart \stiffnessY:=50 \MaxForceY:=200 \PosAttractor:=
myPos;
```

Sets up a reference spring force, with a stiffness of 50 N/m and a maximum force of 200 N in the y-direction of the work object. The attractor position is specifically set.

#### Syntax

```
FCRefSprForceCart
[ '\ StiffnessX ':=' < expression (IN) of num > ]
[ '\ StiffnessY ':=' < expression (IN) of num > ]
[ '\ StiffnessZ ':=' < expression (IN) of num > ]
[ '\ MaxForceX ':=' < expression (IN) of num > ]
[ '\ MaxForceY ':=' < expression (IN) of num > ]
[ '\ MaxForceZ ':=' < expression (IN) of num > ]
[ '\ PosAttractor ':=' < expression (IN) of pos > ] ';' 
```

#### Related information

| For information about       | See                                     |
|-----------------------------|---|
| Setting up force reference  | <a href="#">FCCondForce on page 69</a>  |
| Setting up torque reference | <a href="#">FCCondTorque on page 85</a> |
| Activating reference values | <a href="#">FCAct on page 63</a>        |

*Continues on next page*

| For information about         | See                                |
|-------------------------------|------------------------------------|
| Deactivating reference values | <a href="#">FCDeact on page 90</a> |

## 7 RAPID reference information

---

### 7.1.23 FRefStart

#### Force Control

### 7.1.23 FRefStart

---

#### Usage

**FRefStart** is used to activate previously set up force, torque or movement references.

---

#### Basic example

```
FRefForce \Fx:=10;  
FRefTorque \Tx:=10;  
FAct tool1;  
FRefStart;
```

After execution of this code, both the force and the torque references will be active.  
See also [More examples on page 118](#).

---

#### Arguments

FRefStart

---

#### Program execution

##### Execution behavior:

- **FRefStart** activates any references set up since the last **FRefStart** instruction. All reference values activated by the first **FRefStart** will be deactivated by a new **FRefStart**.
- Several reference instructions can be activated by a **FRefStart** instruction. However, not all instructions will be valid, see [Conflicting reference values on page 47](#).

---

#### More examples

##### Example 1

```
FRefForce \Fx:=10;  
FRefSpiral FCPLANE_XY, 50, 100, 10;  
FAct tool1;  
FRefStart;  
WaitTime 10;  
FRefForce \Fx:=10;  
FRefStart;
```

At first, both reference force and reference movement are used. After 10 seconds the reference movement is stopped without ever releasing the reference force.

##### Example 2

```
FRefCircle FCPLANE_XY, 60, 100;  
FRefLine LinX, 200, 50;  
FAct tool1;  
FRefStart;
```

In this example two instruction set up the reference movement in x direction. The value of the last instruction is used in this case. The movement in y direction will be according to the circle setup but the movement in the x direction will be according to the line setup.

*Continues on next page*

---

### Syntax

FCRefStart

---

### Related information

| For information about         | See                                   |
|-------------------------------|---------------------------------------|
| Deactivating reference values | <a href="#">FCRefStop on page 120</a> |

## 7 RAPID reference information

---

### 7.1.24 FCRefStop

#### Force Control

### 7.1.24 FCRefStop

---

#### Usage

FCRefStop is used to deactivate reference values. References can be either force, torque or movement references.

The same start and stop instruction is used for all references. The FCRefStop instruction stops all started references.

#### Basic example

```
FCRefForce \Fy:=10;  
FCRefTorque \Ty:=10;  
FCRefAct tool1;  
FCRefStart;  
WaitTime 10;  
FCRefStop;
```

The reference force and torque are deactivated after 10 seconds.

#### Arguments

FCRefStop

#### Limitations

FCRefStop cannot stop only some of the active references, e.g. stop the reference movement but maintain the reference force. However, this can be done by a new setup instruction followed by a new start instruction. See [FCRefStart on page 118](#).

#### Syntax

FCRefStop

#### Related information

| For information about       | See                                    |
|-----------------------------|--|
| Activating reference values | <a href="#">FCRefStart on page 118</a> |



## 7.1.25 FCRefTorque

## Usage

FCRefTorque is used to specify a reference torque for Force Control. This instruction is only used to set up the reference torque, not to activate it. Activation is done with instruction FCRefStart.

Once activated the robot will start to move in order to achieve the reference torque. The reference torque is usually set up by using a constant torque, but it is possible to use an oscillating reference torque.

## Basic example

```
FCRefTorque Ty:=10;
```

Setup a constant reference torque of 10 Nm around the positive y direction of the force control coordinate system.

See also [More examples on page 122](#).

## Arguments

```
FCRefTorque [\Tx] [\Ty] [\Tz] [\Amp] [\Period]
```

[\Tx]

*Reference torque around x direction*

Data type: num

Defines the constant torque reference around the x direction of the force control coordinate system. If this argument is omitted there will be zero reference torque in this direction.

[\Ty]

*Reference torque around y direction*

Data type: num

Defines the constant torque reference around the y direction of the force control coordinate system. If this argument is omitted there will be zero reference torque in this direction.

[\Tz]

*Reference torque around z direction*

Data type: num

Defines the constant torque reference around the z direction of the force control coordinate system. If this argument is omitted there will be zero reference torque in this direction.

[\Amp]

*Amplitude*

Data type: fcxyznum

The magnitude of the optional oscillating part of the torque reference, in the unit Nm. If Amp is used, Period should also be used.

*Continues on next page*

## 7 RAPID reference information

### 7.1.25 FCRefTorque

#### Force Control

#### Continued

[ \Period ]

Data type: fcxyznum

The period time for the optional oscillating part of the reference torque, in the unit seconds. If Period is used, Amp should also be used.

#### Program execution

Execution behavior:

- The reference force is specified in the force control coordinate system.
- The reference torque must be set up before activating the references with FCRefStart.

#### More examples

##### Example 1

```
FCRefTorque \Ty:=20 \Tz:=10;
```

Setup a constant reference torque of 20 Nm around the positive y direction and 10Nm around the positive z direction of the force control coordinate system.

##### Example 2

```
VAR fcxyznum myAmp:=[0,0,10];  
VAR fcxyznum myPeriod := [0,0,1];  
FCRefTorque \Tz:=10 \Amp:=myAmp \Period:=myPeriod;
```

Sets up an oscillating reference torque between 0 and 20 Nm with a period of 1 second.

#### Syntax

```
FCRefTorque  
[ '\ Tx ' := < expression (IN) of num > ]  
[ '\ Ty ' := < expression (IN) of num > ]  
[ '\ Tz ' := < expression (IN) of num > ]  
[ '\ Amp ' := < expression (IN) of fcxyznum > ]  
[ '\ Period ' := < expression (IN) of fcxyznum > ] ';' 
```

#### Related information

| For information about         | See                                    |
|-------------------------------|--|
| Setting up force reference    | <a href="#">FCRefForce on page 105</a> |
| Activating reference values   | <a href="#">FCRefStart on page 118</a> |
| Deactivating reference values | <a href="#">FCRefStop on page 120</a>  |
| The data type fcxyznum        | <a href="#">fcxyznum on page 182</a>   |

## 7.1.26 FCResetDampingTune

### Usage

`FCResetDampingTune` is used to reset the damping in force directions, previously set up by `FCSetDampingTune`. `FCResetDampingTune` resets to the actual value set by the instruction `FCAct`, not to the value in the configuration file.

### Basic example

#### Example

```
FCResetDampingTune;
```

Resets the damping in force direction.

### Arguments

`FCResetDampingTune`

### Program execution

Execution behaviour:

- Reset damping value.

### Syntax

```
FCResetDampingTune' ;'
```

### Related information

| For information about                 | See   |
|---------------------------------------|---|
| Set the damping in force direction    | <a href="#">FCSetDampingTune on page 126</a>  |
| Configuration parameters for damping. | <a href="#">Damping in Force x Direction - Damping in Force z Direction on page 204</a> |

## 7 RAPID reference information

---

### 7.1.27 FCResetLPFilterTune

*Force Control*

### 7.1.27 FCResetLPFilterTune

---

#### Usage

`FCResetLPFilterTune` is used to reset the low pass filter cut off frequency to the configured value. This will change the response of force loop according to description in [Damping and LP-filter on page 49](#).

#### Basic examples

##### Example

```
FCResetLPFilterTune
```

Resets the low pass filter to configured value.

#### Arguments

```
FCResetLPFilterTune
```

#### Program execution

Execution behavior:

- Resets the force loop to the configured cut off frequency value.

#### Syntax

```
FCResetLPFilterTune;
```

#### Related information

| For information about                          | See  |
|--|--|
| Setting the parameter for the low pass filter. | <a href="#">Bandwidth of force loop filter on page 207</a> |
| Instruction how to set low pass filter         | <a href="#">FCSetLPFilterTune on page 128</a>              |

## 7.1.28 FCResetMaxForceChangeTune

### Usage

FCResetMaxForceChangeTune is used to reset the force ramp to the value that is specified in system parameter [Max Ref Force Change on page 211](#).

### Basic example

#### Example

```
FCResetMaxForceChangeTune ;
```

Reset the force change ramp to the value defined in system parameter [Max Ref Force Change on page 211](#).

### Arguments

```
FCResetMaxForceChangeTune ;
```

### Program execution

#### Execution behaviour:

- FCResetMaxForceChangeTune **needs to be run if**  
FCSetMaxForceChangeTune **has been used to change the force ramp.**

### Syntax

```
FCResetMaxForceChangeTune
```

### Related information

| For information about                     | See   |
|---|---|
| Defining maximum force ramping.           | <a href="#">Max Ref Force Change on page 211</a>    |
| Defining a temporary force ramping value. | <a href="#">FCSetMaxForceChangeTune on page 129</a> |

## 7 RAPID reference information

---

### 7.1.29 FCSetDampingTune

Force Control

### 7.1.29 FCSetDampingTune

---

#### Usage

FCSetDampingTune is used to tune the damping in the force control coordinate systems. The parameters tuned are those described in [Damping in Torque x Direction - Damping in Torque z Direction on page 205](#) and [Damping in Force x Direction - Damping in Force z Direction on page 204](#).

Damping can be set in the configuration file or by the instruction FCAct. The difference is that this instruction can be used when force control is active.

FCSetDampingTune tunes the actual values set by the instruction FCAct, not the value in the configuration file.

---

#### Basic example

##### Example

```
VAR num xdamp:=100;  
VAR num ydamp:=200;  
VAR num zdamp:=200;  
VAR num rxdamp:=100;  
VAR num rydamp:=100;  
VAR num rzdamp:=100  
FCSetDampingTune xdamp, ydamp, zdamp, rxdamp, rydamp, rzdamp;
```

In this example the dampings are increased in the linear y and z directions, which makes the robot less compliant in these directions.

---

#### Arguments

FCSetDampingTune xdamp, ydamp, zdamp, rxdamp, rydamp, rzdamp

##### xdamp

**Data type:** num

A percentage value on how much the damping should change in the linear x direction.

##### ydamp

**Data type:** num

A percentage value on how much the damping should change in the linear y direction.

##### zdamp

**Data type:** num

A percentage value on how much the damping should change in the linear z direction.

##### rxdamp

**Data type:** num

A percentage value on how much the damping should change in the rotational x direction.

*Continues on next page*

**rydamp****Data type:** num

A percentage value on how much the damping should change in the rotational y direction.

**[\RampTime]****Data type:** num

How fast the damping should change. Default value is 0.15.

**rzdamp****Data type:** num

A percentage value on how much the damping should change in the rotational z direction.

**Program execution**

The instruction can be used to change damping while force control is active.

**Syntax**

```
FCSetDampTune
[ xdamp ':' '=' ] < expression (IN) of num > ' , '
[ ydamp ':' '=' ] < expression (IN) of num > ' , '
[ zdamp ':' '=' ] < expression (IN) of num > ' , '
[ rxdamp ':' '=' ] < expression (IN) of num > ' , '
[ rydamp ':' '=' ] < expression (IN) of num > ' , '
[ rzdamp ':' '=' ] < expression (IN) of num >
[ '\ ' RampTime' ':' '=' < expression (IN) of num > ] ';' ;
```

**Related information**

| For information about             | See   |
|-----------------------------------|---|
| Reset damping in force direction. | <a href="#">FCResetDampingTune on page 123</a>  |
| Damping kinematics.               | <a href="#">Damping in Force x Direction - Damping in Force z Direction on page 204</a> |

## 7 RAPID reference information

### 7.1.30 FCSetLPFilterTune

#### Force Control

### 7.1.30 FCSetLPFilterTune

#### Usage

FCSetLPFilterTune is used change the response of force loop according to description in [Damping and LP-filter on page 49](#).

#### Basic examples

##### Example 1

```
FCSetLPFilterTune 2;
```

Set the force loop cut off frequency to 2 Hz. A low value will make the force control less compliant but more stable.

#### Arguments

```
FCSetLPFilterTune CutOffFreq;
```

CutOffFreq

*Cut off frequency*

Data type: num

Cut off frequency

#### Program execution

Execution behaviour:

- Set cut off frequency.

#### Limitations

Instruction cannot be executed when force control is active.

#### Syntax

```
FCSetLPFilterTune  
[CutOffFreq ':= ' ] < expression (IN) of num> ';' ;
```

#### Related information

| For information about                         | See   |
|---|---|
| Setting the parameter for low pass filter.    | <a href="#">Bandwidth of force frame filter on page 206</a> |
| Instruction how to reset the low pass filter. | <a href="#">FCResetLPFilterTune on page 124</a>             |



#### CAUTION

The cut off frequency effects the force loop stability.



### 7.1.31 FCSetMaxForceChangeTune

#### Usage

`FCSetMaxForceChangeTune` defines a temporary ramp value to be used instead of that specified in system parameter [Max Ref Force Change on page 211](#).

This is useful if the ramping needs to be at low value when ramping up, but can be faster when force references are stopped.

It is also useful if the process consists of several steps, where the initial contact needs to be slower than changes later in the process.

#### Basic example

##### Example

```
FCSetMaxForceChangeTune 1000;
```

This temporarily changes the force ramp to 1000 N/s.

##### Example 2

```
FCRefForce \Fx:=100;
FCAct tool1;
FCRefStart; ! This will now ramp with value from configuration
WaitTime 10;
FCSetMaxForceChangeTune 1000; ! This will now ramp with 1000 N/s
FCRefForce \Fx:=10;
FCRefStart;
```

#### Arguments

```
FCSetMaxForceChangeTune ForceChange
```

ForceChange

**Data type:** num

Specifies the temporary force ramp in N/s.

A value between 0 and 10,000 N/s.

#### Program execution

**Execution behaviour:**

- `FCSetMaxForceChangeTune` changes the force ramp (force change) for the next `FCRefStart` or `FCRefStop` instruction.

#### Syntax

```
FCSetMaxForceChangeTune
[ForceChange':=' ] <expression (IN) of num>';'
```

#### Related information

| For information about                             | See   |
|---|---|
| Defining maximum force ramping.                   | <a href="#">Max Ref Force Change on page 211</a>      |
| Resetting the force ramp to the configured value. | <a href="#">FCResetMaxForceChangeTune on page 125</a> |

## 7 RAPID reference information

---

### 7.1.32 FCSpdChgAct

#### Force Control

### 7.1.32 FCSpdChgAct

---

#### Usage

The `FCSpdChgAct` is used to activate FC SpeedChange function with desired reference and recover behavior. When FC SpeedChange function is active, the robot speed will be reduced/increased in order to keep the measured signal close to the reference.

#### Basic examples

Basic example of the instruction `FCSpdChgAct` is illustrated below.

See also [FCSpdChgAct on page 130](#).

#### Example

```
FCSpdChgAct 200 /RecoverFunName:="local_grind";
```

Activate FC SpeedChange with user-specified recover routine "local\_grind". The measured process signal will be controlled to be 200 by slowing down TCP speed when required.

#### Arguments

```
FCSpdChgAct Reference [\RecoverFunName] [\NonStopAllTime]
              [\MultipleRecover]
```

#### Reference

**Data type:** num

The reference value for the process force. (Process force defined by input, such as Force sensor, current, torque etc.) The measurement will be controlled below this reference value. The value of the reference must be identified in tests during normal conditions.

`[\RecoverFunName]`

**Data type:** string

This parameter specifies the name of user-defined recovery routine. The recovery routine will be executed, if the process force is still too large after the TCP speed already is reduced to the minimum speed. The recovery routine needs to be implemented by the user in order to have desired recover behavior. If no recover routine is specified, the robot will stop immediately when the above recover condition met.

`[\NonStopAllTime]`

**Data type:** switch

This option can only be used when `RecoverFunName` argument is NOT used. The robot will at most slow down to minimum feed rate (speed), which means that the robot will not stop for any overload occurring at minimum speed. USE THIS OPTION WITH CAUTION.

`[\MultipleRecover]`

**Data type:** switch

*Continues on next page*

This option can only be used when `RecoverFunName` argument is used with this option, the user-specified recover procedure will be called multiple times along the path whenever overload happens at minimum feed speed. If this option is not specified, the user-specified recover procedure will be called the first time when recover condition met. If the recover condition is met again along the path, the robot will stop immediately

---

### Program execution

Execution behavior:

- Configure *FC Speed Change* system parameters before calling `FCSpdChgAct`.
- If 6DOF force sensor is used for feedback, `FCCalib` must be called before `FCSpdChgAct`.
- The RobotWare option *Path Recovery* must be installed in order to use `FcSpdChgAct` instruction with recover function. The only exception is to use the `FcSpdChgAct` instruction with `NonStopAllTime`.
- User-specified recovery routine will not be called recursively. Which means, if the recovery condition met when controller is executing user-specified recovery routine, the robot will stop immediately instead of calling user-specified recovery routine from itself.
- If the RAPID program pointer is moved manually, FC SpeedChange function will be deactivated automatically.
- If the RAPID program stops, jogs away from current position, then restarts without regain the path, FC SpeedChange function will be deactivated automatically.

---

### Limitations

- Do NOT change tool and work object frame in RAPID program between `FCSpdChgAct` and `FCSpdChgDeact`.

---

### More examples

More examples of how to use the instruction `FCSpdChgAct` are illustrated below.

#### Example 1

```
FCSpdChgAct 200;
```

Activate FC SpeedChange function with reference 200. No user-specified recover behavior is defined. The robot will stop immediately when recover condition met.

#### Example 2

```
FCSpdChgAct 200 \RecoverFunName:="local_grind";
```

Activate FC SpeedChange function with reference 200 and user-specified recover routine, "local\_grind". Local\_grind will be executed when recover condition met, but will be called only once.

---

### Syntax

```
Instruction
[ Reference ':' '=' ] < expression (IN) of num > ',',
[ RecoverFunName ':' '=' ] < expression (IN) of string > ',',
[ '\ ' NonStopAllTime ] ',','
```

*Continues on next page*

# 7 RAPID reference information

---

7.1.32 FCSpdChgAct  
*Force Control*  
*Continued*

[ '\ ' MultipelRecover ] ';'

---

## Related information

| For information about  | See                                       |
|------------------------|---|
| Deactivate SpeedChange | <a href="#">FCSpdChgDeact on page 133</a> |

#### 7.1.33 FCSpdChgDeact

---

##### Usage

Deactivate FC SpeedChange function.

---

##### Basic examples

Basic example of the instruction `FCSpdChgDeact` is illustrated below.

##### Example

```
FCSpdChgDeact ;
```

Deactivates SpeedChange function.

---

##### Arguments

`FCSpdChgDeact`

There are no arguments to the instruction.

---

##### Syntax

```
FCSpdChgDeact
```

---

##### Related information

| For information about | See                                     |
|-----------------------|---|
| Activate SpeedChange. | <a href="#">FCSpdChgAct on page 130</a> |

## 7 RAPID reference information

---

### 7.1.34 FCSpdChgTunSet

#### Force Control

### 7.1.34 FCSpdChgTunSet

---

#### Usage

FCSpdChgTunSet is used to set FC SpeedChange system parameters to a new value.

---

#### Basic examples

Basic example of the instruction FCSpdChgTunSet is illustrated below.

See also [FCSpdChgTunSet on page 134](#).

#### Example

```
FCSpdChgTunSet 0.2, FC_SPEED_RATIO_MIN;
```

Set FC SpeedChange system parameter "Speed ratio min" to 0.2.

---

#### Arguments

