DOCUMENTATION ISG-kernel

Functional description
Axis compensations

Short description:
FCT-C5

www.isg-stuttgart.de
support@isg-stuttgart.de

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Preface

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This documentation was produced with utmost care. The products and scope of functions described are under continuous development. We reserve the right to revise and amend the documentation at any time and without prior notice.

No claims may be made for products which have already been delivered if such claims are based on the specifications, figures and descriptions contained in this documentation.

Personnel qualifications

This description is solely intended for skilled technicians who were trained in control, automation and drive systems and who are familiar with the applicable standards, the relevant documentation and the machining application.

It is absolutely vital to refer to this documentation, the instructions below and the explanations to carry out installation and commissioning work. Skilled technicians are under the obligation to use the documentation duly published for every installation and commissioning operation.

Skilled technicians must ensure that the application or use of the products described fulfil all safety requirements including all applicable laws, regulations, provisions and standards.

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Links below (DE)

https://www.isg-stuttgart.de/produkte/softwareprodukte/isg-kernel/dokumente-und-downloads

or (EN)

https://www.isg-stuttgart.de/en/products/softwareproducts/isg-kernel/documents-and-downloads

contains further information on messages generated in the NC kernel, online help, PLC libraries, tools, etc. in addition to the current 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

➢ 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.

Attention

Restriction or error

This icon describes restrictions or warns of errors.

Notice

Tips and other notes

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

Example

General example

Example that clarifies the text.

Programing Example

NC programming example

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

Release Note

Specific version information

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

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1 Overview

Task

Axis compensations rectify inaccuracies in tool guidance caused by mechanical errors such as backlash, errors in spindle pitch or temperature fluctuations.

A distinction is made between 7 programming modes:

- Backlash compensation
- Temperature compensation
- Cross compensation
- Plane compensation
- Leadscrew error compensation
- Friction compensation
- Crosstalk compensation

Characteristics

In general, each axis compensation can be:

- activated for all axis types, and
- used with all drive types

The conditions required for their effectiveness are described in the related sections on compensation types.

Parameterisation

Specific parameters must be configured for each axis compensation in order to activate them. They are described for each compensation type in the section “Parameterisation”.

Programming

Axis compensations can be activated and deactivated in the NC program with the command X[COMP…].

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.

The friction compensation functionality is described in FCT-C25.

2 Backlash compensation

2.1 Overview

Task

Backlash compensation has the purpose of compensating for the deviation between the real and calculated actual position of an axis caused by mechanical backlash.

Effectiveness

Backlash compensation can be activated for **all** axis types.

The effect of backlash can be compensated for **all** drive types.

Parameterisation

With regard to backlash compensation,

- the type of mechanical backlash P-AXIS-00021
- the amount of mechanical backlash P-AXIS-00103
- the distribution of mechanical backlash P-AXIS-00243

can be parameterised in the axis parameter record [AXIS].

2.2 Description

Mechanical backlash

The play between the

- the drive and a moving machine part or
- between a sensor and a moving machine part is referred to as mechanical backlash.

For a moving machine part, mechanical backlash results in a deviation between the commanded position and the actual position. This especially has an effect when the direction of motion is reversed.

A distinction is made between the following kinds of mechanical backlash:

- Positive backlash
- Negative backlash

Positive backlash

Positive backlash occurs in systems in which

- the measuring system is connected directly to the drive and
- the backlash occurs between the drive and the moving mechanical part.

When the direction of movement reverses, the measuring system will detect a position change although the machine part is not yet moving due to the backlash.
This leads to a situation in which the machine part does not reach the commanded position, but travels too short by the backlash amount because the sensor that indirectly measures the position of the machine part is **ahead** of the machine part's **actual position**.

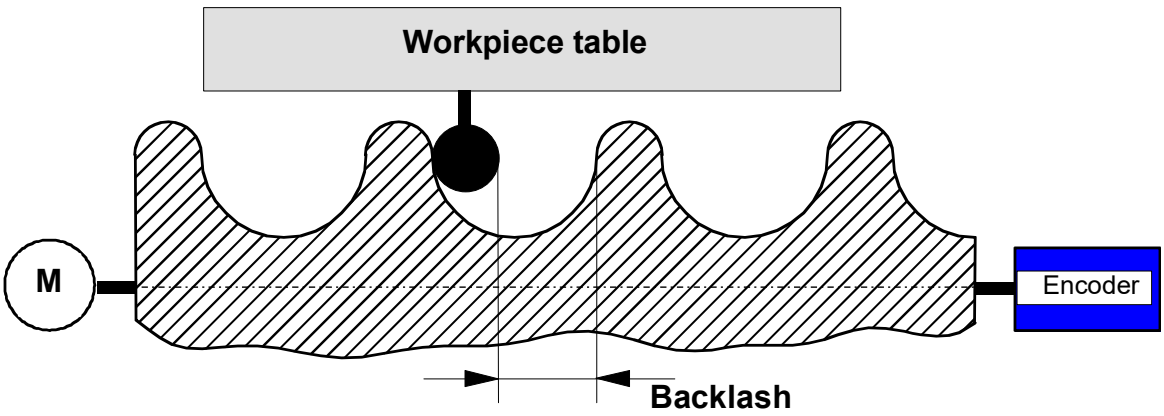


Fig. 1: Positive backlash

Negative backlash

Negative backlash is encountered in systems in which the backlash occurs between the moving machine part and the measuring system. When the direction is reversed, the machine part directly moves in the new direction without the measuring system detecting a position change.
In this case, the machine part moves further by the backlash amount than is required by the command because the sensor that directly measures the position of the machine part **lags behind** the position of the machine part.

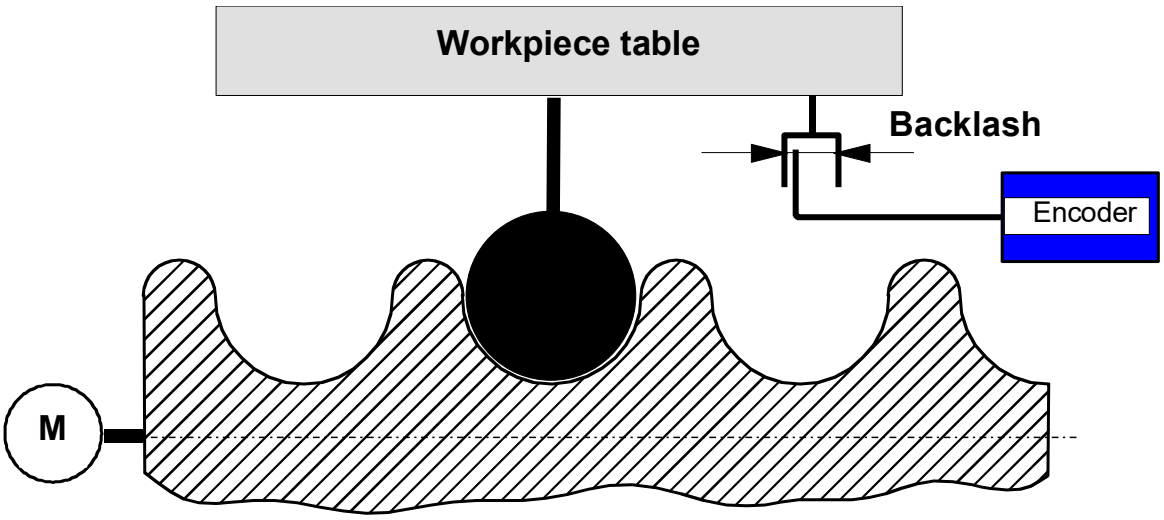


Fig. 2: Negative backlash

Backlash compensation

The size of the backlash P-AXIS-00103 during on position control is taken into consideration depending on the type of mechanical backlash P-AXIS-00021 and acts on the calculation of the command variables.

Notice

The display of the absolute command position or actual position of the moving machine part does **not** include the compensation values and therefore represents the position of an ideal machine.

Effectiveness

When backlash compensation is selected, it is active directly after controller start-up, regardless of whether homing has taken place [FCT-M1//Description].

The algorithm compensates for the backlash in the 1st cycle of the path motion. A large backlash can cause strong excitation in the machine. To prevent this, the backlash can be distributed over several position control cycles P-AXIS-00243.

2.3 Parameterisation

2.3.1 Overview

ID	Parameter	Description
P-AXIS-00021	anwahl_losekomp	Selection and type of mechanical backlash
P-AXIS-00103	lose	Size of mechanical backlash
P-AXIS-00243	n_backlash_cyc	Distribution of mechanical backlash

2.3.2 Description

P-AXIS-00021	**Selection of backlash compensation**	
Description	The selection of backlash compensation is done using this parameter. The type of backlash (the backlash between the table and the drive or the backlash between the drive and the measuring system) depends on the mathematical sign of P-AXIS-00103 (getriebe[i].lose).	
Parameter	lr_param.anwahl_losekomp	
Data type	UNS16	
Data range	0: No backlash compensation 1: Last axis motion occurred in pos. direction. 2: Last axis motion occurred in neg. direction.	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
drive types.	----	
Remarks		

P-AXIS-00103	**Size of backlash**	
Description	The parameter defines the size of backlash.	
Parameter	getriebe[i].lose	
Data type	SGN16	
Data range	SGN16 range 0 < backlash: backlash betw. drive and slide	
Axis types	T, R, S	
Dimension	T: 0.1µm	R,S: 0.0001 °
Default value	0	
drive types.	----	
Remarks		

2.3.3 CNC objects

Name	BC::actual backlash		
Description	Backlash compensation: current effective compensation offset		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0093
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[-]
Remarks			

Name	BC::conf. backlash		
Description	Backlash compensation: Size of backlash This value is defined in P-AXIS-00103 [▶ 11].		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>00AF
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

Name	BC::delta backlash		
Description	Backlash compensation: Change in compensation value in current cycle		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0095
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[-]
Remarks			

Name	BC::sum backlash		
Description	Backlash compensation: Compensation value at the current position without filter		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0094
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[-]
Remarks			

2.4 Error messages

Errors in the configuration of batch compensation result in deactivation of the function for the axis affected and an error message (warning) is output:

P-ERR-110392

2.5 Parameterisation example

Example

Excerpt from the axis parameter list

```
getriebe[0].lose           1000   #0,1 µm backlash
lr_param.anwahl_losekomp   1      #Positive direction
lr_param. n_backlash_cyc   10     #Number of filter cycles
```

3 Temperature compensation

3.1 Overview

Deformation and its effect

Temperature changes cause an expansion or contraction of machine parts.

Deformations cause offsets in the axis positions that are not detected by the machine's position measuring system and lead to inaccuracies in the finished workpiece.

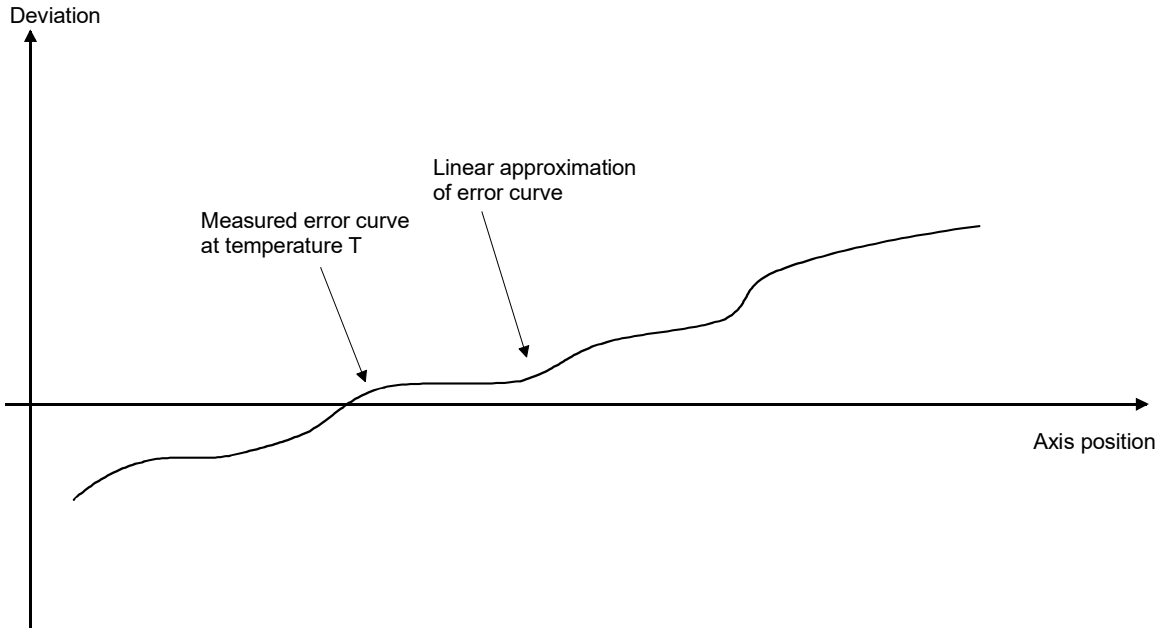


Fig. 3: Temperature-dependent falsification of the axis position

Compensation

Temperature compensation provides a function to correct the command variable of the axis depending on the current temperature and axis position.

