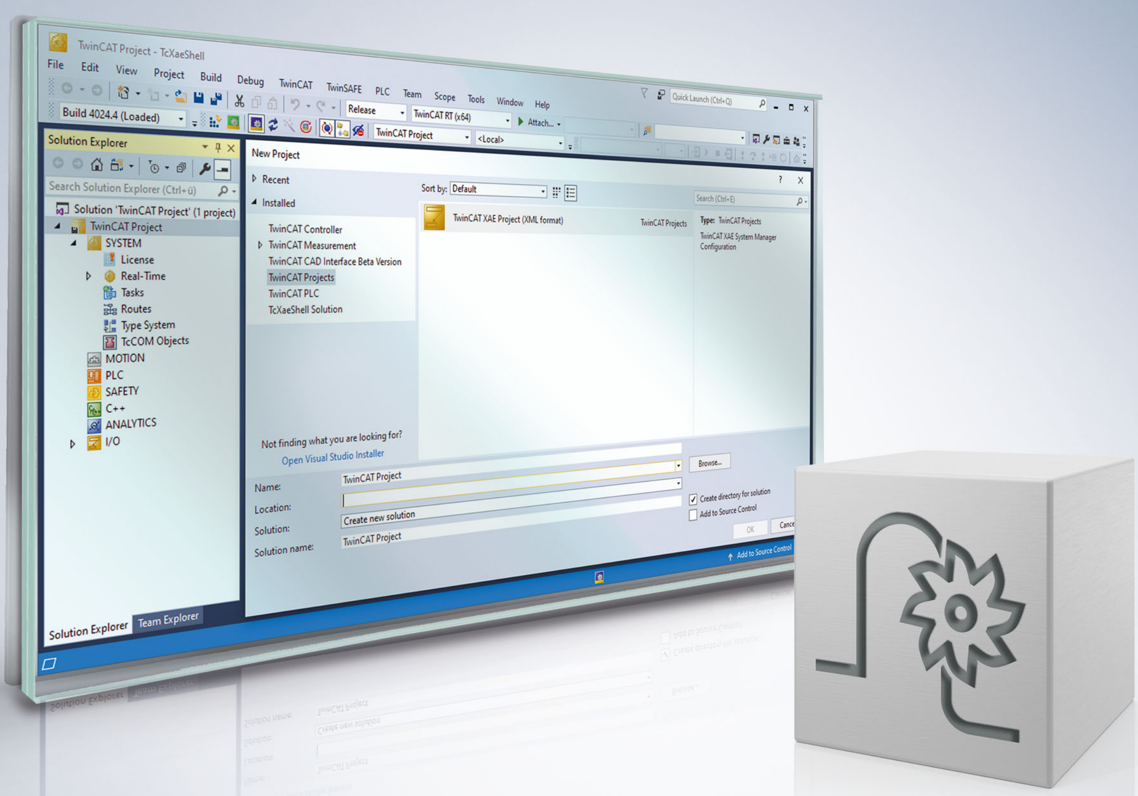
BECKHOFF New Automation Technology

Functional description | EN

# TF5200 | TwinCAT 3 CNC

## Distance control




12/18/2023 | Version: 1.34

# Notes on the documentation

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.
It is essential that the documentation and the following notes and explanations are followed when installing and commissioning the components.
It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

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The documentation has been prepared with care. The products described are, however, constantly under development.
We reserve the right to revise and change the documentation at any time and without prior announcement.
No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

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# General and safety instructions

**Icons used and their meanings**

This documentation uses the following icons next to the safety instruction and the associated text. Please read the (safety) instructions carefully and comply with them at all times.

**Icons in explanatory text**

1. Indicates an action.

⇨ Indicates an action statement.

**⚠ DANGER**

**Acute danger to life!**

If you fail to comply with the safety instruction next to this icon, there is immediate danger to human life and health.

**⚠ CAUTION**

**Personal injury and damage to machines!**

If you fail to comply with the safety instruction next to this icon, it may result in personal injury or damage to machines.

***NOTICE***

**Restriction or error**

This icon describes restrictions or warns of errors.

**Tips and other notes**

This icon indicates information to assist in general understanding or to provide additional information.

**General example**

Example that clarifies the text.

**NC programming example**

Programming example (complete NC program or program sequence) of the described function or NC command.

**Specific version information**

Optional or restricted function. The availability of this function depends on the configuration and the scope of the version.

# Table of contents

# List of figures

# 1 Overview

### Task

Distance (and height control) has the task of controlling the distance of tools to workpieces. This takes place by additional electronic probe systems or sensors which detect the actual distance and then send the measurement to the controller.

### Characteristics

Distance control is used for example:

- to compensate for workpiece thickness tolerances
- to prevent the tool from contacting the workpiece in the event of surface unevenness

### Parametrisation

Extensive settings must be configured in the axis list for distance control. The section Parameter [▸ 47] contains a complete list.

### Programming

Distance control is activated and deactivated either by the NC program by the axis-specific NC command <axisname> [ DIST_CTRL ...] [▸ 38] or by the PLC.

### *Mandatory note on references to other documents*

For the sake of clarity, links to other documents and parameters are abbreviated, e.g. [PROG] for the Programming Manual or P-AXIS-00001 for an axis parameter.

For technical reasons, these links only function in the Online Help (HTML5, CHM) but not in pdf files since pdfs do not support cross-linking.

# 2 Description

**Task**

Motions are generated by electronic probe systems or sensors. These motions should superimpose the programmed positions of axes when an NC program is interpolated.

This control helps to implement

- distance control (e.g. contact with the curved surface of a plate) or
- height control (e.g. to compensate for workpiece thickness tolerances).

Fig. 1: Specifying the ideal workpiece surface for height control

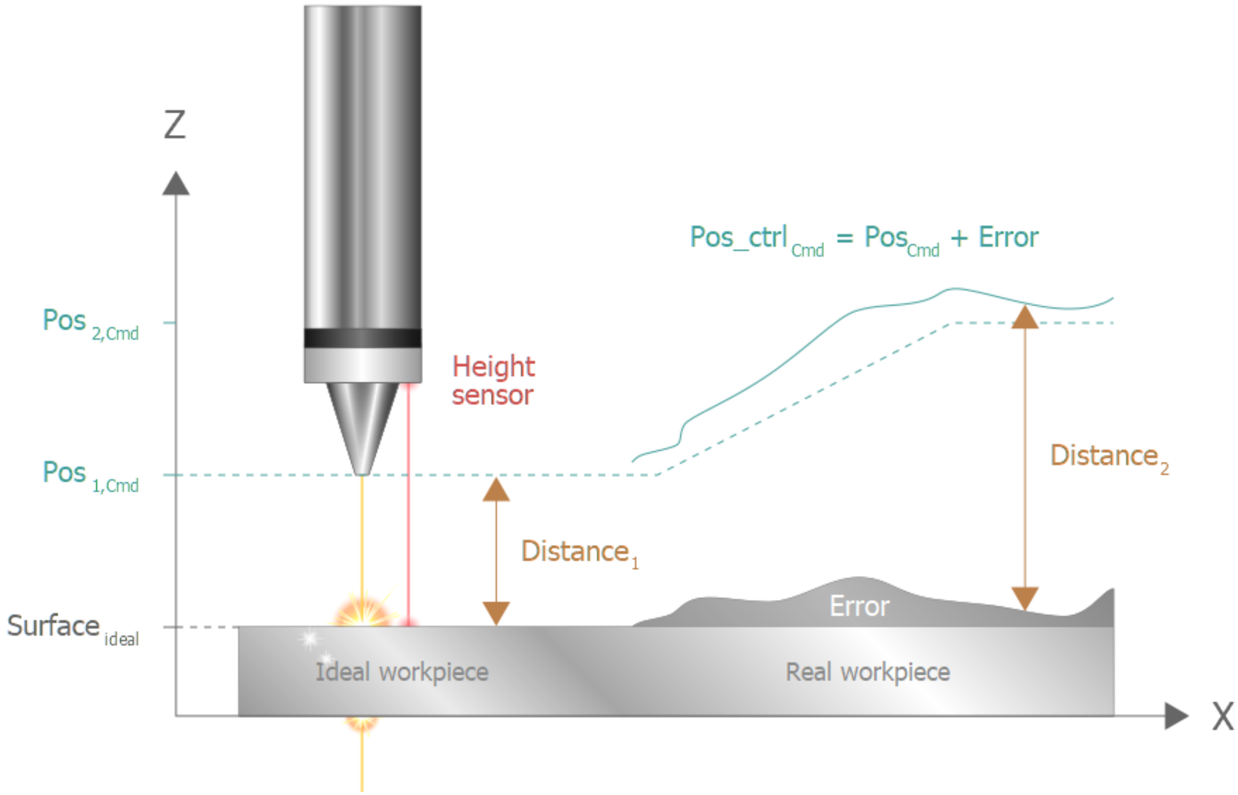



Fig. 2: Specifying the distance to workpiece for height control

### Characteristics

A second measuring system is connected to the control system via an encoder. This measuring system can output axis-specific compensation values to an axis in addition to the interpolated command point to correct the actual position of the axis.

Distance control is enabled and disabled in the

- NC program or
- via the SPS.

Variables relevant to distance control can be parameterised via the axis machine data.

Distance control operates in the interpolation cycle of the control system (GEO task).

> Distance control is only available for SERCOS, PROFIdrive or CANopen drives.

### Parameterisation overview

The motion generated by distance control can be influenced by machine data.

- Activating a mean value or a low pass filter
- Maximum permissible correction value
- Maximum additive axis velocity
- Maximum permissible actual value jump of the probe system
- Maximum upper axis position
- Minimum lower axis position
- Tolerance value
- Dynamic weighting dependent on distance
  (as of CNC Build V2.11.2804.02)
- Dynamic weighting dependent on lowering movement(as of CNC Build V2.11.2807.13)

Enable/disable is executed either by the NC program or the PLC.

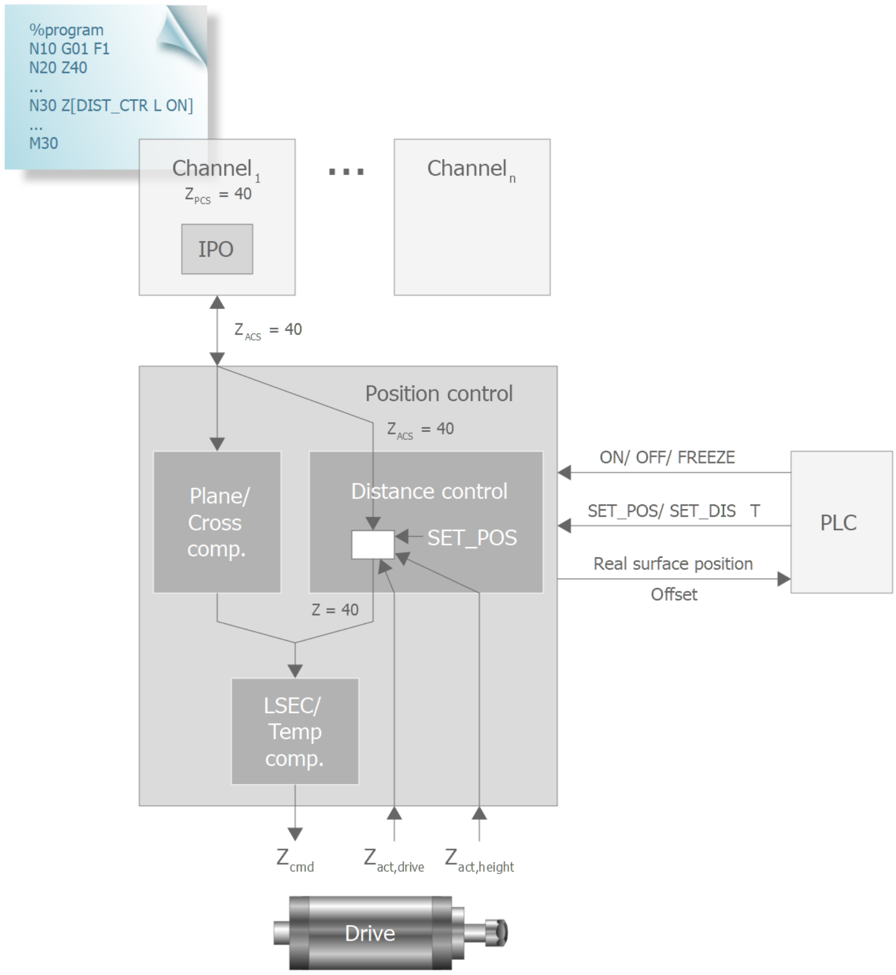



Fig. 3: Structure of distance control in conjunction with other compensations

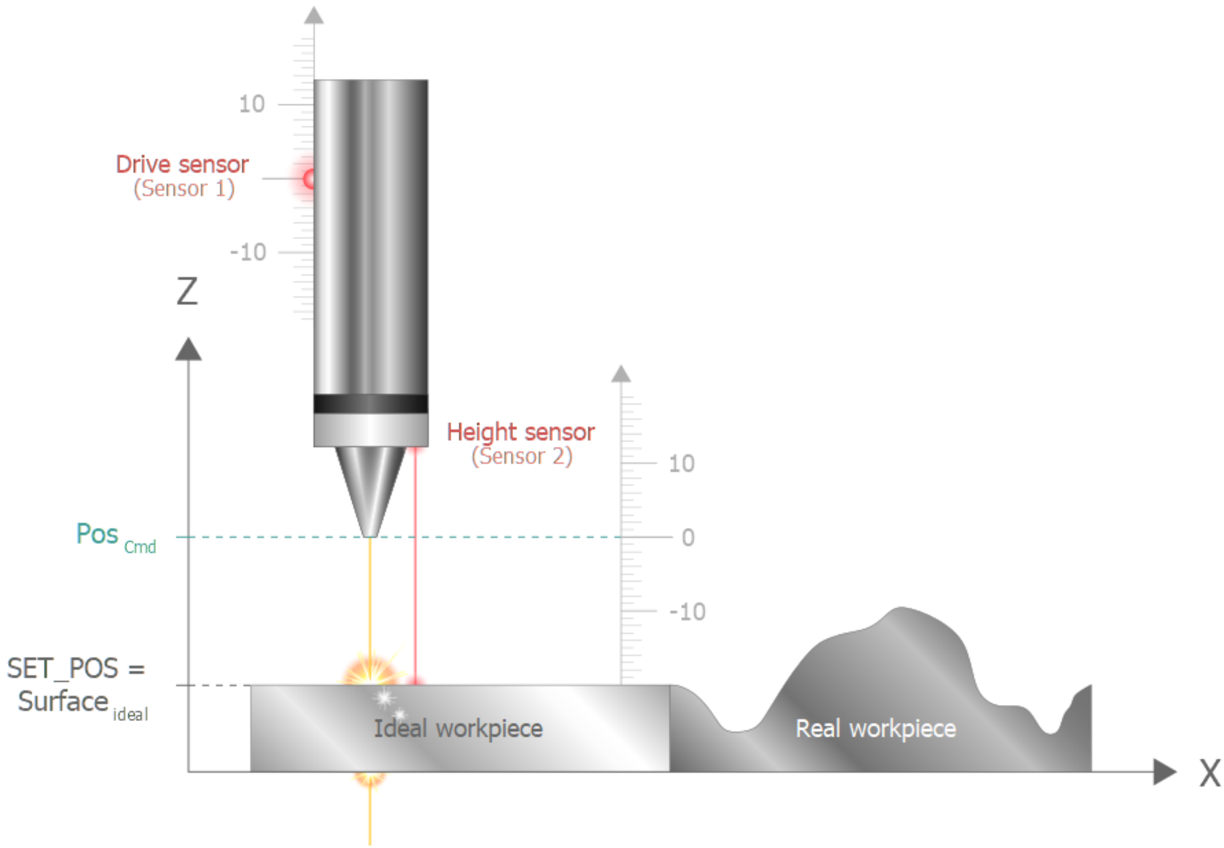



Fig. 4: Sensing the workpiece surface

### Correction of set position

The actual workpiece surface produces a height offset:

$$Offset = Surface_{real} - Surface_{ideal}$$

where

$$Surface_{real} = Drivesensor + Heightsensor$$

$$Surface_{ideal} = Set_{pos}$$ ¶

This results in a correction of the programmed command position $Pos_{Cmd}$ of the tool as follows:

$$Pos'_{cmd} = Pos_{cmd} + Offset$$

$$Pos'_{cmd} = Pos_{cmd} + Drivesensor + Heightsensor - Set_{pos}$$

## Configuration overview

The encoder of the electronic probe system is connected to the controlled axis as actual value encoder 2. Make sure that the first configured encoder is used for axis position control and the second encoder for distance control. Encoder for distance control.

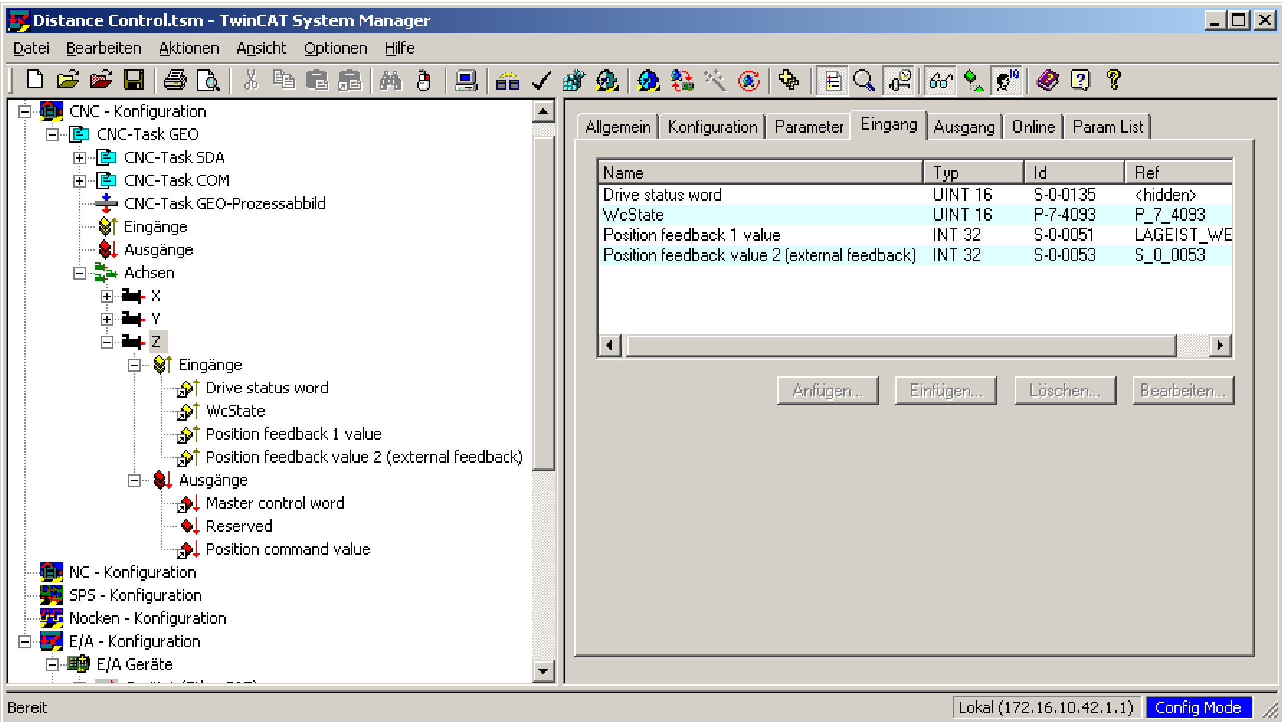



Fig. 5: TwinCAT configuration example for SERCOS (ID S-0-0053)