```
FCSpdChgTunSet value, type;
```

value

Data type: num

Value to be set for the FC SpeedChange system parameter.

type

Data type: fcspdchgtunetype

The FC SpeedChange system parameter whose value is to be set (FC\_SPEED\_RATIO\_MIN, FC\_NO\_OF\_SPEED\_LEVELS). Only two FC SpeedChange system parameters can be tuned by this instruction, as shown in the following table:

| Parameter          | Type                  |
|--------------------|-----------------------|
| Speed ratio min    | FC_SPEED_RATIO_MIN    |
| No of speed levels | FC_NO_OF_SPEED_LEVELS |

---

#### Program execution

Execution behaviour:

- Set new values to tunable FC SpeedChange system parameters.
- 

#### More examples

More examples of how to use the instruction FCSpdChgTunSet are illustrated below.

#### Example 1

```
FCSpdChgTunSet 3, FC_NO_OF_SPEED_LEVELS;
```

Set FC SpeedChange system parameter "No of speed levels" to 3.

---

*Continues on next page*

**Limitations**

FCSpdChgTunSet will not set system parameter to the new value if called inside FCSpdChgAct - FCSpdChgDeact instruction block. It must be called before activating FC Speed Change. The valid value for the system parameters are shown in the following table:

| Parameter          | Type       |
|--------------------|------------|
| Speed ratio min    | 0.02 - 1.0 |
| No of speed levels | 2 - 10     |

**Syntax**

```
FCSpdChgTunSet
[ value ':= ' ] < expression (IN) of num> ', '
[ type ':= ' ] < expression (IN) of fcspdchgtunetype> ';'

```

**Related information**

| For information about            | See  |
|----------------------------------|--|
| Set tune parameters to original. | <a href="#">FCSpdChgTunReset on page 136</a> |

## 7 RAPID reference information

---

### 7.1.35 FCSpdChgTunReset

#### Force Control

### 7.1.35 FCSpdChgTunReset

---

#### Usage

`FCSpdChgTunReset` reset tuneable FC SpeedChange system parameters to original value stored in configuration.

---

#### Basic examples

Basic examples of the instruction `FCSpdChgTunReset` are illustrated below.

See also [FCSpdChgTunReset on page 136](#).

#### Example

```
FCSpdChgTunReset FC_SPEED_RATIO_MIN
```

Reset FC SpeedChange system parameter "Speed ratio min" to its original value.

---

#### Arguments

```
FCSpdChgTunReset type;
```

type

Data type: `fcspdchgtunetype`

The FC SpeedChange system parameter whose value is to be reset (`FC_SPEED_RATIO_MIN`, `FC_NO_OF_SPEED_LEVELS`). Only two FC SpeedChange system parameters can be reset by this instruction, as shown in the following table:

| Parameter          | Type                               |
|--------------------|------------------------------------|
| Speed ratio min    | <code>FC_SPEED_RATIO_MIN</code>    |
| No of speed levels | <code>FC_NO_OF_SPEED_LEVELS</code> |

---

#### Program execution

Execution behaviour:

- Reset tunable FC SpeedChange system parameters.

---

#### More examples

More examples of how to use the instruction `FCSpdChgTunReset` are illustrated below.

#### Example

```
FCSpdChgTunReset FC_NO_OF_SPEED_LEVELS;
```

Reset FC SpeedChange system parameter "No of speed levels"

---

#### Limitations

`FCSpdChgTunReset` will not reset system parameter if called inside `FCSpdChgAct` - `FCSpdChgDeact` instruction block. It must be called outside the `FCSpdChgAct` - `FCSpdChgDeact` instruction block.

---

#### Syntax

```
FCSpdChgTunReset  
[ type ':' ] < expression (IN) of fcspdchgtunetype >;
```

*Continues on next page*



---

#### Related information

| For information about | See  |
|-----------------------|--|
| Set tune parameters.  | <a href="#">FCSpdChgTunSet on page 134</a> |

## 7 RAPID reference information

---

### 7.1.36 FCSupvForce

*Force Control*

### 7.1.36 FCSupvForce

---

#### Usage

`FCSupvForce` is used to set up force supervision in Force Control. The supervision is activated when Force Control is activated with the instruction `FCAct`.

The force supervision is set up by defining minimum and maximum limits for the force in the directions of the force control coordinate system. Once activated, the supervision will stop the execution if the force is outside the allowed values.

The force supervision is specified in the force control coordinate system. This coordinate system is setup by the user with the instruction `FCAct`.

---

#### Basic example

```
FCSupvForce \Xmin:=-200 \Xmax:=200;
```

Defines force supervision that checks that the force in the x direction of the force control coordinate system is between -200 N and 200 N. This means that the force magnitude must be smaller than 200 N in both positive and negative x direction. No restrictions are used for the force in other directions.

See also [More examples on page 139](#).

---

#### Arguments

```
FCSupvForce [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]
```

`[\XMin]`

*Minimum force in x direction*

**Data type:** num

Lower limit for force in the x direction of the force control coordinate system. A negative value limits the maximum force in the negative x direction.

The unit is Newton and the default value is negative infinity.

`[\XMax]`

*Maximum force in x direction*

**Data type:** num

Upper limit for force in the x direction of the force control coordinate system. A negative value limits the minimum force in negative x direction.

The unit is Newton and the default value is positive infinity.

`[\YMin]`

*Minimum force in y direction*

**Data type:** num

Lower limit for force in the y direction of the force control coordinate system. A negative value limits the maximum force in the negative y direction.

The unit is Newton and the default value is negative infinity.

`[\YMax]`

*Maximum force in y direction*

**Data type:** num

*Continues on next page*

Upper limit for force in the y direction of the force control coordinate system. A negative value limits the minimum force in negative y direction.

The unit is Newton and the default value is positive infinity.

[ \ZMin ]

*Minimum force in z direction*

Data type: num

Lower limit for force in the z direction of the force control coordinate system. A negative value limits the maximum force in the negative z direction.

The unit is Newton and the default value is negative infinity.

[ \ZMax ]

*Maximum force in z direction*

Data type: num

Upper limit for force in the z direction of the force control coordinate system. A negative value limits the minimum force in negative z direction.

The unit is Newton and the default value is positive infinity.

## Program execution

Execution behavior:

- If the supervision conditions are exceeded, execution stops with an emergency error.

## More examples

### Example 1

```
FCSupvForce \Xmin:=-100 \Xmax:=100 \Ymin:=-100 \Ymax:=100 \Zmin:=-100 \ZMax:=100;
```

This supervision does not allow the force to be larger than 100 N in any of the directions (positive or negative x, y and z). Note that the force may be 100 N in both x, y and z direction, resulting in a total force magnitude of 173 N.

## Syntax

```
FCSupvForce
[ '\ ' XMin ' := ' < expression (IN) of num > ]
[ '\ ' XMax ' := ' < expression (IN) of num > ]
[ '\ ' YMin ' := ' < expression (IN) of num > ]
[ '\ ' YMax ' := ' < expression (IN) of num > ]
[ '\ ' ZMin ' := ' < expression (IN) of num > ]
[ '\ ' ZMax ' := ' < expression (IN) of num > ] ';' ;'
```

## Related information

| For information about                    | See                                      |
|--|--|
| Setting up torque supervision.           | <a href="#">FCSupvTorque on page 150</a> |
| Setting up position supervision.         | <a href="#">FCSupvPos on page 144</a>    |
| Setting up tool orientation supervision. | <a href="#">FCSupvOrient on page 141</a> |

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.36 FCSupvForce

#### Force Control

#### Continued

| For information about                       | See  |
|---|--|
| Setting up TCP speed supervision.           | <a href="#">FCSupvTCPSpeed on page 148</a>   |
| Setting up reorientation speed supervision. | <a href="#">FCSupvReoriSpeed on page 146</a> |
| Activate supervision.                       | <a href="#">FCAct on page 63</a>             |

## 7.1.37 FCSupvOrient

### Usage

`FCSupvOrient` is used to set up an supervision for the tool orientation. The supervision is activated when Force Control is activated with the instruction `FCAct`. An orientation supervision is set up by defining a maximum angle and a maximum rotation from a reference orientation. The reference orientation is either defined by the current z direction of the tool, or by specifying an orientation in relation to the z direction of the work object.

Once activated, the tool orientation must be within the limits otherwise the supervision will stop the execution.

### Basic example

```
FCSupvOrient \MaxAngle:= 30;
```

In this example, no supervision coordinate system is specified. This means that the supervision coordinate system is the same as the tool coordinate system at the time of execution of this instruction. When this supervision is activated it will stop the execution if the tool's z axis deviates more than 30 degrees from the z axis of the supervision coordinate system.

See also [More examples on page 142](#).

### Arguments

```
FCSupvOrient [\OrientSupvFrame] [\MaxAngle] [\MaxRot] [\Outside]
```

`[\OrientSupvFrame]`

***Orient supervision coordinate system***

**Data type:** orient

`OrientSupvFrame` is used to set the supervision coordinate system in which the tool orientation supervision is defined. The coordinate system is set by an orient in relation to the work object coordinate system. If `OrientSupvFrame` is omitted, the tool coordinate system at the time of execution is used as supervision coordinate system.

*Continues on next page*

## 7 RAPID reference information

### 7.1.37 FCSupvOrient

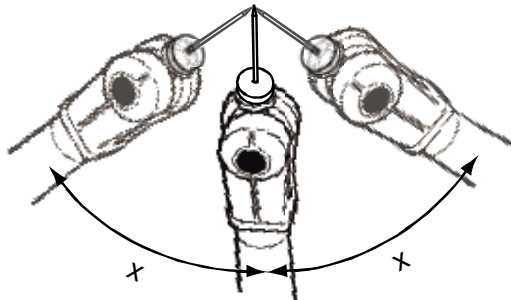
#### Force Control

#### Continued

[ \MaxAngle ]

Data type: num

The maximum angle between the z direction of the tool and the z direction of the supervision coordinate system. The unit is degrees



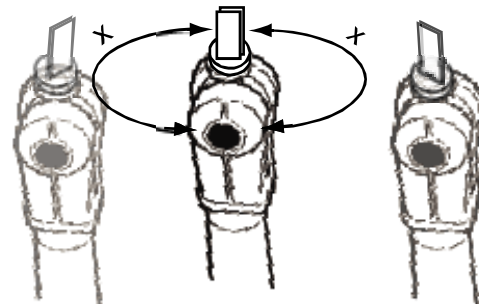
xx0500001913

|   |          |
|---|----------|
| x | MaxAngle |
|---|----------|

[ \MaxRot ]

Data type: num

The maximum rotation angle around the z axis of the tool, compared to the z direction of the supervision coordinate system. The unit is degrees



xx0500001912

|   |        |
|---|--------|
| x | MaxRot |
|---|--------|

### Program execution

Execution behavior:

- If the supervision conditions are exceeded, execution stops with an emergency error.

### More examples

#### Example 1

```
FCSupvOrient \MaxRot:= 90;
```

In this example, the supervision coordinate system is set to the same as the tool coordinate system at the time of execution. If the rotation is larger than 90 degrees around the z axis the supervision will stop the execution.

#### Example 2

```
VAR orient my_orient:=[0,0,1,0];
```

*Continues on next page*

```
FCSupvOrient \OrientSupvFrame:=my_orient \MaxAngle:=30 \MaxRot:=45;
```

In this example the z direction of the supervision coordinate system is in negative z direction of the work object coordinate system.

The supervision will stop the execution if:

- The tool's z direction deviates more than 30 degrees from the z direction of the supervision coordinate system.
- The tool's rotation around the z axis deviates more than 45 degrees from the supervision coordinate system.

## Syntax

```
FCSupvOrient
[ '\ ' OrientSupvFrame ':= ' < expression (IN) of pose > ]
[ '\ ' MaxAngle ':= ' < expression (IN) of num > ]
[ '\ ' MaxRot ':= ' < expression (IN) of num > ] ';'

```

## Related information

| Form information about                     | See  |
|--|--|
| Setting up position supervision            | <a href="#">FCSupvPos on page 144</a>        |
| Setting up force supervision               | <a href="#">FCSupvForce on page 138</a>      |
| Setting up torque supervision              | <a href="#">FCSupvTorque on page 150</a>     |
| Setting up TCP speed supervision           | <a href="#">FCSupvTCPSpeed on page 148</a>   |
| Setting up reorientation speed supervision | <a href="#">FCSupvReoriSpeed on page 146</a> |
| Activating supervision                     | <a href="#">FCAct on page 63</a>             |

## 7 RAPID reference information

---

### 7.1.38 FCSupvPos

#### Force Control

### 7.1.38 FCSupvPos

---

#### Usage

`FCSupvPos` is used to set up position supervision in Force Control. Supervision is activated when Force Control is activated with the instruction `FCAct`.

Position supervision is set up by defining a volume in space for the TCP. Once activated, the supervision will stop the execution if the TCP is outside this volume.

---

#### Basic example

```
VAR fcbboxvol my_box:= [-500, 500, -500, 500, -500, 500];  
FCSupvPos \Box:= my_box;
```

Sets up a position supervision where the TCP must stay between -500 mm and 500 mm in all directions of the work object coordinate system.

See also [More examples on page 145](#).

---

#### Arguments

`FCSupvPos` [`\PosSupvFrame`] [`\Box`] | [`\Cylinder`] | [`\Sphere`]

[`\PosSupvFrame`]

*Position supervision coordinate system*

**Data type:** pose

This parameter sets the coordinate system in which the TCP position supervision is defined. The coordinate system is set by a pose in relation to the work object coordinate system. The default value is the unity pose, meaning that if the parameter is omitted the position TCP supervision is defined in the work object coordinate system.

[`\Box`]

**Data type:** fcbboxvol

Defines a box-shaped volume that the TCP must be inside.

One, and only one, of the arguments `Box`, `Cylinder` and `Sphere` must be used.

[`\Cylinder`]

**Data type:** fccylindervol

Defines a cylinder-shaped volume that the TCP must be inside.

One, and only one, of the arguments `Box`, `Cylinder` and `Sphere` must be used.

[`\Sphere`]

**Data type:** fcspherevol

Defines a sphere-shaped volume that the TCP must be inside.

One, and only one, of the arguments `Box`, `Cylinder` and `Sphere` must be used.

---

#### Program execution

Execution behavior:

- If the supervision conditions are exceeded, execution stops with an emergency error.

*Continues on next page*



**More examples****Example 1**

```
VAR fcbboxvol my_box:= [-9e9, 9e9, -9e9, 9e9, 300, 800];
FCSupvPos \Box:= my_box;
```

Sets up a position supervision where the TCP must stay between 300 mm and 800 mm in the z direction of the work object coordinate system. No limits are set for the x and the y directions.

**Example 2**

```
VAR fccylindervol my_cyl:= [300, 0, -200, 500, 250];
VAR pose my_cs := [[0,0,600],[0.7071,0,0.7071,0]];
FCSupvPos \PosSupvframe:=my_cs \Cylinder:=my_cyl;
```

In this example the cylinder is not directly specified in the work object coordinate system but in a new coordinate system defined in relation to the work object coordinate system.

**Syntax**

```
FCSupvPos
[ '\ PosSupvFrame ':=' < expression (IN) of pose > ]
[ '\ Box ':=' < expression (IN) of fcbboxvol > ]
| [ '\ Cylinder ':=' < expression (IN) of fccylindervol > ]
| [ '\ Sphere ':=' < expression (IN) of fcspherevol > ] ';' ;
```

**Related information**

| For information about                      | See  |
|--|--|
| The data type fcbboxvol                    | <a href="#">fcbboxvol on page 162</a>        |
| The data type fccylindervol                | <a href="#">fccylindervol on page 166</a>    |
| The data type fcspherevol                  | <a href="#">fcspherevol on page 180</a>      |
| Setting up force supervision               | <a href="#">FCSupvForce on page 138</a>      |
| Setting up torque supervision              | <a href="#">FCSupvTorque on page 150</a>     |
| Setting up tool orientation supervision    | <a href="#">FCSupvOrient on page 141</a>     |
| Setting up TCP speed supervision           | <a href="#">FCSupvTCPSpeed on page 148</a>   |
| Setting up reorientation speed supervision | <a href="#">FCSupvReoriSpeed on page 146</a> |
| Activate supervision                       | <a href="#">FCAct on page 63</a>             |

## 7 RAPID reference information

---

### 7.1.39 FCSupvReoriSpeed

#### Force Control

### 7.1.39 FCSupvReoriSpeed

---

#### Usage

`FCSupvReoriSpeed` is used to set up reorientation speed supervision in Force Control. The supervision is activated when Force Control is activated with the instruction `FCAct`.

The reorientation speed supervision is set up by defining minimum and maximum limits for the reorientation speed around the axis of the work object coordinate system. Once activated, the supervision will stop the execution if the values of the reorientation speed are too high.

There are two speed supervisions: `FCSupvReoriSpeed` and `FCSupvTCPSPeed`, which is described in section [FCSupvTCPSPeed on page 148](#).

Both supervisions may be required because:

- A robot axis can rotate with high speed while the TCP is stationary.
- The TCP can be far from the rotating axis and a small axis rotation may result in a high speed movement of the TCP.

---

#### Basic example

```
FCSupvReoriSpeed \XMin:=-100 \XMax:=100;
```

Defines torque supervision that checks that the torque speed in the x direction the work object coordinate system is between -100 deg/s and 100 deg/s. No restriction is put on the reorientation speed in other directions.

---

#### Arguments

```
FCSupvReoriSpeed [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]
```

`[\XMin]`

*Minimum speed around the x direction*

**Data type:** num

Lower limit for reorientation speed around the x direction of the work object coordinate system. A negative value limits the maximum speed in the negative x direction.

The unit is degrees/s and the default value is -50.

`[\XMax]`

*Maximum speed around the x-direction*

**Data type:** num

Upper limit for reorientation speed around the x direction of the work object coordinate system. A negative value limits the minimum speed around negative x direction.

The unit is degrees/s and the default value is 50.

`[\YMin]`

*Minimum speed around the y direction*

**Data type:** num

*Continues on next page*

Lower limit for reorientation speed around the y direction of the work object coordinate system. A negative value limits the maximum speed around the negative y direction.

The unit is degrees/s and the default value is -50.

[ \YMax ]

*Maximum speed around the y direction*

Data type: num

Upper limit for TCP speed around the y direction of the work object coordinate system. A negative value limits the minimum speed around negative y direction.

The unit is degrees/s and the default value is 50.

[ \ZMin ]

*Minimum speed around the z direction*

Data type: num

Lower limit for TCP speed around the z direction of the work object coordinate system. A negative value limits the maximum speed around the negative z direction.

The unit is degrees/s and the default value is -50.

[ \ZMax ]

*Maximum speed around the z direction*

Data type: num

Upper limit for TCP speed around the z direction of the work object coordinate system. A negative value limits the minimum speed around negative z direction.

The unit is degrees/s and the default value is 50.

## Syntax

```
FCSupvReoriSpeed
[ '\ ' XMin ':' < expression (IN) of num > ]
[ '\ ' XMax ':' < expression (IN) of num > ]
[ '\ ' YMin ':' < expression (IN) of num > ]
[ '\ ' YMax ':' < expression (IN) of num > ]
[ '\ ' ZMin ':' < expression (IN) of num > ]
[ '\ ' ZMax ':' < expression (IN) of num > ] ';'

```

## Related information

| For information about              | See  |
|------------------------------------|--|
| Setting up force supervision       | <a href="#">FCSupvForce on page 138</a>    |
| Setting up torque supervision      | <a href="#">FCSupvTorque on page 150</a>   |
| Setting up position supervision    | <a href="#">FCSupvPos on page 144</a>      |
| Setting up orientation supervision | <a href="#">FCSupvOrient on page 141</a>   |
| Setting up TCP speed supervision   | <a href="#">FCSupvTCPSpeed on page 148</a> |
| Activating the supervision         | <a href="#">FCAct on page 63</a>           |

## 7 RAPID reference information

---

### 7.1.40 FCSupvTCPSpeed

#### Force Control

### 7.1.40 FCSupvTCPSpeed

---

#### Usage

FCSupvTCPSpeed is used to set up TCP speed supervision in Force Control. The supervision is activated when Force Control is activated with the instruction FCAct. The TCP speed supervision is set up by defining minimum and maximum limits for the TCP speed in the directions of the work object coordinate system. Once activated, the supervision will stop the execution if too high TCP speed values are detected.

There are two speed supervisions: FCSupvTCPSpeed and FCSupvReoriSpeed, which is described in section [FCSupvReoriSpeed on page 146](#).

Both supervisions may be required because:

- A robot axis can rotate with high speed while the TCP is stationary.
- The TCP can be far from the rotating axis and a small axis rotation may result in a high speed movement of the TCP.

---

#### Basic example