The compensation values are determined according to the following equation:

$$\Delta s\ (T,s) = offset_0(T) + coefficient(T) * [s-s_0]$$

where:

s = current position of the axis

T = current reference temperature

S_0 = reference position of the axis

$Offset_0(T)$ = temperature-dependent deviation from reference position

Coefficient = temperature-dependent ratio of deviation to distance from reference position

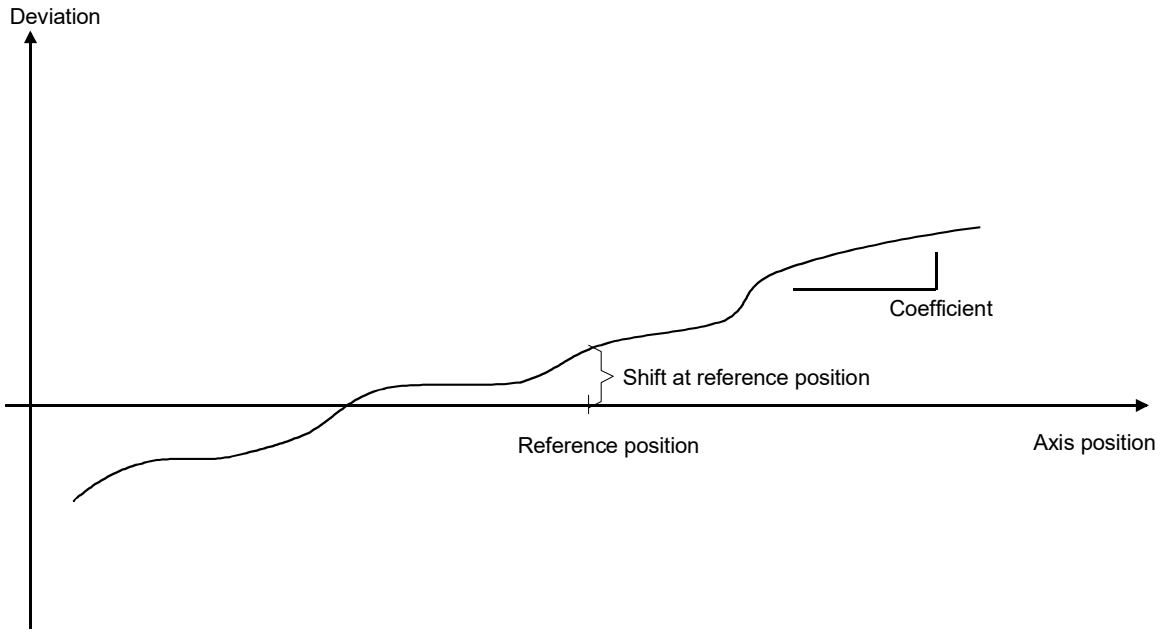


Fig. 4: Parameter of temperature compensation for a temperature T

Effectiveness

The temperature compensation is effective if:

- it was activated for the axis and
- the axis is homed.

3.2 Parameterisation

Activate

Temperature compensation is activated in the axis machine data record [AXIS] of the required axis using P-AXIS-00271:

```
kopf.achs_nr                                    1
#
# temperature compensation on/off
lr_param.temp_comp                 1
```

Compensation can also be activated using a write access to the CNC object via the GEO task:

TEMPC::is_active Index group = 0x120300, Index offset = 0x10041

Reference measurement

Before specifying the parameters of temperature compensation, a reference measurement must first be carried out using an external position measuring system. It determines the deviations of the axis positions between the internal and external measuring system at different temperatures.

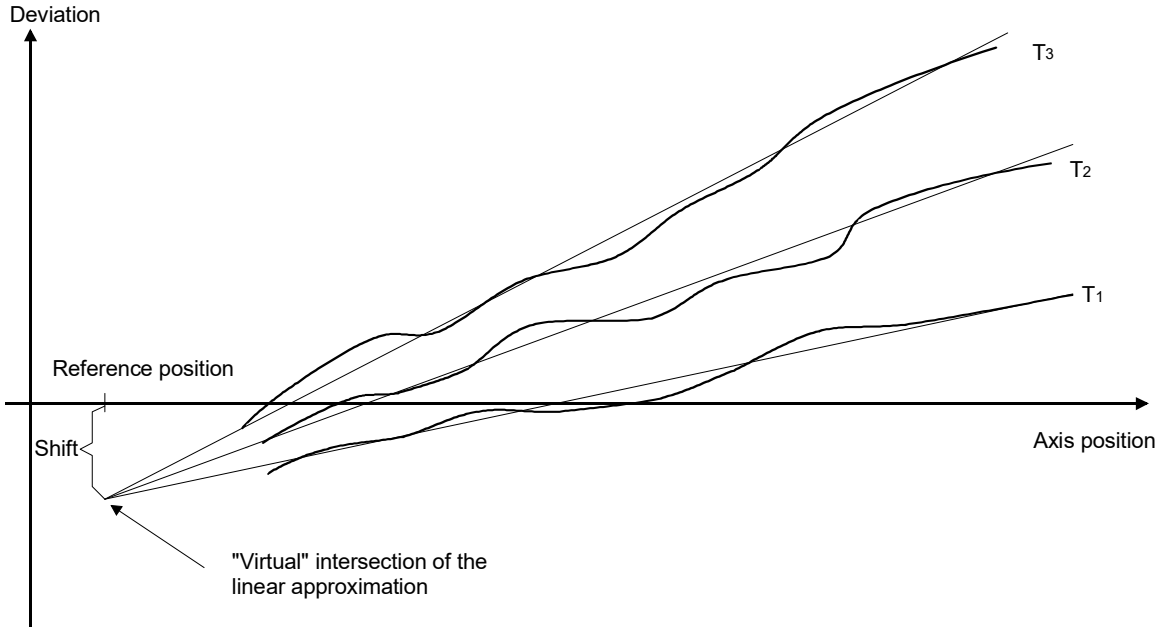


Fig. 5: Reference measurement at different temperatures

Determine parameters

The parameters reference position, offset and coefficient can be taken from the measurement curves. The values at a given temperature can be set later from the curves. Temperatures that are not measured can be interpolated or extrapolated from the measured temperature curves.

If the virtual intersection of the approximated linear curves is chosen as the reference position, the offset is independent of temperature. In this case, only the coefficient must be reset for different temperatures.

Influence of temperature

The individual parameters can be set by the PLC depending on the current temperature. To do this, a corresponding temperature signal (sensor) is transmitted to the PLC which then derives the parameters from it.

Explicit activation in NC program

```
lr_param.temp_comp_manual_activation          0
```

- 0 (default): The CNC activates temperature compensation automatically as soon as the required preconditions are met (e.g. the axis is homed).
- 1: Temperature compensation must be activated manually in the NC program using the COMP command (see Section “Selecting and deselecting axis compensations in the NC program [▶ 107]").

Compensation is deselected:

- at the end of the NC program
- at CNC reset and
- on release of the axis.

Change parameters

Each of the parameters can be changed by downloading the axis list:

```
kopf.achs_nr                                        1
#
# temperature compensation on/off
lr_param.temp_comp          1
# reference position
lr_param.temp_comp_position_0              100 [0.1µm]
# reference offset
lr_param.temp_comp_offset_0                 40 [0.1µm]
lr_param.temp_comp_coefficient            4000 [µm/m]
#
```

In addition to the download option, there is also the option of writing and reading the parameters via direct access to the GEO task via CNC objects. For example, the first axis can be addressed via the following index group and index offset:

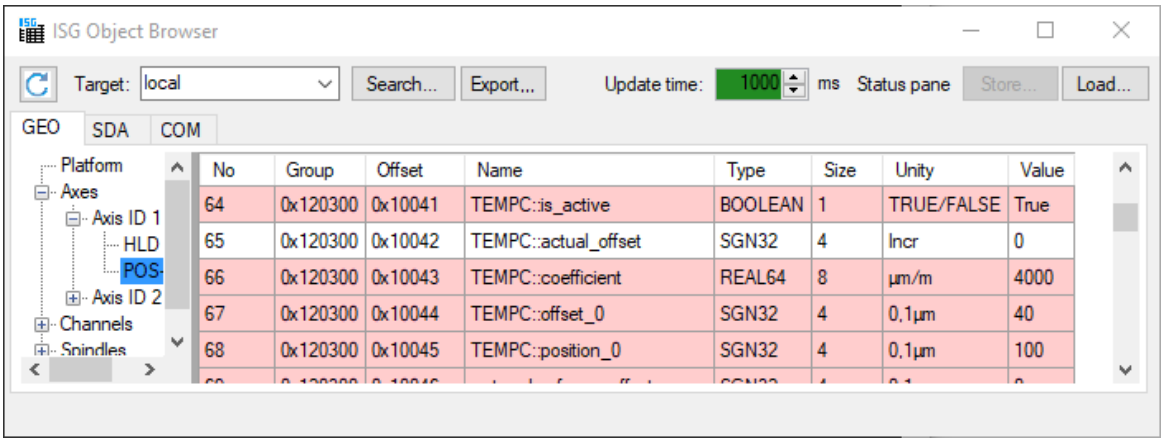


Fig. 6: Access to CNC objects of temperature compensation

Monitoring and coupling/decoupling

The compensation values are recalculated for each interpolation cycle. If the change per cycle exceeds the given maximum axis acceleration, this change can be output filtered over multiple cycles.

For this the number of cycles of the sin² filter can be defined in the axis parameter list. By default, this is set to one cycle.

```
kopf.achs_nr                          1
#
# Cycle of the sin² filter
lr_param.temp_comp_n_cycles          20
```

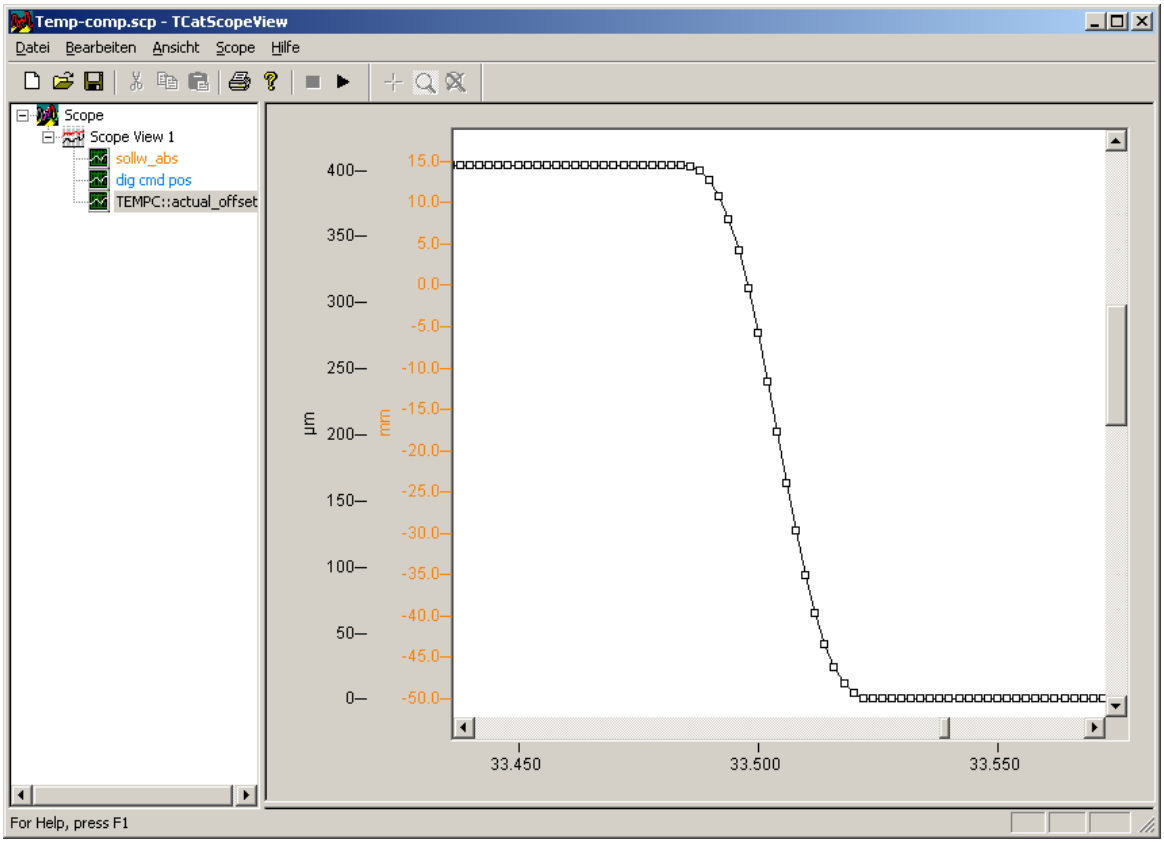


Fig. 7: Deactivating compensation values with a sin² filter over 20 cycles by deactivating temperature compensation temporarily

Display the compensation

In addition to the download option, there is also the option of writing and reading the parameters via direct access to the CNC objects of the GEO task. For example, the 1st axis can be addressed using the following index group and index offset:

TEMPC::is_active	Index group = 0x120300, Index offset = 0x10041
TEMPC::is_active	Index group = 0x120300, Index offset = 0x10042

Display the axis position

When temperature compensation is activated, the normal command and actual positions of the axis are displayed unchanged.