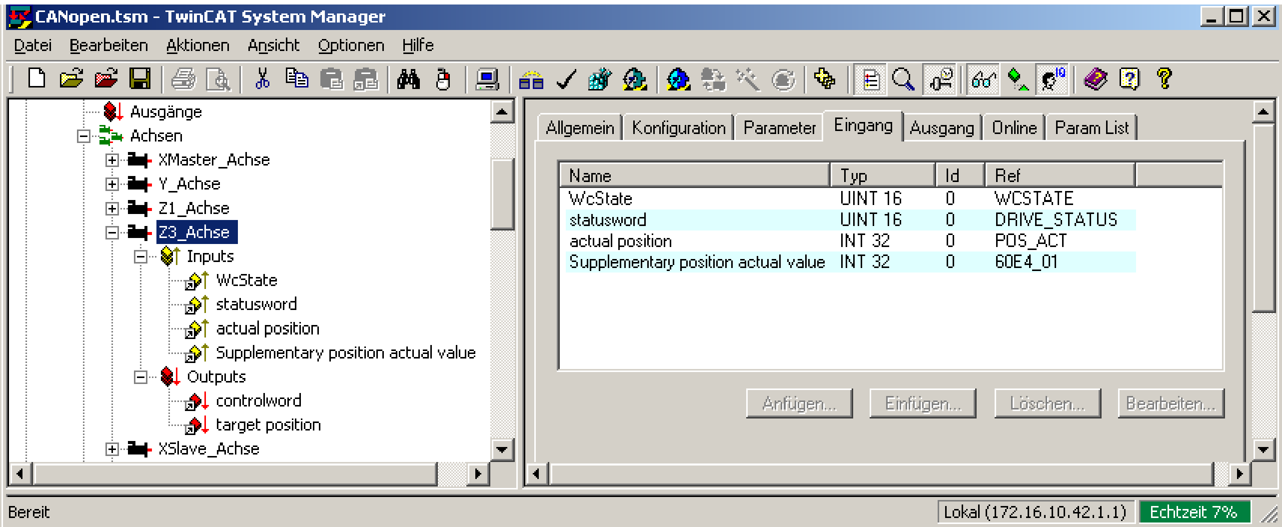



Fig. 6: TwinCAT configuration example for CANopen DS402 (PDO 0x60E4, Subindex 1)

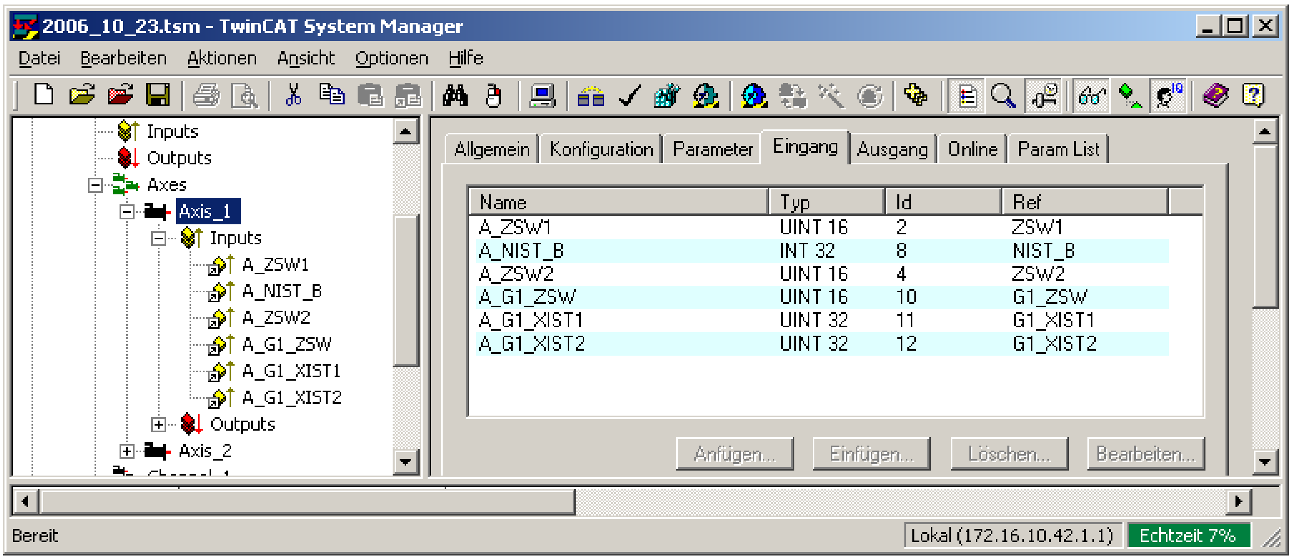



Fig. 7: TwinCAT configuration example for ProfiDrive (G1_XIST2)

**NOTICE**

The axis-specific feed override and the axis-specific feedhold enable act on distance control (see [HLI// Control commands of an axis]).

When override is 0 or when feedhold is set, distance control is no longer active and the current value is frozen.

# 3 Control

Distance control can be used optionally with P, PI, PD or PID controllers. This helps to combine the different advantages of the individual controllers. If distance control with a P-only controller does not work fast enough or problems occur with oscillation, we advise you to execute control as a PD controller. The I component should only be considered for permanent control deviations.

Characteristics of individual controllers for distance control:

| | |
|---|---|
| P controller | Weights the output value and affects distance control dynamics. Can be set using P-AXIS-00759 [▸ 55]. |
| I controller | Permanent control deviations are completely compensated after a certain time. If there is no permanent control deviation, we advise you to disable the I component using P-AXIS-00764 [▸ 55] = 0 to avoid a negative effect on distance control dynamics. |
| D controller | The faster the distance values change, the stronger the reaction of the D controller. This helps to reduce oscillations. Can be set using P-AXIS-00765 [▸ 56]. |

**Step-by-step and iterative parameterisation of the controller:**

1. Setting the proportional component using P-AXIS-00759 [▸ 55]:
   First set the controller as a P-only controller. This means disabling the I and D controllers by using P-AXIS-00764 [▸ 55]=0 and P-AXIS-00765 [▸ 56]=0, respectively. To avoid controller instability, start with a low Kp factor. Normally, a good start value is Kp=0.2. Then observe the response of the control loop at a defined input step, i.e. a change in distance. You can increase the Kp factor step by step until there is a recognisable but rapid drop in oscillation.
2. Setting the integral component using P-AXIS-00764 [▸ 55]:
   The integral component ensures that permanent control deviations are completely compensated after a certain time. If there are no permanent control deviations, you should disable the integral component.
3. The controller then operates as a PI controller. To avoid instability, start with a high integral action time value Tn. Normally, a good start value is Tn=5. In analogy to section 1, observe the response of the control loop at a defined change in distance and gradually reduce Tn. A good value for Tn is reached when the control deviation is compensated within the required time without causing any undesirable oscillations.
4. Setting the derivative component using P-AXIS-00765 [▸ 56]:
   The controller is then used as a PID or a PD controller. Again, start with a passive value for the derivative action time Tv. Normally, a good start value is Tv=0.01. As before, increase the derivative component step by step and observe the step response. The aim is to damp oscillations as much as possible without negatively affecting control loop dynamics.
5. Readjusting:
   To obtain the best controller response, you can even readjust the parameters again. For example, you can correct the P component upwards by using the D component.

# 4 Smoothing sensor data

Sensor values may be noisy. This can make the distance controller excite the system with oscillations. Filters can help to smooth the input signal and improve the performance of the distance controller.

The following sections describe the effect of the filters and the influence of the individual parameters on the filter effect in a single test. For this test, a millimetre high obstacle approx. 2.8mm high was crossed by a sensor. The distance controller is disabled for this test in order to demonstrate the effect of the filters without any feedback from the distance controller.

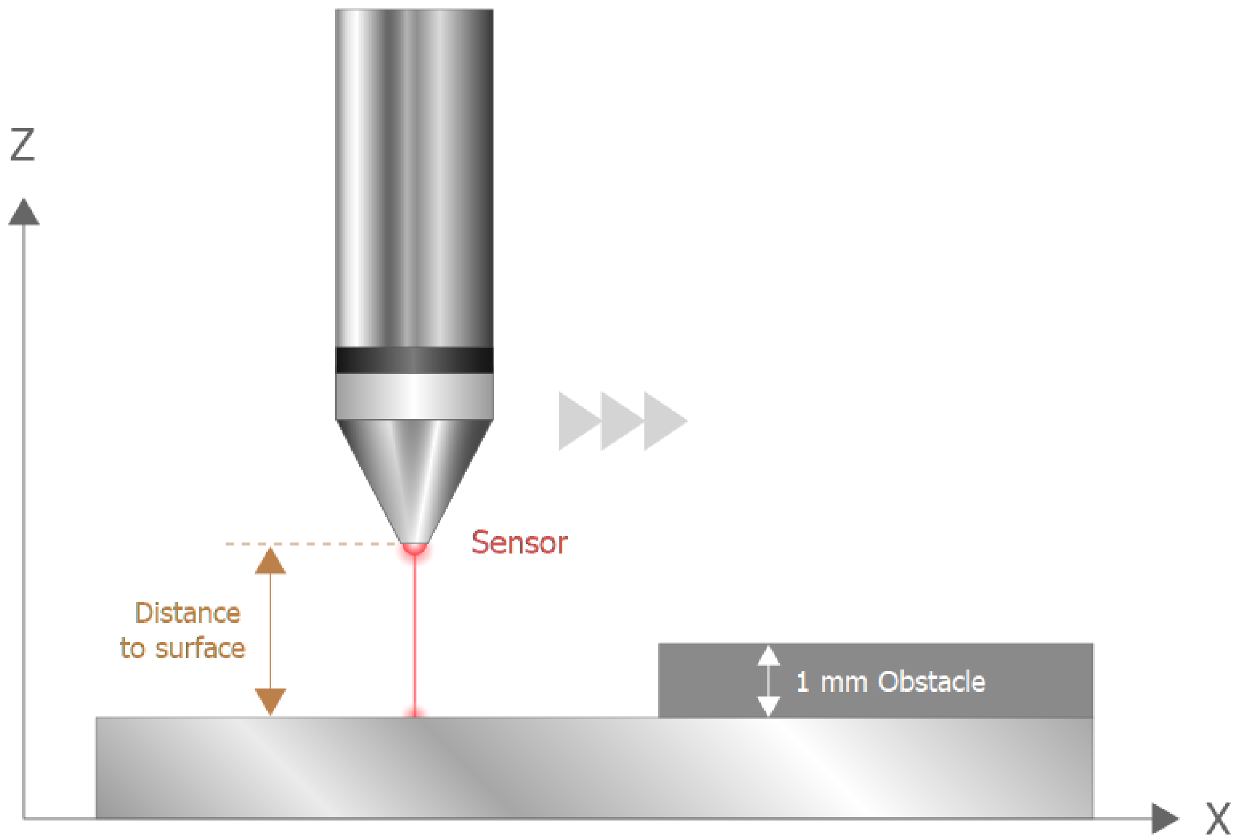



Fig. 8: Test set-up to determine the filter effect

The figure below shows the unfiltered sensor data recorded.

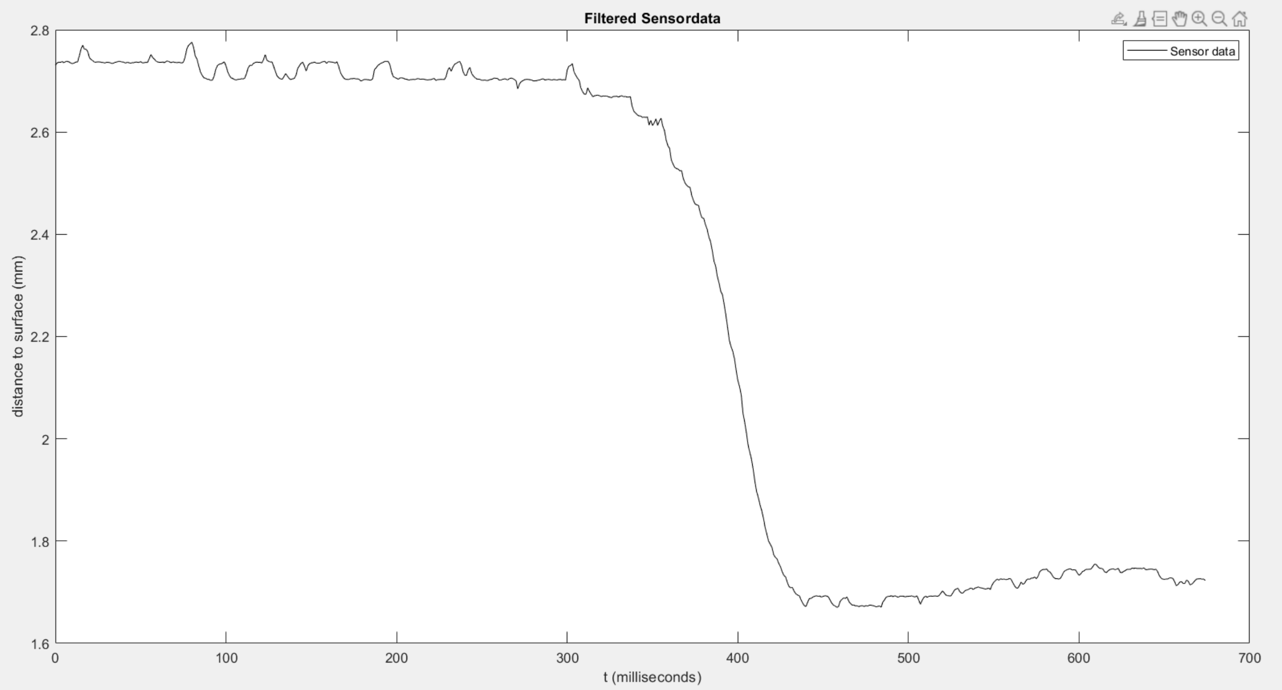



Fig. 9: Unfiltered sensor data when crossing over an obstacle

When you select a filter, remember that the filters introduce a dead time into the system. For the distance controller, this means a slower reaction to changes in distance. When you configure the filter, you must compromise between filter effect and filter delay.

The aim of configuring the filter is to achieve the best possible smoothing of the measured values when traversing the smooth plane and, at the same time, the lowest possible delay when reacting to an obstacle.

**In order to optimise the performance of the distance control, you can also adjust the PID controller at the same time as you configure a suitable filter.**

**⚠ WARNING**

**When you configure filters, remember that an enabled distance controller automatically causes a feedback on the filter. This can lead to undesired behaviour of the distance controller and even result in oscillations on the axis.**

## 4.1 Moving averaging filter

The moving average filter is the sequence of arithmetic averages over a number P-AXIS-00413 [▶ 48] of measured values

**Influence of the parameter:**

It is possible to achieve good smoothing of sensor data with a moving average filter. However, smoothing sensor data causes a relatively large delay in the system. The following conditions for the parameters are active: The more measured values are included in the filter via P-AXIS-00413 [▶ 48], the better the smoothing, but the greater the reaction delay involved.

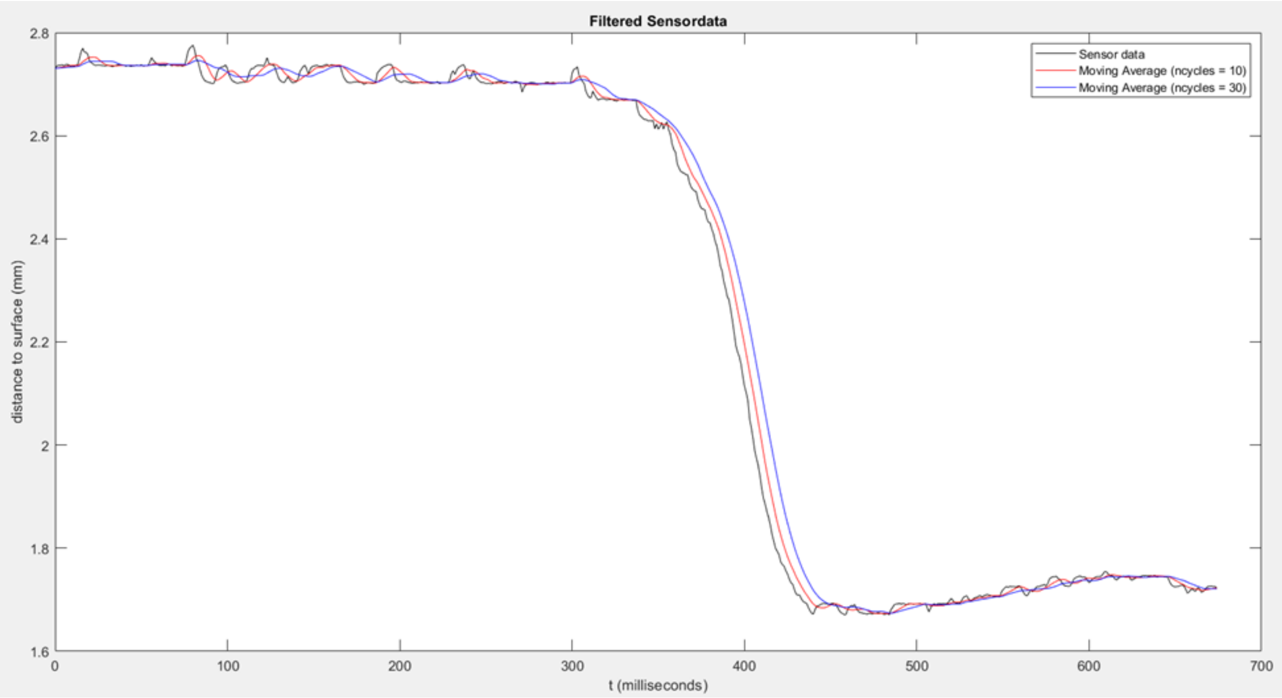



Fig. 10: Different filter effect with varying n_cycles

**Example parameters: Moving averaging filter**

```
kenngr.distc.filter_type MOVING_AVERAGE    #Filter type
#                   Number of included measured values
kenngr.distc.n_cycles    20
```

## 4.2 Exponentially weighted averaging filter

The exponentially weighted averaging filter expands the moving averaging filter by an exponential weighting of the included sensor data. Current measured values are weighted more heavily than older measured values. The weighting of individual measured values is calculated based on a smoothing factor (P-AXIS-00784). The smoothing factor indicates the percentage weighting of the current measured value.

### 4.2.1 Influence of parameters

**Smoothing factor (P-AXIS-00784):**

The greater the weighting of the current measured value, the lower the filter effect but the faster the reaction to changes in the distance.