```
FCSupvTCPSpeed \XMin:=-100 \XMax:=100;
```

Defines TCP speed supervision that checks that the TCP speed in the x direction the work object coordinate system is between -100mm/s and 100mm/s. No restriction is put on the TCP speed in other directions.

---

#### Arguments

```
FCSupvTCPSpeed [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]
```

`[\XMin]`

*Minimum speed in the x direction*

Data type: num

Lower limit for TCP speed in the x direction of the work object coordinate system. A negative value limits the maximum speed in the negative x direction.

The unit is mm/s and the default value is -250.

`[\XMax]`

*Maximum speed in the x direction*

Data type: num

Upper limit for TCP speed in the x direction of the work object coordinate system. A negative value limits the minimum speed in negative x direction.

The unit is mm/s and the default value is 250.

`[\YMin]`

*Minimum speed in the y direction*

Data type: num

Lower limit for TCP speed in the y direction of the work object coordinate system. A negative value limits the maximum speed in the negative y direction.

The unit is mm/s and the default value is -250.

*Continues on next page*

[ \YMax ]

*Maximum speed in the y direction***Data type:** num

Upper limit for TCP speed in the y direction of the work object coordinate system.  
A negative value limits the minimum speed in negative y direction.

The unit is mm/s and the default value is 250.

[ \ZMin ]

*Minimum speed in the z direction***Data type:** num

Lower limit for TCP speed in the z direction of the work object coordinate system.  
A negative value limits the maximum speed in the negative z direction.

The unit is mm/s and the default value is -250.

[ \ZMax ]

*Maximum speed in the x direction***Data type:** num

Upper limit for TCP speed in the z direction of the work object coordinate system.  
A negative value limits the minimum speed in negative z direction.

The unit is mm/s and the default value is 250.

**Program execution****Execution behavior:**

- If the supervision conditions are exceeded, execution stops with an emergency error.

**Syntax**

```
FCSupvTCPSpeed
[ '\ ' XMin ' := ' < expression (IN) of num > ]
[ '\ ' XMax ' := ' < expression (IN) of num > ]
[ '\ ' YMin ' := ' < expression (IN) of num > ]
[ '\ ' YMax ' := ' < expression (IN) of num > ]
[ '\ ' ZMin ' := ' < expression (IN) of num > ]
[ '\ ' ZMax ' := ' < expression (IN) of num > ] ';'

```

**Related information**

| For informationa about                     | See  |
|--|--|
| Setting up force supervision               | <a href="#">FCSupvForce on page 138</a>      |
| Setting up torque supervision              | <a href="#">FCSupvTorque on page 150</a>     |
| Setting up position supervision            | <a href="#">FCSupvPos on page 144</a>        |
| Setting up orientation supervision         | <a href="#">FCSupvOrient on page 141</a>     |
| Setting up reorientation speed supervision | <a href="#">FCSupvReoriSpeed on page 146</a> |
| Activating the supervision                 | <a href="#">FCAct on page 63</a>             |

## 7 RAPID reference information

---

### 7.1.41 FCSupvTorque Force Control

#### 7.1.41 FCSupvTorque

---

##### Usage

`FCSupvTorque` is used to set up torque supervision in Force Control. The supervision is activated when Force Control is activated with the instruction `FCAct`. The torque supervision is set up by defining minimum and maximum limits for the torque in the directions of the force control coordinate system. Once activated, the supervision will stop the execution if the torque is outside the allowed values.

##### Basic example

```
FCSupvTorque \Xmin:=-100 \Xmax:=100;.
```

Defines torque supervision that checks that the torque around the x axis is between -100 Nm and 100 Nm. This means that the torque magnitude must be smaller than 100 Nm in both clockwise and counterclockwise around the x axis. No restrictions are used for the torque in other directions

See also [More examples on page 151](#).

##### Arguments

```
FCSupvTorque [\XMin] [\XMax] [\YMin] [\YMax] [\ZMin] [\ZMax]
```

`[\XMin]`

*Minimum torque around the x axis*

**Data type:** num

Lower limit for torque around the x axis of the force control coordinate system. A negative value limits the maximum torque in the opposite direction around the x axis.

The unit is Nm and the default value is negative infinity.

`[\XMax]`

*Maximum torque around the x axis*

**Data type:** num

Upper limit for torque around the x axis of the force control coordinate system. A negative value limits the minimum torque around negative x axis.

The unit is Nm and the default value is positive infinity.

`[\YMin]`

*Minimum torque around the y axis*

**Data type:** num

Lower limit for torque around the y axis of the force control coordinate system. A negative value limits the maximum torque in the opposite direction around they axis.

The unit is Nm and the default value is negative infinity.

`[\YMax]`

*Maximum torque around the y axis*

**Data type:** num

*Continues on next page*

Upper limit for torque around the y axis of the force control coordinate system. A negative value limits the minimum torque around negative y axis.

The unit is Nm and the default value is positive infinity.

[ \ZMin ]

*Minimum torque around the z axis*

Data type: num

Lower limit for torque around the z axis of the force control coordinate system. A negative value limits the maximum torque in the opposite direction around the z axis.

The unit is Nm and the default value is negative infinity.

[ \ZMax ]

*Maximum torque around the z axis*

Data type: num

Upper limit for torque around the z axis of the force control coordinate system. A negative value limits the minimum torque around negative z axis

The unit is Nm and the default value is positive infinity.

## Program execution

Execution behavior:

- If the supervision conditions are exceeded, execution stops with an emergency error.

## More examples

### Example 1

```
FCSupvTorque \Xmin:=-100 \Xmax:=100 \Ymin:=-100 \Ymax:=100;.
```

Defines torque supervision that checks that the torque around the x and z axes are between -100 Nm and 100 Nm. This means that the torque magnitude must be smaller than 100 Nm in both clockwise and counter-clockwise around the x and y axes. No restrictions are used for the torque around the z axis.

## Syntax

```
FCSupvTorque
[ '\ XMin ' := < expression (IN) of num > ]
[ '\ XMax ' := < expression (IN) of num > ]
[ '\ YMin ' := < expression (IN) of num > ]
[ '\ YMax ' := < expression (IN) of num > ]
[ '\ ZMin ' := < expression (IN) of num > ]
[ '\ ZMax ' := < expression (IN) of num > ] ';'

```

## Related information

| For information about            | See  |
|----------------------------------|--|
| Setting up force supervision     | <a href="#">FCSupvForce on page 138</a>    |
| Setting up position supervision  | <a href="#">FCSupvPos on page 144</a>      |
| Setting up TCP speed supervision | <a href="#">FCSupvTCPspeed on page 148</a> |

*Continues on next page*

## 7 RAPID reference information

---

### 7.1.41 FCSupvTorque

#### *Force Control*

#### *Continued*

| For information about                      | See  |
|--|--|
| Setting up reorientation speed supervision | <a href="#">FCSupvReoriSpeed on page 146</a> |
| Activating the supervision                 | <a href="#">FCAct on page 63</a>             |



## 7.2 Functions

### 7.2.1 FCGetForce

#### Usage

The function `FCGetForce` is used to retrieve the force sensor readings. The measured force and torque is returned in a force vector. It is possible to transform the measured force and torque from the force sensor coordinate system to either the tool coordinate system or the work object coordinate system. If the system has been calibrated, i.e. the instruction `FCCalib` has been executed, it is possible to return the force and torque without any offset. In a calibrated system it is also possible to remove the force and torque due to gravity from the sensor readings and only show contact force

#### Basic example

```
VAR fcforcevector myForceVector;
myForceVector:= FCGetForce();
```

In this example `FCGetForce` gets the values from the sensor and saves it in the variable `myForceVector`. If the system has not been calibrated, using the instruction `FCCalib`, raw measurement data will be returned. That means the sensor offset will be included in the result. If the system has been calibrated, only the force and torque corresponding to the gravity and contact forces will be shown. See also [More examples on page 154](#).

#### Return value

**Data type:** `fcforcevector`

The function returns a value of the data type `fcforcevector`, whose components are force and torque in three dimensions (i.e. x, y and z).

#### Arguments

```
FCGetForce ([\Tool] [\Wobj] | [\ContactForce])
```

`[\Tool]`

**Data type:** `tooldata`

If a tool is specified the returned force will be transformed to the coordinate system of this tool.

`[\Wobj]`

**Data type:** `wobjdata`

If a work object is specified the returned force will be transformed to the coordinate system

`[\ContactForce]`

**Data type:** `switch`

This option will remove the present gravity force from the result, displaying only contact forces. Note that this option is only allowed if the system has been calibrated before using the function `FCGetForce`.

*Continues on next page*

## 7 RAPID reference information

---

### 7.2.1 FCGetForce

#### Force Control

#### Continued

---

#### Program execution

##### Execution behavior:

- If the sensor has not been calibrated the returned force is the same as if the sensor had not yet been mounted on the robot, and depends on the sensor manufacturer. Some sensors are offset compensated at startup, which means that the result will be the same as if the sensor had been calibrated, but some are not.
  - The resulting torque is in the origin of the new coordinate system. When a transformation is done it is assumed that the contact is in the TCP.
- 

#### More examples

##### Example 1

```
VAR fcforcevector myForceVector;  
myForceVector:=FCGetForce(\ContactForce);
```

In this example the force and torque due to gravity is removed, meaning that what we see is only contact forces.

##### Example 2

```
VAR fcforcevector myForceVector;  
myForceVector:=FCGetForce(\WObj:=wobj2);
```

In this example the force readings are transformed to the work object coordinate system before returned.

##### Example 3

```
VAR fcforcevector myForceVector;  
myForceVector:=FCGetForce(\Tool:=tool2);
```

In this example the force readings are transformed to the tool coordinate system before returned. It is necessary that the sensor is calibrated or else the function will return an error.

---

#### Syntax

```
FCGetForce '('  
  ['\' Tool ':'='] < persistent (PERS) of tooldata >  
  | [ '\ WObj ':'='] < persistent (PERS) of wobjdata >  
  [ '\ ContactForce ] ')'
```

A function with a return value of the data type `fcforcevector`.

---

#### Related information

| For information about                    | See                                       |
|--|---|
| The data type <code>fcforcevector</code> | <a href="#">fcforcevector on page 170</a> |
| Identifying the load                     | <a href="#">FCLoadID on page 158</a>      |

## 7.2.2 FCGetProcessData

### Usage

The function `FCGetProcessData` is used to retrieve six different variables gathered in a data type called `fcprocessdata`. If no arguments are used the `fcprocessdata` returned will be from the moment when the function was executed.

### Basic example

```
VAR fcprocessdata mydata;
mydata := FCGetProcessData()
```

In this example `FCGetProcessData` retrieves the values from the system and saves it in a variable called `mydata`.

See [More examples on page 155](#).

### Return value

Data type: `fcprocessdata`

The function returns a variable of type `fcprocessdata` and its components are

- Condition Status
- Time
- Measured position in Reference movement coordinate system
- Measured speed in the work object frame.
- Measured Force in the force sensor coordinate system
- Measured force in Force Control coordinate system

### Arguments

```
FCGetProcessData (\DataAtTrigTime)
```

`[\DataAtTrigTime]`

Data type: `switch`

If this argument is used the function will return `fcprocessdata` from the moment when the user defined condition was fulfilled.

### More examples

#### Example 1

```
VAR fcprocessdata mydata;
mydata := FCGetProcessData(\DataAtTrigTime);
```

In this example `FCGetProcessData` get the values from when the user defined condition was true and saves it in a variable `mydata`.

#### Example 2

```
!Sets up a force condition.
FCCondForce \Xmin:=-40,TimeOut:=20;
!Defines a horizontal force in positive x-direction.
FCRefForce \Fx:= 20;

!Start the force references
```

*Continues on next page*

## 7 RAPID reference information

---

### 7.2.2 FCGetProcessData

#### Force Control

#### Continued

```
FCRefStart;  
!Wait until conditions are met or timeout  
FCCondWaitWhile;  
  
!Saves the condition data at trig time  
assemblydata:= FCGetProcessData(\dataattrigtime);  
  
!Check if the force condition or TimeOut triggered the condition  
IF (assemblydata.conditionstatus.force = FALSE) THEN  
    !The Force conditions are met  
ELSE  
    !No conditions are met and program has done a timeout.  
ENDIF
```

In this example the force in base frame must be larger than -40N. If the condition is not met the program will do a timeout after 20 seconds.

---

#### Limitations

No limitations.

---

#### Syntax

```
FCGetProcessData '('  
    [ '\ ' DataAtTrigTime ':' < expression (IN) of datatype > ] ')'
```

A function with a return value of the data type `fcprocessdata`.

---

#### Related information

| For information about      | See                                       |
|----------------------------|---|
| <code>fcprocessdata</code> | <a href="#">fcprocessdata on page 174</a> |

### 7.2.3 FCIsForceMode

---

#### Usage

The function `FCIsForceMode` is used to retrieve information whether or not the system is in force control mode.

---

#### Basic example

```
VAR bool fc_mode;  
fc_mode := FCIsForceMode();
```

In this example `FCIsForceMode` returns `TRUE` if force mode is activated.

---

#### Return value

Data type: `bool`

The function returns `TRUE` when force control is activated, `FALSE` when it is deactivated.

---

#### Syntax

`FCIsForceMode`

A function with no arguments and a return value of the data type `bool`.

## 7 RAPID reference information

---

### 7.2.4 FCLoadID

#### Force Control

### 7.2.4 FCLoadID

---

#### Usage

The function `FCLoadID` is used to identify the load the sensor feels. Robot axes 5 and 6 move the load while the force sensor is used to detect the mass and center of gravity of the load.

The identified load is returned in a `loaddata` variable. At the present only the mass and center of gravity is identified. Inertias are set to zero. The identified load is used to calibrate the force sensor.



#### Note

It is important to get an accurate definition of the load in order to get a correct calibration of the sensor. If `loadidErr` is higher than 0.1, the load identification is not optimal and it is recommended to check the sensor coordinate system, see [FC Sensor on page 21](#) and the PMC matrix, see [PMC Sensor Setup on page 24](#).

See also [Troubleshooting drifting robot on page 61](#).



#### Note

`FCLoadID` shall not be used when the sensor is room fixed.

---

#### Basic example

```
VAR loaddata my_load;  
my_load := FCLoadID();
```

In this example the load in the sensor coordinate system is identified and the value is saved in the variable `my_load`.

See also [More examples on page 160](#).

---

#### Return value

Data type: `loaddata`

The function returns a variable of type `loaddata` with the identified mass and center of gravity expressed in the force sensor coordinate system.

---

#### Arguments

```
FCLoadID ([\MaxMoveAx5] [\MaxMoveAx6] [\ReadingsPerPoint]  
          [\PointsPerAxis] [\loadidErr] [\WarningsOff])
```

`[\MaxMoveAx5]`

*Maximum movement of axis 5*

Data type: `num`

This parameter decides the maximum movement of robot axis 5 during the load identification procedure. Based on the present position of the robot axis 5, it will move at the most `MaxMoveAx5` degrees in both directions.

The unit is degrees. The default value is 180 degrees.

*Continues on next page*

`[\MaxMoveAx6]`**Maximum movement of axis 6****Data type:** num

This parameter decides the maximum movement of robot axis 6 during the load identification procedure. Based on the present position of the robot axis 6, it will move at the most `MaxMoveAx6` degrees in both directions.

The unit is degrees. The default value is 180 degrees.

`[\ReadingsPerPoint]`**Data type:** num

The number of readings in every point on the axis. The default value is 6 and an average of the readings is calculated.

`[\PointsPerAxis]`**Data type:** num

The number of points on each axis to make the readings on. The default value is 6. A larger value slows down the identification but may improve the result.

`[\LoadidErr]`**Data type:** num

`LoadidErr` is an INOUT parameter that returns a value between 0 and 1 depending on the result of the load identification. A value higher than 0.1 indicates that the identification is not optimal.

`[\WarningsOff]`**Data type:** switch

`WarningsOff` is used to disable displaying a message that axis 5 and axis 6 will move outside the specified maximum degrees. The warning message may be useful when running in manual mode, but in automatic mode it is better switched off.

*Continues on next page*

## 7 RAPID reference information

### 7.2.4 FCLoadID

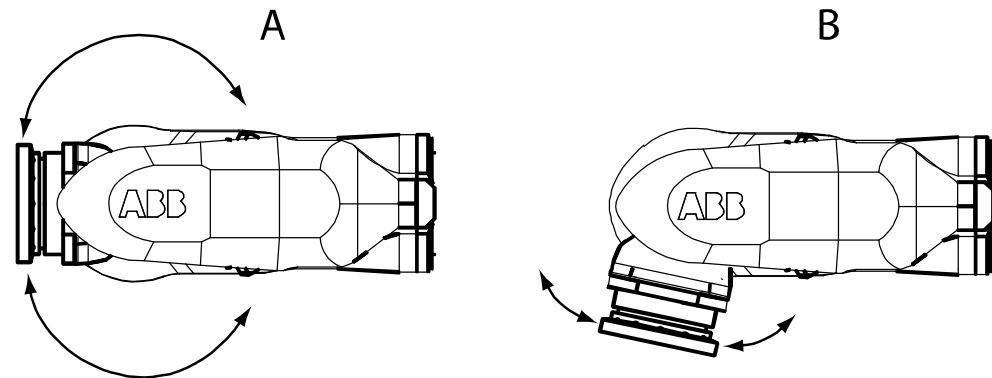
#### Force Control

#### Continued

#### Program execution

Axis 5 is moved the same angle in both directions from the current position. The same is the case for axis 6.

Even if the movement range is not limited by `MaxMoveAx5` the movement is limited by the robot itself. If the axis is near its end position, the movement will be small and affect the accuracy of the load identification.



|   |  |
|---|--|
| A | The position of axis 5 allows large movements which result in a better load identification.  |
| B | The position of axis 5 allows only a small movement in one direction. The movement in the other direction will be equally small. This results in a poor load identification. |

#### More examples

##### Example 1

```
VAR num my_status;  
VAR loaddata my_sensor_load;  
my_sensor_load:= FCLoadID(\MaxMoveAx5:=30 \MaxMoveAx6:=90  
    \ReadingsPerPoint:= 6 \PointsPerAxis:= 5 \LoadIDErr:=  
    my_status);
```

The identified load is returned defined in the sensor coordinate system. The robot will move a maximum of 30 degrees in the direction of axis 5 and 90 degrees in direction of axis 6 based on the present robot position. The identification will be based on 6 readings in every point and 5 points on each axis. The variable `my_status` will show the status of the accomplished load identification.

#### Syntax

```
FCLoadID '('  
    [ '\ ' MaxMoveAx5 ':' < expression (IN) of num > ]  
    [ '\ ' MaxMoveAx6 ':' < expression (IN) of num > ]  
    [ '\ ' ReadingsPerPoint ':' < expression (IN) of num > ]  
    [ '\ ' PointsPerAxis ':' < expression (IN) of num > ]  
    [ '\ ' LoadidErr ':' < expression (INOUT) of num > ]  
    [ '\ ' WarningsOff ] ')'
```

A function with a return value of the data type `loaddata`.

*Continues on next page*



---

### Related information

| For information about        | See                                |
|------------------------------|------------------------------------|
| Calibrating the force sensor | <a href="#">FCCalib on page 66</a> |

## 7 RAPID reference information

---

### 7.3.1 fcboxvol

#### Force Control

## 7.3 Data types

### 7.3.1 fcboxvol

---

#### Usage

`fcboxvol` is used by the Force Control instruction `FCCondPos` and `FCSupvPos`. It defines a cubic volume that is used to verify if the TCP is inside or outside the volume.

---

#### Description

`fcboxvol` consists of minimum and maximum values in the directions x, y and z. The numbers refer to the unit mm. By default, the directions refer to the work object coordinate system, but can be changed with arguments in `FCCondPos` and `FCSupvPos`.

---

#### Components

`xmin`

**Data type:** num

Minimum value in the x direction. The unit is mm.

`xmax`

**Data type:** num

Maximum value in the x direction. The unit is mm.

`ymin`

**Data type:** num

Minimum value in the y direction. The unit is mm.

`ymax`

**Data type:** num

Maximum value in the y direction. The unit is mm.

`zmin`

**Data type:** num

Minimum value in the z direction. The unit is mm.

`zmax`

**Data type:** num

Maximum value in the z direction. The unit is mm.

---

#### Examples

##### Example 1