The corrections are only calculated and included before output to the drive bus and can therefore be viewed in the position values of the drive bus (dig_cmd_pos, dig_act_pos).

3.2.1 Overview

ID	Parameter	Description
P-AXIS-00789	lr_param.crosstalk	Activate crosstalk compensation

ID	Parameter	Description
P-COMP-00063	kw.crosstalk.master_ax_nr	Log. Axis number of the master axis
P-COMP-00064	kw.crosstalk.n_cycles	Number of cycles for ‘smooth switching’
P-COMP-00065	kw.crosstalk.last_index	Last index of compensation value table
P-COMP-00066	kw.crosstalk.acceleration	Accelerations of the master axis
P-COMP-00067	kw.crosstalk.correction	Compensation values for the slave axis
P-COMP-00073	kw.crosstalk.manual_activation	Manual activation

3.2.2 Description

P-AXIS-00271	**Selection of temperature compensation**	
Description	The parameter selects the temperature compensation.	
Parameter	lr_param.temp_comp	
Data type	BOOLEAN	
Data range	0/1	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Drive types	----	
Remarks		

P-AXIS-00272	Parameterisation of temperature compensation (Basic position)	
Description	The compensation values are approximated by a linear straight line. This straight line is defined by a basic position, an offset at this position and a geometrical pitch. Depending on the temperature, these parameters can be adjusted e.g. by the PLC.	
Parameter	lr_param.temp_comp_position_0	
Data type	SGN32	
Data range	MIN(SGN32) < temp_comp_position_0 < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm	R,S: 0.0001°
Default value	0	
Drive types	----	
Remarks		

P-AXIS-00273	Parameterisation of temperature compensation (Offset)	
Description	The compensation values are approximated by a linear straight line. This straight line is defined by a basic position, an offset at this position and a geometrical pitch. Depending on the temperature, these parameters can be adjusted e.g. by the PLC.	
Parameter	lr_param.temp_comp_offset_0	
Data type	SGN32	
Data range	MIN(SGN32) < temp_comp_offset_0 < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm	R,S: 0.0001°
Default value	0	
Drive types	----	
Remarks		

P-AXIS-00274	Parameterisation of temperature compensation (Geometrical pitch)	
Description	The compensation values are approximated by a straight line. This straight line is defined by a basic position, an offset at this position and a geometrical pitch. Depending on the temperature these parameters can be adjusted e.g. by the PLC.	
Parameter	lr_param.temp_comp_coefficient	
Data type	REAL64	
Data range	-10000 ≤ temp_comp_coefficient ≤ 10000	
Axis types	T, R, S	
Dimension	T: µm/m	R,S: ----
Default value	0	
Drive types	----	
Remarks		

P-AXIS-00275	Distribution of the temperature compensation on several cycles	
Description	The compensation values are recalculated for each interpolation cycle. If the change per cycle exceeds the given maximum axis acceleration, this change can be output filtered over multiple cycles. For this the number of cycles of the sin² filter can be defined in the axis parameter list.	
Parameter	lr_param.temp_comp_n_cycles	
Data type	UNS16	
Data range	0 < temp_comp_n_cycles < 20	
Axis types	T, R, S	
Dimension	T: Number of interpolation cycles	R,S: Number of interpolation cycles
Default value	0	
Drive types	----	
Remarks		

P-AXIS-00482	Manual activation of the temperature compensation	
Description	The CNC turns the temperature compensation on when it is selected in the axis parameter list (P-AXIS-00271) and the required preconditions are met (e.g. the axis is homed). If the parameter is set to 1, the temperature compensation must be manually turned on in the NC program via an NC command (see [PROG//Switching axis compensation on/off in the NC program]). In addition, the compensation is turned off at the end of the NC program, during CNC reset and axis release.	
Parameter	lr_param.temp_comp_manual_activation	
Data type	BOOLEAN	
Data range	0: Automatic activation (default). 1: Manual activation in NC program.	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Drive types	----	
Remarks		

3.2.3 CNC objects

Name	TEMPC:: activated		
Description	Temperature compensation: active, activate using P-AXIS-00271 [▶ 20]		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0041
Data type	BOOLEAN	**Length**	1
Attributes	read/ write	**Unit**	[-]
Remarks	TRUE/FALSE		

Name	TEMPC::f_is_active		
Description	This object reads whether temperature compensation is activated . This means that all preconditions, such as axis is referenced and all necessary enables are on, must be fulfilled.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>01D8
Data type	BOOLEAN	**Length**	1
Attributes	read	**Unit**	[-]
Remarks			

Name	TEMPC::actual_offset		
Description	Temperature compensation: current compensation value		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0042
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

Name	TEMPC::coefficient		
Description	Temperature compensation: current coefficient See also P-AXIS-00274 [▶ 21] The temperature compensation values are approximated by a straight line. The straight line is defined by a basic position, an offset at this position and a geometrical pitch.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0043
Data type	REAL64	**Length**	8
Attributes	read/ write	**Unit**	[µm/m]
Remarks			

Name	TEMPC::offset_0		
Description	Temperature compensation: Start offset characteristic See also P-AXIS-00273 [▶ 21] The temperature compensation values are approximated by a straight line. The straight line is defined by a basic position, an offset at this position and a geometrical pitch.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0044
Data type	SGN32	**Length**	4
Attributes	read/ write	**Unit**	[0.1 µm]
Remarks			

Name	TEMPC::position_0		
Description	Temperature compensation: Start position characteristic See also P-AXIS-00272 [▶ 21] The temperature compensation values are approximated by a straight line. The straight line is defined by a basic position, an offset at this position and a geometrical pitch.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0045
Data type	SGN32	**Length**	4
Attributes	read/ write	**Unit**	[0.1 µm]
Remarks			

3.3 Example

Initialisation

Compensation is activated in the X axis by the following settings:

```
lr_param.temp_comp                        1
lr_param.temp_comp_position_0           100 [0.1µm]
lr_param.temp_comp_offset_0              40 [0.1µm]
lr_param.temp_comp_coefficient         4000 [µm/m]
lr_param.temp_comp_n_cycles              20
```

Programing Example

NC program

The following NC program was used for the test:

```
N10: G90 G01 X0 F1000
G04 1
N10 X100
G04 1
N10 X80
G04 1
N10 X50
G04 1
N20 X-200
G04 1

$GOTO [N10]
M30
```

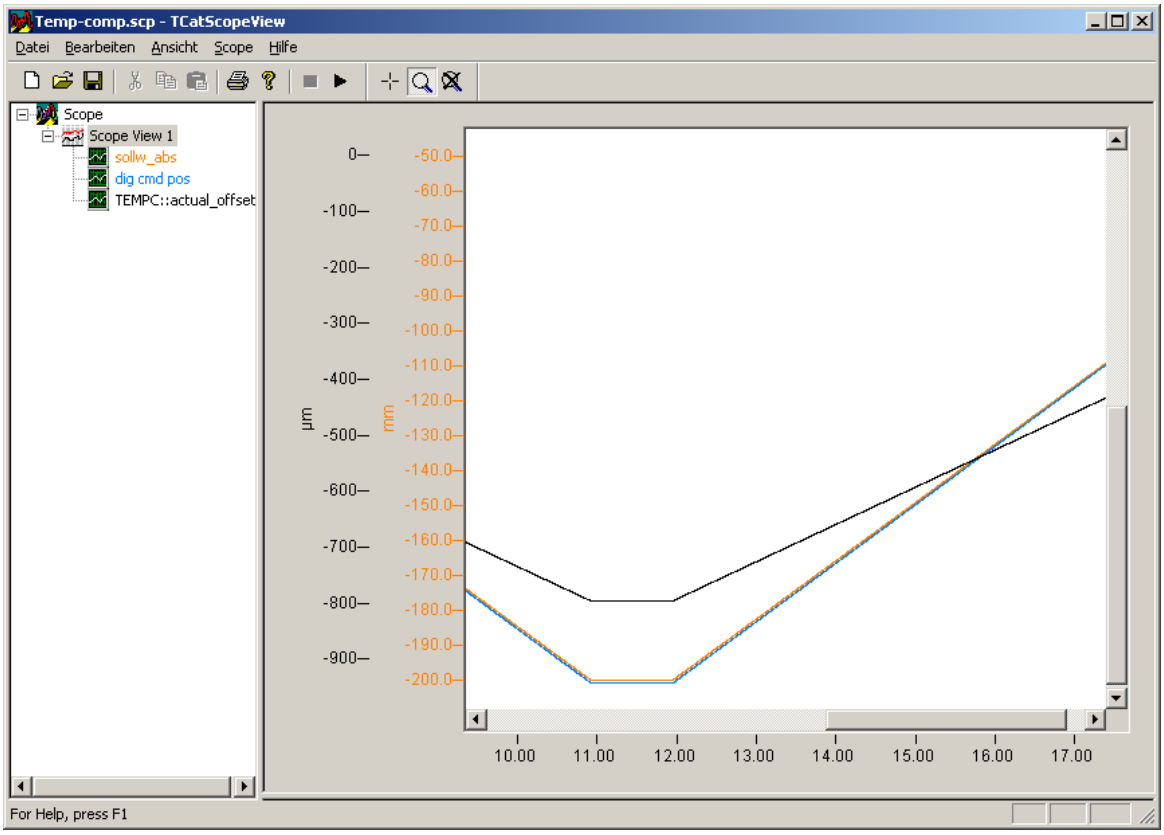


Fig. 8: Logged compensation values dependent on axis position.

4 Axis compensations with compensation value lists

4.1 Compensation value lists

Storing compensation values

Data for the compensation processes

- Cross compensation
- Plane compensation
- Leadscrew error compensation
- Friction compensation and
- crosstalk compensation

are stored for each axis in so-called compensation value lists that are loaded when the controller starts up. It is also possible to update the lists at a later date.

Notice

It is possible to activate all the compensation processes for an axis simultaneously.
When you use leadscrew error compensation, it is recommended to include a possible backlash directly in the compensation table of the leadscrew error compensation (double-sided compensation P-COMP-00021).

Notice

As of CNC Build V3.1.3079.06 you can adjust the size of the compensation value lists.

Providing the compensation value lists

The following entries must be present in the start-up description [STUP] in order to signal the compensation table to the controller:

Variable name	Type	Meaning
zahl_kw	UNS16	Number of offset value lists
achs_kw[i]	String	Name of datafile
achs_kw_log_ax_nr[i]	UNS16	Logical number of axis for which the compensation value list is valid.

Attention

If the compensation value list is configured by the TwinCAT System Manager, these entries are assigned automatically in the start-up description.

Programing Example

Excerpt from the start-up list *hochlauf.lis*:

```
:
zahl_kw                    3
#
achs_kw_log_ax_nr[0]       1
achs_kw[0]                 ..\listen\achskw1.lis
#
achs_kw_log_ax_nr[1]       2
achs_kw[1]                 ..\listen\achskw2.lis
#
achs_kw_log_ax_nr[2]       6
achs_kw[2]                 ..\listen\achskw6.lis
:
```

Structure of the compensation value list

The compensation value list consists of

- a list header containing general data and
- the body of the list where the compensation algorithms are configured and containing the actual compensation tables.

List header

The list header is identified in the list by the structure variable **kopf** . It contains the following elements:

Variable name	Type	Meaning
kopf.achs_nr	UNS16	Logical number of compensation value list
kopf.log_achs_name	String	Name of the axis, which is only used for diagnostic purposes

Attention

If the compensation value list is configured by the TwinCAT System Manager, these entries are made automatically in the compensation value list.

Body of the list

The list body contains general data and the compensation tables. The entries in the list body are identified by the structure variable **kw** and **frict_comp** . It contains the following substructures for each of the compensation processes:

Variable name	Meaning
kw.crosscomp.	Data structure for cross compensation
kw.crosscomp2	Data structure for plane compensation (2-dimensional cross compensation)
kw.ssfk.	Data structure for leadscrew error compensation
kw.crosstalk.	Data structure for cross compensation
frict_comp	Data structure for friction compensation

Updating the compensation table

The compensation table can be updated while the controller is running, provided the conditions for the effectiveness of a compensation are fulfilled.