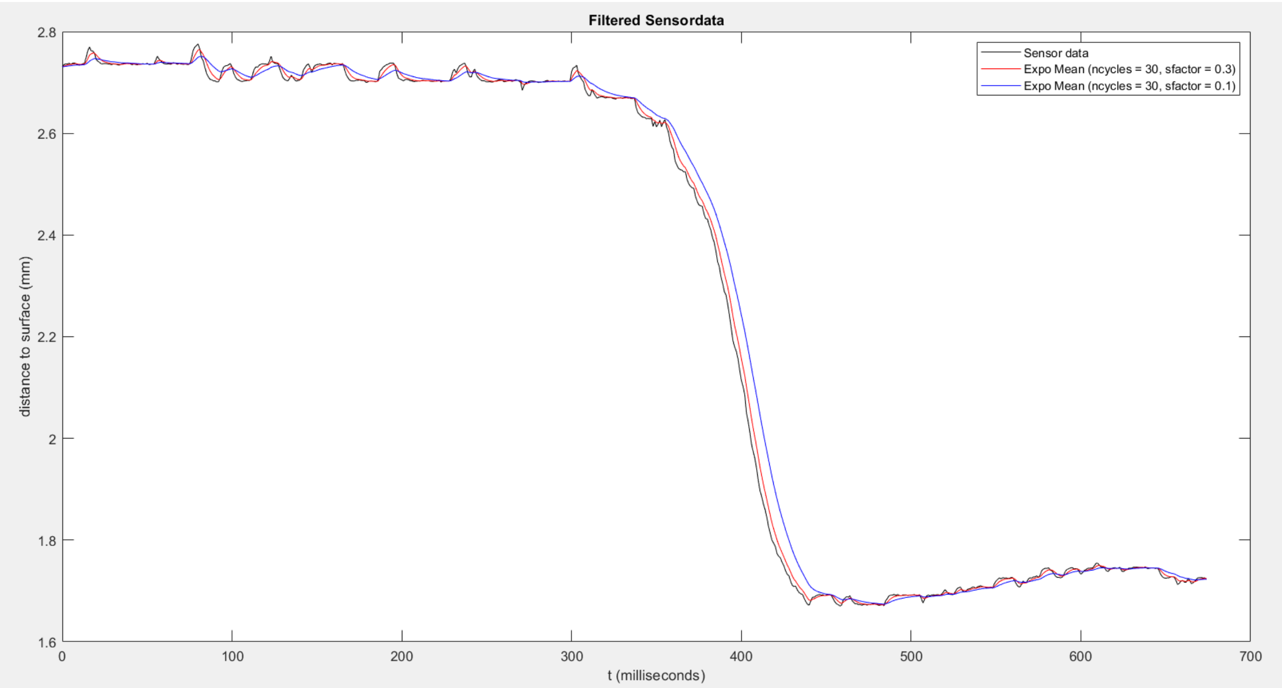



Fig. 11: Different filter effect due to smoothing factor

**Number of measured values - n_cycles (P-AXIS-00413):**

The more measured values are included in the filter via P-AXIS-00413, the better the smoothing, but the greater the reaction delay involved. The greater the smoothing factor, the smaller the influence of P-AXIS-00413. Also, the influence of P-AXIS-00413 decreases steadily with increasing numbers due to the exponential weighting.

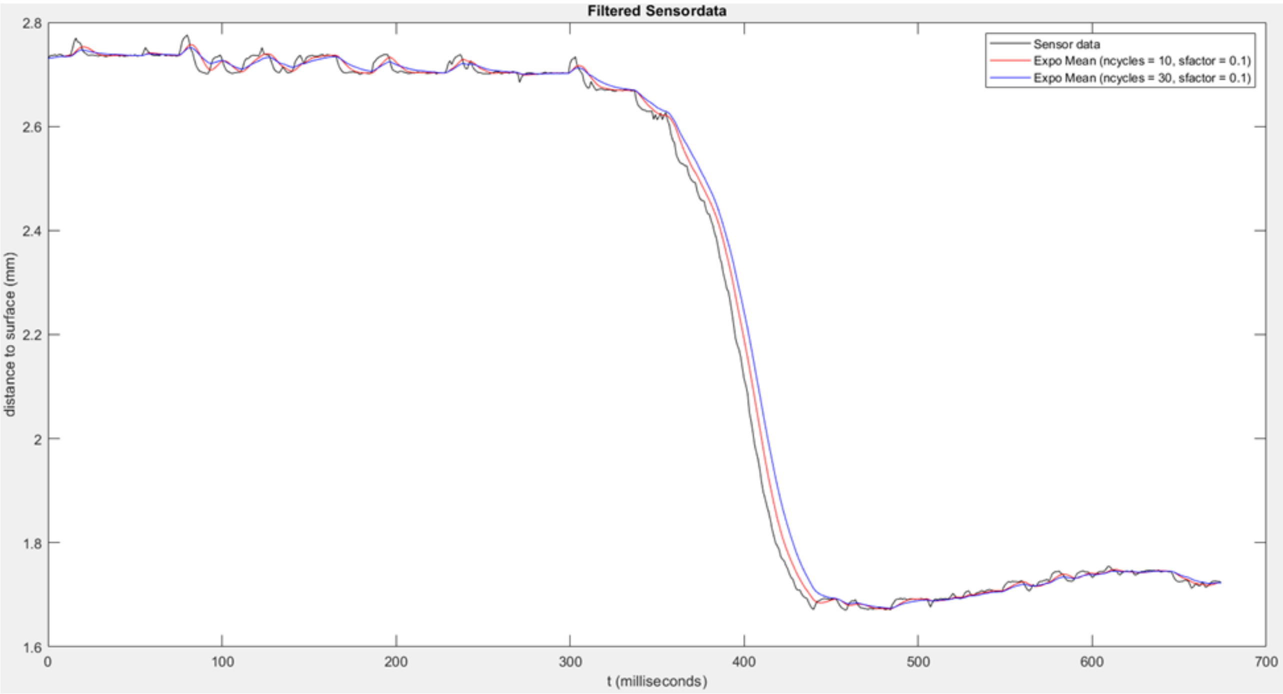



Fig. 12: Different filter effect with varying n_cycles

### Example parameters: Exponentially weighted averaging filter

```
kenngr.distc.filter_type   EXPO_MEAN #Filter type
kenngr.distc.n_cycles      30        #Number of included measured values
kenngr.distc.smoothing_factor 0.3    #Smoothing factor
```

## 4.3 Low-pass filters

The oscillation tendency may be suppressed better by using a low-pass filter if the sensor signal is subject to heavy noise.

### Example parameters

```
kenngr.distc.filter_type LOWPASS # Low-pass filter
kenngr.distc.low_pass_filter_order 2 # Low-pass filter
kenngr.distc.low_pass_filter_fg_f0 30 # Low-pass filter freq 30 Hz
```

## 4.4 Kalman filter with averaging filter model

The Kalman filter tries to estimate the next measured values of the sensor based on a prediction model. The filter first builds the prediction and then refines it by the specified uncertainty of the measured values. The basis of the prediction is the moving averaging filter [▶ 19].

## 4.4.1 Influence of parameters:

**Number of measured values - n_cycles (P-AXIS-00413):**

The parameter P-AXIS-00413 [▸ 48] specifies the number of measured values that are included in the prediction model of the moving averaging filter. Accordingly, the larger the number of included measured values, the better the smoothing effect. The prediction characteristic of the Kalman filter reduces the dead time compared to a conventional moving averaging filter. However, it should be noted that the dead time of the prediction model leads to an oscillation at large changes in distance. The distance increases as the number of included measured values rises (P-AXIS-00413).

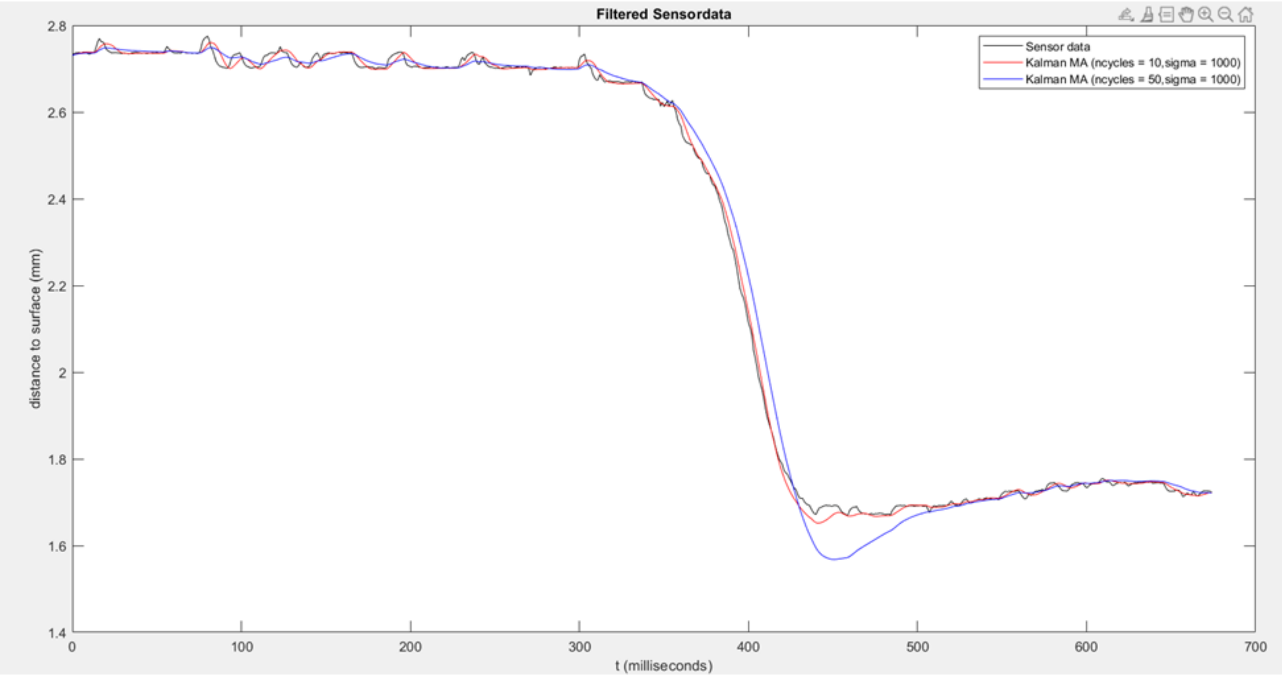



Fig. 13: Different filter effect with varying n_cycles

**Degree of uncertainty - sigma (P-AXIS-00783):**

The parameter P-AXIS-00783 [▶ 57] indicates the degree of uncertainty of the recorded measured values. The lower the specified uncertainty of the measured values, the more the prediction from the moving averaging filter is approximated to the actual measured values.

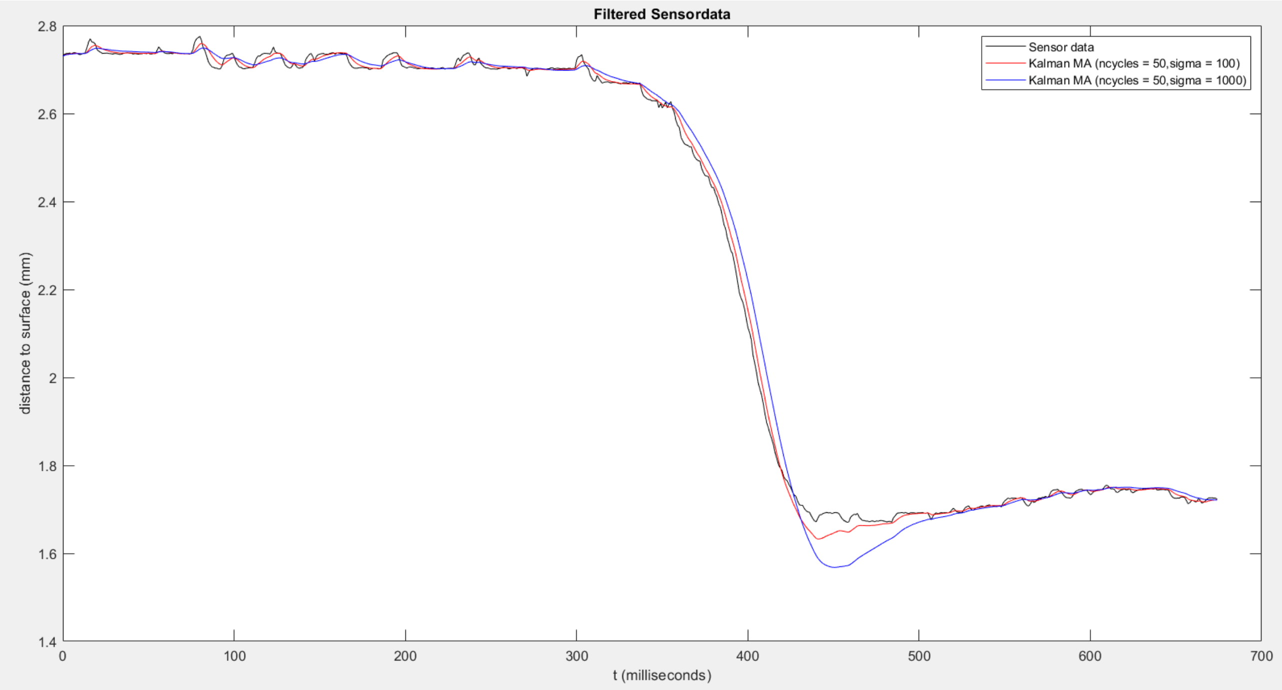



Fig. 14: Different filter effect with varying sigma

### Example parameters: Kalman filter with averaging filter model

```
kenngr.distc.filter_type    KALMAN_MA   #Filter type
kenngr.distc.n_cycles       30          #Number of included measured values
kenngr.distc.kalman_sigma   1000        #Uncertainty of measured values
```

## 4.5 Kalman filter with exponential model

The Kalman filter tries to estimate the next measured values of the sensor based on a prediction model. The filter first builds the prediction and then refines it by the uncertainty of the measured values. The basis of the prediction is the exponentially weighted averaging filter [▸ 20].

### 4.5.1 Influence of parameters:

**Number of measured values - n_cycles (P-AXIS-00413):**

The parameter P-AXIS-00413 specifies the number of measured values that are included in the prediction model of the exponentially weighted averaging filter. Accordingly, the larger the number of included measured values, the better the smoothing effect. The prediction characteristic of the Kalman filter reduces the dead time compared to a conventional exponential averaging filter. However, it should be noted that the dead time of the averaging filter leads to an oscillation with large changes in distance. The distance increases as the number of included measured values rises (P-AXIS-00413).

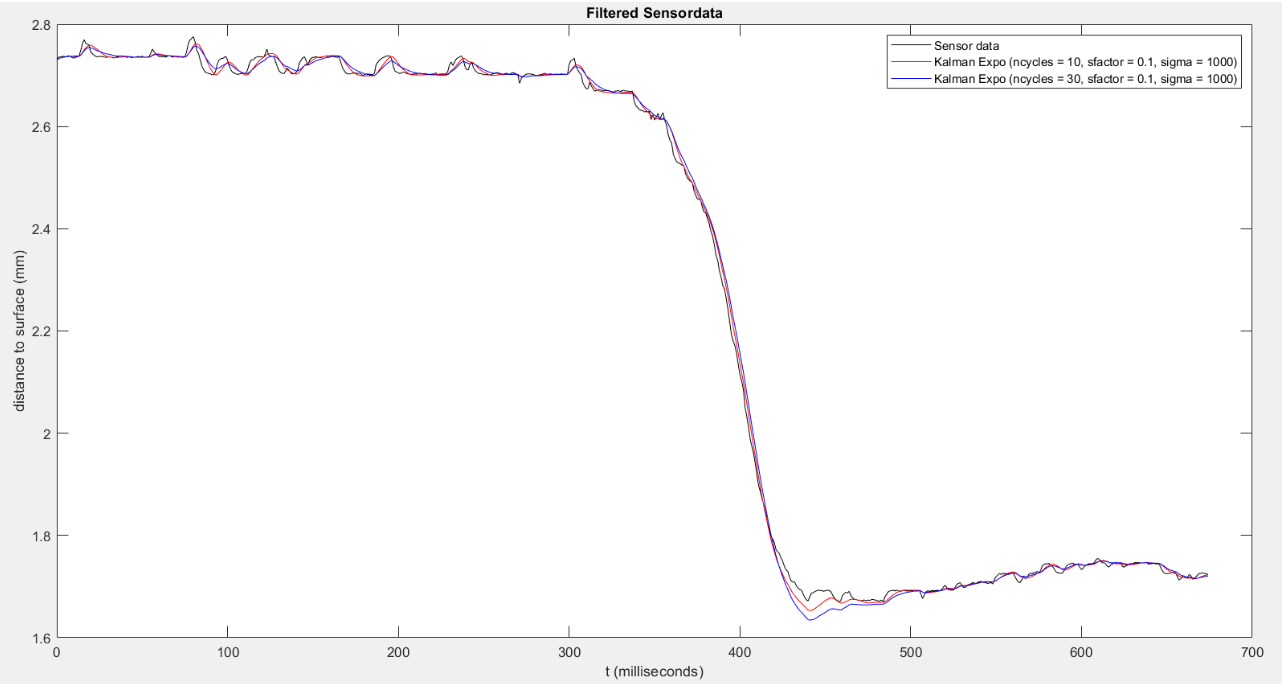



Fig. 15: Different filter effect with varying n_cycles

### Smoothing factor (P-AXIS-00784)

The section Exponentially weighted averaging filter [▶ 20] explains the influence of the smoothing factor on the exponentially weight averaging filter. The oscillation caused by the dead time of the filter can be improved by a higher weighting of the current measured value. At the same time, however, this reduces the smoothing effect.

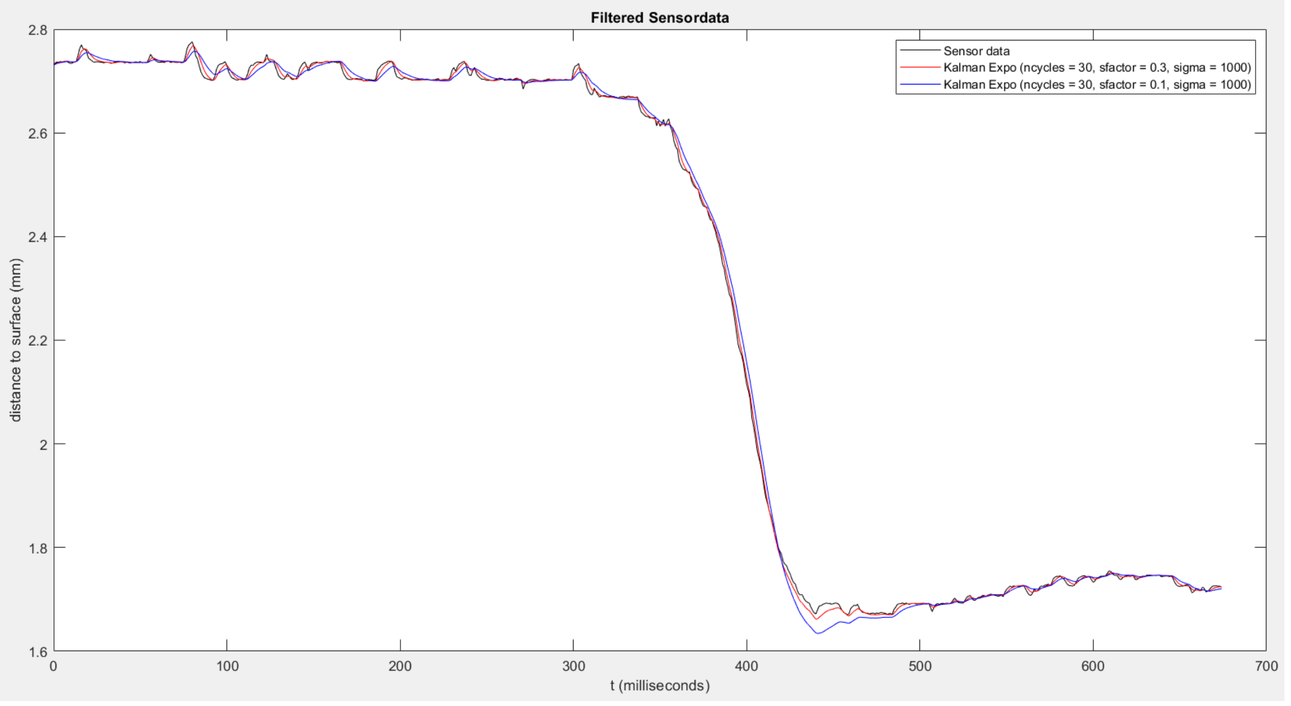



Fig. 16: Different filter effect with varying smoothing factor

**Degree of uncertainty - sigma (P-AXIS-00783):**

The parameter P-AXIS-00783 indicates the degree of uncertainty of the recorded measured values. The lower the specified uncertainty of the measured values, the more the prediction from the moving averaging filter is approximated to the actual measured values.