```
VAR fcboxvol my_box:= [-100, 100, -200, 200, -300, 300];  
FCCondPos \Box:= my_box, 60;
```

In this example, a condition is set up to be true while the TCP is inside a box.

*Continues on next page*

### Structure

```
< dataobject of fcboxvol >
  < xmin of num >
  < xmax of num >
  < ymin of num >
  < ymax of num >
  < zmin of num >
  < zmax of num >
```

### Related information

| For information about            | See                                   |
|----------------------------------|---------------------------------------|
| Setting up position condition.   | <a href="#">FCCondPos on page 76</a>  |
| Setting up position supervision. | <a href="#">FCSupvPos on page 144</a> |

## 7 RAPID reference information

---

### 7.3.2 fccondstatus

#### Force Control

### 7.3.2 fccondstatus

---

#### Usage

`fccondstatus` is used to define which of the conditions position, speed, force and time that are fulfilled.



#### Note

By default all components are set to true, if a condition is triggered the component defining that condition is set to false.

---

#### Components

`position`

**Data type:** bool

Defines if the `position` condition is triggered.

`speed`

**Data type:** bool

Defines if the `speed` condition is triggered.

`force`

**Data type:** bool

Defines if the `force` condition is triggered.

`time`

**Data type:** bool

Defines if the `time` condition is triggered.

---

#### Examples

##### Example 1

```
!Sets up a force condition.
FCCondForce \Xmin:=-40,Timeout:=20;

!Defines a horisontal force in positive x-direction.
FCRefForce \Fx:= 20;

!Start the force references
FCRefStart;
!Wait until conditions are triggered or timeout
FCCondWaitWhile;

!Saves the condition data at trig time
assemblydata:= FCGetProcessData(\dataattrigtime);

!Check if the force condition or Timeout trigged the condition
IF (assemblydata.conditionstatus.force = FALSE) THEN
    !The Force conditions are triggered
```

*Continues on next page*

ELSE

!No conditions are triggered and program has done a timeout.

In this example the force in base frame must be larger than -40N. If the condition is not triggered the program will do a timeout after 20 seconds.

---

#### Structure

```
< dataobject of fccondstatus >  
< position of bool >  
< speed of bool >  
< force of bool >  
< time of bool >
```

---

#### Related information

| For information about       | See                                       |
|-----------------------------|---|
| The data type fcprocessdata | <a href="#">fcprocessdata on page 174</a> |

## 7 RAPID reference information

---

### 7.3.3 fccylindervol

#### Force Control

### 7.3.3 fccylindervol

---

#### Usage

`fccylindervol` is used by the Force Control instruction `FCCondPos` and `FCSupvPos`. It defines a cylinder volume that is used to verify if the TCP is inside or outside the volume.

---

#### Description

`fccylindervol` consists x, y and z values for the center of the cylinder bottom, and values for height and radius. The numbers refer to mm and height is always in the z direction. By default, the directions refer to the work object coordinate system, but can be changed with arguments in `FCCondPos` and `FCSupvPos`.

---

#### Components

`xcbottom`

Data type: num

X value for the center of the bottom of the cylinder. The unit is mm.

`ycbottom`

Data type: num

Y value for the center of the bottom of the cylinder. The unit is mm.

`zcbottom`

Data type: num

Z value for the center of the bottom of the cylinder. The unit is mm.

`height`

Data type: num

The height of the cylinder. The unit is mm.

`radius`

Data type: num

The radius of the cylinder. The unit is mm.

---

#### Examples

##### Example 1

```
VAR fccylindervol my_cylinder:= [-100, 100, -200, 200, -300, 300];  
FCCondPos \Cylinder:= my_cylinder, 60;
```

In this example, a condition is set up to be true while the TCP is inside a cylinder.

---

#### Structure

```
< dataobject of fccylindervol >  
  < xcbottom of num >  
  < ycbottom of num >  
  < zcbottom of num >  
  < height of num >  
  < radius of num >
```

*Continues on next page*

---

### Related information

| For information about           | See                                   |
|---------------------------------|---------------------------------------|
| Setting up position condition   | <a href="#">FCCondPos on page 76</a>  |
| Setting up position supervision | <a href="#">FCSupvPos on page 144</a> |

## 7 RAPID reference information

---

### 7.3.4 fcdamping

#### Force Control

### 7.3.4 fcdamping

---

#### Usage

`fcdamping` is used by the instruction `FCAct` to specify the correlation between a contact force and the resulting speed.

#### Description

In Force Control, a contact force will make the TCP move with a speed proportional to the contact force. A contact torque will make the tool reorient with a speed proportional to the contact torque. A `fcdamping` variable defines the proportions between a force and the resulting speed, and a torque and the resulting reorientation speed, in the directions x, y and z.

The values are given as a percentage of the system parameter values defined in the type *FC Kinematics*.

#### Components

##### `xdamp`

##### *Damping in the x direction*

Data type: `num`

Force damping (relation between force and TCP speed) in the x direction. A smaller value means that the robot is more sensitive. By default the value is 100% (of the system parameter value), and allowed values are between 50% and infinity.

##### `ydamp`

##### *Damping in the y direction*

Data type: `num`

Force damping (relation between force and TCP speed) in the y direction. A smaller value means that the robot is more sensitive. By default the value is 100% (of the system parameter value), and allowed values are between 50% and infinity.

##### `zdamp`

##### *Damping in the z direction*

Data type: `num`

Force damping (relation between force and TCP speed) in the z direction. A smaller value means that the robot is more sensitive. By default the value is 100% (of the system parameter value), and allowed values are between 50% and infinity.

##### `rx damp`

##### *Damping in the rotational x direction*

Data type: `num`

Torque damping (relation between torque and tool reorientation speed) around the x direction. A smaller value means that the robot is more sensitive. By default the value is 100% (of the system parameter value), and allowed values are between 50% and infinity.

*Continues on next page*



rydamp

***Damping in the rotational y direction*****Data type:** num

Torque damping (relation between torque and tool reorientation speed) around the y direction. A smaller value means that the robot is more sensitive. By default the value is 100% (of the system parameter value), and allowed values are between 50% and infinity.

rzdamp

***Damping in the rotational z direction*****Data type:** num

Torque damping (relation between torque and tool reorientation speed) around the z direction. A smaller value means that the robot is more sensitive. By default the value is 100% (of the system parameter value), and allowed values are between 50% and infinity.

**Examples****Example 1**

```
VAR fcdamping my_damping:=[50,100,100,300,300,300];
FCAct tool1 \DampingTune:=my_damping;
```

In this example, Force Control is activated with a more sensitive force damping in the x direction while the torque damping is stiffer in all directions.

**Structure**

```
< dataobject of fcdamping >
  < xdamp of num >
  < ydamp of num >
  < zdamp of num >
  < rxdamp of num >
  < rydamp of num >
  < rzdamp of num >
```

**Related information**

| For information about                                | See  |
|--|--|
| Activating Force Control.                            | <a href="#">FCAct on page 63</a>                   |
| System parameters of the type <i>FC Kinematics</i> . | <a href="#">The FC Kinematics type on page 202</a> |

## 7 RAPID reference information

---

### 7.3.5 fcforcevector

#### Force Control

### 7.3.5 fcforcevector

---

#### Usage

`fcforcevector` is used by the instruction `FCGetForce` to return force and torque in three dimensions (i.e. x, y and z).

---

#### Components

`xforce`

**Data type:** `num`

The force in x direction. The unit is N.

`yforce`

**Data type:** `num`

The force in y direction. The unit is N.

`zforce`

**Data type:** `num`

The force in z direction. The unit is N.

`xtorque`

**Data type:** `num`

The torque in x direction. The unit is Nm.

`ytorque`

**Data type:** `num`

The torque in y direction. The unit is Nm.

`ztorque`

**Data type:** `num`

The torque in z direction. The unit is Nm.

---

#### Example

In this example `FCGetForce()` get the values from the sensor and saves it in a variable `myForceVector`.

```
VAR fcforcevector myForceVector;  
myforceVector := FCGetForce();
```

#### Structure

```
< dataobject of fcforcevector >  
  < xforce of num >  
  < yforce of num >  
  < zforce of num >  
  < xtorque of num >  
  < ytorque of num >  
  < ztorque of num >
```

*Continues on next page*

---

### Related information

| For information about | See                                    |
|-----------------------|--|
| FCGetForce            | <a href="#">FCGetForce on page 153</a> |

## 7 RAPID reference information

---

### 7.3.6 fcframe

#### *Force Control*

### 7.3.6 fcframe

---

#### Usage

- work object coordinate system
- tool coordinate system
- path coordinate system

---

#### Example

```
VAR tooldata tool1:=[TRUE,[[97.4,0,223],[1,0,0,0]], [5,[23,0,75],  
[1,0,0,0],0,0,0]];  
VAR fcframe refcoordsys:=FC_REFFRAME_TOOL;
```

---

#### Predefined data

| Constant         | Comment                       |
|------------------|-------------------------------|
| FC_REFFRAME_TOOL | Tool coordinate system        |
| FC_REFFRAME_WOBJ | Work object coordinate system |

---

#### Characteristics

`fcframe` is an alias data type for `num` and consequently inherits its characteristics.

### 7.3.7 fclindir

#### Usage

`fclindir` is used by the instruction `FCRefLine` and specifies the the reference direction.

#### Example

```
FCRefLine FC_LIN_X, 500, 100;
```

Sets up, but does not activate, a linear shaped reference movement in the x-direction. The maximum speed is 500 mm/s and the amplitude is 100 mm.

#### Predefined data

| Constant | Comment                      |
|----------|------------------------------|
| FC_LIN_X | Reference in the x direction |
| FC_LIN_Y | Reference in the y direction |
| FC_LIN_Z | Reference in the z direction |

#### Characteristics

`fclindir` is an alias data type for `num` and consequently inherits its characteristics.

#### Related information

| For information about | See                                   |
|-----------------------|---------------------------------------|
| FCRefLine.            | <a href="#">FCRefLine on page 107</a> |

## 7 RAPID reference information

---

### 7.3.8 fcprocessdata

#### Force Control

### 7.3.8 fcprocessdata

---

#### Usage

`fcprocessdata` is used by the function `FCGetProcessdata` to retrieve data.

---

#### Description

`fcprocessdata` contains components, which are useful for supervising force control for assembly.

---

#### Components

`conditionstatus`

**Data type:** `fccondstatus`

Shows which of the conditions that are fulfilled.

`time`

**Data type:** `num`

Gives the time since the `FCCondWaitWhile` was executed.

`poseinrefcs`

**Data type:** `pose`

Gives the measured position and orientation in the reference movement coordinate system.

`speedinwobjframe`

**Data type:** `fcspeedvector`

Gives the linear and reorientation speed in the work object.

`sensorforce`

**Data type:** `fcforcevector`

Gives the measured force and torque in the force sensor coordinate system.

`forceframeforce`

**Data type:** `fcforcevector`

The measured force and torque in the force control coordinate system.

`force_control_active`

**Data type:** `bool`

Shows if force control is active.

---

#### Examples

In the examples below the variable `mydata` of the data type `fcprocessdata` is created. `FCGetProcessData` returns the data immediately or retrieves it when the wait while condition is triggered, and it is saved in `mydata`.

#### Example 1

```
VAR fcprocessdata mydata;
mydata := FCGetProcessData();
mydata.conditionstatus.position;
```

*Continues on next page*

```
TPWrite "If false, the position condition was triggered: "
\Bool:=mydata.conditionstatus.position;
```

This example shows if the position condition was triggered.

#### Example 2

```
VAR fcprocessdata mydata;
mydata := FCGetProcessData();
TPWrite "Force in z direction, from sensor: "
\Num:=mydata.sensorforce.zforce;
```

This example shows the force in the force sensor z direction. The unit is Newton.

#### Example 3

```
VAR fcprocessdata mydata;
mydata := FCGetProcessData();
TPWrite "Speed in x direction of the work object: "
\Num:=mydata.speedinwobjframe.vx;
```

This example shows the speed in the x direction of the work object. The unit is mm/s.

#### Structure

```
< dataobject of fcprocessdata >
< conditionstatus of fccondstatus >
< time of num >
< poseinrefcs of pose >
< speedinwobjframe of fcspeedvector >
< sensorforce of fcforcevector >
< forceframeforce of forcevector >
< force_control_active of bool >
```

#### Related information

| For information about | See  |
|-----------------------|--|
| fccondstatus          | <a href="#">fccondstatus on page 164</a>     |
| fcforcevector         | <a href="#">fcforcevector on page 170</a>    |
| fcgetprocessdata      | <a href="#">FCGetProcessData on page 155</a> |
| fcspeedvector         | <a href="#">fcspeedvector on page 178</a>    |

## 7 RAPID reference information

---

### 7.3.9 fcplane *Force Control*

### 7.3.9 fcplane

---

#### Usage

`fcplane` is used by the instructions `FCRefCircle` and `FCRefSpiral`. It defines in which plane the movement should be carried out.

---

#### Example

```
VAR fcplane myplane:=FCPLANE_XY;  
FCRefSpiral myplane, 50, 100, 10;
```

Sets up a spiral shaped reference movement in the xy plane.

---

#### Limitations

`fcplane` can only define the three basic planes of the reference movement coordinate system. To define another plane, use the instruction `FCRefMoveFrame` to reorient the reference movement coordinate system.

---

#### Predefined data

| Constant   | Comment      |
|------------|--------------|
| FCPLANE_XY | the xy plane |
| FCPLANE_XZ | the xz plane |
| FCPLANE_YZ | the yz plane |

---

#### Characteristics

`fcplane` is an alias data type for `num` and consequently inherits its characteristics.

---

#### Related information

| For information about:                  | Also see                                   |
|---|--|
| Setting up circular reference movement. | <a href="#">FCRefCircle on page 103</a>    |
| Setting up spiral reference movement    | <a href="#">FCRefSpiral on page 113</a>    |
| Defining another plane.                 | <a href="#">FCRefMoveFrame on page 109</a> |



### 7.3.10 fcrotmdir

#### Usage

`fcrotmdir` is used by the instruction `FCRefRot` and specifies a rotation around a chosen axis.

#### Example

```
FCRefRot FC_ROT_Z, 5, 10;
```

Sets up a rotation around the work object z direction. When activated the TCP will rotate back and forth around the z-axis with an amplitude of 10 degrees. The maximum speed will be 5 degrees per second.

#### Predefined data

| Constant | Comment                    |
|----------|----------------------------|
| FC_ROT_X | Rotation around the x axis |
| FC_ROT_Y | Rotation around the y axis |
| FC_ROT_Z | Rotation around the z axis |

#### Characteristics

`fcrotmdir` is an alias data type for `num` and consequently inherits its characteristics.

#### Related information

| For information about. | Also see                             |
|------------------------|--------------------------------------|
| FCRefRot               | <a href="#">FCRefRot on page 111</a> |

## 7 RAPID reference information

---

### 7.3.11 fcspeedvector

#### Force Control

### 7.3.11 fcspeedvector

---

#### Usage

`fcspeedvector` is used by the instruction `FCGetProcessdata` to return speed in and around three dimensions (i.e. x, y and z).

---

#### Components

`vx`

**Data type:** `num`

The speed in x direction. The unit is mm/s

`vy`

**Data type:** `num`

The speed in y direction. The unit is mm/s

`vz`

**Data type:** `num`

The speed in z direction. The unit is mm/s.

`wx`

**Data type:** `num`

The speed around the x axis. The unit is deg/s.

`wy`

**Data type:** `num`

The speed around the y axis. The unit is deg/s.

`wz`

**Data type:** `num`

The speed around the z axis. The unit is deg/s.

---

#### Examples

##### Example

```
VAR fcprocessdata mydata;  
mydata := FCGetProcessData();  
mydata.speedinwobjframe.vx;
```

In this examples a variable `mydata` is created and the data type is `fcprocessdata`. `FCGetProcessData` returns the data either from when the function is called or when the user defined condition were set true and saves it in `mydata`. The datatype of `speedinwobjframe` is `fcspeedvector`, so by adding `vx` you get the speed in the x direction. The unit is mm/s.

---

#### Structure

```
< dataobject of fcspeedvector >  
  < vx of num >  
  < vy of num >  
  < vz of num >
```

*Continues on next page*

< wx of num >

< wy of num >

< wz of num >

---

#### Related information

| For information about | See  |
|-----------------------|--|
| fcprocessdata         | <a href="#">fcprocessdata on page 174</a>    |
| FCGetProcesData       | <a href="#">FCGetProcessData on page 155</a> |

## 7 RAPID reference information

---

### 7.3.12 fcspherevol

#### Force Control

### 7.3.12 fcspherevol

---

#### Usage

`fcspherevol` is used by the Force Control instruction `FCCondPos` and `FCSupvPos`. It defines a spherical volume that is used to verify if the TCP is inside or outside the volume.

---

#### Description

`fcspherevol` consists `x`, `y` and `z` values for the center of the sphere, and a radius value. By default, the directions refer to the work object coordinate system, but can be changed with arguments in `FCCondPos` and `FCSupvPos`.

---

#### Components

`xC`

Data type: num

X value for the center of the sphere. The unit is mm.

`yC`

Data type: num

Y value for the center of the sphere. The unit is mm.

`zC`

Data type: num

Z value for the center of the sphere. The unit is mm.

`radius`

Data type: num

The radius of the sphere. The unit is mm.

---

#### Examples

##### Example 1

```
VAR fcspherevol my_sphere:= [-100, 100, -200, 20];  
FCCondPos \Sphere:= my_sphere, 60;
```

In this example, a condition is set up to be true while the TCP is inside a sphere.

---

#### Structure

```
< dataobject of fcspherevol >  
  < xc of num >  
  < yc of num >  
  < zc of num >  
  < radius of num >
```

---

#### Related information

| For information about           | See                                   |
|---------------------------------|---------------------------------------|
| Setting up position condition   | <a href="#">FCCondPos on page 76</a>  |
| Setting up position supervision | <a href="#">FCSupvPos on page 144</a> |

---

### 7.3.13 fcspdchgtunetype

#### Usage

`fcspdchgtunetype` is used by the instructions `FCSpdChgTunSet` and `FCSpdChgTunReset` to select which system parameter should be changed.

The alternatives are:

- Speed ratio min
- No of speed levels

#### Examples

In this example the FC SpeedChange system parameter *Speed ratio min* is set to 0.2.