Attention

After start-up, updating or re-initialisation, it is “almost” not permissible to command a rapid program start or exchange an axis without requesting axis positions.
First, the NC channel must be synchronised in relation to axis positions.

4.2 Cross compensation

Cross compensation permits the compensation of rectangularity errors or errors that arise due to deflection of the axis.

Compensation process

Cross compensation (also called sag compensation) permits the compensation of an axis position depending on the command position of another axis.

The axis whose command positions influences the compensation value is called the master axis. The axis for which compensation is active is called the slave axis.

A master axis can also be the salve axis of another master axis.

Notice

Cross compensation data is specified in the compensation value list of the **slave axis** .

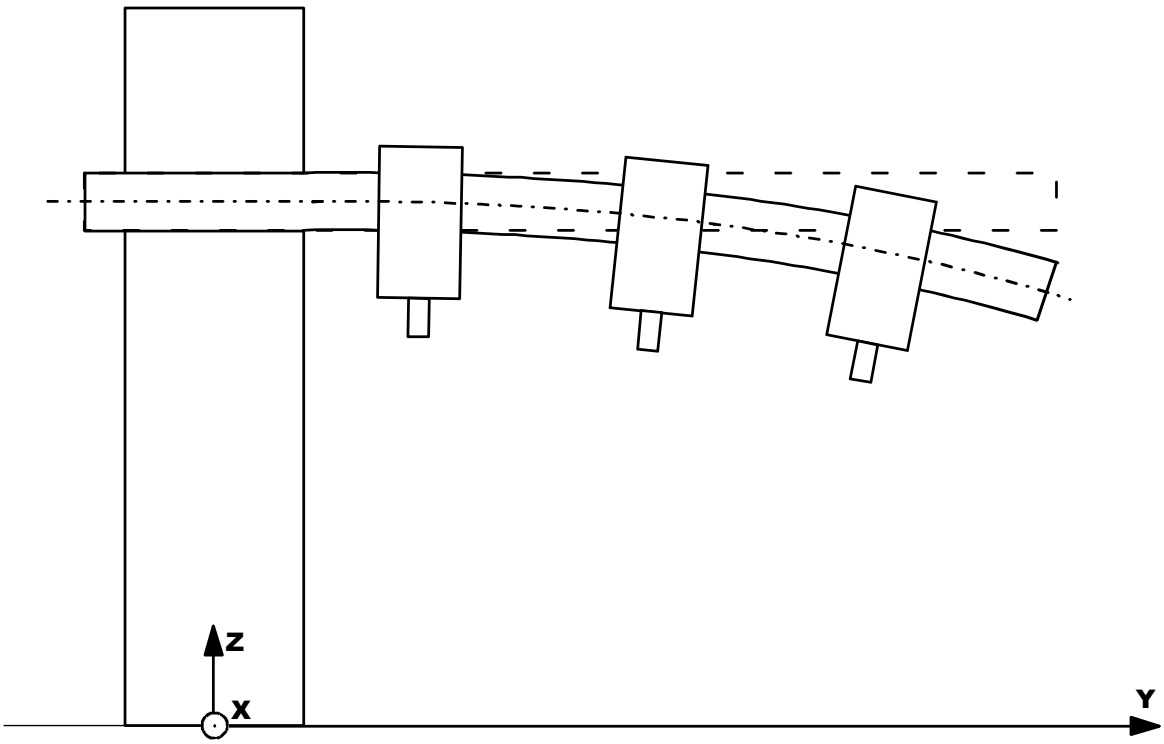


Fig. 9: Application example for cross compensation (Y: Master, Z: Slave).

Properties

- A master axis has one or several slave axes.
- A slave has only one master axis.
- Cross compensation can also be used for the master and slave axes of a gantry combination.
- A compensation value can be specified for each interpolation point.
- Interpolation between interpolation points is linear.
- Cross compensation is available for all drive types.
- Compensations can only be viewed in the positions directly output to the drive (not in the normal display data) since compensation takes place outside normal calculations.
- As of CNC Build V3.1.3079.06 you can adjust the size of the compensation table. The parameter P-COMP-00060 [▶ 34] defines the maximum number of table entries. The actual number of entries used by P-COMP-00004 [▶ 35]

Effectiveness

Cross compensation is only effective if all the following conditions are fulfilled:

- The function was activated for the slave axis.
- The compensation value table was provided.
- Master and slave axes are linear axes. As of CNC Build v263.1504, cross compensation can also be used for rotary axes or spindles.
- The master axis was referenced. Therefore there is no need to reference the slave axis.

4.2.1 Parameter

4.2.1.1 Overview

Activation

Cross compensation is activated in the axis machine data record of the slave axis by P-AXIS-00047:

Variable name	Type	Meaning
lr_param.crosscomp	BOOLEAN	0: no cross compensation 1: Cross compensation active

Programing Example

Excerpt from the axis parameter list:

```
:
lr_param.crosscomp      1
:
```

Notice

Cross compensation can also be used for a gantry axis group. A compensation value table must then be specified for each individual axis in the gantry combination (cross compensation slave).

Compensation value tables can therefore have different settings for each gantry axis.

Activating/deactivating

Cross compensation (ON if master axis is referenced and compensation is activated) can be switched on or off at any time when the slave axis is at standstill. The slave axis command positions displayed are offset with the offset values.

Filter:

When the master axis is referenced, inconsistencies may occur when compensation values are calculated for a moved slave axis. These inconsistencies can be smoothed by using a $\sin^2$ filter. The parameter P-COMP-00026 (n_cycles) switches the filter order to activate it.

Management data of the cross compensation table

General data of the list body is entered in the structure **kw.crosscomp.**.*. It contains the following elements.

Management data elements

Variable name	Type	Meaning
unit	BOOLEAN	Unit of the length entries: 0: Encoder increments 1: metric (in 0.1 µm)
last_index	SGN32	Last valid index in the slave axis table. As of CNC Build V3.1.3079.06 the maximum possible of table entries can be defined in P-COMP-00060 [▶ 34]. In previous Builds the default value is 1000. The table always starts with index 0
master_ax_nr	UNS16	Axis number of the master axis; its command position acts as the input variable of the compensation table.
n_cycles	UNS16	Number of cycles of $\sin^2$ filter.
manual_activation	BOOLEAN	0: (Default) The CNC activates cross compensation automatically as soon as the required conditions are met (e.g. the master axis is referenced). 1: Cross compensation must be activated explicitly in the NC program by the COMP command (see section “Selecting/ deselecting axis compensations in the NC program”) [▶ 107]. Compensation is deactivated at the end of the NC program, when the CNC is reset or when the axis is released.

Compensation values for cross compensation

The corresponding compensation value of the slave axis is entered in the table **kw.crosscomp.table[i].*** for every interpolation point. The compensation table is valid for positive and negative directions of motion.

Compensation value table

Variable name	Type	Meaning
table[i].setpoint	SGN32	Interpolation point of master axis for which the slave axis must be compensated.
table[j][i].correction	SGN32	Relative compensation value for the salve axis at interpolation point i

Special feature for rotary master axis

As of CNC Build v263.1504, cross compensation can also be used for rotary axes or spindles. A modulo calculation of the axis position is carried out in the position controller for these axis types.

If a cross compensation master axis is a modulo axis, a "modulo transition" also takes place in the compensation table in the modulo transition of the axis position of this master axis. To prevent a jump from occurring at this point of the compensation value process of the slave axis, the same compensation value must be specified in the compensation table at the modulo transition.

4.2.1.2 Description

P-AXIS-00047	**Activation of cross compensation**	
Description	This parameter activates the cross compensation.	
Parameter	lr_param.crosscomp	
Data type	BOOLEAN	
Data range	0/1	
Axis types	T	
Dimension	T: ----	
Default value	0	
Drive types	----	
Remarks		

P-COMP-00060	**Maximum number of table entries for cross compensation**	
Description	This cross compensation parameter (FCT-C5 [▶ 30]) saves the memory space required for a particular number of table entries. The size of the actually used compensation table is defined by `last_index` (P-COMP-00004) and `last_index` must be smaller than `max_points`.	
Parameter	kw.crosscomp.max_points	
Data type	UNS32	
Data range	0 <= P-COMP-00060	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	1001	
Remarks	The parameter value can no longer be changed after start-up or after lists are reloaded. Otherwise error ID 110639 is output. If P-COMP-00060 is not specified (or assigned the value 0), the default value is assigned to P-COMP-00060 for downward compatibility reasons. To avoid the default assignment, memory can be saved for an axis that does not use cross compensation [▶ 30] by assigning the value 1 to P-COMP-00060. This parameter is available as of CNC Build V3.3079.06	

P-COMP-00003	Unit of the length entries	
Description	The parameter defines the unit to be used for the length entries of compensation values.	
Parameter	kw.crosscomp.unit	
Data type	BOOLEAN	
Data range	0: Encoder increments 1: Metric (in 0.1 µm)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00004	Last index of compensation value table	
Description	This parameter determines the last valid index in the table of the master axis. The table always starts with index 0	
Parameter	kw.crosscomp.last_index	
Data type	SGN32	
Data range	0 ≤ last_index < P-COMP-00060 [▶ 34]	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks	P-COMP-00060 [▶ 34] is available as of Build V3.1.3079.06. The upper limit in previous CNC versions is 1000.	

P-COMP-00005	Logical axis number of the master axis	
Description	This parameter determines the logical number of the master axis whose command position is used to calculate the input variable of the compensation value table of the slave axis.	
Parameter	kw.crosscomp.master_ax_nr	
Data type	UNS16	
Data range	1 ≤ master_ax_nr ≤ MAX (UNS16)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00026	**Number of cycles for ‘smooth switching’**	
Description	This parameter determines the number of cycles for which cross compensation is activated/ deactivated smoothly.	
Parameter	kw.crosscomp.n_cycles	
Data type	UNS16	
Data range	0 ≤ n_cycles ≤ 20 (maximum number of cycles for which cross compensation is activated/ deactivated, application-specific)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00029	**Manual activation**	
Description	Cross compensation is automatically activated by the CNC if it selected in the axis parameters (P-AXIS-00047) and the required conditions are met (e.g. axis is homed). If the parameter is set to the value 1, cross compensation must be activated explicitly by an NC command (see [PROG//Selecting/deselecting axis compensations in the NC program]. In addition, compensation is deselected at the end of the NC program, at CNC reset and on axis release.	
Parameter	kw.crosscomp.manual_activation	
Data type	BOOLEAN	
Data range	0: Automatic activation 1: Manual activation in NC program	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00006	**Interpolation point of the master axis**	
Description	This parameter determines the interpolation points of the master axis on which the slave axis has to be corrected.	
Parameter	kw.crosscomp.table[i].setpoint	
Data type	SGN32	
Data range	MIN(SGN32) ≤ setpoint < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00007	**Compensation values for the slave axis**	
Description	This parameter determines the relative compensation values for the slave axis at interpolation points 'i'.	
Parameter	kw.crosscomp.table[i].correction	
Data type	SGN32	
Data range	MIN(SGN32) ≤ correction < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

4.2.1.3 CNC objects

Name	CROSSC::f_is_active		
Description	Cross compensation: active, activate using Description [▶ 34] This means that all preconditions must be met, such as the axis is homed and all necessary enables are on.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>004F
Data type	BOOLEAN	**Length**	1
Attributes	read	**Unit**	[-]
Remarks			

Name	CROSSC::activated		
Description	This object reads whether cross compensation is activated via P-AXIS-00047 [▶ 34].		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>01D6
Data type	BOOLEAN	**Length**	1
Attributes	read	**Unit**	[-]
Remarks			

Name	CROSSC::actual_offset		
Description	Cross compensation: current effective offset		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0035
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

Name	CROSSC::delta_offset		
Description	Cross compensation: change in compensation value compared to previous cycle		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0034
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

4.2.2 Example of a compensation value list

Programing Example

Example of a compensation value list for cross compensation

```
# ***************************************
#  Axis compensation data for Z-axis
# ***************************************

kopf.achs_nr                          3
kopf.log_achs_name                    Z
kw.crosscomp.last_index               99 /*Last valid index of the
table*/
kw.crosscomp.master_ax_nr             1  /*Log. ax. number of the master
axis*/
kw.crosscomp.unit                     1  /*0:Incr. 1:Metric in 0.1 µm*/
kw.crosscomp.n_cycles                 20
#
kw.crosscomp.table[0].setpoint        10735
kw.crosscomp.table[0].correction      3
kw.crosscomp.table[1].setpoint        11523
kw.crosscomp.table[1].correction      5
:
:
kw.crosscomp.table[99].setpoint       10000000  /*at 1000 mm of axis 3*/
kw.crosscomp.table[99].correction     1000      /*corr. of 0.1 mm for
axis 1*/
```

4.2.3 Error messages

Errors in the configuration of the cross compensation result in deactivation of the function for the affected axis and to the output of an error message (warning message).