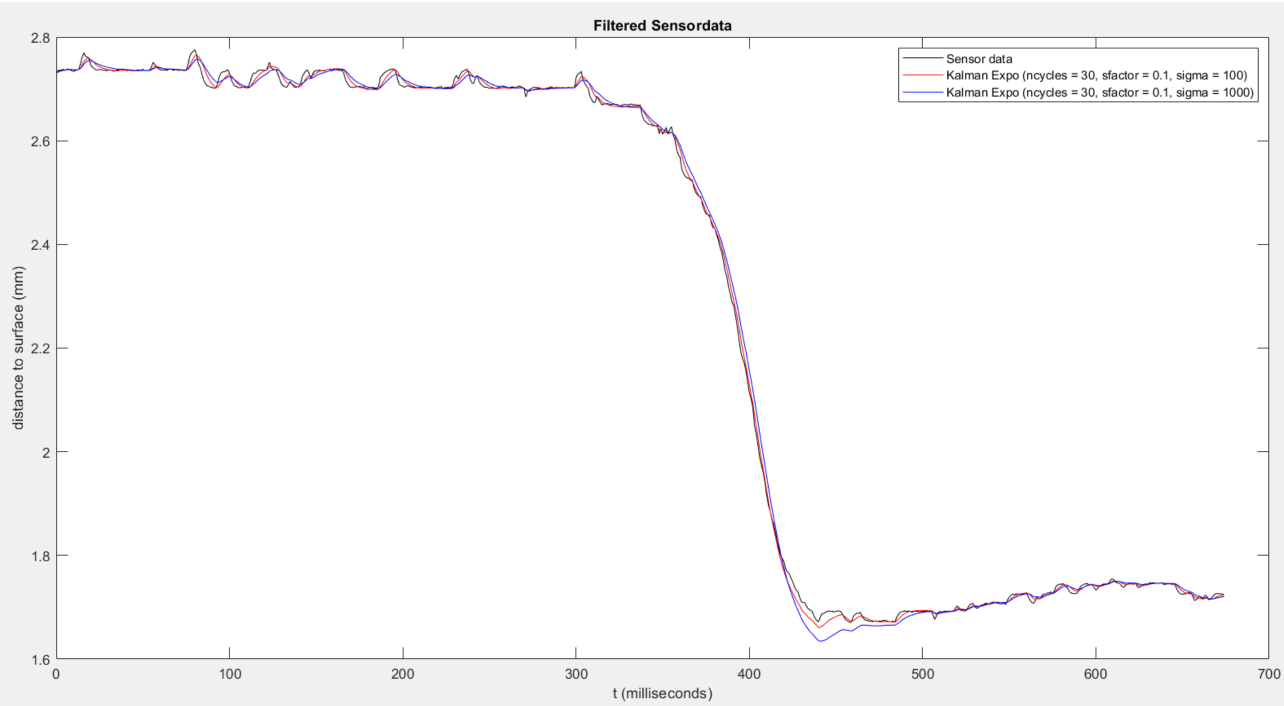



Fig. 17: Different filter effect with varying sigma

### Example parameters: Kalman filter with exponential model

```
kenngr.distc.filter_type  KALMAN_EXPO     #Filter type
kenngr.distc.n_cycles      30         #Number of included measured values
kenngr.distc.kalman_sigma  1000       #Uncertainty of measured values
kenngr.distc.smoothing_factor  0.3   #Smoothing factor
```

# 5 Operation mode of distance control

Distance control is integrated after interpolation and superimposes the programmed motion. Distance control acts independently of the current state of the interpolator, i.e. it is active even when it is waiting for acknowledgements (e.g. M functions).

Distance control determines the actual absolute position of the workpiece surface with the aid of the axis motor encoder and an additional encoder sensor. The two encoders are coupled to one another, i.e. the values of the two encoders always act in opposite directions when the axes move.

The axis-specific feed override and feedhold act on distance control (see [HLI//Control commands of an axis]). When override is 0 or when the axis-specific feedhold is set, the current value of distance control is frozen.

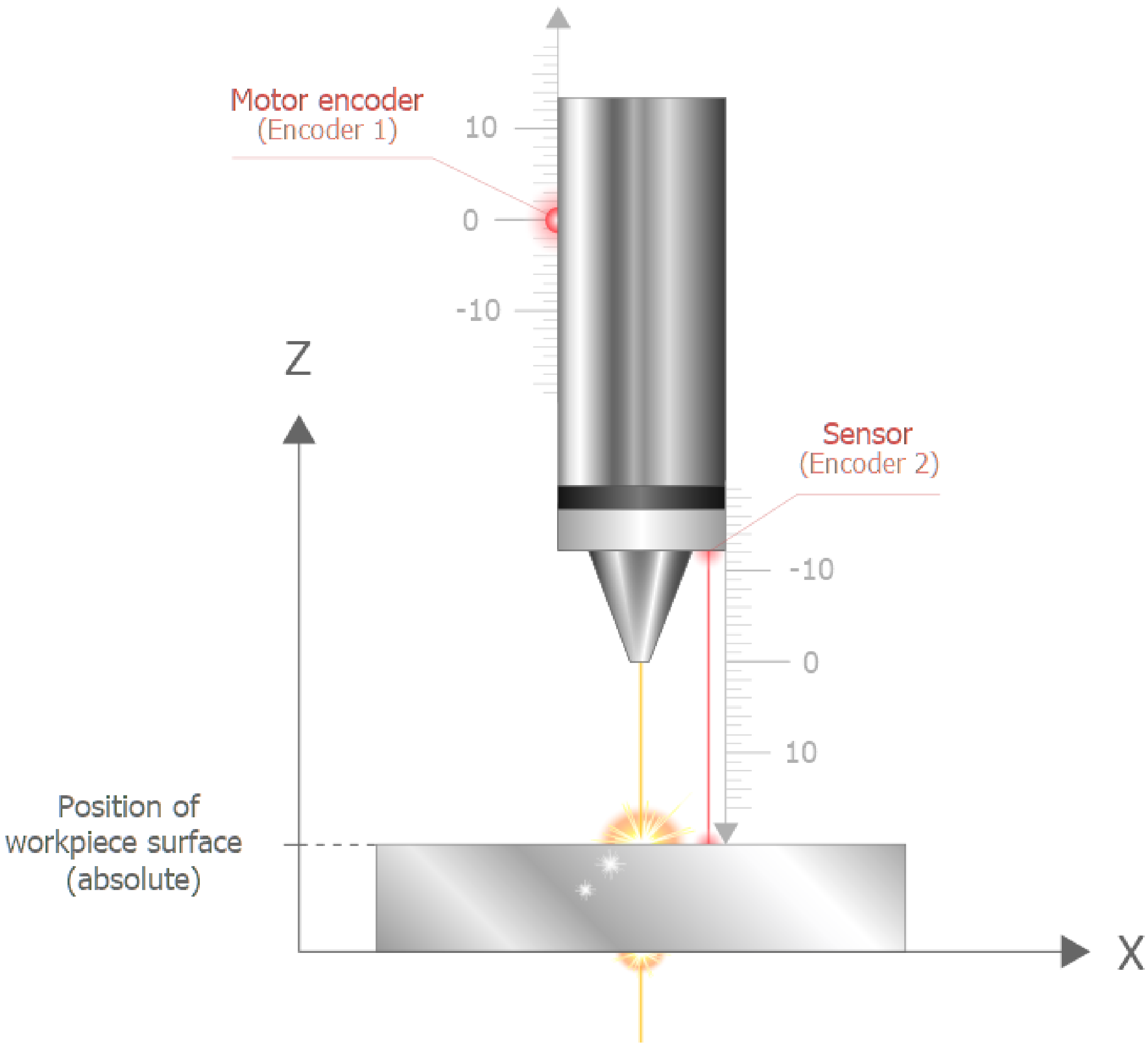



Fig. 18: Sensing the workpiece surface

> The encoder position of the motor and the sensor position must act in opposite directions when the Z axis is lifted or lowered.
>
> For example, if the Z axis is lifted and the encoder value of the motor increases, the encoder value of the sensor must be reduced. If required, the parameter P-AXIS-00230 can be used to invert the motion direction of the sensor.

## 5.1 Specifying the workpiece surface (SET_POS, surface)

**Calculating deviation**

The deviation of the real workpiece surface from the specified command position (SET_POS) is determined in each cycle by the electronic probe. Deviation results from:

Deviation = motor encoder + sensor encoder - set position (SET_POS)

= actual workpiece surface position - set position (SET_POS)

To compensate for the workpiece surface deviation, the drive position is additionally moved by the calculated offset of the distance control:

Drive setpoint = programmed setpoint (PCS) + distance control offset

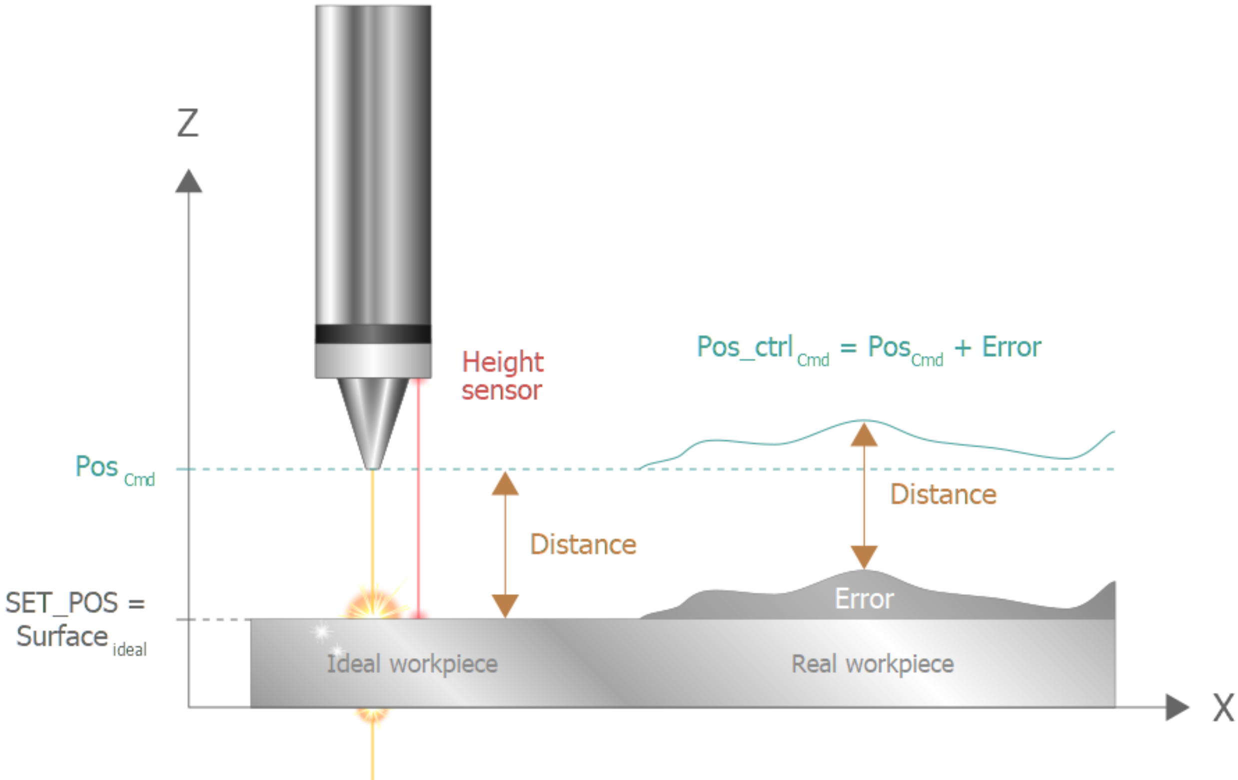



Fig. 19: Specifying the ideal workpiece surface for distance control

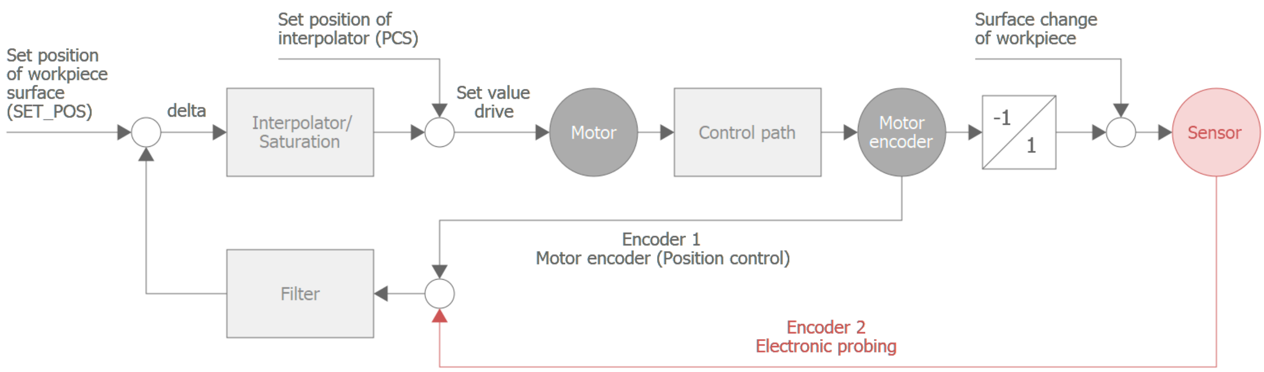



Fig. 20: Block diagram of distance control

### Selecting and deselecting via the NC program

The NC program activates and deactivates distance control and also freezes the current correction value. Example:

```
N10 Z[DIST_CTRL SET_POS=30] Set the position
Nxx Z[DIST_CTRL ON] Select
…
Nxx Z[DIST_CTRL OFF] Deselect
N999 M30
```

The complete CNC syntax is described in the Programming [▶ 38] chapter.

### Typical sequence

Typical sequence for activating distance control:

1. The tool is replaced.
2. X and Y axes move to machining position.
3. Distance control is activated and the workpiece set position is set. The Z axis must then be located within the detection range of the distance sensor.
4. Sensor or probe ring signals distance; distance control corrects height errors.
5. Z axis is lowered.
6. Distance control is active; thickness tolerances or position differences are compensated.

Deactivating distance control:

1. Distance control is deactivated via the NC program
2. Distance control is inactive; thickness tolerances or position differences are no longer compensated; and the current offset remains active until the next position request.

**Operating principle**

With distance control, deviations in the position of the workpiece surface (actual position) can be corrected with respect to a specified set position:

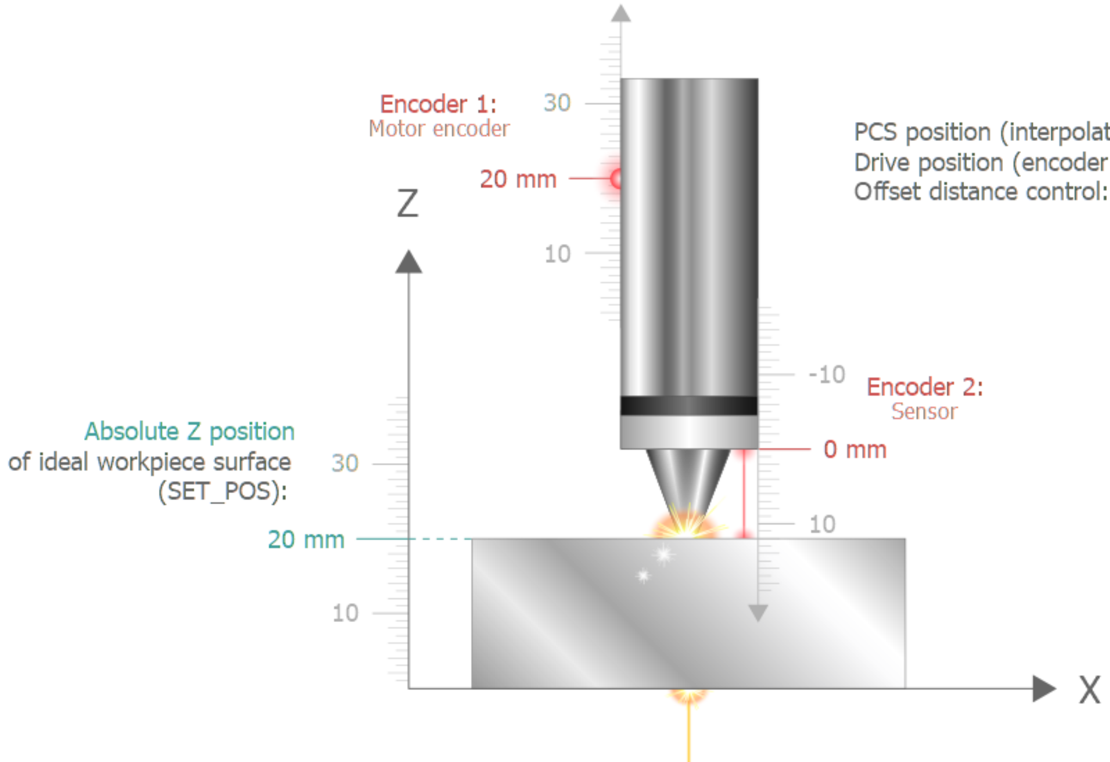



Fig. 21: Ideal workpiece

**Deviation**

A deviation from the ideal workpiece surface (e.g. with a thinner workpiece) is detected by the sensor (encoder 2):

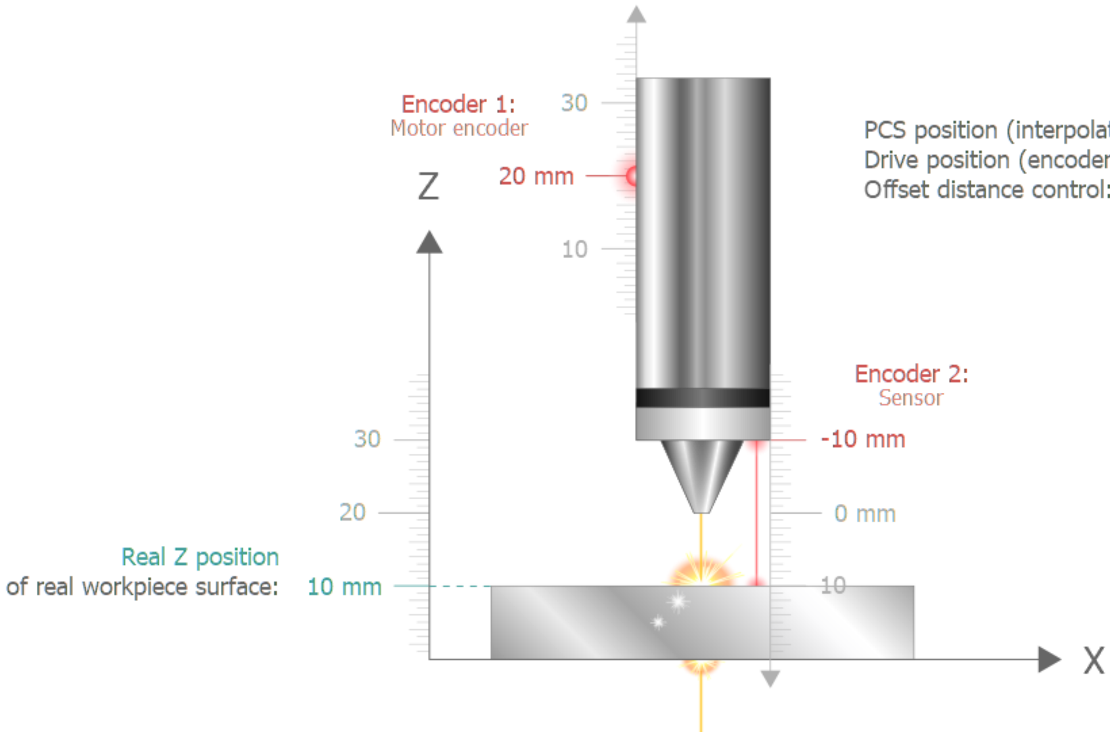



Fig. 22: Real workpiece without distance control

**Offset compensation**

After activation of distance control with SET_POS=20 mm (expected workpiece height), the offset is compensated by distance control. As a result, there is no need to adapt the NC program (PCS position). The NC program assumes a constant workpiece surface of Z=20 mm.