```
FCSpdChgTunSet 0.2, FC_SPEED_RATIO_MIN;
```

#### Predefined data

| Constant              | Comment            |
|-----------------------|--------------------|
| FC_SPEED_RATIO_MIN    | Speed ratio min    |
| FC_NO_OF_SPEED_LEVELS | No of speed levels |

#### Characteristics

`fcspdchgtunetype` is an alias data type for `num` and consequently inherits its characteristics.

#### Related information

| For information about                                       | See  |
|---|--|
| Setting FC SpeedChange system parameter to a new value      | <a href="#">FCSpdChgTunSet on page 134</a>   |
| Reset FC SpeedChange system parameter to its original value | <a href="#">FCSpdChgTunReset on page 136</a> |

## 7 RAPID reference information

### 7.3.14 fcxyznum

#### Force Control

### 7.3.14 fcxyznum

#### Usage

**fcxyznum** is used by the Force Control instruction **FCRefForce** and **FCRefTorque**. It is used to define amplitude and period that are specified in three directions.

#### Description

**fcxyznum** consist of one value in each direction x, y and z.

#### Components

x

Data type: num  
Value in the x direction.

y

Data type: num  
Value in the y direction.

z

Data type: num  
Value in the z direction.

#### Examples

##### Example 1

```
VAR fcxyznum my_amp:=[10,0,0];  
VAR fcxyznum my_period:=[1,0,0];  
FCRefForce \Amp:=my_amp \Period:=my_period;
```

In this example, an oscillating force reference with amplitude 10 N and period of 1 second in the x direction of the force control coordinate system.

#### Predefined data

List the predefined data of this datatype and their values.

| Constant | Value     | Comment                         |
|----------|-----------|---------------------------------|
| pi       | 3.1415926 |                                 |
| EOF_BIN  | -1        | End of file (binary)            |
| EOF_NUM  | 9.998E36  | End of file (decimal numerical) |

#### Structure

```
< dataobject of fcxyznum >  
  < x of num >  
  < y of num >  
  < z of num >
```

*Continues on next page*

---

### Related information

| For information about | See                                     |
|-----------------------|---|
| Force reference       | <a href="#">FCRefForce on page 105</a>  |
| Torque reference      | <a href="#">FCRefTorque on page 121</a> |

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## 8 System parameters

### 8.1 Type *Robot*

#### 8.1.1 Use FC Master

---

**Parent**

*Use FC Master* belongs to the type *Robot*, in the topic *Motion*.

---

**Cfg name**

use\_fc\_master

---

**Description**

Defines which *FC Master* to use for the robot.

---

**Usage**

*Use FC Master* is given the same value as the parameter *Name* of the *FC Master* to use.

---

**Prerequisite**

An *FC Master* must be defined.

---

**Allowed values**

A string with maximum 32 characters.

---

**Related information**

[The \*FC Master\* type on page 187.](#)

## 8 System parameters

---

### 8.1.2 Use PMC Sensor

#### 8.1.2 Use PMC Sensor

---

**Parent**

*Use PMC Sensor* belongs to the type *Robot*, in the topic *Motion*.

---

**Cfg name**

use\_pmc\_sensor

---

**Description**

Defines which *PMC Sensor* should be used for the robot.

---

**Usage**

*Use PMC Sensor* is given the same value as the parameter *Name* of the *PMC Sensor* to use.

---

**Prerequisites**

A *PMC Sensor* must be defined.

---

**Allowed values**

A string with maximum 32 characters.

---

**Related information**

[The \*PMC Sensor\* type on page 226.](#)

## 8.2 Type *FC Master*

### 8.2.1 The FC Master type

---

#### Overview

This section describes the type *FC Master* which belongs to the topic *Motion*. Each parameter of this type is described in a separate information topic in this section.

---

#### Cfg name

FC\_MASTER

---

#### Type description

The type *FC Master* specifies which *FC Sensor*, *FC Kinematics* and *FC Application* to use for Force Control.

# 8 System parameters

---

## 8.2.2 Name

### 8.2.2 Name

|                |   |
|----------------|---|
| Parent         | <i>Name</i> belongs to the type <i>FC Master</i> , in the topic <i>Motion</i> .                           |
| Cfg name       | name  |
| Description    | The name of the <i>FC Master</i> .  |
| Usage          | Used to reference the <i>FC Master</i> from the parameter <i>Use FC Master</i> in the type <i>Robot</i> . |
| Allowed values | A string with maximum 32 characters   |

### 8.2.3 Use FC Sensor

---

**Parent**

*Use FC Sensor* belongs to the type *FC Master*, in the topic *Motion*.

---

**Cfg name**

`use_fc_sensor`

---

**Description**

Defines which *FC Sensor* to use.

---

**Usage**

*Use FC Sensor* is given the same value as the parameter *Name* of the *FC Sensor* to use.

---

**Prerequisites**

An FC sensor must be defined.

---

**Allowed values**

A string with maximum 32 characters.

---

**Related information**

[\*The FC Sensor type on page 193.\*](#)

## 8 System parameters

---

### 8.2.4 Use FC Kinematics

#### 8.2.4 Use FC Kinematics

---

**Parent**

*Use FC Kinematics* belongs to the type *FC Master*, in the topic *Motion*.

---

**Cfg name**

`use_fc_kinematics`

---

**Description**

Defines which *FC Kinematics* to use.

---

**Usage**

*Use FC Kinematics* is given the same value as the parameter *Name* of the *FC Kinematics* to use.

---

**Allowed values**

A string with maximum 32 characters.

---

**Related information**

[The \*FC Kinematics\* type on page 202](#)

### 8.2.5 Use FC Application

---

**Parent**

*Use FC Application* belongs to the type *FC Master*, in the topic *Motion*.

---

**Cfg name**

use\_fc\_application

---

**Description**

Defines which *FC Application* to use.

---

**Usage**

*Use FC Application* is given the same value as the parameter *Name* in the *FC Application* to use.

---

**Allowed values**

A string with maximum 32 characters.

---

**Related information**

[\*The FC Application type on page 208\*](#)

## 8 System parameters

---

### 8.2.6 Use FC Speed Change

### 8.2.6 Use FC Speed Change

---

**Parent**

*Use FC Speed Change belongs to the type FC Master, in the topic Motion.*

---

**Cfg name**

`use_fc_speed_change`

---

**Description**

Defines which *FC Speed Change* to use.

---

**Usage**

*Use FC Speed Change* is given the same value as the parameter *Name* in the *FC Speed Change* to use.

---

**Allowed values**

A string with maximum 32 characters.

---

**Related information**

[\*The FC Application type on page 208.\*](#)



## 8.3 Type *FC Sensor*

### 8.3.1 The FC Sensor type

#### Overview

This section describes the type *FC Sensor*, which belongs to the topic *Motion*. Each parameter of this type is described in a separate information topic in this section.

#### Cfg name

FC\_SENSOR

#### Type description

The type *FC Sensor* is used to define the Force Control sensor. The sensor can be either fixed in the room or mounted on a robot, as specified by the parameter *Force Sensor Mount Unit Name*. It can be a full-fledged sensor measuring both force and torque (6 DOF) or a sensor measuring only force, which is specified by the parameter *Force Sensor Type*.

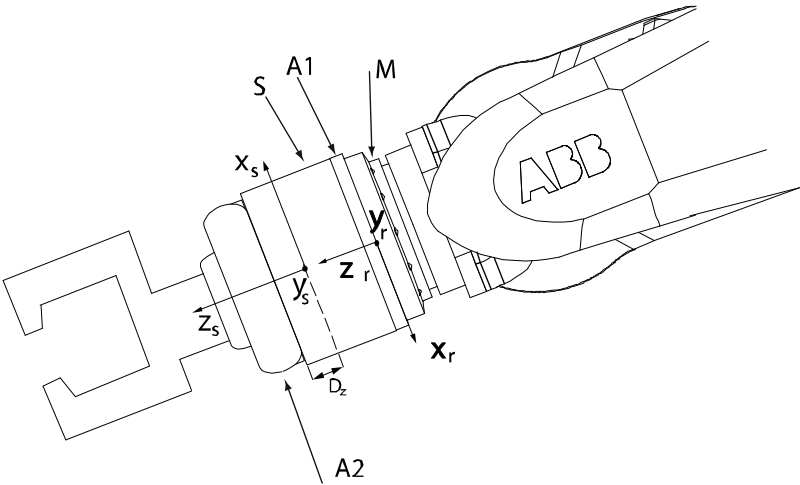
The sensor has a built in coordinate system measuring forces in x, y and z directions. In order to translate the measured values to other coordinate systems, the sensor coordinate system must be defined. *Force Sensor Frame x - z* defines the position of the sensor coordinate system relative the robot's tool0 coordinate system (robot mounted sensor) or the world coordinate system (room fixed sensor). *Force Sensor Frame q1 - q4* defines the orientation of the sensor coordinate system, relative the robot's tool0 coordinate system (robot mounted sensor) or the world coordinate system (room fixed sensor).

*Continues on next page*

8 System parameters

8.3.1 The FC Sensor type  
Continued

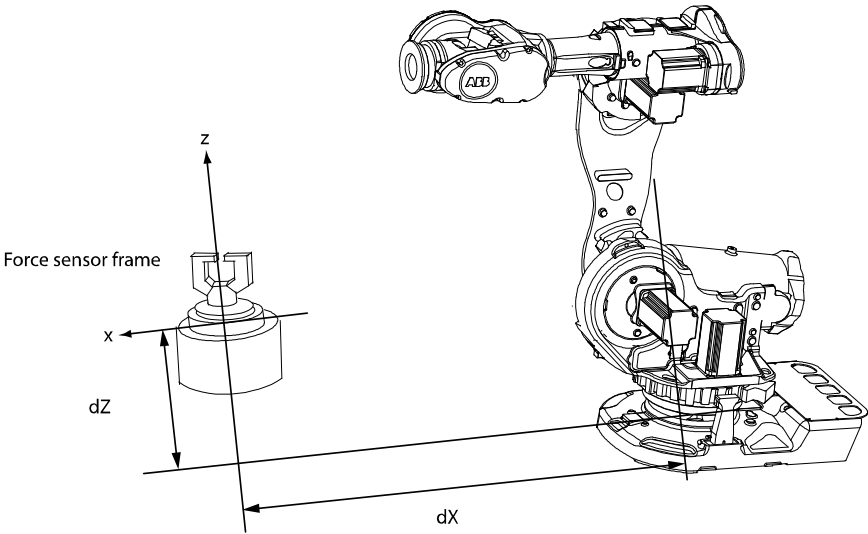
Illustration - robot mounted sensor



xx0500001554

|    |  |
|----|--|
| x  | Coordinate system for the robot's tool0.   |
| x  | Coordinate system for the sensor.  |
| M  | Robot tool flange.   |
| A1 | Adapter plate on the inside (not always used).   |
| A2 | Adapter plate on the outside (not always used).  |
| D  | "Basic transform Dz" is the distance between the sensor front and the coordinate system of the sensor. |
| S  | Force sensor.  |

Illustration - room fixed sensor



xx0600003077

Continues on next page

Force Sensor Frame = (dX,0,dZ), (1, 0, 0, 0)

## 8 System parameters

---

### 8.3.2 Name

#### 8.3.2 Name

---

**Parent**

*Name* belongs to the type *FC Sensor*, in the topic *Motion*.

---

**Cfg name**

name

---

**Description**

Defines the name of the *FC Sensor*.

---

**Usage**

*Name* is used to reference the *FC Sensor* from the parameter *Use FC Sensor* in the type *FC Master*.

---

**Allowed values**

A string with maximum 32 characters.

**Note**

The name of the FC sensor must be the same as for the PMC sensor (for example, *fc\_sensor1*), see also [Name on page 227](#).

#### 8.3.3 Force Sensor Mount Unit Name

---

**Parent**

*Force Sensor Mount Unit Name* belongs to the type *FC Sensor*, in the topic *Motion*.

---

**Cfg name**

force\_sensor\_mount\_unit\_name

---

**Description**

Defines on which mechanical unit the force sensor is mounted.

---

**Usage**

The value should be ROB\_1, ROB\_2, ROB\_3 or ROB\_4 when the sensor is mounted on a robot. When the sensor is room fixed the value should be left empty.

---

**Allowed values**

ROB\_1, ROB\_2, ROB\_3, ROB\_4 or empty.

## 8 System parameters

---

### 8.3.4 Force Sensor Type

#### 8.3.4 Force Sensor Type

|                |  |
|----------------|--|
| Parent         | <i>Force Sensor Type</i> belongs to the type <i>FC Sensor</i> , in the topic <i>Motion</i> .   |
| Cfg name       | <code>force_sensor_type</code>   |
| Description    | Defines the type of sensor.  |
| Usage          | If it is a 6 degree of freedom sensor measuring both force and torque the value should be <i>Force and Torque</i> . If it is a pure force sensor the value should be <i>Only Force</i> . |
| Allowed values | <i>Force and Torque</i><br><i>Only Force</i>   |

### 8.3.5 Force Sensor Frame x - z

---

**Parent**

*Force Sensor Frame x - z* belongs to the type *FC Sensor*, in the topic *Motion*.

---

**Cfg name**

force\_sensor\_frame\_pos\_x

force\_sensor\_frame\_pos\_y

force\_sensor\_frame\_pos\_z

---

**Description**

Defines the position of the force sensor frame in relation to tool0 (robot mounted sensor) or the world frame (room fixed sensor).

---

**Usage**

If the sensor is mounted on a robot, the sensor frame is specified with regard to the robot's tool0 coordinate system. *Force Sensor Frame x - z* defines the distance from the center of the robot's mounting plate to the center of the sensor's coordinate system.

Normally *Force Sensor Frame x* and *Force Sensor Frame y* are set to zero. *Force Sensor Frame z* specifies the thickness of the sensor including the adaptor between robot and sensor (if any).

Consult the sensor supplier for detailed data if the measurement origin is not at the surface of the sensor.

If the sensor is fixed in the room the sensor frame is defined in relation to the world frame (robot base in normal cases). Assuming that the sensor z direction is facing the robot 2 meters away from the robot base in the x-direction at 1.5 m height, *Force Sensor Frame x* should be set to 2, *Force Sensor Frame y* to 0 and *Force Sensor Frame z* to 1.5.

---

**Allowed values**

A value between -10 and 10 meters.

## 8 System parameters

---

### 8.3.6 Force Sensor Frame q1 - q4

#### 8.3.6 Force Sensor Frame q1 - q4

---

**Parent**

*Force Sensor Frame q1 - q4* belong to the type *FC Sensor*, in the topic *Motion*.

---

**Cfg name**

force\_sensor\_frame\_orient\_u0  
force\_sensor\_frame\_orient\_u1  
force\_sensor\_frame\_orient\_u2  
force\_sensor\_frame\_orient\_u3

---

**Description**

Defines the orientation of the force sensor coordinate system with respect to the robot's tool0 coordinate system (robot mounted sensor) or the world coordinate system (room fixed sensor). The orientation is specified as four quaternion values.

---

**Allowed values**

A value between -1 and 1.

---

**Related information**

For more information on how to calculate quaternions, see the section about the data type `orient` in *Technical reference manual - RAPID Instructions, Functions and Data types*.



#### 8.3.7 Noise level

---

**Parent**

*Noise level* belongs to the type *FC Sensor*, in the topic *Motion*.

---

**Cfg name**

force\_sensor\_noise

---

**Description**

Defines the highest noise level at which a force sensor calibration should be allowed. Used to check that the robot is standing still at a force sensor calibration for example.

---

**Usage**

If the process is noisy and FCCalib or FC LoadId fails the value can be increased.

---

**Allowed values**

A value between 1 and 1000.

## 8 System parameters

---

### 8.4.1 The FC Kinematics type

## 8.4 Type *FC Kinematics*

### 8.4.1 The FC Kinematics type

---

#### Overview

This section describes the type *FC Kinematics* which belongs to the topic *Motion*. Each parameter of this type is described in a separate information topic in this section.

---

#### Cfg name

FC\_KINEMATICS

---

#### Type overview

The type *FC Kinematics* is used to define Force Control damping. Damping is a definition of how large contact force is required for the robot to move at a certain speed.

### 8.4.2 Name

---

**Parent**

*Name* belongs to the type *FC Kinematics*, in the topic *Motion*.

---

**Cfg name**

name

---

**Description**

*Name* defines the name of the *FC Kinematics*.

---

**Usage**

*Name* is used to reference the *FC Kinematics* from the parameter *Use FC Kinematics* in the type *FC Master*.

---

**Allowed values**

A string with maximum 32 characters.

## 8 System parameters

### 8.4.3 Damping in Force x Direction - Damping in Force z Direction

### 8.4.3 Damping in Force x Direction - Damping in Force z Direction

---

#### Parent

*Damping in Force x Direction - Damping in Force z Direction* belong to the type *FC Kinematics*, in the topic *Motion*.

---

#### Cfg name

damping\_fx  
damping\_fy  
damping\_fz

---

#### Description

*Damping in Force ... Direction* defines the damping of forces in kinematics in the x, y, or z direction.

---

#### Usage

Defines how many Newtons are required to make the robot move 1 m/s. The higher the value, the less responsive the robot gets.

The damping can be different in different directions. That is why there is one parameter for x, one for y and one for z.

The damping can be tuned (as a percentage of the system parameter values) by the RAPID instruction `FCAct`.



#### WARNING

A too low damping value can make the robot unstable.

Make sure the damping is not too low, even if the tuning level in the `FCAct` instruction is 50%. If the robot drifts away by itself, or if it vibrates, increase the damping value.

---

#### Allowed values

A value between min and 10,000,000 Ns/m.



#### Note

For each robot type there exists minimum allowed values of the damping. It is not possible to set the damping lower than these values.

## 8.4.4 Damping in Torque x Direction - Damping in Torque z Direction

## Parent

*Damping in Torque x Direction - Damping in Torque z Direction* belong to the type *FC Kinematics*, in the topic *Motion*.

## Cfg name

damping\_tx  
damping\_ty  
damping\_tz

## Description

*Damping in Torque ... Direction* defines the damping of torque in kinematics in the x, y, or z direction.

## Usage

Defines how many Nm are required to make the robot move 1 rad/s. The higher the value, the less responsive the robot gets.