The following error messages then appear:

- ID 110639
- ID 70242
- ID 70244
- ID 70245
- ID 70246
- ID 70247
- ID 70248
- ID 70249
- ID 70250
- ID 70432

4.3 Plane compensation

With plane compensation, axis misalignments can be compensated for as a function of the position of two master axes. One application case, for example, is the compensation of the Z axis depending on X and Y.

Compensation process

Plane compensation allows the compensation of an axis position depending on the command positions of 2 axes.

The two axes whose command positions influence the compensation value are called master axes. The axis for which compensation is active is called the slave axis.

One of the master axes can also be a slave axis itself.

Notice

Cross compensation data is specified in the compensation value list of the **slave axis** .

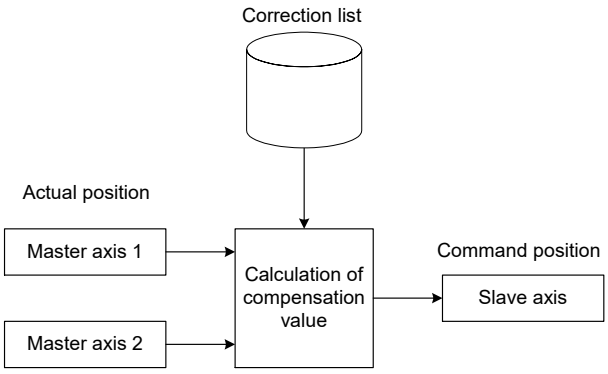


Fig. 10: Schematic of the compensation value calculation for plane compensation

Characteristics

- The two master axes form a 2-axis coordinate system; in the simplest case it is the X-Y plane (master axis 1 = X axis, master axis 2 = Y axis).
- This coordinate system is divided into squares or rectangles like a chessboard.
- The edge length of the squares or the edge lengths of the rectangles can be parameterised.
- The corners of the squares or rectangles form the interpolation points of the table (see figure below).
- A compensation value can be specified for each interpolation point.
- Interpolation between interpolation points is linear (see 2nd figure below).
- Outside the table, the compensation values at the edge of the table remain effective.
- As of CNC Build V3.1.3079.06 you can adjust the size of the compensation table. The maximum number of table entries can be set by P-COMP-00061 [▶ 48] and The actual number of entries used is specified by P-COMP-00010 [▶ 49] and P-COMP-00011 [▶ 50].

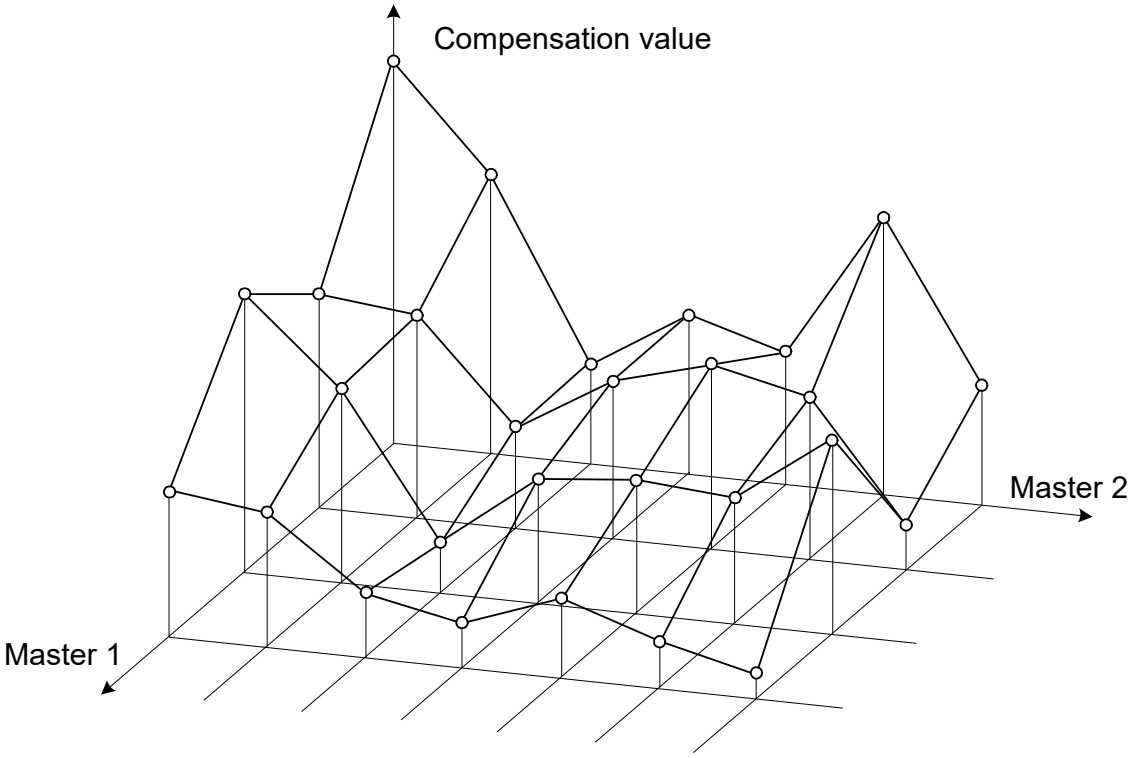


Fig. 11: Specify compensation values at the interpolation points

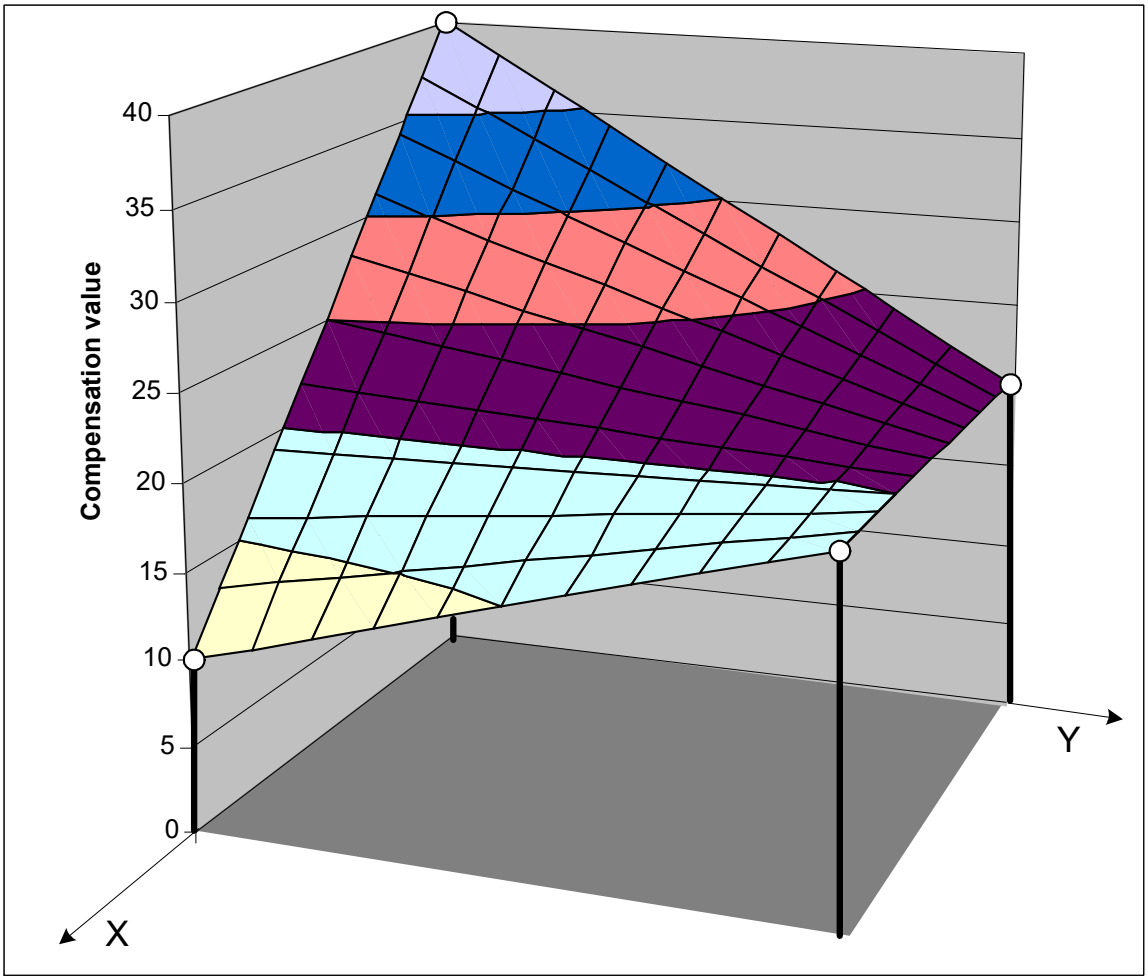


Fig. 12: Linear interpolation between the 4 interpolation points of a square

Effectiveness

Plane compensation is only effective if all the following conditions are fulfilled:

- The function was activated for the slave axis.
- The compensation value table was provided.
- Master and slave axes are linear axes. As of CNC Build v263.1504, plane compensation can also be used for rotary axes or spindles.
- Master axes have an absolute measuring system or were referenced.

4.3.1 Parameter

4.3.1.1 Overview

Activation

Plane compensation is activated in the axis machine record of the slave axis by P-AXIS-00174:

Variable name	Type	Meaning
lr_param.crosscomp2	BOOLEAN	0: no plane compensation 1: Plane compensation active

Programing Example

Excerpt from the axis parameter list:

```
:
lr_param.crosscomp2     1
:
```

Activating/deactivating

Plane compensation (ON if master axes are referenced and compensation is activated) can be switched on or off at any time when the slave axis is at standstill. The slave axis command positions displayed are offset with the offset values.

Filter:

When master axes are referenced, inconsistencies may occur when compensation values are calculated for a moved slave axis. These inconsistencies can be smoothed by using a $\sin^2$ filter. The parameter P-COMP-00027 [▶ 52] (n_cycles) switches the filter order to activate it.

Special feature for rotary master axes

As of CNC Build v263.1504, plane compensation can also be used for rotary axes or spindles. A modulo calculation of the axis position is carried out in the position controller for these axis types.

If a plane compensation master axis is a modulo axis, a "modulo transition" also takes place in the compensation table in the modulo transition of the axis position of this master axis. To prevent a jump from occurring at this point of the compensation value process of the slave axis, the same compensation value must be specified in the compensation table at the modulo transition.

Management data of the plane compensation table

The general data of the list body parameterise the axes involved, the limits of the compensation range, etc. General data is entered in the structure **kw.crosscomp2**.*. It contains the following elements.

Management data elements

Variable name	Type	Meaning
unit	BOOLEAN	Unit of the length entries: 0: Encoder increments 1: metric (in 0.1 µm)
grid	STRING	Type of interpolation point sample grid: QUADRATIC: Identical grid structure, interval for both master axes RECTANGULAR: Different grid structure, interval1 and interval2 for both master axes
interval	UNS32	Interval between 2 interpolation points in 0.1 µm for the two master axes (grid = QUADRATIC)
interval1	UNS32	Interval of the first master axis between 2 interpolation points in 0.1 µm (grid = RECTANGULAR)
interval2	UNS32	Interval of 2nd master axis between 2 interpolation points in 0.1 µm (grid = RECTANGULAR)
last_index_master1	SGN32	Last valid index in the table for master axis 1 (see Limits of compensation table [▶ 46]). The table always starts with index 0
last_index_master2	SGN32	Last valid index in the table for master axis 2 (see Limits of compensation table [▶ 46]). The table always starts with index 0
start_position_master1	SGN32	Position of master axis 1 at which the compensation table starts
start_position_master2	SGN32	Position of master axis 2 at which the compensation table starts
master1_ax_nr	UNS16	Log. axis number of master axis 1
master2_ax_nr	UNS16	Log. axis number of master axis 2
n_cycles	UNS16	Number of cycles of $\sin^2$ filter.
manual_activation	BOOLEAN	0: Default: The CNC activates plane compensation automatically as soon as the required conditions are met (e.g. the master axes are referenced) 1: Plane compensation must be activated explicitly in the NC program by the COMP command (see section “Selecting/deselecting axis compensations in the NC program [▶ 107]“). Compensation is deactivated at the end of the NC program, when the CNC is reset or when the axis is released.

Limits of compensation table

As of CNC Build V3.1.3079.06 the maximum possible of table entries can be defined in P-COMP-00061 [▶ 48]. In previous builds, the entries “last_index_master1”(P-COMP-00010 [▶ 49]) and “last_index_master2” (P-COMP-00011 [▶ 50]) are limited to 100 entries.

This rigid limitation non longer applies. Note only that:

P-COMP-00010 [▶ 49] x P-COMP-00011 [▶ 50] <= P-COMP-00061 [▶ 48]

Compensation values of plane compensation

The corresponding compensation value of the slave axis is entered in the table **kw.crosscomp2.table[j][i].*** for every interpolation point.