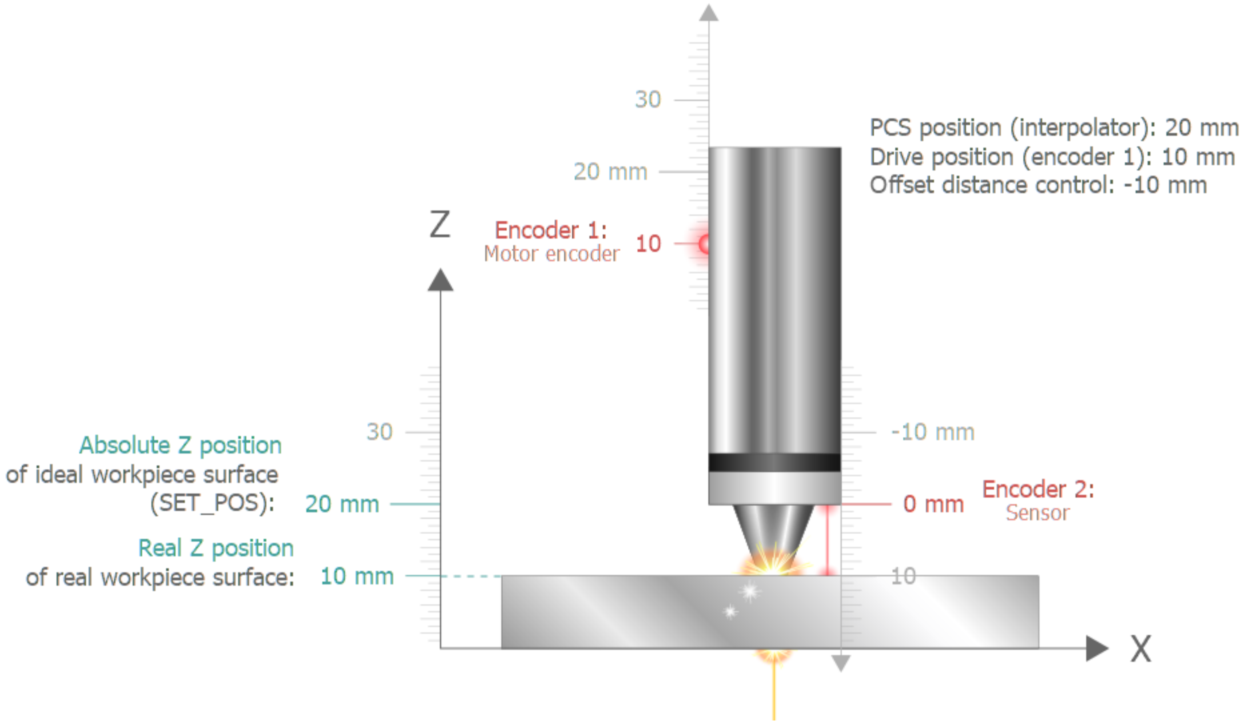



Fig. 23: Real workpiece with distance control

Distance control is automatically deactivated if an axis error or a CNC reset occurs.

At program end, distance control remains active.

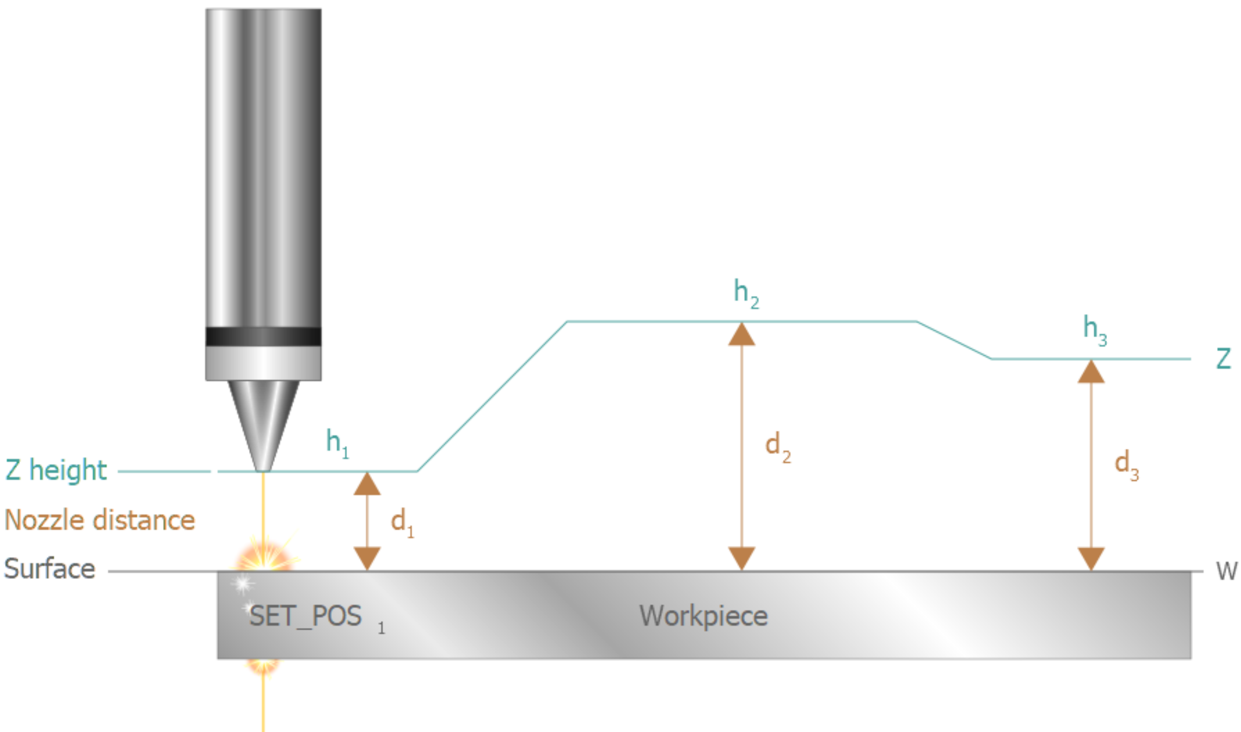



Fig. 24: Constant workpiece surface with changed tool distance

### Height changes

Changes in the workpiece surface are compensated by distance control. The NC program therefore assumes a plane workpiece. Height changes in the workpiece surface can be defined by programming the axis. At Z=SET_POS the TCP tip touches the workpiece surface.

## 5.2 Specifying the distance (SET_DIST, distance)

Specifying the set distance for distance control is only available as of CNC Build V2.11.2800.28.

**Distance**

In addition to specifying the workpiece surface for a given tool height (*see previous section*), the distance between the tool and the workpiece can also be specified directly in the NC program or via the PLC as of CNC Build V2.11.2800.28.

When distance is commanded via the PLC interface, the set distance can be respecified in every cycle.

In this case tool height is no longer changed by the NC program but is changed explicitly by distance control. This is especially of advantage when a constant distance needs to be maintained to a workpiece surface of any curvature.

For large changes, distance control is supported by additional programming of the Z axis.

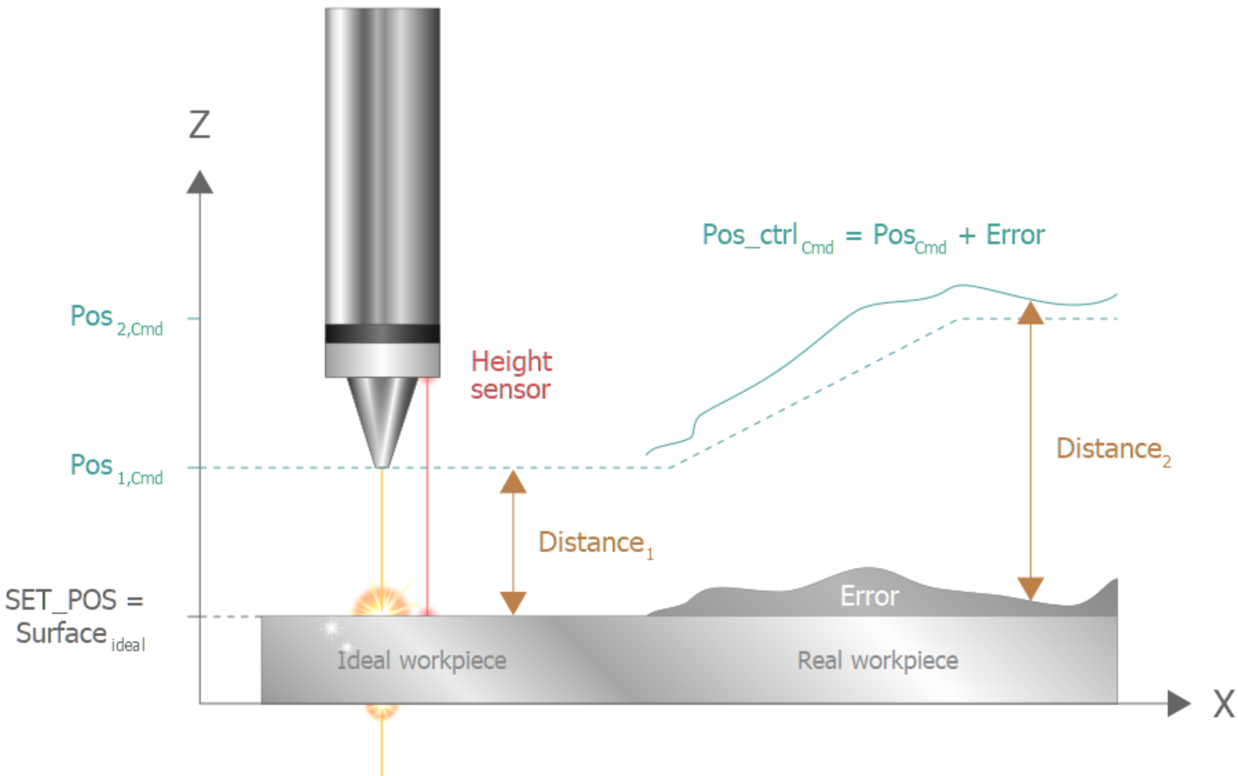



Fig. 25: Specifying the distance to workpiece for height control

| NOTICE |
| --- |
| If distance control is activated in "constant distance" mode, no further changes in distance to the workpiece can be specified for this axis in the NC program by explicit programming of the Z axis. |

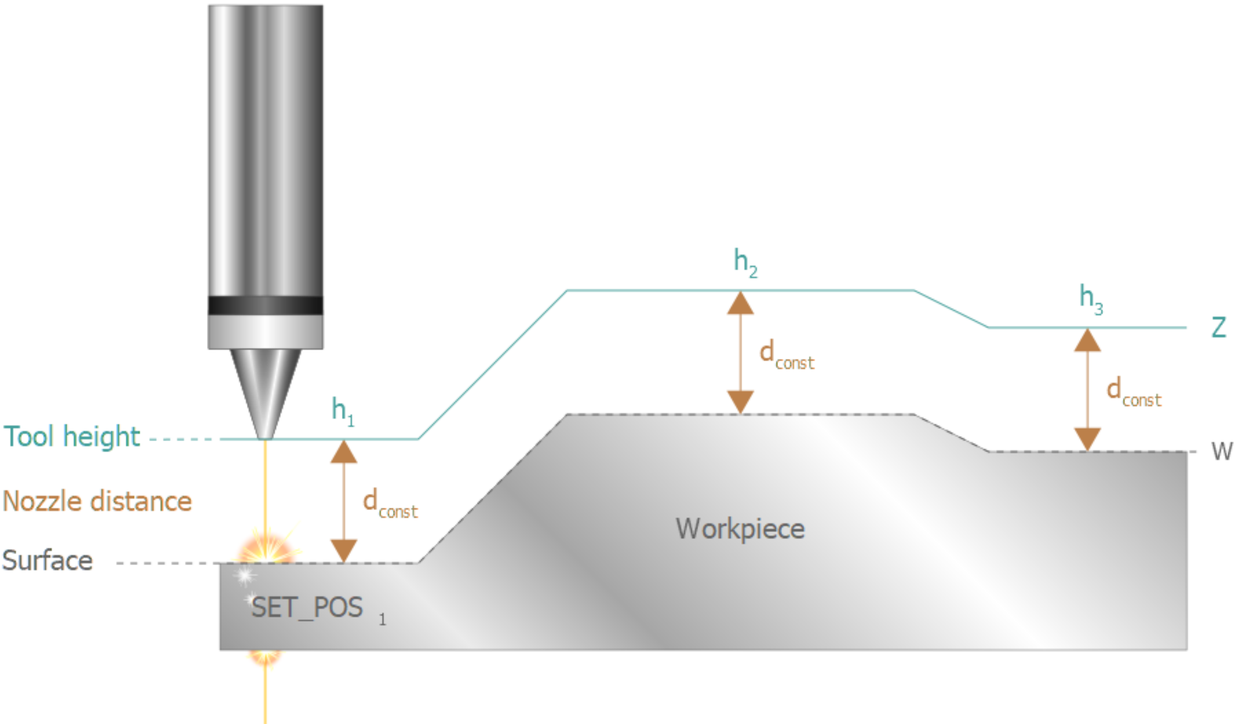



Fig. 26: Profiled workpiece surface with constant tool distance

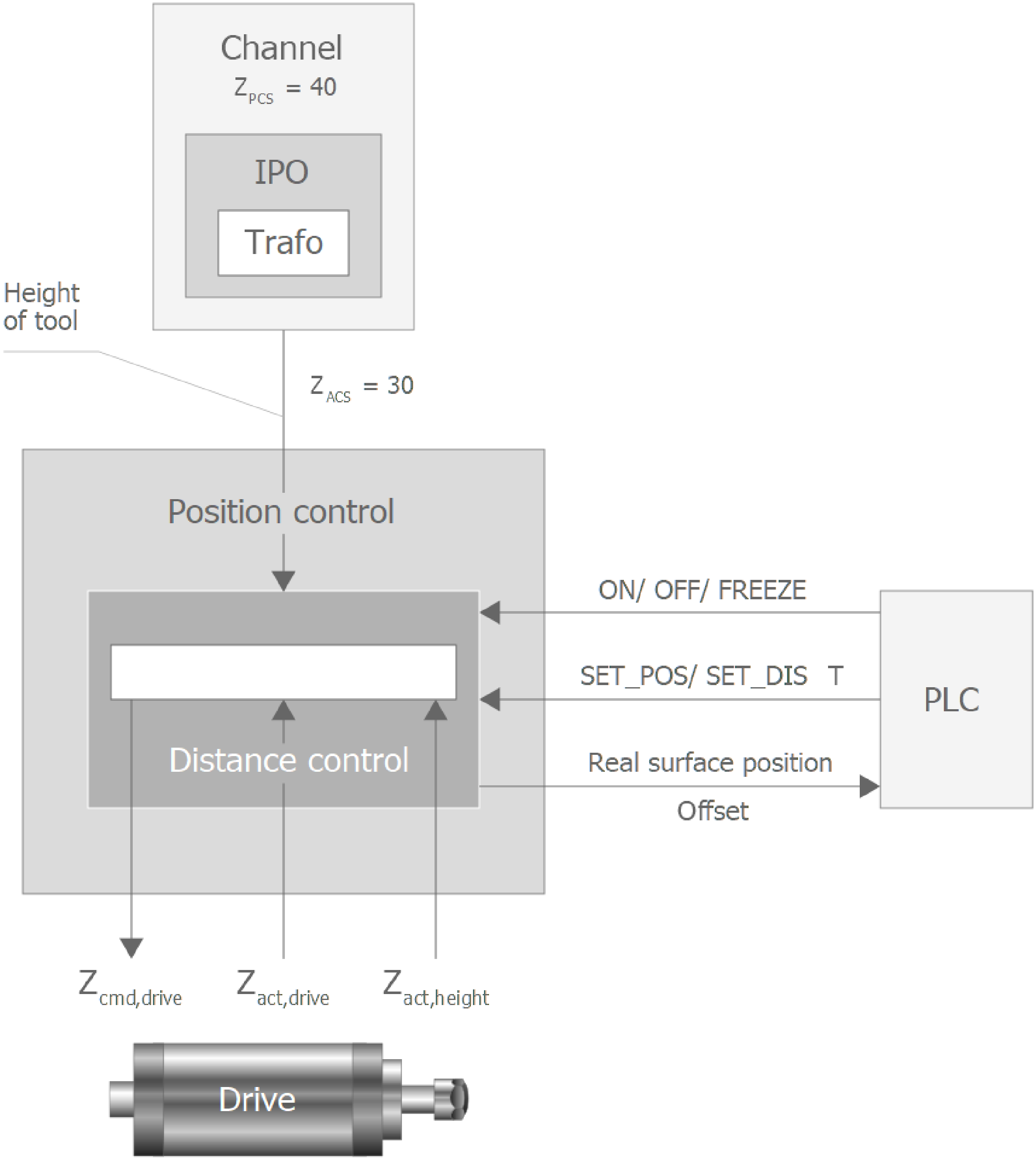



Fig. 27: Specifying the distance: distance

When the Z axis is lifted, distance control must be frozen (FREEZE) or deactivated (OFF), otherwise distance control prevents lifting/lowering.