The damping can be different in different directions. That is why there is one parameter for x, one for y and one for z.

The damping can be tuned (as a percentage of the system parameter values) by the RAPID instruction `FCAct`.

**WARNING**

Too low a damping value can make the robot unstable.

Make sure the damping is not too low, even if the tuning level in the `FCAct` instruction is 50%. If the robot slowly rotates by itself, or if it vibrates, increase the damping value.

## Allowed values

A value between minimum and 10,000,000 Nms/rad.

**Note**

For each robot type there is a minimum allowed value for damping. It is not possible to set the damping value lower than the minimum value.

## 8 System parameters

---

### 8.4.5 Bandwidth of force frame filter

#### 8.4.5 Bandwidth of force frame filter

---

**Parent**

*Bandwidth of force frame filter* belongs to the type *FC Kinematics*, in the topic *Motion*.

---

**Cfg name**

force\_frame\_filter\_bandwidth

---

**Description**

*Bandwidth of force frame filter* defines the bandwidth in Hz of a low pass filter used to filter measured forces, used for example in force conditions.

---

**Usage**

In applications where the measured force/torque are too noisy this parameter can be used to filter the signals in order to eliminate false triggering and errors.

---

**Allowed values**

A value between 0 and 125. A value larger than 100 will switch the filter off.

### 8.4.6 Bandwidth of force loop filter

---

**Parent**

*Bandwidth of force loop filter* belongs to the type *FC Kinematics*, in the topic *Motion*.

---

**Cfg name**

force\_loop\_filter\_bandwidth

---

**Description**

*Bandwidth of force loop filter* defines the bandwidth in Hz of a low pass filter used in the force control loop.

---

**Usage**

If the robot reacts too slowly for changes in contact force an increase of this parameter will make the robot more adaptable. Too high value will cause instability.

---

**Allowed values**

A value between 0.1 and 250. Default value is 3 Hz. A higher value will make the robot move compliant but may cause instability.

## 8 System parameters

---

### 8.5.1 The FC Application type

## 8.5 Type *FC Application*

### 8.5.1 The FC Application type

---

#### Overview

This section describes the type *FC Application* which belongs to the topic *Motion*. Each parameter of this type is described in a separate information topic in this section.

---

#### Cfg name

FC\_APPLICATION

---

#### Type description

The type *FC Application* defines a number of limits for the reference values used in Force Control.



### 8.5.2 Name

---

**Parent**

*Name* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

name

---

**Description**

*Name* defines the name of the *FC Application*.

---

**Usage**

*Name* is used to reference the *FC Application* from the parameter *Use FC Application* in the type *FC Master*.

---

**Allowed values**

A string with maximum 32 characters.

## 8 System parameters

---

### 8.5.3 Max Ref Force

#### 8.5.3 Max Ref Force

---

**Parent**

*Max Ref Force* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_force

---

**Description**

*Max Ref Force* defines the maximum allowed reference force.

---

**Usage**

The reference force, specified by the instruction `FCRefForce`, cannot be larger than *Max Ref Force*. If a larger value is used in `FCRefForce` the execution will continue with a reference force equal to *Max Ref Force* and a warning is shown in the event log.

---

**Allowed values**

A value between 0 and max.

**Note**

There is a maximum allowed reference that depends on the robots default load. This maximum force is equal to the robots type default load, times the gravity constant.

For a 60kg default load the highest allowed force is  $60 \cdot 9,81 = 589\text{N}$ .

If a higher value is set in *Max Ref Force* than the maximum allowed the higher value will be ignored.

### 8.5.4 Max Ref Force Change

---

**Parent**

*Max Ref Force Change* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_force\_change

---

**Description**

*Max Ref Force Change* defines the maximum allowed change in the reference force.

---

**Usage**

When the instruction `FCRefStart` is executed, the force is ramped up to the desired reference force specified in `FCRefForce`. This ramping is determined by *Max Ref Force Change*.

If a very large oscillating reference force is specified in `FCRefForce`, the oscillations are limited so that the change in force never exceeds *Max Ref Force Change*.

---

**Allowed values**

A value between 0 and 10,000 N/s.

## 8 System parameters

---

### 8.5.5 Max Ref Torque

### 8.5.5 Max Ref Torque

---

**Parent**

*Max Ref Torque* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_torque

---

**Description**

*Max Ref Torque* defines the maximum allowed reference torque.

---

**Usage**

The reference torque, specified by the instruction `FCRefTorque`, cannot be larger than *Max Ref Torque*. If a larger value is used in `FCRefTorque` the execution will continue with a reference torque equal to *Max Ref Torque* and a warning is shown in the event log.

---

**Allowed values**

A value between 0 and max Nm.

**Note**

There is a maximum allowed reference that depends on the robots default load.

### 8.5.6 Max Ref Torque Change

---

**Parent**

*Max Ref Torque Change* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_torque\_change

---

**Description**

*Max Ref Torque Change* defines the maximum allowed reference torque change.

---

**Usage**

When the instruction `FCRefStart` is executed, the torque is ramped up to the desired reference torque specified in `FCRefTorque`. This ramping is determined by *Max Ref Torque Change*.

If a very large oscillating reference torque is specified in `FCRefTorque`, the oscillations are limited so that the change in torque never exceeds *Max Ref Torque Change*.

---

**Allowed values**

A value between 0 and 100,000 Nm/s.

## 8 System parameters

---

### 8.5.7 Max Ref TCP Speed

#### 8.5.7 Max Ref TCP Speed

---

**Parent**

*Max Ref TCP Speed* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_lin\_speed

---

**Description**

*Max Ref TCP Speed* defines the maximum allowed linear speed for the reference movement of Force Control.

---

**Usage**

The reference movement, specified by the instructions `FCRefSpiral`, `FCRefCircle` or `FCRefLine`, cannot generate a speed larger than *Max Ref TCP Speed*. If the specified reference movement would result in a larger TCP speed, the speed will be limited to *Max Ref TCP Speed*.

---

**Allowed values**

A value between 0 and 10 m/s.

### 8.5.8 Max Ref Rot Speed

---

**Parent**

*Max Ref Rot Speed* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_rot\_speed

---

**Description**

*Max Ref Rot Speed* defines the maximum allowed rotational speed for the reference movement of Force Control.

---

**Usage**

The reference movement cannot generate a rotational speed larger than *Max Ref Rot Speed*. If the specified reference movement would result in a larger rotational speed, the speed will be limited to *Max Ref Rot Speed*.

---

**Allowed values**

A value between 0 and 10 rad/s.

## 8 System parameters

---

### 8.5.9 Max Ref TCP Acc

#### 8.5.9 Max Ref TCP Acc

---

##### Parent

*Max Ref TCP Acc* belongs to the type *FC Application*, in the topic *Motion*.

---

##### Cfg name

max\_lin\_acc

---

##### Description

*Max Ref TCP Acc* defines the maximum allowed linear acceleration for the reference movement of Force Control.

---

##### Usage

When the instruction `FCRefStart` is executed, the TCP speed is ramped up to the desired reference movement specified in `FCRefSpiral`, `FCRefCircle` or `FCRefLine`. This ramping is determined by *Max Ref TCP Acc*.

---

##### Allowed values

A value between 0 and 100 m/s<sup>2</sup>.



##### Note

If the value is set too high the reference movement will result in a speed supervision error.



### 8.5.10 Max Ref Rot Acc

---

**Parent**

*Max Ref Rot Acc* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_rot\_acc

---

**Description**

*Max Ref Rot Acc* defines the maximum allowed rotational acceleration for the reference movement of Force Control.

---

**Usage**

When the instruction `FCRefStart` is executed, the rotational speed is ramped up to the desired reference movement. This ramping is determined by *Max Ref Rot Acc*.

---

**Allowed values**

A value between 0 and 100 rad/s<sup>2</sup>.

**Note**

If the value is set to high the reference movement will lead to a speed supervision error.

## 8 System parameters

---

### 8.5.11 Speed superv override

#### 8.5.11 Speed superv override

---

**Parent**

*Speed superv override* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

`spd_superv_override_factor`

---

**Description**

*Speed superv override* is a parameter used to modify the default speed supervision. This parameter modifies the speed superv in force control mode by a factor from 1 to 20.

---

**Usage**

When the robot is in force control mode the speed supervision might trig even during normal usage. If this happens it can be adjusted by defining a higher value of the parameter `speed superv override`

---

**Allowed values**

A value between 1 and 20.

#### 8.5.12 Largest measured contact force

---

**Parent**

Largest measured contact force belongs to the type FC Application, in the topic Motion.

---

**Cfg name**

axc\_force\_max

---

**Description**

If measured contact force is larger than this value it is set to this value. The unit is N. The default value is 100 000 meaning this functionality is not active.

---

**Usage**

The parameter Largest measured contact force defines a truncation of measured force. If a measured force is larger than this value it is still assumed to be equal to this value. This can be useful in certain lead-tech applians but should otherwise not be used.

---

**Allowed values**

A value between 0 and 100 000.

## 8 System parameters

---

### 8.5.13 Lowest measured contact force

#### 8.5.13 Lowest measured contact force

---

**Parent**

*Lowest measured contact force* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

axc\_force\_min

---

**Description**

If measured contact force is less than this value, it is set to zero. The unit is N.

---

**Usage**

*Lowest measured contact force* defines a threshold for the force, which needs to be exceeded in order to effect the robot position/speed. Too low a value might cause the robot to drift.

---

**Allowed values**

A value between 0 and 1000.

#### 8.5.14 Largest measured contact torque

---

**Parent**

*Largest measured contact torque* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

axc\_torque\_max

---

**Description**

If a measured contact torque is larger than this value, it is set to this value. The unit is Nm. The default value is 100 000, meaning this function is inactive.

---

**Usage**

The parameter *Largest measured contact torque* defines a function of measured torque, if measured torque is larger than this value it is still assumed to be equal to this value. This can be useful in certain lead-tech applications but should otherwise not be used.

---

**Allowed values**

A value between 0 and 100 000.

## 8 System parameters

---

### 8.5.15 Lowest measured contact torque

#### 8.5.15 Lowest measured contact torque

---

**Parent**

*Lowest measured contact torque* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

axc\_torque\_min

---

**Description**

If a measured contact torque is less than this value, it is set to zero. The unit is Nm.

---

**Usage**

*Lowest measured contact torque* defines a threshold for the torque, which needs to be exceeded in order to effect the robot position/speed. Too low a value might cause the robot to drift.

---

**Allowed values**

A value between 0 and 1000.

#### 8.5.16 Keep contact force at stop

---

**Parent**

*Keep contact force at stop* belongs to the type FC Application, in the topic *Motion*.

---

**Cfg name**

keep\_contact\_when\_deactivating\_fc

---

**Description**

Defines whether the robot should be allowed to remain in contact when force control execution is stopped.

---

**Usage**

If set to TRUE, the robot will keep the contact when the force control execution is stopped because of an emergency stop.

The currently active references will remain active during the stop, and when the force control execution is restarted. Additionally, it will be allowed to call FCDeact without a preceding call to FCRefStop, so that the robot remains in contact when switching to position control. After the switch, the active references are stopped.

---

**Allowed values**

TRUE/FALSE

## 8 System parameters

---

### 8.5.17 Max Press TCP Speed

#### 8.5.17 Max Press TCP Speed

---

**Parent**

*Max Press TCP Speed* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

`max_lin_speed_press`

---

**Description**

Defines the maximum allowed TCP speed in FC Press instructions.

---

**Usage**

This parameter defines the highest TCP speed that can be used in FC Press instructions.

---

**Allowed values**

A value between 0 and 10 (m/s).



#### 8.5.18 Max Press Rot Speed

---

**Parent**

*Max Press Rot Speed* belongs to the type *FC Application*, in the topic *Motion*.

---

**Cfg name**

max\_rot\_speed\_press

---

**Description**

Defines the maximum allowed reorient speed in FC Press instructions.

---

**Usage**

This parameter defines the highest reorient speed that can be used in FC Press instructions.

---

**Allowed values**

A value between 0.01 and 1 (rad/s).

## 8 System parameters

---

### 8.6.1 The PMC Sensor type

## 8.6 Type *PMC Sensor*

### 8.6.1 The PMC Sensor type

---

#### Overview

This section describes the type *PMC Sensor*, which belongs to the topic *Motion*. Each parameter of the type is described in a separate information topic in this section.

---

#### Cfg name

PMC\_SENSOR

---

#### Type description

The type *PMC Sensor* describes a sensor connected to the robot controller via a voltage measurement box.

## 8.6.2 Name

---

**Parent**

*Name* belongs to the type *PMC Sensor*, in the topic *Motion*.

---

**Cfg name**

name

---

**Description**

Defines the name of the *PMC Sensor*.

---

**Usage**

Used to reference the *PMC Sensor* from the parameter *Use PMC Sensor* in the type *Robot*.

---

**Allowed values**

A string with maximum 32 characters.

**Note**

The name of the PMC sensor must be the same as for the FC sensor (e.g. `fc_sensor1`), see also [Name on page 196](#).

## 8 System parameters

---

### 8.6.3 Use PMC Sensor Setup

#### 8.6.3 Use PMC Sensor Setup

---

**Parent**

*Use PMC Sensor Setup* belongs to the type *PMC Sensor*, in the topic *Motion*.

---

**Cfg name**

`use_pmc_sensor_setup`

---

**Description**

Defines which *PMC Sensor Setup* to use.

---

**Usage**

*Use PMC Sensor Setup* is given the same value as the parameter *Name* of the *PMC Sensor Setup* to use.

---

**Prerequisites**

A *PMC Sensor Setup* must be defined.

---

**Allowed values**

A string with maximum 32 characters defining a PMC sensor setup.

---

**Related information**

[\*The PMC Sensor Setup type on page 229\*](#)

## 8.7 Type PMC Sensor Setup

### 8.7.1 The PMC Sensor Setup type

#### Overview

This section describes the type *PMC Sensor Setup*, which belongs to the topic *Motion*. Each parameter of the type is described in a separate information topic in this section.

#### Cfg name

PMC\_SENSOR\_SETUP

#### Type description

The type *PMC Sensor Setup* is used to specify sensor calibration data.  
The sensor calibration data is delivered from the sensor supplier in a file.

#### Illustration

This is an example of a sensor calibration file from ATI, showing where to find different values. Set these values for the respective parameter.