Compensation value table

Variable name	Type	Meaning
table[j][i].correction	SGN32	Compensation value of slave axis at interpolation point [j][i], see figure below.

Notice

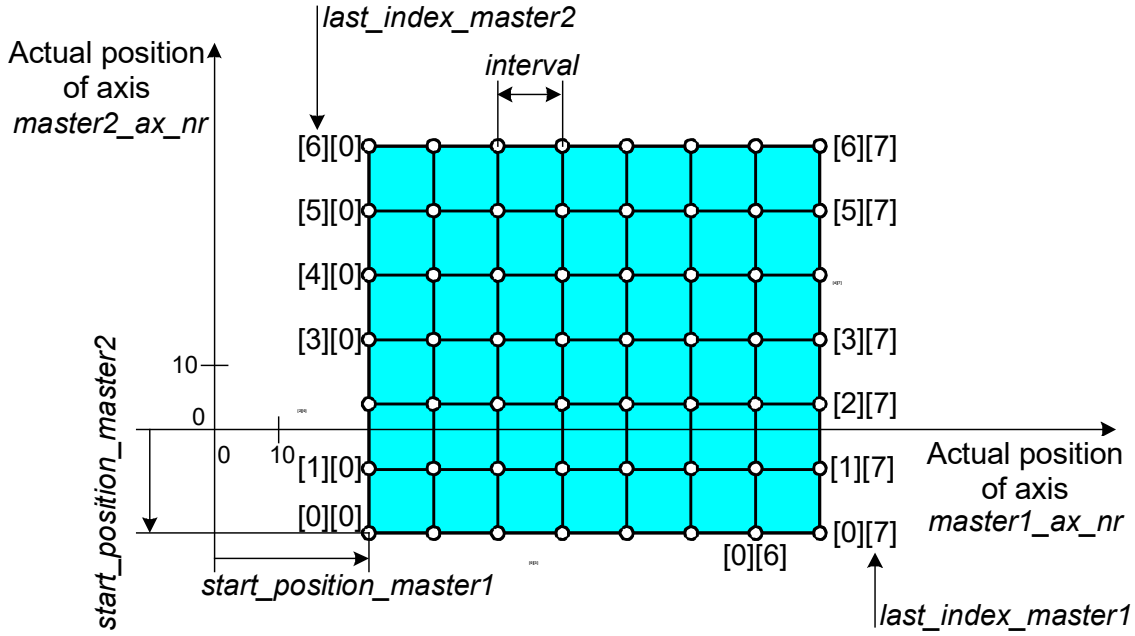
When interpolation points are indexed in the compensation value table, the **1.** index j always refers to the **2.** master axis (see figure below).

Index j -> master axis 2

Index i -> master axis 1

Notice

Unassigned interpolation points are assigned the value 0 in the compensation value table. This value is also used in the calculation.




```
kw.crosscomp2.interval                    100000
kw.crosscomp2.last_index_master1               7
kw.crosscomp2.last_index_master2               6
kw.crosscomp2.start_position_master1      220000
kw.crosscomp2.start_position_master2     -160000
kw.crosscomp2.unit                             1
kw.crosscomp2.master1_ax_nr                    1
kw.crosscomp2.master2_ax_nr                    2

kw.crosscomp2.table[0][0].correction           0
                              ...
kw.crosscomp2.table[6][7].correction         324
```

Fig. 13: Compensation value list parameters

4.3.1.2 Description

P-AXIS-00174	**Activation of plane compensation**
Description	This parameter activates the plane compensation (2-dimensional cross compensation).
Parameter	lr_param.crosscomp2
Data type	BOOLEAN
Data range	0/1
Axis types	T
Dimension	T: ----
Default value	0
Drive types	----
Remarks	

P-COMP-00061	Maximum number of table entries for plane compensation	
Description	This plane compensation parameter (FCT-C5 [▶ 41]) saves the memory space required for a particular number of table entries. The size of the actually used compensation table is defined by `last_index:master1` (P-COMP-00010) and `last_index_master2` (P-COMP-00011) and the following must apply: (`last_index_master1` + 1) * (`last_index_master2` + 1) <= `max_points` If `max_points` is not specified (or assigned the value 0), the previous restrictions apply to `last_index_master1` and `last_index_master2`. • 0 <= `last_index_master1` <= 100 • 0 <= `last_index_master2` <= 100	
Parameter	kw.crosscomp2.max_points	
Data type	UNS32	
Data range	0 <= P-COMP-00061	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	10201 (*)	
Remarks	The parameter value can no longer be changed after start-up or after lists are reloaded. Otherwise error ID 110640 is output. If P-COMP-00061 is not specified (or assigned the value 0), the default value is assigned to P-COMP-00061 for downward compatibility reasons. To avoid the default assignment, memory can be saved for an axis that does not use plane compensation [▶ 41] by assigning the value 1 to P-COMP-00061. * composition of the default value: 101*101 =10201 This parameter is available as of CNC Build V3.3079.06	

P-COMP-00008	Unit of the length entries	
Description	This parameter defines the unit of the length / position entries.	
Parameter	kw.crosscomp2.unit	
Data type	BOOLEAN	
Data range	0: Encoder increments 1: Metric (in 0.1 µm)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00009	Distance between interpolation points	
Description	This parameter defines the distance between two interpolation points if both axes use an identical grid (P-COMP-000031(grid) = QUADRATIC).	
Parameter	kw.crosscomp2.interval	
Data type	UNS32	
Data range	0 < interval < MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00010	Last index of master axis 1	
Description	This parameter determines the last valid index in the table of master axis 1 (maximum value is 100). The table always starts with index 0.	
Parameter	kw.crosscomp2.last_index_master1	
Data type	SGN32	
Data range	0 ≤ P-COMP-00010 <= 100	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks	As of Build V3.1.3079.06, P-COMP-00010 is freely assignable. There is no upper limit. However, the condition of P-COMP-00061 [▶ 48] must be complied with. P-COMP-00010 * P-COMP-00011 [▶ 50] <= P-COMP-00061 [▶ 48] **Attention**: If this parameter is re-interpreted, all the values in the compensation value table (P-COMP-00016 [▶ 51]) must be read in again.	

P-COMP-00011	Last index of master axis 2	
Description	This parameter determines the last valid index in the table of the two master axes (maximum 100 values). The table always starts with index 0.	
Parameter	kw.crosscomp2.last_index_master2	
Data type	SGN32	
Data range	0 ≤ P-COMP-00011 <= 100	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks	As of Build V3.1.3079.06, P-COMP-00011 is freely assignable. There is no upper limit. However, the condition of P-COMP-00061 [▶ 48] must be complied with. P-COMP-00010 [▶ 49] * P-COMP-00011 <= P-COMP-00061 [▶ 48] **Attention**: If this parameter is re-interpreted, all the values in the compensation value table (P-COMP-00016 [▶ 51]) must be read in again.	

P-COMP-00012	Start position of master axis 1	
Description	This parameter determines the start position of master axis 1 in the compensation table.	
Parameter	kw.crosscomp2.start_position_master1	
Data type	SGN32	
Data range	MIN(SGN32) ≤ start_position_master1 < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00013	Start position of master axis 2	
Description	This parameter determines the start position of master axis 2 in the compensation table.	
Parameter	kw.crosscomp2.start_position_master2	
Data type	SGN32	
Data range	MIN(SGN32) ≤ start_position_master2 < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00014	Logical axis number of the master axis 1	
Description	This parameter defines the logical axis number of the first master axis.	
Parameter	kw.crosscomp2.master1_ax_nr	
Data type	UNS16	
Data range	1 ≤ master1_ax_nr ≤ MAX (UNS16)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00015	Logical axis number of the master axis 2	
Description	This parameter defines the logical axis number of the second master axis.	
Parameter	kw.crosscomp2.master2_ax_nr	
Data type	UNS16	
Data range	1 ≤ master2_ax_nr ≤ MAX (UNS16)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00016	Compensation values for the slave axis	
Description	This parameter defines the relative compensation values of the slave axis at interpolation points [j][i]. When indexing the interpolation points in the compensation list, the first index j refers to the second master axis.	
Parameter	kw.crosscomp2.table[j][i].correction	
Data type	SGN32	
Data range	MIN(SGN32) ≤ correction < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00027	Number of cycles for ‘smooth switching’	
Description	This parameter determines the number of cycles for which plane compensation is activated/ deactivated smoothly.	
Parameter	kw.crosscomp2.n_cycles	
Data type	UNS16	
Data range	0 ≤ n_cycles ≤ 20 (maximum number of cycles for which cross compensation is activated/ deactivated, application-specific)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00030	Manual activation	
Description	Plane compensation is automatically activated by the CNC if it selected in the axis parameters (P-AXIS-00174) and the required conditions are met (e.g. axis is homed). If the parameter is set to value 1, plane compensation must be activated explicitly by an NC command (see [PROG//Selecting/deselecting axis compensations in the NC program]. In addition, compensation is deselected at the end of the NC program, at CNC reset and on axis release.	
Parameter	kw.crosscomp2.manual_activation	
Data type	BOOLEAN	
Data range	0: Automatic activation 1: Manual activation in NC program	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00032	Distance between the interpolation points of the first master axis	
Description	The parameter defines the interval between two interpolation points for the first master axis if both master axes use a different grid (P-COMP-00031(grid) = RECTANGULAR).	
Parameter	kw.crosscomp2.interval1	
Data type	UNS32	
Data range	0 < interval1 < MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00033	Distance between the interpolation points on the second master axis	
Description	The parameter defines the interval between two interpolation points for the first master axis if both master axes use a different grid (P-COMP-00031(grid) = RECTANGULAR).	
Parameter	kw.crosscomp2.interval2	
Data type	UNS32	
Data range	0 < interval2 < MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

4.3.1.3 CNC objects

Name	CROSSC::f_is_active		
Description	Cross compensation: active, activate using Description [▶ 34] This means that all preconditions must be met, such as the axis is homed and all necessary enables are on.		
Task	GEO (Port 551)		
Index group	0x120300	Index offset	0x<A_{ID}>004F
Data type	BOOLEAN	Length	1
Attributes	read	Unit	[-]
Remarks			

Name	CROSSC::delta_offset		
Description	Cross compensation: change in compensation value compared to previous cycle		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0034
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

Name	CC2::correction		
Description	Plane compensation: current effective offset		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0052
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

Name	CC2::activated		
Description	This object reads whether plane compensation is activated via P-AXIS-00174 [▶ 47].		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>01D7
Data type	BOOLEAN	**Length**	1
Attributes	read	**Unit**	[-]
Remarks			

4.3.2 Examples of compensation value lists

Example

Compensation value list for plane compensation

Available as of V3.1.3079.06

The parameterisation example below reserved a maximum number of table entries of 50000 entries. The actual number of entries used is defined by the product of “last_index_master1” and “last_index_master2”.

```
# ****************************************
#  Axis compensation data X axis
# ****************************************

kopf.achs_nr                                    1
kopf.log_achs_name                              X

# Reserve maximum number of table entries
kw.crosscomp2.max_points                    50000
kw.crosscomp2.last_index_master1             1000
kw.crosscomp2.last_index_master2               20

kw.crosscomp2.table[  0][  0].correction       -3
kw.crosscomp2.table[  0][  1].correction       -1
```

etc.

```
kw.crosscomp2.table[ 20][ 999].correction      58
kw.crosscomp2.table[ 20][1000].correction      49
```