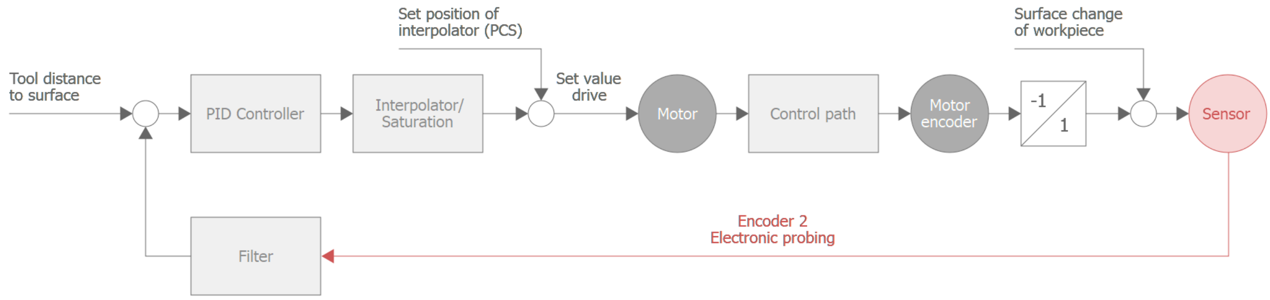



Fig. 28: Block diagram of distance control with distance specification

# 6 Programming

```
Syntax:
```

*<axis_name>* **[DIST_CTRL** [**ON** [ **DRYRUN** ] [ **CONST_DIST** ]] | [**OFF** | **CHECK_POS** | **FREEZE** | **REF**]
**SET_POS**=.. **SET_DIST**=.. [ **KP**=.. ] [ **I_TN**=.. ] [ **D_TV**=.. ] [ **FILTER_TYPE**=.. ]
[ **N_CYCLES**=.. ] [ **FG_F0**=.. ] [ **ORDER**=.. ] [ **SMOOTH_FACT**=.. ] [ **KALMAN_SIGMA**=.. ]
[ **NO_MOVE** ] [ **VAL1**=.. - **VAL5**=.. ] { \ } **]**

| | |
|---|---|
| *<axis_name>* | Name of the axis supporting the tool. |
| DIST_CTRL | Identifier for the "Sensed spindles" function. Must always be programmed as the first keyword. |
| ON | Distance control on when workpiece surface is specified. A set position (SET_POS) must be set at switch-on. |
| CONST_DIST | Activate distance control (ON) when a constant distance to the workpiece surface is specified. A distance must be set with SET_DIST at switch-on. [as of Build V2.11.2804.03] |
| OFF | Deactivate distance control. |
| CHECK_POS | Check whether position is within the tolerance window. |
| FREEZE | Freeze the control distance across the workpiece. The axis position or the output correction value is maintained. Axis tracking is interrupted. |
| DRYRUN | In combination with ON, the axis is not tracked in DRYRUN mode when there are changes in the workpiece surface. This allows data to be evaluated without feedback from the controller (e.g. filter effect). **[as of V3.1.3079.23]**<br>When distance control is activated, a set position must be set with SET_POS if the workpiece surface is specified.<br>When distance control is activated, a set distance must be set with SET_DIST if a constant distance from the workpiece surface is specified. |
| REF | Reference measuring system (sensor) (only if there is no absolute measuring system). |

| | |
|---|---|
| SET_POS=.. | Specify the workpiece surface in [mm, inch] (absolute position). In the event of reset or program end, the set position is reset, i.e. a new set position must be specified before distance control is reactivated. |
| SET_DIST=.. | Specify the constant distance to the workpiece surface in [mm, inch]. In the event of reset or program end, the distance is reset, i.e. a new distance must be specified before distance control is reactivated. |
| KP=.. | Weighting the distance control output values. Parameterisation can be executed analogous to P-AXIS-00759 [▶ 55]. The value range is limited to 0.0 < KP <= 2.0. For KP values less than 1.0, the distance control dynamics are reduced; for KP values greater than 1.0, the dynamics are increased.<br>A KP factor less than 1.0 reduces 1 possible distance control oscillation and steadies control in the event of minor distance errors. **[as of V2.11.2809.06 or V3.1.3079.06]** |
| I_TN=.. | Integral action time of the PID controller in [s]. The integral action time defines the time after which the P and I components of the manipulated variable are equal. Parameterisation can be executed analogous to P-AXIS-00764 [▶ 55]. The value range is limited to 0.0 <= I_TN <= 50.0. A large integral action time produces greater control stability. The shorter the integration action time, the greater the I component and the faster the control. A short integral action time excites oscillations more strongly. **[as of V2.11.2809.06 or V3.1.3079.06]** |
| D_TV=.. | Derivative action time of the PID controller in [s]. The derivative action time defines the time after which the P and D components of the manipulated variable are equal. Parameterisation can be executed analogous to P-AXIS-00765 [▶ 56]. The value range is limited to 0.0 <= D_TV <= 2.0. The larger the derivative action time, the stronger the D component. **[as of V2.11.2809.06 or V3.1.3079.06]** |
| FILTER_TYPE=.. | Filter type to filter sensor values according to P-AXIS-00782 [▶ 56]. **[as of V3.1.3079.23]** |
| N_CYCLES=.. | Number the measured values used for filtering according to P-AXIS-00413 [▶ 48]. **[as of V3.1.3079.23]** |
| FG_F0=.. | Cut-off frequency for the low-pass filter in [Hz] according to P-AXIS-00508. **[as of V3.1.3079.23]** |
| ORDER=.. | Order of the low-pass filter according to P-AXIS-00507. **[as of V3.1.3079.23]** |
| SMOOTH_FACT=.. | Smoothing factor of the exponential averaging filter according to P-AXIS-00784. Specifies the weighting of the current measured value. |
| KALMAN_SIGMA=.. | Uncertainty of the included measured values according to P-AXIS-00783 [▶ 57]. **[as of V3.1.3079.23]** |
| NO_MOVE | By default, the resulting correction offset is deactivated when distance control is switched off. This motion can be suppressed by specifying NO_MOVE in combination with OFF. The channel is initialised with the changed axis position. The position offset is only deactivated at the next axis motion programmed in the NC program. |
| VAL1=..-VAL5=.. | Five freely assignable values in real format. |
| \ | Separator ("backslash") for clear programming of the command over multiple lines. |

The keywords ON/OFF, FREEZE, DRYRUN, CHECK_POS and REF in the same command sequence mutually cancel each other out.

The keywords SET_POS, SET_DIST and VAL1-VAL5 can always be programmed in combination with each other.

If distance control is still active at program end, it is not automatically deselected.

When a reset or axis error occurs, active distance control is always deselected automatically.

Parameters of the PID controller are not reset at program end.

### Programming examples for distance control

```
%DIST_1
; Set expected position of the workpiece surface
N10 Z[DIST_CTRL SET_POS=30]

N20 Z[DIST_CTRL ON]           ;Select
; …
Nxx Z[DIST_CTRL OFF]         ;Deselect
N999 M30
```

```
%DIST_2
; Select + set expected position of the workpiece surface
N10 Z[DIST_CTRL ON SET_POS=30]

; …
Nxx Z[DIST_CTRL FREEZE]       ;Hold position
; …
Nxx Z[DIST_CTRL OFF]          ;Deselect
N999 M30
```

```
%DIST_3
; Select + set expected position of the workpiece surface
N10 Z[DIST_CTRL ON SET_POS=50]

; Deactivate distance control; Z axis does not move
Nxx Z[DIST_CTRL OFF NO_MOVE]
; The generated compensation offset is included for motion to the target point
; 100.
Nxx G0 Z100
N999 M30
```

```
%DIST_4
; Set distance parameters
N10 Z[DIST_CTRL SET_POS=30 SET_DIST=10]
; Select with specified workpiece surface (SET_POS)
N20 Z[DIST_CTRL ON]
; …
Nxx Z[DIST_CTRL OFF]           ;Deselect
; …
; Select with specified workpiece surface (SET_DIST)
Nxx Z[DIST_CTRL ON CONST_DIST]
; …
Nxx Z[DIST_CTRL OFF           ;Deselect
N999 M30
```

```
%DIST_5
N10 Z[DIST_CTRL FILTER_TYPE=KALMAN_MA] ;Select filter type
; Parametrise filter
N20 Z[DIST_CTRL N_CYCLES=30 KALMAN_SIGMA=1000]
; Activate distance control
N30 Z[DIST_CTRL ON CONST_DIST SET_DIST=1].
; …
; Change filter
Nxx Z[DIST_CTRL FILTER_TYPE=KALMAN_EXPO SMOOTH_FACT=0.3]
.
.
Nxx Z[DIST_CTRL OFF]; Deselect
N999 M30
```

# 7 Various distance control options

## 7.1 Option: Use of distance sensor and motor encoder

This option is available starting at CNC Build V2.11.2804.02 and higher.

**Distance sensor**

Normally the distance is just measured by the distance sensor. The actual position of the Z axis is not included.

Deviation = Set distance - Sensor value

$\Delta d = d_{com} - d_{act}$ (controller$_{DistCtrl}$: $Z_{offset,i} = Z_{offset,i-1} + \Delta d$)

$d_{act}$ = Filter ($d'_{act}$)

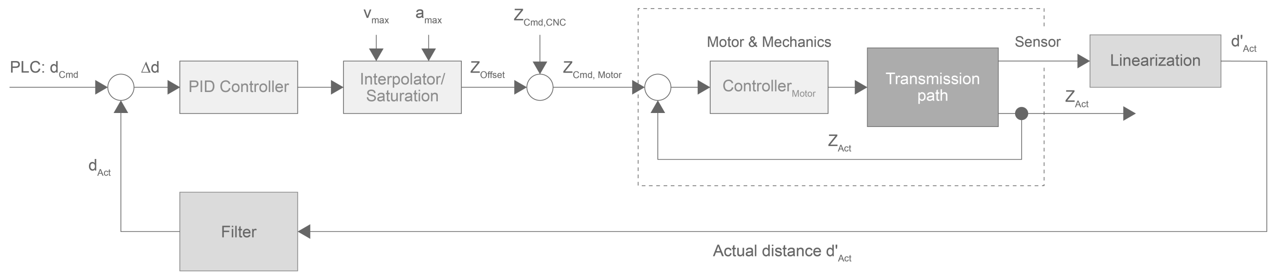



Fig. 29: Block diagram of distance control with distance sensor

### Distance sensor and motor encoder

As an extension, both the distance sensor and the Z actual value sensor can be used. The inverse coupling of the two encoders (motor, distance) generally causes a reduction in oscillation tendency.

Deviation = Set distance - Sensor value

$\Delta d = d_{com} - d_{act}$ $(Z_{offset,i} = Z_{offset,i-1} + d\varepsilon)$

$d_{act} = filter\ (d'_{act} + Z_{act} - Z_{com}) = filter\ (d'_{act} - \Delta Z)$

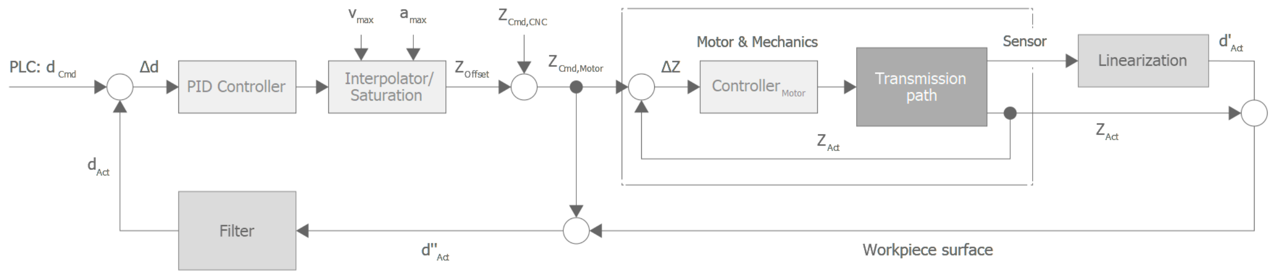



Fig. 30: Block diagram with distance sensor and motor encoder

### Example parameters

kenngr.distc.mode_dist_use_both_encoder 1 # motor and distance encoder active

## 7.2 Option: Weighting of acceleration dependent on distance deviation

This option is available starting at CNC Build V2.11.2804.02 and higher.

#### Acceleration weighting

To reduce a possible oscillation the acceleration can be reduced for small deviations.

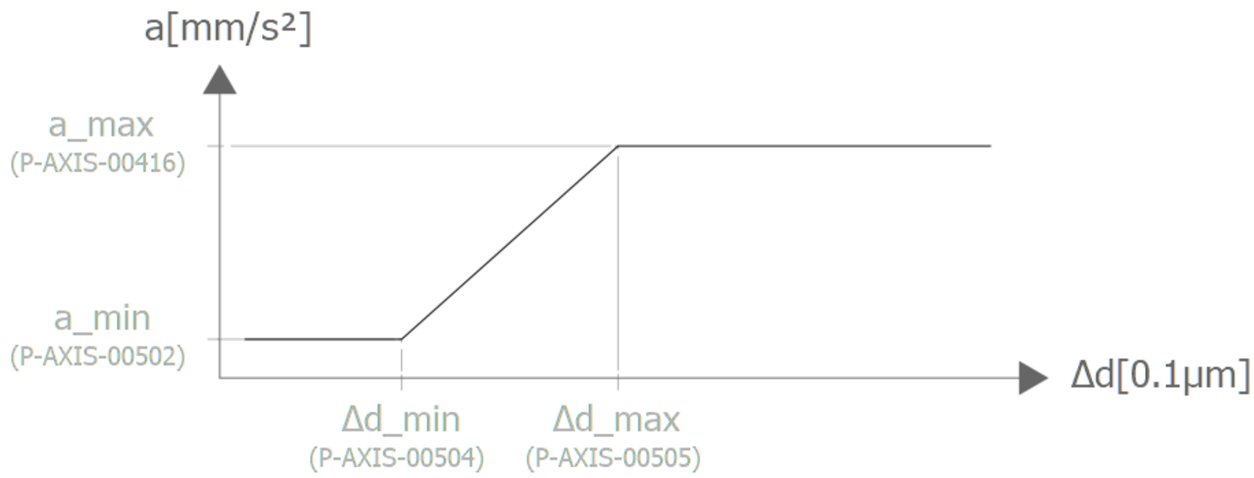



Fig. 31: Distance-dependent acceleration weighting

#### Example parameters

| | | |
|---|---|---|
| kenngr.distc.use_adaptive_acceleration | 1 | # adaptive acceleration active |
| kenngr.distc.a_min | 1000 | # [mm/s*s] Min. acceleration |
| kenngr.distc.a_max | 10000 | # [mm/s*s] Max. acceleration |
| kenngr.distc.dist_error_a_min | 250 | # [0.1 µm] Min. distance error |
| kenngr.distc.dist_error_a_max | 500 | # [0.1 µm] Max. distance error |

## 7.3 Option: Dead time reduction

This option is available starting at CNC Build V2.11.2804.02 and higher.

**Dead time reduction**

The dead time of distance control can be reduced by an optimized schedule of the CNC. This setting is generally recommended.

**Example parameters**

```
kenngr.distc.optimized_scheduling 1 # Scheduling active
```

# 7.4 Option: Dynamic weighting of the lowering movement

This option is available starting at CNC Build V2.11.2807.13 and higher.

**Dynamic weighting of the lowering movement**

The “dynamic weighting of the lowering movement” option can be used to reduce the speed and acceleration of the lowering movement towards the workpiece. The lifting movement normally uses high dynamics in order to be able to avoid obstacles or protrusions quickly. The weighting can be used to reduce the dynamics of the lowering movement compared to the lifting movement in order to approach the workpiece more slowly.

This option can also be combined with the “acceleration weighting dependent on distance deviation” option.

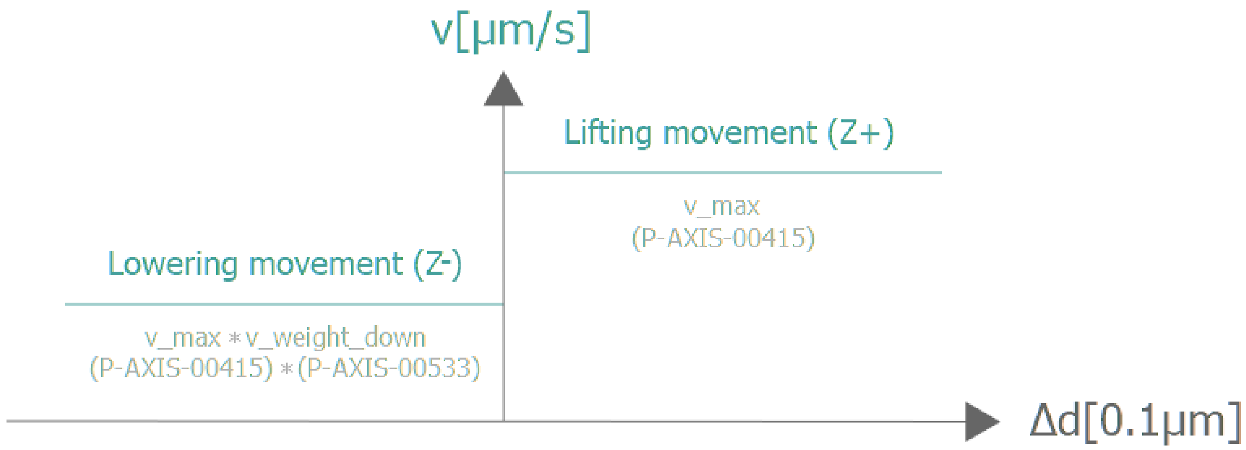



Fig. 32: Reduction in velocity by dynamic weighting of the lowering movement

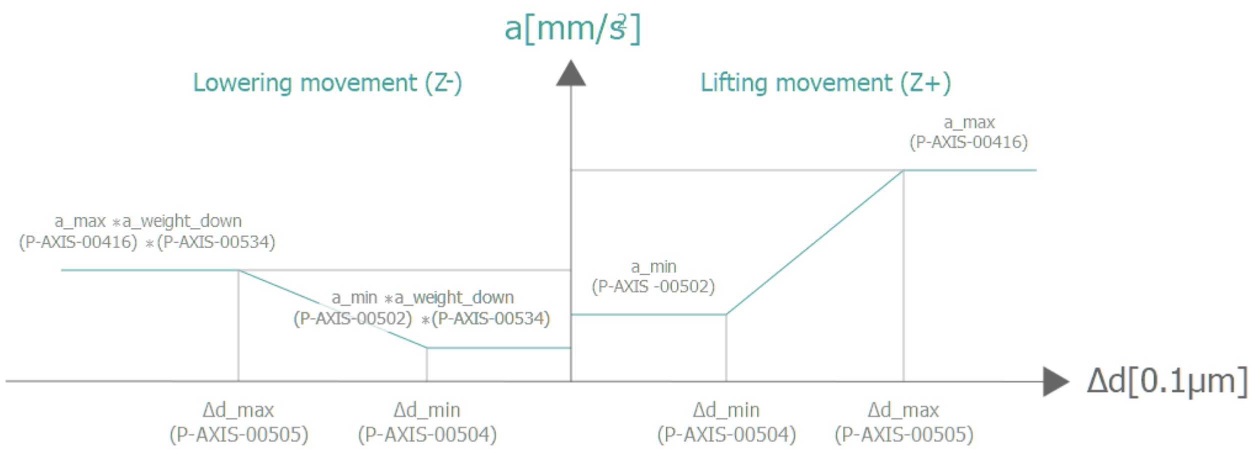



Fig. 33: Reduction in acceleration by dynamic weighting of the lowering movement

**Example parameters**

| | | |
|---|---|---|
| kenngr.distc.v_weight_down | 500 | # Lowering movement at 50% velocity of P-AXIS-00415 |
| kenngr.distc.a_weight_down | 300 | # Lowering movement at 30% acceleration of P-AXIS-00416 |

# 7.5 Changing parameters

The parameters kenngr.distc.v_max (P-AXIS-00415) and kenngr.distc.a_max (P-AXIS-00416) for speed and acceleration which distance control uses to correct deviations by constance control can be changed using ISG Objects.

The objects provided are in the GEO task and are:

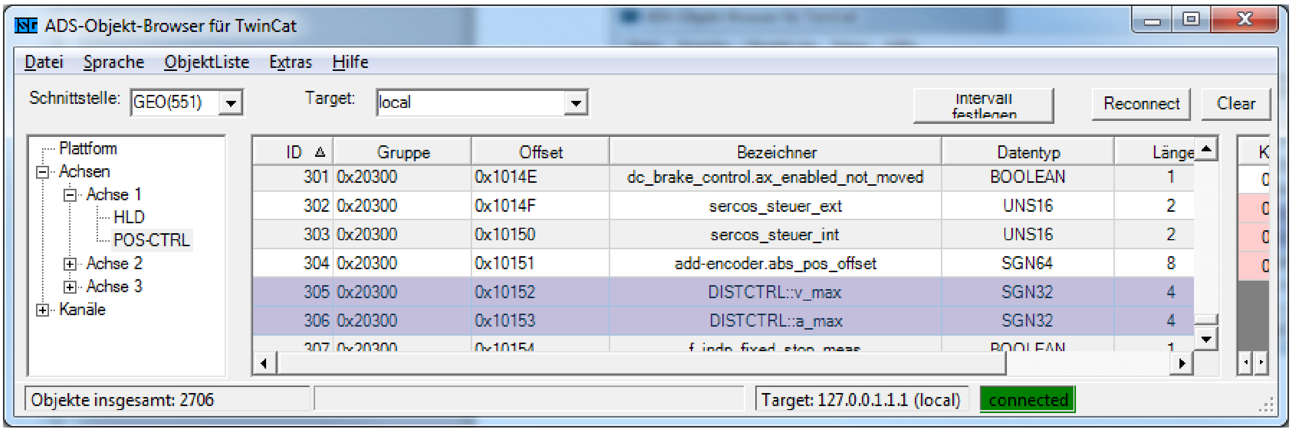
| Name | Type | Unit | Index-Group | Index-Offset |
|---|---|---|---|---|
| DISTCTRL::v_max | SGN32 | µm/s | 0x20300 | 0x10152 (*) |
| DISTCTRL::a_max | SGN32 | mm/s^2 | 0x20300 | 0x10153 (*) |

(*) for the first axis, otherwise + 0x10000 * axis_index (e.g. 0x30152 for the third axis)

Take note that the new values are only adopted and active in the internal distance control work data for the following transitions for security reasons:

1. from INACTIVE to ACTIVE state or
2. from FREEZE to ACTIVE state

Parameters can be changed directly from the ISG object browser.