```
<?xml version="1.0" encoding="utf-8"?>
<!-- NOTE: To ensure compatibility between your software and future F/T calibrations -->
<!-- (such as recalibrations of your transducer or future purchases), -->
<!-- ATI does not support parsing of this file. The only supported methods for -->
<!-- loading calibration data are the ATIDAQFT ActiveX component and the -->
<!-- ATI DAQ F/T C Library. -->

fx1 --> fx2
fx6 fx max fx scale

<FTSensor Serial="FT5381" BodyStyle="Omega160" Family="DAQ" NumGages="6" CalFileVersion="1.0">
  <Calibration PartNumber="SI-2500-400" CalDate="10/3/2003" ForceUnits="N" TorqueUnits="N-m" DistUnits="m" OutputMode="Ground
  Referenced Differential" OutputRange="20" HWTempComp="True" GainMultiplier="1" OutputBipolar="True">
    <Axis Name="Fx" values="0.27293 0.02898 -0.38518 -36.65347 3.51659 30.75918" max="2500" scale="0.117956981472102"/>
    <Axis Name="Fy" values="2.57404 38.10677 -1.10337 -20.79499 -1.49793 -17.92840" max="2500" scale="0.117956981472102"/>
    <Axis Name="Fz" values="17.60863 -0.66609 18.55354 -0.14025 18.26839 -0.31532" max="6250" scale="0.0432583259084836"/>
    <Axis Name="Tx" values="-0.13557 0.26087 -32.80647 0.20501 32.57637 -0.63268" max="400" scale="1.20269312636217"/>
    <Axis Name="Ty" values="35.81364 -1.41660 -19.29225 0.45183 -19.19687 0.13446" max="400" scale="1.20269312636217"/>
    <Axis Name="Tz" values="1.11569 18.01493 -1.02168 -19.50561 -1.26141 -16.71202" max="400" scale="1.09881087335522"/>
  </Calibration>
</FTSensor>
```

en0500001553



#### Tip

If the sensor manufacturer is ABB or ATI Automation it is possible to load the sensor parameters from the supplied CD instead of manually typing them in RobotStudio. For information on how to load the sensor parameters, see [Basic setup on page 18](#).



#### CAUTION

Remember to always double-check your sensor calibration before running anything the first time.

# 8 System parameters

---

## 8.7.2 Name

### 8.7.2 Name

|                |  |
|----------------|--|
| Parent         | <i>Name belongs to the type <b>PMC Sensor Setup</b>, in the topic <b>Motion</b>.</i>   |
| Cfg name       | name   |
| Description    | Defines the name of the <i>PMC Sensor Setup</i> .  |
| Usage          | Used to reference the <i>PMC Sensor Setup</i> from the parameter <i>Use PMC Sensor Setup</i> in the type <i>PMC Sensor</i> . |
| Allowed values | A string with maximum 32 characters.   |

#### 8.7.3 Use Board Type

---

**Parent**

*Use Board Type* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

board\_type

---

**Description**

This will show the board type "DSQC686" if that board is used.  
If an acromag board is used this can be ignored.

---

**Usage**

This will be filled in and shown by the controller if the board type "DSQC686" is used.

---

**Allowed values**

"DSQC686" or blank.

## 8 System parameters

---

### 8.7.4 Measurement board number

#### 8.7.4 Measurement board number

---

**Parent**

*Measurement board number* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

board

---

**Description**

This will be the board number if the board DSQC686 is used.  
If an acromag board is used this can be ignored.

---

**Usage**

This will be filled in and shown by the controller if the board type DSQC686 is used.  
If any additional axis is used, set *Measurement board number* to 2.

---

**Allowed values**

Numeric value.  
Default value is 1.

---

**Additional information**

The voltage measurement board will allocate node 4-7. An additional axes can only use node 1-3. When using an additional axis, the board position for the voltage measurement box needs to be set to 2.



### 8.7.5 Type of sensor interface

---

**Parent**

*Type of sensor interface* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

sensor\_type

---

**Description**

Describes the used sensor interface.

---

**Usage**

In the standard Force Control case this should not be changed. If the sensor interface is used in another way, this can be set to match the setup. Default setting is 1 =ATI\_STANDARD.

---

**Allowed values**

| Value | Name         | Description   |
|-------|--------------|---|
| 1     | ATI_STANDARD | Normal setup  |
| 2     | ONLY_ACROMAG | Use when acromag board is used for voltage measurements |
| 4     | ONLY_DSQC686 | Use when DSQC686 board is used for voltage measurements |

---

**Additional information**

To be able to run a robot system with Force Control option without a measurement board connected, *Type of sensor interface* can be set to 2 ONLY\_ACROMAG. No Force Control instructions can be run in this case.

## 8 System parameters

---

### 8.7.6 Disable check of saturation

#### 8.7.6 Disable check of saturation

---

**Parent**

*Disable check of saturation* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

saturation\_check\_disabled

---

**Description**

By default there is a saturation check of voltage input from force/torque sensor. This parameter can disable or enable this check.

---

**Usage**

If the force sensor in use does not work correctly with the saturation check, set the value to TRUE to disable the supervision.

---

**Allowed values**

TRUE/FALSE.

#### 8.7.7 Time in saturation before warning

---

**Parent**

*Time in saturation before warning* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

max\_time\_in\_sat\_warn

---

**Description**

Defines the time in seconds that output levels from force/torque sensor should be in saturation before warning appears.

---

**Usage**

Set the desired time sensor gauges that should saturate before warning appears.

---

**Allowed values**

A numeric value.

Default: 0.5 s

## 8 System parameters

---

### 8.7.8 Time in saturation before error

#### 8.7.8 Time in saturation before error

---

**Parent**

*Time in saturation before error* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

max\_time\_in\_sat\_err

---

**Description**

Defines the time in seconds that output levels from force/torque sensor should be in saturation before error message appears.

---

**Usage**

Set the desired time sensor gauges that should saturate before error message appears.

---

**Allowed values**

A numeric value.  
Default: 1 s

### 8.7.9 Max voltage for external AD card

---

**Parent**

*Max voltage for external AD card* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg Name**

max\_voltage

---

**Description**

The value should be set to the voltage working range of the AD board (in the voltage measurement box). The range is assumed to be + - this value.

---

**Usage**

If the AD board hardware is configured for + - 10V as working range, set the value to 10.

---

**Allowed values**

0-100

## 8 System parameters

---

### 8.7.10 Max voltage output from sensor

#### 8.7.10 Max voltage output from sensor

---

**Parent**

*Max voltage output from sensor* belongs to the type *PMC Sensor setup*, in the topic *Motion*.

---

**Cfg name**

max\_sensor\_output\_voltage

---

**Description**

The voltage output range of the sensor. This is normally both positive and negative.

---

**Usage**

This value is normally set to 5V and this corresponds to a voltage range from -5V to +5V.

---

**Allowed values**

Numeric value between 0 and 10.

### 8.7.11 Sat. level, percentage of sensor volt

---

**Parent**

*Sat. level, percentage of sensor volt* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

saturation\_check\_percentage

---

**Description**

This is the percentage of the maximum input voltage for the AD board that will be considered as saturated.

---

**Usage**

Set the value to the input voltage that is considered to be saturated.  
The value is a percentage of the *Max voltage output from sensor*. See [Max voltage output from sensor on page 238](#).

---

**Allowed values**

Numeric value 0-100.  
Default value is 99.

---

**Example**

*Max voltage output from sensor* is set to 5 V.  
*Sat. level, percentage of sensor volt* is set to 99%.The controller will report saturation when the voltage measured is 4.95 V.

# 8 System parameters

---

## 8.7.12 Sensor serial number

### 8.7.12 Sensor serial number

|                |   |
|----------------|---|
| Parent         | <i>Sensor serial number</i> belongs to the type <i>PMC Sensor Setup</i> , in the topic <i>Motion</i> .                                    |
| Cfg name       | serial_number   |
| Description    | Defines the serial number of the sensor.  |
| Usage          | <i>Sensor serial number</i> is used to compare the serial number on the physical sensor with the serial number in the configuration file. |
| Allowed values | A string with maximum 32 characters.  |



#### 8.7.13 Disable Force Sensor Cable Check

---

**Parent**

*Disable Force Sensor Cable Check* belongs to the type *PMC Sensor Setup* in the topic *Motion*.

---

**Cfg name**

safety\_channel\_disabled

---

**Description**

Some force sensors have a separate safety channel, which delivers a voltage above a certain level when the sensor is working. Safety channel is always connected to input U6 on the DAQ board.

---

**Usage**

If the force sensor in use does not have the safety channel feature, set this value to TRUE and disable the supervision.

---

**Allowed values**

TRUE/FALSE

## 8 System parameters

---

### 8.7.14 Safety Channel Voltage

#### 8.7.14 Safety Channel Voltage

|                |  |
|----------------|--|
| Parent         | <i>Safety Channel Voltage</i> belongs to the type <i>PMC Sensor Setup</i> in the topic <i>Motion</i> .                                   |
| Cfg name       | safety_channel_level   |
| Description    | Defines the minimum allowed voltage from the safety channel. The absolute value of the safety channel input is compared with this value. |
| Usage          | If a separate safety channel is used with the force sensor, set this value to the minimum allowed voltage before the system is stopped.  |
| Allowed values | 0-100  |

## 8.7.15 fx 1 - fx 6

## Parent

*fx 1 - fx 6* belong to the type *PMC Sensor Setup*, in the topic *Motion*.

## Cfg name

fx\_value1  
fx\_value2  
fx\_value3  
fx\_value4  
fx\_value5  
fx\_value6

## Description

Defines how the six input voltages are scaled to create a measured force in the x direction.

## Usage

The force sensor sends six input voltages to the voltage measurement box ( $U_0$ ,  $U_1$ , ...  $U_5$ ). Some of these are very dependent on the force in the x direction, while others are more dependent on forces in other directions. The contribution from the first input voltage to the force measurement in the x direction is specified in *fx 1*. The contribution from the second signal is specified in *fx 2*, and so on. These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

## Example

This is how the measured force in the x direction is calculated:

$$F_x = \frac{fx1}{fxScale} U_0 + \frac{fx2}{fxScale} U_1 + \frac{fx3}{fxScale} U_2 + \frac{fx4}{fxScale} U_3 + \frac{fx5}{fxScale} U_4 + \frac{fx6}{fxScale} U_5$$

xx0600003087

## Allowed values

A numeric value.

## 8 System parameters

---

### 8.7.16 fy 1 - fy 6

#### 8.7.16 fy 1 - fy 6

---

##### Parent

*fy 1 - fy 6* belong to the type *PMC Sensor Setup*, in the topic *Motion*.

---

##### Cfg name

fy\_value1  
fy\_value2  
fy\_value3  
fy\_value4  
fy\_value5  
fy\_value6

---

##### Description

Defines how the six input voltages are scaled to create a measured force in the y direction.

---

##### Usage

The force sensor sends six input voltages to the voltage measurement box ( $U_0$ ,  $U_1$ , ...  $U_5$ ). Some of these are very dependent on the force in the y direction, while others are more dependent on forces in other directions. The contribution from the first input voltage to the force measurement in the y direction is specified in *fy 1*. The contribution from the second signal is specified in *fy 2*, and so on. These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

---

##### Example

This is how the measured force in the y direction is calculated:

$$F_y = \frac{fy1}{fyScale} U_0 + \frac{fy2}{fyScale} U_1 + \frac{fy3}{fyScale} U_2 + \frac{fy4}{fyScale} U_3 + \frac{fy5}{fyScale} U_4 + \frac{fy6}{fyScale} U_5$$

xx0600003088

---

##### Allowed values

A numeric value.

## 8.7.17 fz 1 - fz 6

## Parent

*fz 1 - fz 6* belong to the type *PMC Sensor Setup*, in the topic *Motion*.

## Cfg name

fz\_value1  
fz\_value2  
fz\_value3  
fz\_value4  
fz\_value5  
fz\_value6

## Description

Defines how the six input voltages are scaled to create a measured force in the z direction.

## Usage

The force sensor sends six input voltages to the voltage measurement box ( $U_0$ ,  $U_1$ , ...  $U_5$ ). Some of these are very dependent on the force in the z direction, while others are more dependent on forces in other directions. The contribution from the first input voltage to the force measurement in the z direction is specified in *fz 1*. The contribution from the second signal is specified in *fz 2*, and so on.

These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

## Example

This is how the measured force in the z direction is calculated:

$$F_z = \frac{fz1}{fzScale} U_0 + \frac{fz2}{fzScale} U_1 + \frac{fz3}{fzScale} U_2 + \frac{fz4}{fzScale} U_3 + \frac{fz5}{fzScale} U_4 + \frac{fz6}{fzScale} U_5$$

xx0600003089

## Allowed values

A numeric value.

## 8 System parameters

---

8.7.18 tx 1 - tx 6

### 8.7.18 tx 1 - tx 6

---

#### Parent

tx 1 - tx 6 belong to the type *PMC Sensor Setup*, in the topic *Motion*.

---

#### Cfg name

tx\_value1  
tx\_value2  
tx\_value3  
tx\_value4  
tx\_value5  
tx\_value6

---

#### Description

Defines how the six input voltages are scaled to create a measured torque in the x direction.

---

#### Usage

The force sensor sends six input voltages to the voltage measurement box ( $U_0$ ,  $U_1$ , ...  $U_5$ ). Some of these are very dependent on the torque in the x direction, while others are more dependent on torques in other directions. The contribution from the first input voltage to the torque measurement in the x direction is specified in tx 1. The contribution from the second signal is specified in tx 2, and so on.

These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

---

#### Example

This is how the measured torque in the x direction is calculated:

$$Tx = \frac{tx1}{txScale} U_0 + \frac{tx2}{txScale} U_1 + \frac{tx3}{txScale} U_2 + \frac{tx4}{txScale} U_3 + \frac{tx5}{txScale} U_4 + \frac{tx6}{txScale} U_5$$

xx0600003090

---

#### Allowed values

A numeric value.

## 8.7.19 ty 1 - ty 6

## Parent

*ty 1 - ty 6* belong to the type *PMC Sensor Setup*, in the topic *Motion*.

## Cfg name

ty\_value1  
ty\_value2  
ty\_value3  
ty\_value4  
ty\_value5  
ty\_value6

## Description

Defines how the six input voltages are scaled to create a measured torque in the y direction.

## Usage

The force sensor sends six input voltages to the voltage measurement box ( $U_0$ ,  $U_1$ , ...  $U_5$ ). Some of these are very dependent on the torque in the y direction, while others are more dependent on torques in other directions. The contribution from the first input voltage to the torque measurement in the y direction is specified in *ty 1*. The contribution from the second signal is specified in *ty 2*, and so on. These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

## Example

This is how the measured torque in the y direction is calculated:

$$T_y = \frac{ty1}{tyScale} U_0 + \frac{ty2}{tyScale} U_1 + \frac{ty3}{tyScale} U_2 + \frac{ty4}{tyScale} U_3 + \frac{ty5}{tyScale} U_4 + \frac{ty6}{tyScale} U_5$$

xx0600003091

## Allowed values

A numeric value.

## 8 System parameters

---

8.7.20 tz 1 - tz 6

### 8.7.20 tz 1 - tz 6

---

#### Parent

tz 1 - tz 6 belong to the type *PMC Sensor Setup*, in the topic *Motion*.

---

#### Cfg name

tz\_value1  
tz\_value2  
tz\_value3  
tz\_value4  
tz\_value5  
tz\_value6

---

#### Description

Defines how the six input voltages are scaled to create a measured torque in the z direction.

---

#### Usage

The force sensor sends six input voltages to the voltage measurement box ( $U_0$ ,  $U_1$ , ...  $U_5$ ). Some of these are very dependent on the torque in the z direction, while others are more dependent on torques in other directions. The contribution from the first input voltage to the torque measurement in the z direction is specified in *tz 1*. The contribution from the second signal is specified in *tz 2*, and so on.

These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

---

#### Example

This is how the measured torque in the z direction is calculated:

$$T_z = \frac{tz1}{tzScale} U_0 + \frac{tz2}{tzScale} U_1 + \frac{tz3}{tzScale} U_2 + \frac{tz4}{tzScale} U_3 + \frac{tz5}{tzScale} U_4 + \frac{tz6}{tzScale} U_5$$

xx0600003092

---

#### Allowed values

A numeric value.



### 8.7.21 fx scale - tz scale

---

**Parent**

*fx scale - tz scale* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

**Cfg name**

fx\_scale  
fy\_scale  
fz\_scale  
tx\_scale  
ty\_scale  
tz\_scale

---

**Description**

Scaling factor for the weighted output from the sensor.

---

**Usage**

The force sensor sends six input voltages to the voltage measurement box ( $U_0$ ,  $U_1$ , ...  $U_5$ ). The voltage of each signal is multiplied by a factor (e.g. *fx 1* to *fx 6*). The results are summed up to a weighted output from the sensor (e.g. of the force in the x direction). By dividing this weighted sensor output with a scaling factor, the corresponding force (or torque) is calculated.

These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

---

**Allowed values**

A numerical value.

Unit: V/N (for *fx scale - fz scale*) or V/Nm (for *tx scale - tz scale*)

## 8 System parameters

---

### 8.7.22 *fx max - tz max*

#### 8.7.22 *fx max - tz max*

---

##### Parent

*fx max - tz max* belongs to the type *PMC Sensor Setup*, in the topic *Motion*.

---

##### Cfg name

*fx\_value\_max*  
*fy\_value\_max*  
*fz\_value\_max*  
*tx\_value\_max*  
*ty\_value\_max*  
*tz\_value\_max*

---

##### Description

The sensor's specified maximum force or torque in the respective direction.

---

##### Usage

*fx max* specifies the maximum force in the x direction that the sensor can measure reliably. In the same way, *fy max* and *fz max* specify the maximum force in the y and z direction, respectively. *tx max*, *ty max* and *tz max* specify the maximum torque in the x, y and z direction, respectively.

These values are specified by the sensor supplier, see [The PMC Sensor Setup type on page 229](#).

---

##### Allowed values

A numeric value.

Unit: N (for *fx max - fz max*) or Nm (for *tx max - tz max*)

## 8.8 Type *FC Speed Change*

### 8.8.1 The FC Speed Change Type

---

#### Overview

This section describes the type *FC Speed Change*, which belongs to the topic *Motion*. Each parameter of the type is described in a separate information topic in this section.

---

#### Cfg name

FC\_SPEED\_CHANGE

---

#### Type description

The type *FC Speed Change* has a number of parameters used for the SpeedChange functionality available with the RobotWare option Machining FC.

# 8 System parameters

---

## 8.8.2 Name

### 8.8.2 Name

---

**Parent**

*Name* belongs to the type *FC Speed Change*, in the topic *Motion*.

---

**Cfg name**

name

---

**Description**

Defines the name of the *FC Speed Change*.

---

**Usage**

*Name* is used to reference the *FC Speed Change* from the parameter *Use FC Speed Change* in the type *FC Master*.

---

**Allowed values**

A string with maximum 32 characters.

### 8.8.3 Speed ratio min

---

**Parent**

*Speed ratio min* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

speed\_ratio\_min

---

**Description**

Defines the minimum allowed speed ratio.

---

**Usage**

This parameter defines the lowest robot speed to be used ( $\text{speed\_ratio\_min} * \text{programmed\_speed}$ ).

---

**Allowed values**

A value between 0.02 and 1.

# 8 System parameters

---

## 8.8.4 No of speed levels

### 8.8.4 No of speed levels

|                |   |
|----------------|---|
| Parent         | <i>No of speed levels</i> belongs to the type <i>FC Speed Change</i> in topic <i>Motion</i> . |
| Cfg name       | no_of_speed_levels  |
| Description    | Defines the number of discrete speed levels.  |
| Usage          | This parameter defines the number of discrete speed levels to be used.                        |
| Allowed values | A value between 2 and 10.   |

### 8.8.5 Speed ratio delta

---

**Parent**

*Speed ratio delta* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

speed\_ratio\_delta

---

**Description**

Limits the speed change when ramping the speed ratio to a new value.

---

**Usage**

The parameter limits acceleration/deceleration due to the SpeedChange functionality. A low value will give slower but smoother speed changes.

---

**Allowed values**

A value between 0.0001 and 1.

## 8 System parameters

---

### 8.8.6 Speed max update period

### 8.8.6 Speed max update period

---

**Parent**

*Speed max update period* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

speed\_max\_update\_period

---

**Description**

Defines the minimum time in seconds between speed changes.

---

**Usage**

This parameter defines the period of time after a speed change, during which the sensor signal will be disregarded. A short time will give faster reactions to overload but may cause the speed to vary too frequently.

---

**Allowed values**

A value between 0 and 1.



### 8.8.7 Feedback type

---

**Parent**

*Feedback type* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

`fdb_type`

---

**Description**

Defines the type of feedback to be used.

---

**Usage**

This parameter is used to decide which type of feedback should control the speed, that is, which sensor input is to be used for speed change control.

The parameter *Disable check of saturation* can be used if it is likely that the power output will reach saturation level.

---

**Allowed values**

*Single DAC Input*

*Calib. Force Magn.*

*Uncalib. Force Magn.*

# 8 System parameters

---

## 8.8.8 DAC channel

### 8.8.8 DAC channel

|                |  |
|----------------|--|
| Parent         | <i>DAC channel belongs to the type FC speed change in topic Motion.</i>                                  |
| Cfg name       | fdb_dac_channel  |
| Description    | Defines the channel used on AD board when running Force Controlled SpeedChange in Single DAC Input mode. |
| Usage          | Chose channel to have as analog input from AD board.   |
| Allowed values | A value between 0 and 7 with a default value of 7.   |