Example

Compensation value list for plane compensation

```
# ****************************************
#  Axis compensation data X axis
# ****************************************

kopf.achs_nr                                    1
kopf.log_achs_name                              X
kw.crosscomp2.interval                     100000  /* 10 mm */
kw.crosscomp2.last_index_master1              100
kw.crosscomp2.last_index_master2              200
kw.crosscomp2.start_position_master1      -400000  /* -40 mm */
kw.crosscomp2.start_position_master2      -700000  /* -70 mm */
kw.crosscomp2.unit                              1  /* 0,1 mµ */
kw.crosscomp2.master1_ax_nr                     2
kw.crosscomp2.master2_ax_nr                     3
kw.crosscomp2.n_cycles                         20

kw.crosscomp2.table[  0][  0].correction       -3
kw.crosscomp2.table[  0][  1].correction       -1
kw.crosscomp2.table[  0][  2].correction        4
kw.crosscomp2.table[  0][  3].correction        9
kw.crosscomp2.table[  0][  4].correction       13
kw.crosscomp2.table[  0][  5].correction       17
kw.crosscomp2.table[  0][  6].correction       42
kw.crosscomp2.table[  0][  7].correction       53
```

```
kw.crosscomp2.table[  0][  8].correction        33
kw.crosscomp2.table[  0][  9].correction        42
kw.crosscomp2.table[  0][ 10].correction        19
kw.crosscomp2.table[  0][ 11].correction         7
kw.crosscomp2.table[  0][ 12].correction         2
kw.crosscomp2.table[  0][ 13].correction         0
kw.crosscomp2.table[  0][ 14].correction         5
kw.crosscomp2.table[  0][ 15].correction        -3
kw.crosscomp2.table[  0][ 16].correction        -7
kw.crosscomp2.table[  0][ 17].correction       -11
kw.crosscomp2.table[  0][ 18].correction       -13
kw.crosscomp2.table[  0][ 19].correction       -22
kw.crosscomp2.table[  0][ 20].correction       -34
kw.crosscomp2.table[  0][ 21].correction       -29
kw.crosscomp2.table[  0][ 22].correction       -99
…
kw.crosscomp2.table[200][ 71].correction        45
kw.crosscomp2.table[200][ 72].correction        68
kw.crosscomp2.table[200][ 73].correction        71
kw.crosscomp2.table[200][ 74].correction        90
kw.crosscomp2.table[200][ 75].correction       111
kw.crosscomp2.table[200][ 76].correction       123
kw.crosscomp2.table[200][ 77].correction       134
kw.crosscomp2.table[200][ 78].correction       147
kw.crosscomp2.table[200][ 79].correction       156
kw.crosscomp2.table[200][ 80].correction       176
kw.crosscomp2.table[200][ 81].correction       167
kw.crosscomp2.table[200][ 82].correction       148
kw.crosscomp2.table[200][ 83].correction       132
kw.crosscomp2.table[200][ 84].correction       123
kw.crosscomp2.table[200][ 85].correction       111
kw.crosscomp2.table[200][ 86].correction       101
kw.crosscomp2.table[200][ 87].correction        97
kw.crosscomp2.table[200][ 88].correction        88
kw.crosscomp2.table[200][ 89].correction        83
kw.crosscomp2.table[200][ 90].correction        82
kw.crosscomp2.table[200][ 91].correction        77
kw.crosscomp2.table[200][ 92].correction        68
kw.crosscomp2.table[200][ 93].correction        63
kw.crosscomp2.table[200][ 94].correction        61
kw.crosscomp2.table[200][ 95].correction        59
kw.crosscomp2.table[200][ 96].correction        57
kw.crosscomp2.table[200][ 97].correction        52
kw.crosscomp2.table[200][ 98].correction        56
kw.crosscomp2.table[200][ 99].correction        58
kw.crosscomp2.table[200][100].correction        49
#
End
```

4.3.3 Error messages

Errors in the configuration of the plane compensation result in deactivation of the function for the affected axis and to the output of an error message (warning message).

The following error messages then appear:

- ID 110640
- ID 70182
- ID 70183
- ID 70184
- ID 70185

4.4 Leadscrew error compensation

Compensation process

Leadscrew error compensation (referred to below as LSEC) is an axial compensation.
The position setpoint of the compensated axis is changed by a compensation value in the position controller cycle in order to compensate for leadscrew errors, for instance.

This compensation is cancelled by computation for the measured actual position values so that the compensation performed does not appear in the display data of the controller.

Compensation table

The compensation values are taken from a table in which the profile of the compensation curve is stored as a function of the axis position. The axis positions entered in the table are called interpolation points and the corresponding values of the compensation curve are called compensation values.

The compensation value is linearly interpolated for axis positions that lie between interpolation points.

The table containing compensation values is referred to in the following as the compensation table.

Bilateral/unilateral LSEC

You can specify a separate compensation table for each direction of axis motion; this type of compensation is called bilateral compensation.

With bilateral leadscrew error compensation, any backlash that may be present can also be compensated for; additional backlash compensation (see Section “Backlash compensation [▶ 8]“) is therefore not necessary.

With bilateral leadscrew error compensation, the parameter P-AXIS-00243 [▶ 63] specifies the number of cycles for distribution of the compensation offset in case of a reversal in direction.

If a table is used for both directions of axis motion, it is referred to as unilateral compensation.

- The compensation tables are stored to a file for each axis (compensation value list).
- Axis dynamics are not taken into account in the output of compensation values.

The graphic below shows an example of a compensation value curve. The meaning of the parameters used in the graphic will be explained later.

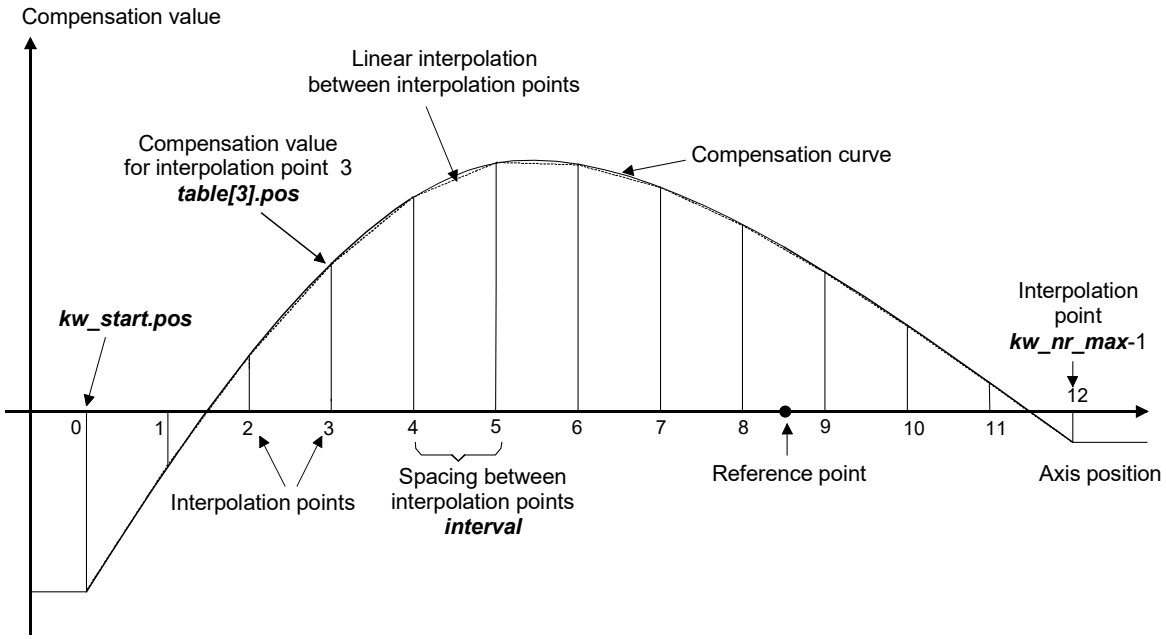


Fig. 14: Compensation table with equidistant interpolation point grid and unilateral compensation

Properties

Leadscrew error compensation (LSEC) has the following characteristics:

- When bilateral compensation is used, the same interpolation point positions must be used for both value tables.
- You can define a compensation table only for a partial motion range of an axis. For axis positions outside the compensation table, the value at either end of the table continues to be used.
- Any compensation value other than 0 can be present at the reference point.
- The distance between interpolation points in the value tables can be selected either equidistant or non-equidistant.
- As of CNC Build V3.1.3079.06 you can adjust the size of the compensation table. The parameter P-COMP-00059 [▶ 64] defines the maximum number of table entries. The actual number of entries used by P-COMP-00020 [▶ 65]

Effectiveness

The LSEC is effective under the following conditions:

- The LSEC was activated for the slave axis.
- A compensation table for the axis must be transferred to the controller.
- he axis was referenced or uses an absolute measuring system.

4.4.1 Parameter

4.4.1.1 Overview

Activation

Leadscrew error compensation (LSEC) is activated in the axis machine data record of the corresponding slave axis by P-AXIS-00175:

Variable name	Type	Meaning
lr_param.ssfk	BOOLEAN	0: no LSEC 1: LSEC active
P-AXIS-00243 [▶ 63] lr_param.n_backlash_cyc	UNS16	Number of cycles with bilateral leadscrew error compensation with reversal of direction

Example

Excerpt from the axis parameter list:

```
:
lr_param.ssfk     1
:
```

Management data of the LSEC table

The general data of the list body parameterises the operation mode of the compensation, e.g. unilateral or bilateral. General data is entered in the structure **kw.ssfk..*** and contains the following elements.

Management data elements

Variable name	Type	Meaning
unit	BOOLEAN	Unit of the length entries: 0: Encoder increments 1: metric (in 0.1 µm)
interval	SGN32	Distance between interpolation points of the compensation table for use if using equidistant interpolation points. If this parameter is = 0, the position of each interpolation point must be specified separately.
kw_startpos	SGN32	Start position of the compensation table (with equidistant interpolation points)
kw_nr_max	SGN32	Number of entries in the compensation table As of CNC Build V3.1.3079.06, the maximum possible number of entries can be defined in P-COMP-00059 [▶ 64] . In previous builds the default value is 1500.
bilateral	BOOLEAN	0: Unilateral compensation 1: Bilateral compensation
modulo	BOOLEAN	Compensation for a modulo axis take place
manual_activation	BOOLEAN	0 (default): The CNC activates leadscrew error compensation automatically as soon as the required conditions are met (e.g. the master axis is referenced) 1: Leadscrew error compensation must be activated explicitly in the NC program by the COMP command (see Section “Selecting/ deselecting axis compensations in the NC program“) [▶ 107] . Compensation is deactivated at the end of the NC program, when the CNC is reset or when the axis is released.
set_pos_without_comp	BOOLEAN	By default, leadscrew error compensation also considers the compensation values generated from other axis compensations, e.g. cross and plane compensation. Direction-dependent leadscrew error compensation (see P-COMP-00021 [▶ 60]) may result in undesired backlash cover. The parameter set_pos_without_comp can disable the inclusion of other compensation values in the calculation. 0: Compensation values of other compensations are considered in the leadscrew error compensation. 1: Compensation values of other compensations are not considered.

LSEC compensation values

The compensation values are specified in the table **kw.ssfk.table[i].***.

The field index i can then assume the value 0 *to* **kw.ssfk.kw_nr_max** –1. The maximum number of entries is specified in [SYSP//Number 2.23].

The compensation values are specified as absolute position errors in the unit specified in **kw.ssfk.unit** (metric in 0.1 µm or incremental). Where:

$[Delta]_{si}$ i-th compensation value

$s_{soll, i}$ i-th command value (interpolation point of the compensation table)

$s_{ist, i}$ i-th actual value (measured with reference measuring system)

Compensation value table

Variable name	Type	Meaning
pos	SGN16	Compensation value for motion in a positive direction (bilateral compensation) and compensation value for use with unilateral compensation.
neg	SGN16	Compensation value for motion in a negative direction. Not used with unilateral SSKF.
setpoint	SGN32	Interpolation point of the axis (programmed value). Only with non equidistant interpolation points.

For use with bilateral compensation, enter position errors for motion in a position direction in the **pos** entry, The interpolation points specified are valid for both directions.

For use with unilateral compensation, also enter position errors in the **pos** Entry. The **neg** entry is omitted.

As opposed to the entry of individual interpolation points for the compensation table, a grid structure can also be used. Entries for interpolation points can then be omitted in the **setpoint** variable in this case.

To use an interpolation point grid, enter the increment of the interpolation point grid in the **kw.ssfk.interval** variable. The interpolation points are then calculation internally from the start position (**kw.ssfk. kw_startpos**) and the increment.

Special features applicable to modulo axes

If a compensation table is configured for a modulo axis (**kw.ssfk.modulo** = 1), a modulo transition also occurs in the compensation table at the modulo transition of the axis position.

This can be used in order to compensate for position errors caused by gears or transmissions for instance.

The following special aspects must be noted:

- The position values of the first and last entries in the compensation list must be identical.
- The number of compensation values is also equal here to the number of entries in the compensation value table.

4.4.1.2 Description

P-AXIS-00175	**Activation of SSFK**	
Description	This parameter activates the lead screw error compensation.	
Parameter	lr_param.ssfk	
Data type	BOOLEAN	
Data range	0/1	
Axis types	T, R	
Dimension	T: ----	R: ----
Default value	0	
Drive types	----	
Remarks		

P-AXIS-00243	**Distribution of the backlash on multiple cycles**	
Description	The parameter defines a number of position control cycles on which the backlash is distributed. The distribution is done according to a $\sin^2$ function. The parameter is also used for bi-directional lead screw error compensation if a change of direction is executed.	
Parameter	lr_param.n_backlash_cyc	
Data type	UNS16	
Data range	0 < n_backlash_cyc < 20	
Axis types	T, R, S	
Dimension	T: Number of interpolation cycles	R,S: Number of interpolation cycles
Default value	0	
Drive types	----	
Remarks	For the values 0 or 1 the output of the backlash to the drive is done abruptly within one cycle. A value larger than 1 creates a distribution according to the $\sin^2$function The use of this feature avoids increasing errors at the workpiece, because for large backlash the machine excitation is reduced.	