# 8 Parameter

## 8.1 Overview

| ID | Parameter | Description |
|---|---|---|
| **P-AXIS-00328** | lr_param.distance_control_on | Enabling of distance control |
| **P-AXIS-00414** | kenngr.distc.max_deviation | Maximum position offset [0.1 µm] |
| **P-AXIS-00415** | kenngr.distc.v_max | Maximum velocity [µm/s] |
| **P-AXIS-00416** | kenngr.distc.a_max | Maximum acceleration [mm/s^2] |
| **P-AXIS-00417** | kenngr.distc.max_act_value_change | Maximum permissible change speed of measured distance [0.1 µm/cycle] |
| **P-AXIS-00418** | kenngr.distc.ref_offset | Reference point offset for control measuring system |
| **P-AXIS-00419** | kenngr.distc.max_pos | Upper limit for measuring system |
| **P-AXIS-00420** | kenngr.distc.min_pos | Lower limit for measuring system |
| **P-AXIS-00421** | kenngr.distc.tolerance | Tolerance band for limits |
| **P-AXIS-00428** | kenngr.distc.check_sw_limit_switch | Consideration of distance control in software limit switch monitoring |
| **P-AXIS-00500** | kenngr.distc. mode_dist_use_both_encoder | Option: Coupling of distance sensor and motor encoder |
| **P-AXIS-00501** | kenngr.distc. use_adaptive_acceleration | Option: Adaptive weighting of acceleration |
| **P-AXIS-00502** | kenngr.distc.a_min | |
| **P-AXIS-00416** | kenngr.distc.a_max | |
| **P-AXIS-00504** | kenngr.distc.dist_error_a_min | |
| **P-AXIS-00505** | kenngr.distc.dist_error_a_max | |
| **P-AXIS-00509** | kenngr.distc.optimized_scheduling | Option: Dead time reduction |
| **P-AXIS-00533** | kenngr.distc.v_weight_down | Velocity weighting for the lowering movement |
| **P-AXIS-00534** | kenngr.distc.a_weight_down | |
| **P-AXIS-00422** | lr_hw[1].encoder_resolution_num | Numerator distance resolution of the additive sensor measuring system [increments] |
| **P-AXIS-00423** | lr_hw[1].encoder_resolution_denom | Denominator distance resolution of the additive sensor measuring system [0.1 µm] |
| **P-AXIS-00230** | lr_hw[1].vz_istw | Sign reversal of actual sensor values |
| **P-AXIS-00424** | lr_hw[1].mode_act_pos | Definition of the sensor value range: Linear scale or modulo handling of sensor values |

| | | |
|---|---|---|
| **P-AXIS-00759** | kenngr.distc.kp | Weighting the distance control output values |
| **P-AXIS-00764** | kenngr.distc.i_tn | Integral action time of the PID controller |
| **P-AXIS-00765** | kenngr.distc.d_tv | Derivative action time of the PID controller |
| **P-AXIS-00782** | kenngr.distc.filter_type | |
| **P-AXIS-00507** | kenngr.distc.low_pass_filter_order | |

| | | |
|---|---|---|
| **P-AXIS-00508** | kenngr.distc.low_pass_filter_fg_f0 | Smoothing sensor data |
| **P-AXIS-00413** | kenngr.distc.n_cycles | |
| **P-AXIS-00783** | kenngr.distc.kalman_sigma | |
| **P-AXIS-00784** | kenngr.distc.smoothing_factor | |

## 8.2 Description

| **P-AXIS-00328** | **Enabling of distance control (spindle with touch probe)** | |
|---|---|---|
| Description | The distance control for a spindle with touch probe is enabled with this parameter. The activation is done by a special command in the NC program [PROG//section 'Distance controlled spindles']. | |
| Parameter | lr_param.distance_control_on | |
| Data type | BOOLEAN | |
| Data range | 0/1 | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00413** | **Filtering of sensor values** | |
|---|---|---|
| Description | Sensor values may be noisy. To keep excitation of the machine low, the setpoints for distance control can be smoothed by a filter. The parameter specified the number of values that are used for filtering. | |
| Parameter | kenngr.distc.n_cycles | |
| Data type | SGN32 | |
| Data range | 0 ≤ n_cycles < 100 | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 4 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00414** | **Maximum position offset** | |
|---|---|---|
| Description | The correction value of the axis that was calculated via distance control may not exceed this machine data item.<br>An error message is issued if this value is exceeded. The correction value is limited. | |
| Parameter | kenngr.distc.max_deviation | |
| Data type | SGN32 | |
| Data range | 0 ≤ max_deviation < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: 0.1µm | R: 0.0001 ° |
| Default value | 50000 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00415** | **Maximum velocity** |
|---|---|

| | | |
|---|---|---|
| Description | The parameter defines the maximum speed at which a position offset is cleared. Distance compensation is dynamically limited to maximum velocity to limit any resulting excitation. | |
| Parameter | kenngr.distc.v_max | |
| Data type | SGN32 | |
| Data range | 0 ≤ v_max < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: 0.001 mm/s | R: 0.001°/s |
| Default value | 5000 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00416** | **Maximum acceleration** | |
|---|---|---|
| Description | The parameter defines the maximum acceleration at which a position offset is cleared. Correction of the distance is limited dynamically with respect to the maximum acceleration to limit the resulting excitation. If no acceleration is specified, the maximum axis acceleration is used automatically (see P-AXIS-00008). | |
| Parameter | kenngr.distc.a_max | |
| Data type | SGN32 | |
| Data range | 0 ≤ a_max < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: 1 mm/s² | R: 1°/s² |
| Default value | 0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | Then this parameter is 0, the maximum axis acceleration P-AXIS-00008 is used. | |

| **P-AXIS-00417** | **Maximum permissible change speed of measured distance** | |
|---|---|---|
| Description | The parameter defines the maximum permissible change in speed of the measured distance within one cycle. After activation of distance control, the sensor’s actual values are monitored for change.<br>When the maximum permissible change speed is exceeded, the error message ID 70329 is output. This detects problems with actual value detection. | |
| Parameter | kenngr.distc.max_act_value_change | |
| Data type | SGN32 | |
| Data range | 0 ≤ max_act_value_change < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: µm/s | R: 0.0001°/s |
| Default value | 5000 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00418** | **Reference point offset for measuring system** | |
|---|---|---|
| Description | The value range of the sensor measuring system can be moved by an offset via this machine data item. This is necessary in the case of absolute position sensors, for example, to define the reference point, i.e. the sensor position that is adjusted if the spindle touches the ideal workpiece surface. | |
| Parameter | kenngr.distc.ref_offset | |
| Data type | SGN32 | |
| Data range | MIN(SGN32) ≤ ref_offset < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: 0.1µm | R: 0.0001 ° |
| Default value | 0 (No offset) | |

| | | |
|---|---|---|
| Drive types | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| P-AXIS-00419 | Upper limit for measuring system | |
|---|---|---|
| Description | The following parameter defines the upper limit of the sensor. An error message is generated if it is exceeded while distance control is active. | |
| Parameter | kenngr.distc.max_pos | |
| Data type | SGN32 | |
| Data range | 0 ≤ max_pos < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: 0.1µm | R: 0.0001 ° |
| Default value | 50000 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| P-AXIS-00420 | Lower limit for measuring system | |
|---|---|---|
| Description | The following value defines the lower limit of the sensor. An error message is generated if it is exceeded while distance control is active. | |
| Parameter | kenngr.distc.min_pos | |
| Data type | SGN32 | |
| Data range | 0 ≤ min_pos < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: 0.1µm | R: 0.0001 ° |
| Default value | -50000 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| P-AXIS-00421 | Tolerance band for limits | |
|---|---|---|
| Description | This parameter defines a minimum distance from the minimum and maximum sensor positions.<br>If this distance is undershot, the CNC generates the error messages ID 70330 or ID 70576. If the tolerance band is specified by zero, the limits of the minimum and maximum sensor positions from the axis parameters P-AXIS-00419 and P-AXIS-00420 have a direct effect. | |
| Parameter | kenngr.distc.tolerance | |
| Data type | SGN32 | |
| Data range | 0 ≤ tolerance < MAX(SGN32) | |
| Axis types | T, R | |
| Dimension | T: 0.1µm | R: 0.0001 ° |
| Default value | 0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| P-AXIS-00428 | Consideration of distance control in software limit switch monitoring |
|---|---|
| Description | This parameter defines whether the calculated distance control offset is included in the software limit switch monitor (see [FCT-A2]). |
| Parameter | kenngr.distc.check_sw_limit_switch |
| Data type | BOOLEAN |
| Data range | 0: Offset of distance control is not considered in software limit switch monitoring (Standard).<br>1: Offset of distance control is considered in software limit switch monitoring. |

| | | |
|---|---|---|
| Axis types | T, R, S | |
| Dimension | T: ---- | R,S: ---- |
| Default value | 0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00500** | **Option: Coupling of distance sensor and motor encoder** | |
|---|---|---|
| Description | As an extension, both the distance sensor and the Z actual value sensor can be used. The inverse coupling of the two sensors can reduce an oscillation tendency. | |
| Parameter | kenngr.distc.mode_dist_use_both_encoder | |
| Data type | BOOLEAN | |
| Data range | 0: No coupling<br>1: Coupling of motor encoder and distance sensor active | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00501** | **Option: Adaptive weighting of acceleration** | |
|---|---|---|
| Description | To reduce a possible oscillation the acceleration can be reduced for small deviations. | |
| Parameter | kenngr.distc.use_adaptive_acceleration | |
| Data type | BOOLEAN | |
| Data range | 0: No adaptive weighting of acceleration<br>1: Adaptive weighting of acceleration active | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | In addition the following limits for acceleration and distance error must be configured: P-AXIS-00502 or P-AXIS-00416 and P-AXIS-00504 or P-AXIS-00505 | |

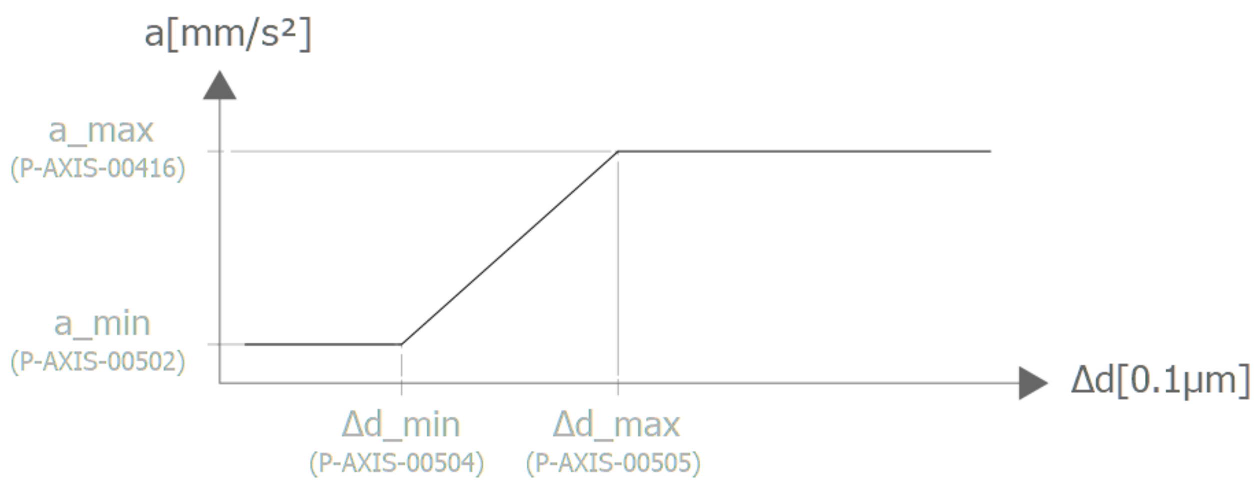



Fig. 34: View Option: Adaptive acceleration weighting

| **P-AXIS-00502** | **Minimum acceleration** |
|---|---|
| Description | The parameter defines the minimal acceleration of distance control. |

| | | |
|---|---|---|
| Parameter | kenngr.distc.a_min | |
| Data type | UNS32 | |
| Data range | 1 ... MAX (UNS32) | |
| Axis types | T, R | |
| Dimension | T: mm/s² | R: mm/s² |
| Default value | 500 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | . | |

| P-AXIS-00504 | Minimum distance error | |
|---|---|---|
| Description | The parameter defines the minimum distance error of distance control up to which a_min (P-AXIS-00502) is used. | |
| Parameter | kenngr.distc.dist_error_a_min | |
| Data type | UNS32 | |
| Data range | 0 ≤ dist_error_a_min < MAX(UNS32) | |
| Axis types | T, R | |
| Dimension | T: 0.1µm | R: 0.0001 ° |
| Default value | 1000 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| P-AXIS-00505 | Maximum distance error | |
|---|---|---|
| Description | The parameter defines the maximum distance error of distance control from which a_max (P-AXIS-00416) is used. | |
| Parameter | kenngr.distc.dist_error_a_max | |
| Data type | UNS32 | |
| Data range | 0 ≤ dist_error_a_max < MAX(UNS32) | |
| Axis types | T, R | |
| Dimension | T: 0.1µm | R: 0.0001 ° |
| Default value | 5000 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| P-AXIS-00507 | Order of the filter | |
|---|---|---|
| Description | The filter's order describes its behaviour with regard to the drop in the frequency response.<br>The following applies: Frequency drop = - P-AXIS-00507 * 20 dB/decade | |
| Parameter | kenngr.distc.low_pass_filter_order | |
| Data type | UNS32 | |
| Data range | 0 … 6 | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 4 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| P-AXIS-00508 | Characteristic frequency of a filter |
|---|---|
| Description | The parameter defines the value of a filter's characteristic frequency. |
| Parameter | kenngr.distc.low_pass_filter_fg_f0 |
| Data type | REAL64 |

| | | |
|---|---|---|
| Data range | 0 ≤ low_pass_filter_fg_f0 < MAX(REAL64) | |
| Axis types | T, R | |
| Dimension | T: Hz | R: Hz |
| Default value | 25 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00509** | **Option: Dead time reduction** | |
|---|---|---|
| Description | The dead time of distance control can be reduced by an optimized schedule of the CNC. | |
| Parameter | kenngr.distc.optimized_scheduling | |
| Data type | BOOLEAN | |
| Data range | 0: Without optimized scheduling<br>1: Optimized scheduling active | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00533** | **Weighting factor for velocity of lowering movement** | |
|---|---|---|
| Description | This parameter weights the velocity (see P-AXIS-00415) of the lowering movement (towards the workpiece). This can be useful since the lifting movement is normally highly dynamic in order to avoid an obstacle or elevation quickly. With the weighting factor it is possible to use a reduced velocity for the lowering movement towards the workpiece. | |
| Parameter | kenngr.distc.v_weight_down | |
| Data type | UNS32 | |
| Data range | 0 ≤ v_weight_down < 2000 | |
| Axis types | T, R | |
| Dimension | T: 0.1% | R: 0.1% |
| Default value | 0 * | |
| Drive types | SERCOS, Profidrive, CANopen | |
| Remarks | * The weighting is deactivated, lifting and lowering movement use the identical velocity P-AXIS-00415.<br>This parameter is available from CNC version V2.11.2807.13 onwards. | |

| **P-AXIS-00534** | **Weighting factor for acceleration of lowering movement** | |
|---|---|---|
| Description | This parameter weights the velocity (see P-AXIS-00416) of the lowering movement (towards the workpiece). This can be useful since the lifting movement is normally highly dynamic in order to avoid an obstacle or elevation quickly. With the weighting factor it is possible to use a reduced acceleration for the lowering movement towards the workpiece. | |
| Parameter | kenngr.distc.a_weight_down | |
| Data type | UNS32 | |
| Data range | 0 ≤ a_weight_down < 2000 | |
| Axis types | T, R | |
| Dimension | T: 0.1% | R: 0.1% |
| Default value | 0 * | |
| Drive types | SERCOS, Profidrive, CANopen | |

| | | |
|---|---|---|
| Remarks | * The weighting is deactivated, lifting and lowering movement use the identical acceleration P-AXIS-00416.<br>This parameter is available from CNC version V2.11.2807.13 onwards. | |

| **P-AXIS-00422** | **Numerator distance resolution of the additive sensor measuring system** | |
|---|---|---|
| Description | The distance resolution of the sensor measuring system is specified as the quotient P-AXIS-00423 in the dimension [increments/0.1 µm] for translatory axes or [increments/10^-4°] for rotary axes. The number of sensor increments must be specified in P-AXIS-00422. | |
| Parameter | lr_hw[i].encoder_resolution_num | |
| Data type | UNS32 | |
| Data range | 0 < encoder_resolution_num < MAX(UNS32) | |
| Axis types | T, R, S | |
| Dimension | T: increments | R,S: increments |
| Default value | 1 | |
| Drive types | ---- | |
| Remarks | This entry is valid for 'lr_hw[i].*' with i ≥ 1!<br>The resolution of the motor sensor 'lr_hw[0].*' is defined by P-AXIS-00233 and P-AXIS-00234. | |

| **P-AXIS-00423** | **Denominator distance resolution of the additive sensor measuring system** | |
|---|---|---|
| Description | The distance resolution of the sensor measuring system is specified as the quotient P-AXIS-00422 / P-AXIS-00423 in the dimension [increments/0.1 µm] for translatory axes or [increments/10^-4°] for rotary axes. The amount of the travel range must be specified in this parameter. | |
| Parameter | lr_hw[i].encoder_resolution_denom | |
| Data type | UNS32 | |
| Data range | 0 ≤ encoder_resolution_denom < MAX(UNS32) | |
| Axis types | T, R, S | |
| Dimension | T: 0.1 µm | R,S: 0.0001° |
| Default value | 1 | |
| Drive types | ---- | |
| Remarks | This entry is valid for 'lr_hw[i].*' with i ≥ 1!<br>The resolution of the motor sensor 'lr_hw[0].*' is defined by P-AXIS-00233 and P-AXIS-00234. | |

| **P-AXIS-00230** | **Sign reversal of actual value** | |
|---|---|---|
| Description | This parameter defines the sign reversal of the actual value. | |
| Parameter | lr_hw[i].vz_istw | |
| Data type | BOOLEAN | |
| Data range | 0/1 | |
| Axis types | T, R, S | |
| Dimension | T: ---- | R,S: ---- |
| Default value | 0 | |
| Drive types | ---- | |
| Remarks | These entries are not taken over when the axis parameters list is updated. Updates only become effective when the controller is rebooted. | |

| **P-AXIS-00424** | **Handling of the additive sensor values** |
|---|---|

| | | |
|---|---|---|
| Description | This parameter defines whether the sensor positions are to be considered as linear or modulo values. By default, it can be handled according to the axis type or an individual default can be defined. When sensor values are handled according to the set axis type (see P-AXIS-00018), values are considered linear for the TRANSLATOR axis type, while modulo handling applies to the ROTATOR axis type. | |
| Parameter | lr_hw[i].mode_act_pos | |
| Data type | UNS16 | |
| Data range | 0, 1, 2 where:<br>0: depending on axis type (default)<br>1 : linear<br>2 : modulo | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 0 | |
| Drive types | ---- | |
| Remarks | This entry is valid for 'lr_hw[i].*' with i ≥ 1!<br>The setting of the sensor value range for the motor sensor 'lr_hw[0].*' is defined by P-AXIS-00122. | |