**8.8.9 Feedback offset**

---

**Parent**

*Feedback offset belongs to the type FC Speed Change in topic Motion.*

---

**Cfg name**

`fdb_offset`

---

**Description**

Defines the offset to be removed from the feedback.

---

**Usage**

The offset is removed from the measured feedback before the value is used in speed change control. Default value is 0.

---

**Allowed values**

A value between -10000 and 10000.

# 8 System parameters

---

## 8.8.10 Use Fdb LP filter

### 8.8.10 Use Fdb LP filter

|                |   |
|----------------|---|
| Parent         | <i>Use Fdb LP filter belongs to the type FC Speed Change in topic Motion.</i>                               |
| Cfg name       | fdb_lp_active   |
| Description    | Defines whether feedback low pass filter should be active.  |
| Usage          | If set to true, the feedback values are low pass filtered before used. May be used to filter noisy signals. |
| Allowed values | TRUE/FALSE.   |

#### 8.8.11 Fdb LP filter bandwidth

---

**Parent**

*Fdb LP filter bandwidth* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

fdb\_lp\_bandwidth

---

**Description**

Defines the bandwidth for feedback low pass filter (Hz).

---

**Usage**

This parameter is used to filter the feedback values used in the speed change control. Setting it lower will slow down the reaction time for the speed change control.

---

**Allowed values**

A value between 1 and 250.

## 8 System parameters

---

### 8.8.12 Maximum TCP speed

#### 8.8.12 Maximum TCP speed

---

**Parent**

*Maximum TCP speed* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

maximum\_tcp\_speed

---

**Description**

Defines the maximum original TCP speed for speed change (m/s).

---

**Usage**

If the user programs a speed above this value, the system will stop.

---

**Allowed values**

A value between 0.01 and 10.

#### 8.8.13 Recover rule fdb ratio

---

**Parent**

*Recover rule fdb ratio* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

recover\_rule\_fdb ratio

---

**Description**

Defines the maximum allowed feedback (fdb) to reference ratio when at lowest possible speed.

---

**Usage**

A feedback to reference ratio larger than this while having reduced speed to lowest level will trig recover behavior or stop robot. The recover function will be activated when the feedback signal is still too high when running at the lowest speed.

---

**Allowed values**

A value between 0.01 and 1000.

## 8 System parameters

---

### 8.8.14 Decrease rule safety fdb ratio

#### 8.8.14 Decrease rule safety fdb ratio

---

**Parent**

*Decrease rule safety fdb ratio* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

dec\_rule\_safety\_fdb\_to\_ref\_ratio

---

**Description**

Defines the maximum feedback to reference ratio.

---

**Usage**

Speed will be reduced if the feedback to reference ratio is above this value for *Decrease rule safety fdb time* regardless of trends and changes of the feedback.

---

**Allowed values**

A value between 0.001 and 1000.

---



#### 8.8.15 Decrease rule safety fdb time

---

**Parent**

*Decrease rule safety fdb time* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

dec\_rule\_safety\_fdb\_time

---

**Description**

Define the maximum time in seconds that the feedback to reference ratio can be continuously over Decrease rule safety fdb ratio before reducing robot speed

---

**Usage**

Speed will be reduced if the feedback to reference ratio is above Decrease rule safety fdb ratio for this time regardless the trend of the feedback

---

**Allowed values**

A value between 0.001 and 1000.

## 8 System parameters

---

### 8.8.16 Fdb trend step size

#### 8.8.16 Fdb trend step size

---

**Parent**

*Fdb trend step size* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

`fdb_trend_step_size`

---

**Description**

Defines the minimum difference between consecutive fdb values to count as a change in feedback.

---

**Usage**

Used for deciding trends in the feedback that is needed for the SpeedChange rules. This parameter is used to compensate the effects of measurement noise on the trend calculation. Usually the value can be set 2 times the noise level

---

**Allowed values**

A value between 0 and 1000.

#### 8.8.17 Decrease rule 1 fdb ratio

---

**Parent**

*Decrease rule 1 fdb ratio* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

dec\_rule1\_fdb\_to\_ref\_ratio

---

**Description**

Part of condition 1 to decrease speed.

---

**Usage**

For ABB internal use only.

---

**Allowed values**

A value between 0.001 and 1000.

# 8 System parameters

---

## 8.8.18 Decrease rule 1 fdb trend

### 8.8.18 Decrease rule 1 fdb trend

|                |   |
|----------------|---|
| Parent         | <i>Decrease rule 1 fdb trend belongs to the type FC Speed Change in topic Motion.</i> |
| Cfg name       | dec_rule1_fdb_trend   |
| Description    | Part of condition 1to decrease speed.   |
| Usage          | For ABB internal use only.  |
| Allowed values | A value between -10 and 10.   |

#### 8.8.19 Decrease rule 2 fdb ratio

---

**Parent**

*Decrease rule 2 fdb ratio* belongs to the type *FC Speed Change* in topic *Motion*.

---

**Cfg name**

dec\_rule2\_fdb\_to\_ref\_ratio

---

**Description**

Part of condition 2 to decrease speed.

---

**Usage**

For ABB internal use only.

---

**Allowed values**

A value between 0.001 and 1000.

## 8 System parameters

---

### 8.8.20 Decrease rule 2 fdb trend

#### 8.8.20 Decrease rule 2 fdb trend

|                |  |
|----------------|--|
| Parent         | <i>Decrease rule 2 fdb trend</i> belongs to the type <i>FC Speed Change</i> in topic <i>Motion</i> . |
| Cfg name       | dec_rule2_fdb_trend  |
| Description    | Part of condition 2to decrease speed.  |
| Usage          | For ABB internal use only.   |
| Allowed values | A value between -10 and 10.  |

#### 8.8.21 Increase rule 1 fdb ratio

---

**Parent**

*Increase rule 1 fdb ratio belongs to the type FC Speed Change in topic Motion.*

---

**Cfg name**

inc\_rule1\_fdb\_to\_ref\_ratio

---

**Description**

Part of condition 1 to increase speed.

---

**Usage**

For ABB internal use only.

---

**Allowed values**

A value between 0.001 and 1000.

# 8 System parameters

---

## 8.8.22 Increase rule 1 fdb trend

### 8.8.22 Increase rule 1 fdb trend

|                |   |
|----------------|---|
| Parent         | <i>Increase rule 1 fdb trend belongs to the type FC Speed Change in topic Motion.</i> |
| Cfg name       | inc_rule1_fdb_trend   |
| Description    | Part of condition 1to increase speed.   |
| Usage          | For ABB internal use only.  |
| Allowed values | A value between -10 and 10.   |



#### 8.8.23 Increase rule 2 fdb ratio

---

**Parent**

*Increase rule 2 fdb ratio belongs to the type FC Speed Change in topic Motion.*

---

**Cfg name**

inc\_rule2\_fdb\_to\_ref\_ratio

---

**Description**

Part of condition 2 to increase speed.

---

**Usage**

For ABB internal use only.

---

**Allowed values**

A value between 0.001 and 1000.

## 8 System parameters

---

### 8.8.24 Increase rule 2 fdb trend

#### 8.8.24 Increase rule 2 fdb trend

---

|                |   |
|----------------|---|
| Parent         | <i>Increase rule 2 fdb trend belongs to the type FC Speed Change in topic Motion.</i> |
| Cfg name       | inc_rule2_fdb_trend   |
| Description    | Part of condition 2 to increase speed.  |
| Usage          | For ABB internal use only.  |
| Allowed values | A value between -10 and 10.   |

---

## 9 Further references

### 9.1 TuneMaster

#### Overview

TuneMaster can be used to monitor forces in Force Control. Forces and torques in both force control coordinate system and sensor coordinate system can be viewed at the same time monitoring 6 signals each (for example x, y, z, wx, wy, wz).

#### Installation

This section only describes what is specific for setting up the TuneMaster for Force control. For more information see *Application manual - TuneMaster*.

#### Procedure

Follow these step to get started with the program.

| Step | Action               | Reference   |
|------|----------------------|---|
| 1    | Install TuneMaster.  | <i>Application manual - TuneMaster</i>                                |
| 2    | Start TuneMaster.    |   |
| 3    | Define test signals. | Specified in section <a href="#">Test signal number on page 275</a> . |

#### Test signal number

To view the forces, a specific number needs to be entered in *Signal ident. man* of every channel in the test signal window.

If the signals are not mapped to a specific axis always use axis 1.

It is important to note that in FC Pressure, the force control coordinate system is automatically rotated in such way that the z-axis of the force control coordinate system is always aligned with the pressure direction specified by the arguments \Fx, \Fy and \Fz to FCPress1LStart. This means that the test signal 209 should always be used for monitoring of the pressure force.

| Signal number | Content (force component )  |
|---------------|-----------------------------|
| 201           | Sensor frame, x-direction.  |
| 202           | Sensor frame, y-direction.  |
| 203           | Sensor frame, z-direction.  |
| 204           | Sensor frame, wx-direction. |
| 205           | Sensor frame, wy-direction. |
| 206           | Sensor frame, wz-direction. |
| 207           | Force frame, x-direction.   |
| 208           | Force frame, y-direction.   |
| 209           | Force frame, z-direction.   |
| 210           | Force frame, wx-direction.  |

*Continues on next page*

## 9 Further references

### 9.1 TuneMaster

*Continued*

| Signal number | Content (force component ) |
|---------------|----------------------------|
| 211           | Force frame, wy-direction. |
| 212           | Force frame, wz-direction. |



xx1800000413

To view the raw sensor signals, specific numbers must be entered in TuneMaster.

| Signal number | Content                        |
|---------------|--------------------------------|
| 1001          | U0                             |
| 1002          | U1                             |
| 1003          | U2                             |
| 1004          | U3                             |
| 1005          | U4                             |
| 1006          | U5                             |
| 1007          | Cable connected                |
| 1008          | Single channel for SpeedChange |

This table specifies the test signals for FCSpeedChange tuning.

| Signal number | Content   |
|---------------|-----------|
| 401           | Reference |

*Continues on next page*

| Signal number | Content                     |
|---------------|-----------------------------|
| 402           | Measurement (process force) |
| 403           | Speed ratio signal          |

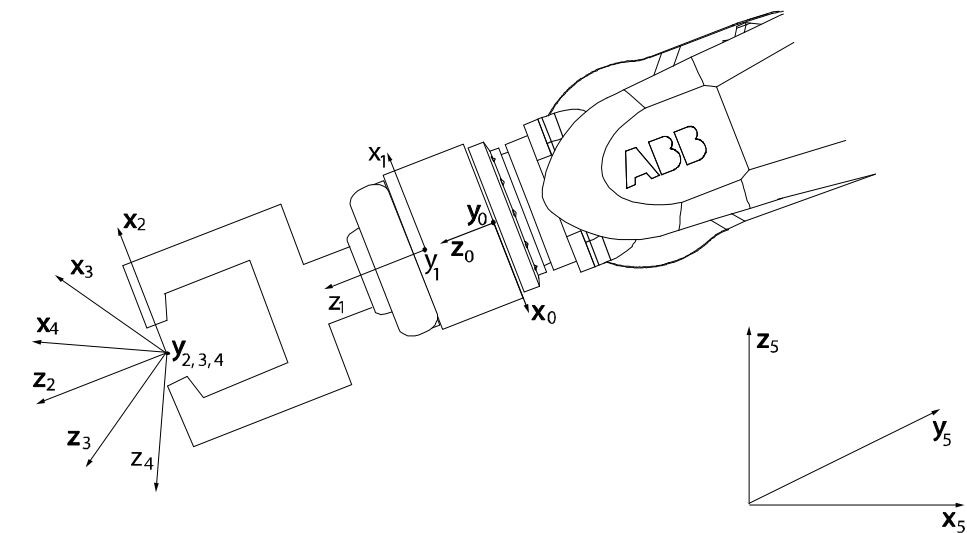
## 9 Further references

### 9.2 The coordinate systems

### 9.2 The coordinate systems

#### About the coordinate systems

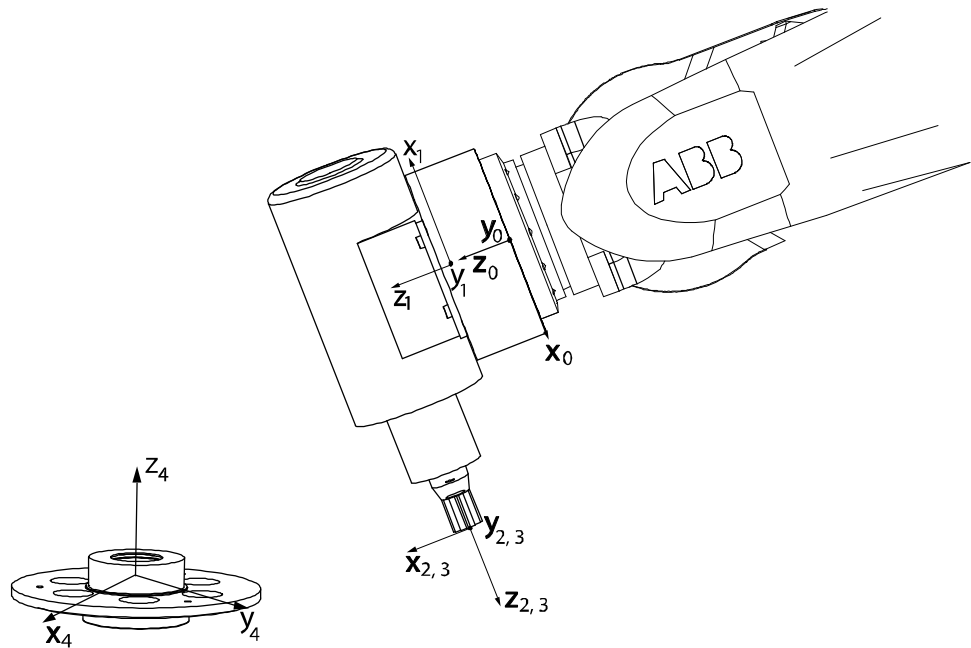
This is an overview over the new coordinate systems created for Force Control.  
For more information about the basic coordination system see related information.



xx0500002050

|            |                                      |
|------------|--------------------------------------|
| X0, Y0, Z0 | Tool 0 coordinate system             |
| X1, Y1, Z1 | Sensor coordinate system             |
| X2, Y2, Z2 | Tool coordinate system               |
| X3, Y3, Z3 | Force control coordinate system      |
| X4, Y4, Z4 | Reference movement coordinate system |
| X5, Y5, Z5 | Work object coordinate system        |

Continues on next page



xx0600003309

|            |                                 |
|------------|---------------------------------|
| X0, Y0, Z0 | Tool 0 coordinate system        |
| X1, Y1, Z1 | Sensor coordinate system        |
| X2, Y2, Z2 | Tool coordinate system          |
| X3, Y3, Z3 | Force control coordinate system |
| X4, Y4, Z4 | Work object coordinate system   |

#### Force control coordinate system

The origin of the force control coordinate system is in the tool center point (TCP). The orientation is defined by the user in relation to the tool coordinate system, the work object coordinate system, or the path coordinate system.

#### Orient condition coordinate system

Orientation condition are defined in this coordinate system. The origin is the same as the work object coordinate system and the orientation is defined by an orient in relation to the work object coordinate system.

#### Orient supervision coordinate system

Orientation supervision are defined in this coordinate system. The origin is the same as the work object coordinate system and the orientation is defined by an orient in relation to the work object coordinate system.

#### Position condition coordinate system

Positions condition are defined in this coordinate system. It is defined by a pose in relation to the work object coordinate system.

#### Position supervision coordinate system

Positions supervision are defined in this coordinate system. It is defined by a pose in relation to the work object coordinate system.

*Continues on next page*

## 9 Further references

---

### 9.2 The coordinate systems

*Continued*

#### Reference movement coordinate system

The origin of the reference movement coordinate system is in the tool center point (TCP). The orientation is defined by the user in relation to the tool coordinate system or the work object coordinate system.

#### Sensor coordinate system

The origin and orientation of the sensor coordinate system depends on the manufacture and how it is mounted.

#### Tool 0 coordinate system

Tool 0 or the wrist coordinate system cannot be changed and is always the same as the mounting flange of the robot.

#### Tool coordinate system

The tool coordinate system is defined by the user.

---

#### Related information

| For information about | See  |
|-----------------------|--|
| Coordinate systems    | <i>Technical reference manual - RAPID Overview</i> |



## 9.3 Force Sensor interface

### 9.3.1 About the Force Sensor interface

---

#### Overview

The force control software has been designed with a generic interface for a 6 degree of freedom (6DOF) force / torque sensor using a voltage measurement box.

*ATI Industrial Automation* have prepared sensors with correct settings, adapter plates and calibration files in order to meet the ABB interface requirements.

This section describes the interface as such and how to adapt a sensor to the requirements.

It is also possible to use a sensor with less than 6 DOF, which means that the robot is force controlled in less directions.

## 9 Further references

### 9.3.2 Voltage measurement box

### 9.3.2 Voltage measurement box

#### Voltage measurement box 3HAC034234-001

The Force Control option requires a voltage measurement box, which is an AD. 6 channels are used to read the force/torque values of a 6 DOF sensor and force from a 1 DOF sensor. One channel is used for a sensor safety signal and one channel is used for the spindle sensor signal used for SpeedChange.

#### Input voltage requirements

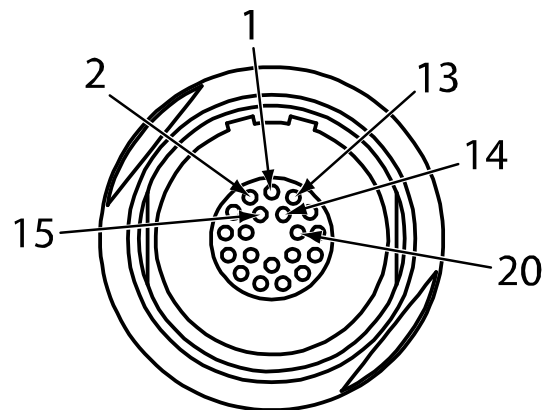
| Voltage description   | Maximum value |
|---|---------------|
| Differential input voltage (for example between $U_{0+}$ and $U_{0-}$ ) | +/- 10 V      |
| Input voltage (relative to 0 V Common)                                  | +/- 10 V      |

#### I/O pin configuration

This is a description of the connectors on the voltage measurement box.

#### Connector X3

Connector X3 is used for connecting the cable from the force sensor. The cable connector should be a Lemo (article number: FGA.3K.320.CLAC60) male connector to match the X3 connector on the box.



xx0900001057

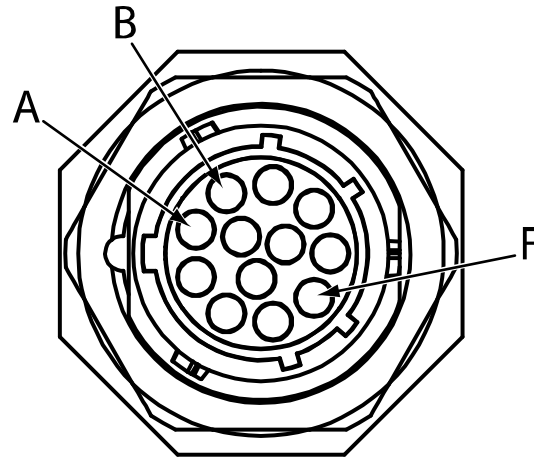
| Pin | Description | Pin | Description                  |
|-----|-------------|-----|------------------------------|
| 1   | $U_{0+}$    | 11  | $U_{5+}$                     |
| 2   | $U_{0-}$    | 12  | $U_{5-}$                     |
| 3   | $U_{1+}$    | 13  | Not used                     |
| 4   | $U_{1-}$    | 14  | SpeedChange single channel + |
| 5   | $U_{2+}$    | 15  | SpeedChange single channel - |
| 6   | $U_{2-}$    | 16  | Safety +                     |
| 7   | $U_{3+}$    | 17  | Safety -                     |
| 8   | $U_{3-}$    | 18  | 0V (common)                  |
| 9   | $U_{4+}$    | 19  | -15 V                        |

*Continues on next page*

| Pin | Description      | Pin | Description |
|-----|------------------|-----|-------------|
| 10  | U <sub>4</sub> - | 20  | +15 V       |

#### Connector X1

Connector X1 is used for connecting the cable to the robot controller.

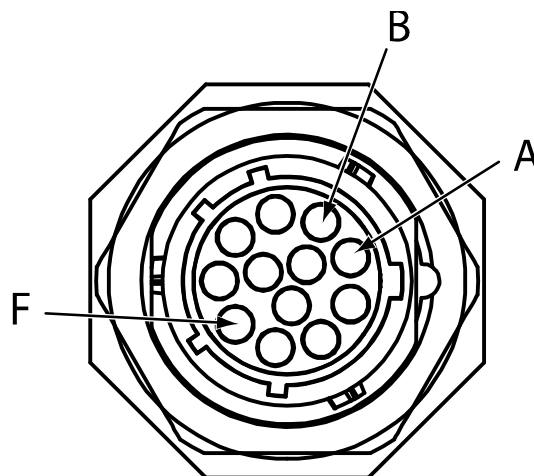


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| Pin | Description | Pin | Description |
|-----|-------------|-----|-------------|
| A   | SDI_AXC_P   | D   | SDO_AXC_N   |
| B   | SDI_AXC_N   | E   | 0 V         |
| C   | SDO_AXC_P   | F   | 24 V        |

#### Connector X2

Connector X2 is used for connecting the cable to the serial measurement link for additional axes. If no additional axes are connected, the jumper connector must be used.



xx0900001059

| Pin | Description | Pin | Description |
|-----|-------------|-----|-------------|
| A   | SDO_SMB_P   | D   | SDI_SMB_N   |
| B   | SDO_SMB_N   | E   | 0 V         |

*Continues on next page*

## 9 Further references

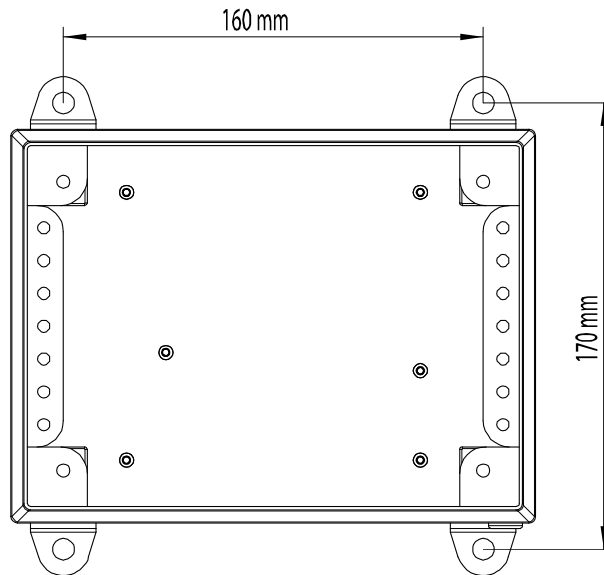
### 9.3.2 Voltage measurement box

*Continued*

| Pin | Description | Pin | Description |
|-----|-------------|-----|-------------|
| C   | SDI_SMB_P   | F   | 24 V        |

#### Hole pattern

When mounting the voltage measurement box, it is attached with four screws in the holes with the following pattern:



xx1000000052

#### Protection class

The voltage measurement box has protection class IP66.

## 9.3.3 Sensor configuration

## Procedure

In order to make the sensor work configuration of a few system parameters is needed. Use RobotStudio and follow these steps. For more information about the parameters see [The PMC Sensor Setup type on page 229](#).

|   | Action  |
|---|---|
| 1 | In the <i>Motion</i> configuration topic select the type <i>PMC Sensor Setup</i> .  |
| 2 | Set <i>Max Voltage</i> , defining the input range of the Acromag card, to a value corresponding to the DIP switch settings on the card, normally 5 or 10 Volt.  |
| 3 | Set up <i>Disable force sensor cable check</i> . There is a safety supervision of the sensor connected to PIN 19&20, which enforces an emergency stop when the signal goes below the value set in <i>Safety Channel Voltage</i> . It is strongly recommended to use a sensor that has a safety channel. If not, <i>Disable force sensor cable check</i> must be set to true.  |
| 4 | <p>Set the calibration values (<i>fx 1 - tz 6</i>) and scale factors (<i>fx scale - tz scale</i>) in order to achieve calibrated forces and torques. These are calculated from the input voltages as follows:</p> $F_x = \frac{fx1}{fxScale} U_0 + \frac{fx2}{fxScale} U_1 + \frac{fx3}{fxScale} U_2 + \frac{fx4}{fxScale} U_3 + \frac{fx5}{fxScale} U_4 + \frac{fx6}{fxScale} U_5$ $F_y = \frac{fy1}{fyScale} U_0 + \frac{fy2}{fyScale} U_1 + \frac{fy3}{fyScale} U_2 + \frac{fy4}{fyScale} U_3 + \frac{fy5}{fyScale} U_4 + \frac{fy6}{fyScale} U_5$ $F_z = \frac{fz1}{fzScale} U_0 + \frac{fz2}{fzScale} U_1 + \frac{fz3}{fzScale} U_2 + \frac{fz4}{fzScale} U_3 + \frac{fz5}{fzScale} U_4 + \frac{fz6}{fzScale} U_5$ $T_y = \frac{ty1}{tyScale} U_0 + \frac{ty2}{tyScale} U_1 + \frac{ty3}{tyScale} U_2 + \frac{ty4}{tyScale} U_3 + \frac{ty5}{tyScale} U_4 + \frac{ty6}{tyScale} U_5$ $T_x = \frac{tx1}{txScale} U_0 + \frac{tx2}{txScale} U_1 + \frac{tx3}{txScale} U_2 + \frac{tx4}{txScale} U_3 + \frac{tx5}{txScale} U_4 + \frac{tx6}{txScale} U_5$ $T_z = \frac{tz1}{tzScale} U_0 + \frac{tz2}{tzScale} U_1 + \frac{tz3}{tzScale} U_2 + \frac{tz4}{tzScale} U_3 + \frac{tz5}{tzScale} U_4 + \frac{tz6}{tzScale} U_5$ <p>xx0600003074</p> |
| 5 | Set <i>fx max</i> , <i>fy max</i> , <i>fz max</i> , <i>tx max</i> , <i>ty max</i> and <i>tz max</i> according to the sensor specifications on maximum load. These parameters specify the max range of the sensor.   |

## 9 Further references

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### 9.3.4 Sensors with less than six degrees of freedom

### 9.3.4 Sensors with less than six degrees of freedom

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#### About this section

This section gives information on how to configure a sensor with less than six degrees of freedom.

#### Pure force sensor

If the system should use a pure force sensor it is important to define that the sensor only measures force. This is done under type *FC Sensor* in the topic *Motion*, by setting the parameter *Force Sensor Type* to *Only Force*.



#### Note

All channels on the voltage measurement box that is not used must be grounded, connected to shield.

#### One DOF sensor

If a sensor with a single direction should be used, connect the sensor positive and negative input to either Pin 1&2 ( $U_0$ ), Pin 3&4 ( $U_1$ ), Pin 5&6 ( $U_2$ ), Pin 7&8 ( $U_3$ ), Pin 9&10 ( $U_4$ ) or Pin 11&12 ( $U_5$ ). Assuming the choice was Pin1&2, all values in the calibration matrix should be set to zero except  $fx\ 1$ . Set  $fx\ 1$  and  $fx\ scale$  so that  $(fx\ 1 / fx\ scale) = (fx\ max / max\ voltage)$ .

### 9.3.5 Room fixed sensor

---

#### Overview

The normal case is to have the sensor mounted on a robot, but there is an option to have the sensor mounted at a stationary position in the work cell. The sensor must then be mounted on a tool or fixture in such a way that the contact force between the robot and the tool is registered.

---

#### Configuration

If the sensor is room fixed this must be defined under type *FC Sensor* in the topic *Motion*, by leaving the parameter *Force Sensor Mount Unit Name* empty.

The origin and the direction of the force sensor coordinate system are specified in relation to the world coordinate system.

---

#### RAPID

The RAPID function `FCLoadID` should not be used with a room fixed sensor.

`Loaddata` is not relevant to the RAPID instruction `FCCalib`, which is only used in order to find the offset for the sensor.



#### Note

The calibration convention is identifying the sensed force given from the sensor, which should be equal to the force with which the surrounding effects the robot. This means that there has to be different signs (+/-) in the calibration configuration if the sensor is room fixed or mounted on a robot.

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