| **P-AXIS-00759** | **Weighting the distance control output values** | |
|---|---|---|
| Description | The parameter weights the cyclic output value of the distance control. This may affect the distance control dynamics. For kp values less than 1.0, the distance control dynamics are reduced; for kp value greater than 1.0, the dynamics are increased. | |
| Parameter | kenngr.distc.kp | |
| Data type | REAL64 | |
| Data range | 0.0 < kp <= 2.0 | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 1.0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | A kp factor less than 1.0 reduces a possible distance control oscillation and steadies the control in the event of minor distance errors. This parameter is available as of CNC Build V2.11.2809.06 or V3.1.3079.06. | |

| **P-AXIS-00764** | **Integral (I) action time of the PID controller** | |
|---|---|---|
| Description | This parameter weights the I component of the PID controller. The integral action time defines the time after which the P and I components of the manipulated variable are equal.<br>A large integral action time produces greater control stability. The shorter the integration action time, the greater the I component and the faster the control.<br>Disable the I component by i_tn = 0. | |
| Parameter | kenngr.distc.i_tn | |
| Data type | REAL64 | |
| Data range | 0.0 <= i_tn <= 50.0 | |
| Axis types | T, R | |
| Dimension | T: s | R: s |
| Default value | 0.0 | |
| drive types. | SERCOS, Profidrive, CANopen | |

| | | |
|---|---|---|
| Remarks | To begin with, it is advisable to select a high initial value for the integral action time setting (e.g. 5) to avoid instability in the control loop. You can then reduce the integral action time step by step to obtain the effect you require. If there are no permanent control deviations, do not use the I component at first.<br>This parameter is available as from Build 2809.06 or 3079.06. | |

| **P-AXIS-00765** | **Derivative (D) action time of the PID controller** | |
|---|---|---|
| Description | This parameter weights the D component of the PID controller. The derivative action time defines the time after which the P and D components of the manipulated variable are equal. The derivative action time stabilises controller behaviour and reduces oscillations. The larger the derivative action time, the stronger the D component. Disable the D component by d_tv=0. | |
| Parameter | kenngr.distc.d_tv | |
| Data type | REAL64 | |
| Data range | 0.0 <= d_tv <= 2.0 | |
| Axis types | T, R | |
| Dimension | T: s | R: s |
| Default value | 0.0 | |
| drive types. | SERCOS, Profidrive, CANopen | |
| Remarks | To begin with, it is advisable to select a low initial value for the derivative action time setting to avoid instability in the control loop (e.g.: 0.01). You can then reduce the derivative action time step by step to obtain the effect you require.<br>This parameter is available as from Build 2809.06 or 3079.06. | |

| **P-AXIS-00782** | **Filter type for smoothing sensor values** | |
|---|---|---|
| Description | In some cases, the sensor values are noisy. The oscillation tendency can be possibly suppressed by using a suitable filter . The following filter types can be selected for distance control:<br>• DEFAULT: Moving average filter where P-AXIS-00413 [▸ 48] = 4<br>• MOVING_AVERAGE: Moving average filter<br>• LOWPASS Low-pass filter<br>• KALMAN_MA: Kalman filter with prediction from average filter<br>• EXPO_MEAN: Exponential weighted average filter<br>• KALMAN_EXPO: Kalman filter with prediction from exponentially weighted average filter | |
| Parameter | kenngr.distc.filter_type | |
| Data type | STRING | |
| Data range | DEFAULT<br>MOVING_AVERAGE<br>LOWPASS<br>KALMAN_MA<br>EXPO_MEAN<br>KALMAN_EXPO | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | DEFAULT | |
| Drive types | SERCOS, Profidrive, CANopen | |

| | |
|---|---|
| Remarks | The following filter parameters are still required for each of the filter types::<br>• MOVING_AVERAGE: P-AXIS-00413 [▸ 48]<br>• LOWPASS: P-AXIS-00507 [▸ 52], P-AXIS-00508 [▸ 52] (As of v3.1.3079.21 this setting replace the parameter P-AXIS-00506)<br>• KALMAN_MA: P-AXIS-00413 [▸ 48], P-AXIS-00783 [▸ 57]<br>• EXPO_MEAN: P-AXIS-00413 [▸ 48], P-AXIS-00784 [▸ 57]<br>• KALMAN_EXPO: P-AXIS-00413 [▸ 48], P-AXIS-00784 [▸ 57], P-AXIS-00783 [▸ 57] |

| **P-AXIS-00783** | **Uncertainty of measurement values** | |
|---|---|---|
| Description | The parameter indicates the degree of deviation of measurement values from actual values.<br>The higher this value, the better the filter effect. However, any overshoots are amplified. | |
| Parameter | kenngr.distc.kalman_sigma | |
| Data type | REAL64 | |
| Data range | 1.0 ≤ P-AXIS-00783 ≤ 10000.0 | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 4 | |
| Drive types | SERCOS, Profidrive, CANopen | |
| Remarks | | |

| **P-AXIS-00784** | **Smoothing factor** | |
|---|---|---|
| Description | The parameter indicates the weighting of the current measurement value.<br>Example:<br>At a smoothing factor of 0.5, 50% of the current value is included in the average value. | |
| Parameter | kenngr.distc.smoothing_factor | |
| Data type | REAL64 | |
| Data range | 0 < P-AXIS-00784 ≤ 1.0 | |
| Axis types | T, R | |
| Dimension | T: ---- | R: ---- |
| Default value | 0.7 | |
| Drive types | SERCOS, Profidrive, CANopen | |
| Remarks | | |

# 8.3 Example of distance axis

### Distance axis

| | | |
|---|---|---|
| # ------ Distance control -------- | | |
| lr_param.distance_control_on | 1 | Enables the distance control function |
| kenngr.distc.max_abweichung | 20000000 | # [0.1µm] Max. permissible deviation |
| kenngr.distc.v_max | 50000 | # [µm/s] Max. velocity of distance controller |
| kenngr.distc.a_max | 10000 | # [mm/s*s] Max. acceleration |
| kenngr.distc.max_istw_sprung | 100000000 | # Max. actual value jump/cycle |
| kenngr.distc.ref_offset | 0 | # Reference point offset |
| kenngr.distc.max_pos | 1500000 | # [0.1µm] Max. position |
| kenngr.distc.min_pos | -1500000 | # [0.1µm] Min. position |
| kenngr.distc.toleranz | 50000 | # [0.1µm] Tolerance value of probing depth |
| kenngr.distc.check_sw_limit_switch | 1 | # Distance control offset monitor |
| kenngr.distc.optimized_scheduling | 1 | # Opt. scheduling active |
| kenngr.distc.mode_dist_use_both_encoder | 1 | # Motor and distance encoder active |
| #kenngr.distc.use_adaptive_acceleration | 1 | Adaptive weighting of acceleration active |
| kenngr.distc.a_min | 1000 | # [mm/s*s] Min. acceleration |
| kenngr.distc.a_max | 10000 | # [mm/s*s] Max. acceleration |
| kenngr.distc.dist_error_a_min | 250 | # [0.1 µm] Min. distance |
| kenngr.distc.dist_error_a_max | 500 | # [0.1 µm] Max. distance |
| kenngr.distc.filter_type | KALMAN_MA | # Kalman filter active |
| kenngr.distc.n_cycles | 20 | # Number of measured values for filtering |
| kenngr.distc.sigma | 1000 | # Uncertainty of measured values |

# 9 PLC interface

## 9.1 Distance control states and transitions

**Alternative commanding via SPS interface**

Basic condition: Distance control is enabled for the axis (see P-AXIS-00328).

In addition to the NC program, distance control can also be commanded via the PLC interface (see [HLI// Distance control]) by specifying the required status transitions (e.g. activating or deactivating) and specifying command positions via the DistanceControl control unit.

The current state of the distance control unit can be viewed in the state of the DistanceControl control unit. The control unit state also includes the current actual position of the workpiece surface, the current distance, the active command source (0=NC program,1=PLC) and the current output position offset.

**Explanation of figure:**

Distance control has 6 internal states which are depicted in the figure below together with the permitted transitions. Transitions, such as a transition to error state, are displayed automatically and cannot be commanded.

A change in the “Active” and “Active constant Distance” states is only permitted in the “Freeze” or “Inactive” states.

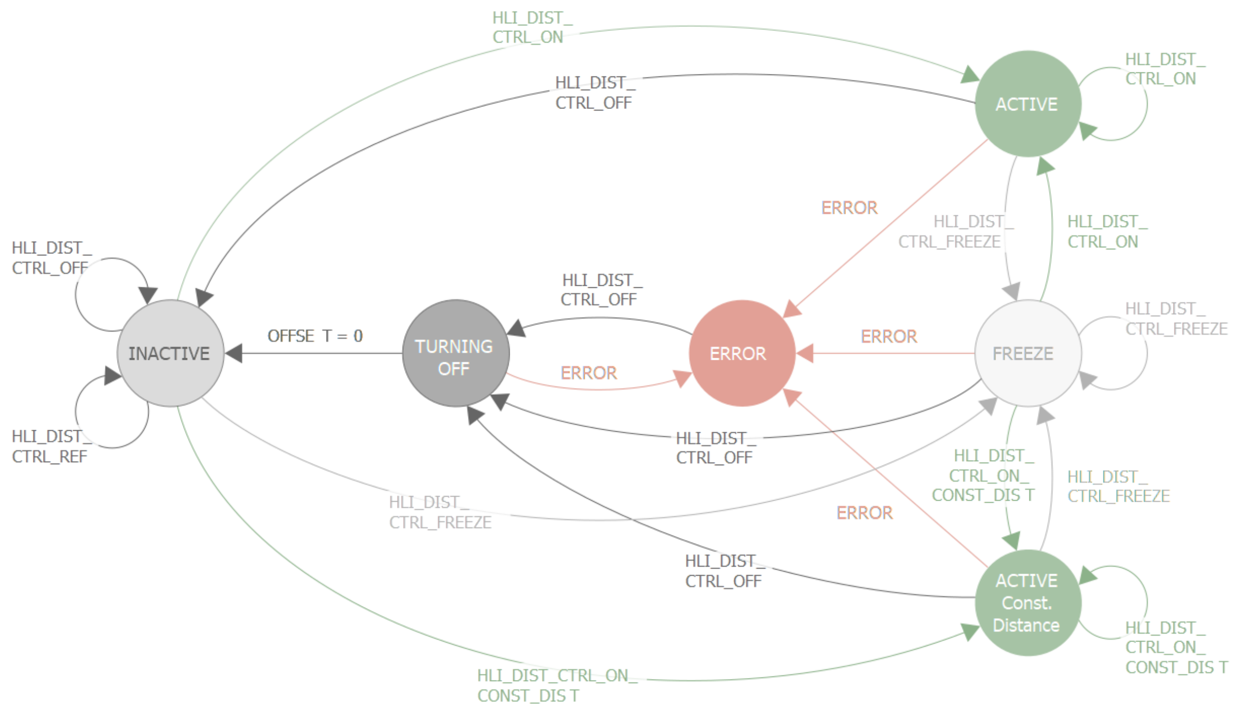



Fig. 35: Distance control state graph and transitions

Defined states of distance control

| State | Value | Meaning |
|---|---|---|
| HLI_DIST_CTRL_STATE_IN ACTIVE | 0 | Distance control is deactivated. The specified offset (“actual_offset”) is 0. |
| HLI_DIST_CTRL_STATE_A CTIVE | 1 | Distance control is active and adjusts the axis to the workpiece surface. |
| HLI_DIST_CTRL_STATE_F REEZE | 2 | Distance control is active. The offset (“actual_offset”) is frozen, i.e. the axis is not adjusted to the workpiece surface. |

| | | |
|---|---|---|
| HLI_DIST_CTRL_STATE_TURNING_OFF | 3 | Distance control was deactivated. The actual active offset (“actual_offset”) is run out. As soon as the offset is 0, an automatic switch to INACTIVE state takes place. |
| HLI_DIST_CTRL_STATE_ACTIVE_CONST_DIST | 4 | Distance control is active and adjusts the axis to the workpiece surface. Continuous specification of the set distance of the tool to the workpiece surface. |
| HLI_DIST_CTRL_STATE_ERROR | 5 | Distance control is in error state, e.g. due to an incorrect state transition or due to an error in the position controller. Only a transition to TURNING OFF is possible to exit this state. |
| HLI_DIST_CTRL_STATE_DRYRUN_CONST_DIST | 6 | Distance control is active, however axis is not adjusted to workpiece surface. This allows the evaluation of data, for example filter effect without feedback from the control system. Continuous commanding of the set distance of the tool to the workpiece surface. |
| HLI_DIST_CTRL_STATE_DRYRUN_SETPOS | 7 | Distance control is active, however axis is not adjusted to workpiece surface. This allows the evaluation of data, for example filter effect without feedback from the control system. |

Permissible transitions to command the distance control

| Transition | Value | Meaning |
|---|---|---|
| HLI_DIST_CTRL_OFF | 0 | Distance control is deactivated. The program switches to the TURNING OFF state in which the position offset is run out. The state then switches automatically to the INACTIVE state. |
| HLI_DIST_CTRL_ON | 1 | Distance control is activated. When activated a command position for the workpiece surface must be transferred in the “position” datum. If no absolute encoder is used, distance control must first be referenced. |
| HLI_DIST_CTRL_FREEZE | 2 | The current position offset is frozen. Axis adjustment to the actual workpiece surface is ended. |
| HLI_DIST_CTRL_REF | 3 | Referencing distance control if no absolute encoder is used. Referencing is only permitted in the INACTIVE state. With this transition a reference position must additionally transferred in the “position” datum. |
| HLI_DIST_CTRL_ON_CONST_DIST | 4 | Activating distance control with continuous distance specification. On activation, a set position must be specified. If the distance sensor supplies no absolute values, distance control must be referenced in advance. |
| HLI_DIST_CTRL_DRYRUN | 5 | Activate distance control for pure evaluation of data. No axis tracking in case of changes to the workpiece surface. When activated a command position for the workpiece surface must be transferred in the “position” datum. If no absolute encoder is used, distance control must first be referenced. |
| HLI_DIST_CTRL_CONST_DIST | 6 | Activate distance control for pure evaluation of data. No axis tracking in case of changes to the workpiece surface. On activation, a set position must be specified. If the distance sensor supplies no absolute values, distance control must be referenced in advance. |

## 9.2 Control commands for distance control

| **Commanding distance control** | |
|---|---|
| Description | This control unit can influence the distance control of the axis. This is dependent on whether the distance control function is selected in the axis parameters (see P-AXIS-00328). |
| Data type | MC_CONTROL_DISTANCE_CONTROL, see description of Control unit with usage check |
| Access | PLC reads state_r and writes command_w + enable_w |
| ST path | gpAx[axis_idx]^.lr_mc_control.distance_control |
| Flow control of commanded values | |
| ST element | **.command_semaphor_rw** |
| Signal flow | PLC → CNC |
| Data type | BOOL |
| Peculiarities | **Consumption data item** |
| Access | CNC accepts the commanded values when this element has the value TRUE. After successful acceptance the CNC sets this value to FALSE.<br>PLC sets this value to TRUE when the commanded value is enabled for acceptance by the CNC. The commanded values can only be updated by the PLC if this element has the value FALSE. |
| Commanded values | |
| ST element | **.command_w** |
| Signal flow | PLC → CNC |
| Data type | HLI_DISTANCE_CONTROL_COMMAND |
| Access | PLC writes |
| Distance control state | |
| ST element | **.state_r** |
| Signal flow | CNC → PLC |
| Data type | HLI_DISTANCE_CONTROL_STATE |
| Access | PLC is reading |
| Redirection | |
| ST element | **.enable_w** |

| **Distance control state** | |
|---|---|
| Description | This entry reads the distance control state. |
| Signal flow | PLC → CNC |
| Data type | HLI_DISTANCE_CONTROL_STATE |
| ST Path | gpAx[*axis_idx*]^.lr_mc_control.distance_control.**state_r** |
| Access | PLC is reading |
| Elements of the data type | |
| Element | **.actual_state** |
| Data type | UDINT |
| Access | PLC is reading |
| Value range/ Description | See table: Distance control states and transitions [▶ 59] |
| Element | **.actual_position** |
| Data type | DINT |
| Unit | 0.1 µm or 0.0001° |
| Access | PLC reads |
| Description | This data item indicates the current actual position of the workpiece surface detected by the sensing controller. |

| | |
|---|---|
| Characteristics | This data item is entered only if distance control is activated in the axis parameters (see P-AXIS-00328). |
| Element | **.actual_offset** |
| Data type | DINT |
| Unit | 0.1 µm or 0.0001° |
| Access | PLC reads |
| Description | This data item indicates the current position offset of distance control by which the axis was moved due to deviations between the actual workpiece surface and the specified position (SET_POS). The following applies in stationary state (constant workpiece surface and position offset completely run out): Position offset = SET_POS – actual_position |
| Characteristics | This data item is entered only if distance control is activated in the axis parameters (see P-AXIS-00328). |

| **Command for distance control** | |
|---|---|
| Description | This entry commands distance control. |
| Signal flow | PLC → CNC |
| Data type | HLI_DISTANCE_CONTROL_COMMAND |
| ST Path | gpAx[*axis_idx*]^.lr_mc_control.distance_control.**command_w** |
| Access | PLC writes |
| Elements of the data type | |
| ST element | **.transition** |
| Data type | UDINT |
| Value range/ Description | See Table - Permissible transitions to command distance control [▶ 61] |
| | |
| ST element | **.position** |
| Data type | DINT |
| Value range | [DINT_MIN, DINT_MAX] |
| Description | The meaning depends on the commanded transition:<br>HLI_DIST_CTRL_ON: Command position of the workpiece surface (SET_POS)<br>HLI_DIST_CTRL_REF: Reference position of the workpiece surface (REF_POS) |

| **Cyclic command for distance control** | |
|---|---|
| Description | This entry specifies cyclic set values are specified (position of workpiece surface or set distance). |
| Signal flow | PLC → CNC |
| Data type | HLIDistanceControlCyclicCommand |
| ST Path | pAC[*axis_idx*]^.addr^.McControlLr_Data.MCControl_DistanceControl.**CyclicCommand** |
| Access | PLC writes |
| Elements of the data type | |
| ST element | **.D_Position** |
| Data type | DINT |
| Value range | [DINT_MIN, DINT_MAX] |
| Description | The meaning depends on the commanded transition:<br>HLI_DIST_CTRL_ON: Command position of the workpiece surface (SET_POS)<br>HLI_DIST_CTRL_REF: Reference position of the workpiece surface (REF_POS) |
| | |
| ST element | **.D_Distance** |
| Data type | DINT |
| Value range | [DINT_MIN, DINT_MAX] |

| | |
|---|---|
| Description | Specification of the distance to workpiece surface after selection by transition HLI_DIST_CTRL_ON_CONST_DIST. |

# 10 Error messages

**The following error messages can occur when distance control is active:**

| | |
|---|---|
| P-ERR-70329 | Actual value change of sensor signal greater than limit |
| P-ERR-70330 | Sensor completely run out |
| P-ERR-70331 | Excessive sensing deviation |
| P-ERR-70332 | Distance control still active at program end |
| P-ERR-70333 | Distance control active for axis that is to be specified. |
| P-ERR-70334 | On repeat selection, deselection of distance control not yet complete |
| P-ERR-70335 | Distance control selected without programmed position |
| P-ERR-70336 | Function is not available |

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| e-mail: | support@beckhoff.com |

### Beckhoff Service

The Beckhoff Service Center supports you in all matters of after-sales service:

- on-site service
- repair service
- spare parts service
- hotline service

| | |
|---|---|
| Hotline: | +49 5246 963-460 |
| e-mail: | service@beckhoff.com |

### Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

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# Index

More Information:
www.beckhoff.com/TF5200

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