P-COMP-00059	Maximum number of table entries for leadscrew error compensation	
Description	This leadscrew error compensation parameter (FCT-C5 [▶ 58]) sets the memory space required for a particular number of table entries. The size of the actually used compensation table is defined by `kw_nr_max` (P-COMP-00020) and `kw_nr_max` must be smaller than `max_points`.	
Parameter	kw.ssfk.max_points	
Data type	UNS32	
Data range	0 <= P-COMP-00059	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	1500	
Remarks	The parameter value can no longer be changed after start-up or after lists are reloaded. Otherwise error ID 110638 is output. If P-COMP-00059 is not specified (or assigned the value 0), the default value is assigned to P-COMP-00059 for downward compatibility reasons. To avoid the default assignment, memory can be saved for an axis that does not use leadscrew error compensation [▶ 58] by assigning the value 1 to P-COMP-00059. This parameter is available as of CNC Build V3.3079.06	

P-COMP-00017	Unit of the length entries	
Description	This parameter defines the unit of the length / position entries.	
Parameter	kw.ssfk.unit	
Data type	BOOLEAN	
Data range	0: Encoder increments 1: Metric (in 0.1 µm)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00018	Distance between interpolation points	
Description	The parameter defines the distance between interpolation points of the compensation table when equidistant interpolation points are used. If this parameter is = 0, the position of each interpolation point must be specified separately.	
Parameter	kw.ssfk.interval	
Data type	SGN32	
Data range	0 ≤ interval < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00019	Start position of compensation values	
Description	This parameter determines the position of the axis at which the compensation table starts.	
Parameter	kw.ssfk.kw_startpos	
Data type	SGN32	
Data range	MIN(SGN32) ≤ kw_startpos < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00020	Number of compensation values	
Description	This parameter defines the number of entries in the compensation table.	
Parameter	kw.ssfk.kw_nr_max	
Data type	SGN32	
Data range	0 ≤ kw_nr_max < P-COMP-00059 [▶ 64]	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks	P-COMP-00059 [▶ 64] is available as of Build V3.1.3079.06.	

P-COMP-00021	Operation mode of compensation	
Description	This parameter defines whether compensation is unilateral or bilateral.	
Parameter	kw.ssfk.bilateral	
Data type	BOOLEAN	
Data range	0: Unilateral compensation 1: Bilateral compensation	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00022	Compensation of a modulo axis	
Description	This parameter defines the compensation table for a modulo axis. A modulo transition also takes place in the compensation table on the modulo transition of the axis position. The number of compensation values must then be equal to the number of entries in the compensation value table.	
Parameter	kw.ssfk.modulo	
Data type	BOOLEAN	
Data range	0: Compensation without modulo handling 1: Compensation for a modulo axis	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00023	Compensation value in positive direction	
Description	This parameter defines a compensation value in case of movement in positive direction at interpolation point 'i'.	
Parameter	kw.ssfk.table[i].pos	
Data type	SGN32	
Data range	MIN(SGN32) ≤ pos < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00024	Compensation value in negative direction	
Description	This parameter defines a compensation value in case of movement in negative direction at interpolation point 'i'.	
Parameter	kw.ssfk.table[i].neg	
Data type	SGN32	
Data range	MIN(SGN32) ≤ neg < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks		

P-COMP-00025	Interpolation points of the axis	
Description	This parameter determines the interpolation points of the axis for which the axis must be corrected.	
Parameter	kw.ssfk.table[i].setpoint	
Data type	SGN64	
Data range	MIN(SGN64) ≤ setpoint < MAX(SGN64)	
Axis types	T, R, S	
Dimension	T: 0.1 µm or increments	R,S: 0.0001° or increments
Default value	0	
Remarks	In CNC Builds V2.11.20xx and higher, the data type is SGN32 and so is the related data range.	

P-COMP-00028	Manual activation	
Description	Leadscrew error compensation is automatically activated by the CNC if it selected in the axis parameters (P-AXIS-00175) and the required conditions are met (e.g. axis is homed). If the parameter is set to value 1, leadscrew error compensation must be explicitly activated by an NC command (see [PROG//Selecting/deselecting axis compensations in the NC program]. In addition, compensation is deselected at the end of the NC program, at CNC reset and on axis release.	
Parameter	kw.ssfk.manual_activation	
Data type	BOOLEAN	
Data range	0: Automatic activation 1: Manual activation in NC program	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

P-COMP-00057	**Consideration of other axis compensations**	
Description	By default, leadscrew error compensation also considers the compensation values generated from other axis compensations, e.g. cross and plane compensation. With direction-dependent spindle leadscrew error compensation (see P-COMP-00021) this may result in the undesirable occurrence of backlash under certain circumstances. The parameter **set_pos_without_comp** can disable the inclusion of other compensation values in the calculation.	
Parameter	kw.ssfk.set_pos_without_comp	
Data type	BOOLEAN	
Data range	0: Compensation values of other compensations are considered in the leadscrew error compensation. 1: Compensation values of other compensations are not considered.	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks		

4.4.1.3 CNC objects

Name	ssfk activated		
Description	Leadscrew error compensation (LSEC);active, activate with P-AXIS-00175 [▶ 63]		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>0038
Data type	BOOLEAN	**Length**	1
Attributes	read	**Unit**	[-]
Remarks			

Name	LSEC::active		
Description	This object reads whether leadscrew error compensation is active. This means that all preconditions must be met, such as the axis is homed and all necessary enables are on. (leadscrew error compensation - LSEC)		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>00D0
Data type	BOOLEAN	**Length**	1
Attributes	read	**Unit**	[-]
Remarks			

Name	LSEC::epsilon		
Description	Leadscrew error compensation: change in compensation value compared to previous cycle Leadscrew error compensation (LSEC)		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>001C
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

Name	LSEC::sum epsilon		
Description	Leadscrew error compensation: sum of all compensation values Leadscrew error compensation (LSEC)		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>001D
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks			

4.4.2 Example - Non-equidistant bilateral SSFK

The diagram below shows a compensation value table with the properties:

- Non-equidistant interpolation points (kw.ssfk.interval = 0)
- Bilateral compensation table (kw.ssfk.bilateral = 1)
- Position specifications in metric system (kw.ssfk.unit = 1)
- Compensation value table with 140 entries (kw.ssfk.kw_nr_max = 140). The index of the position and setpoint entries goes from 0 to 139.

The following values were measured at the third gauged position (table[3]):

Programmed Position $s_{soll,i}$ ith setpoint	pos measurement value $s_{ist,i}$ ith actual value (pos direction)	neg measurement value $s_{ist,i}$ ith actual value (neg direction)	computed pos compensation value $\Delta s_i = s_{ist,i} - s_{soll,i}$	Computed neg compensation value $\Delta s_i = s_{ist,i} - s_{soll,}i$
19866.7 µm	19856.5 µm	19874.7 µm	-102 x 0.1 µm	80 x 0.1 µm

Programing Example

Non-equidistant bilateral SSFK

```
kopf.achs_nr                        2
kopf.log_achs_name                    Y AXIS
kw.ssfk.interval                    0
kw.ssfk.kw_startpos                 -200000
kw.ssfk.kw_nr_max                   140
kw.ssfk.unit                        1
kw.ssfk.bilateral                   1
kw.ssfk.table[0].setpoint           -200000
kw.ssfk.table[1].setpoint           -199306
kw.ssfk.table[2].setpoint           -198667
kw.ssfk.table[3].setpoint           -198001
...
kw.ssfk.table[138].setpoint         334488
kw.ssfk.table[139].setpoint         335591
kw.ssfk.table[0].pos                0
kw.ssfk.table[1].pos                24
kw.ssfk.table[2].pos                -102
...
kw.ssfk.table[139].pos              -55
kw.ssfk.table[0].neg                0
kw.ssfk.table[1].neg                67
kw.ssfk.table[2].neg                80
...
kw.ssfk.table[139].neg              114
```

4.4.3 Error messages

Errors in the configuration of leadscrew error compensation result in deactivation of the function for the affected axis and to the output of an error message (warning message).

The following error messages then appear:

- ID 110217
- ID 110218
- ID 110392
- ID 110474
- ID 110476
- ID 110477
- ID 110478
- ID 110479
- ID110480
- ID 110590
- ID 110638

4.5 Friction compensation

Friction effects in the drive train may cause marks or dimensional variations on the workpiece surface at points in the machining process where a change in axis direction occurs (reversing). The purpose of friction compensation is to minimise these effects and enhance machining results.

Compensation process

Friction compensation reduces position lag and improves surface quality. At the same time, it relieves pressure on the speed controller and when activated, it permits the greater use of dynamic parameters and this reduces machining time.

Notice

Friction compensation can be activated for SERCOS and CANopen drives. This requires the installation of an additive torque interface (additive current) which requires [▶ 83] configuration.

Characteristics

- When friction compensation is selected, it is active directly after controller start-up
- Friction compensation reduces position lag and axis backlash and increases accuracy.
- Friction compensation is available for all drive types.

Effectiveness

Friction compensation is only effective if all the following conditions are fulfilled:

- The function was activated in the axis parameter list with P-AXIS-00522 (TRUE) or was enabled by an NC command.
- The compensation value table [COMP] was provided.

4.5.1 Types of friction and compensation

Friction

Friction basically occurs at points of contact between bodies moving relative to one another. It manifests itself as the force that counteracts the motion.

According to Stribeck, the following friction curves result at different velocities:

- Phase 1: Adhesive friction for standstill (boundary friction)
- Phase 2: Mixed friction, Stribeck friction
- Phase 3: Elastohydrodynamic friction

The constant component of friction at velocity v = 0 results in a surge in frictional force at speed reversal resulting in backlash.

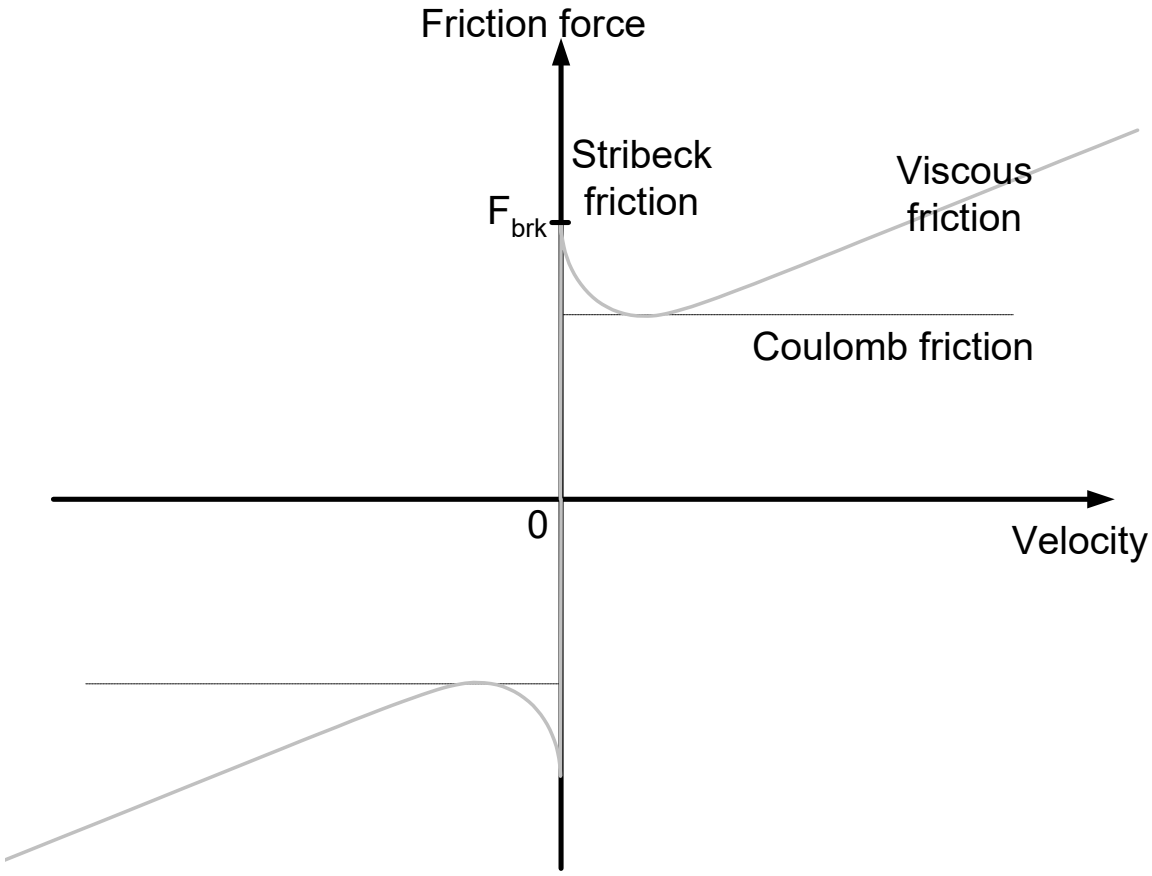


Fig. 15: Theoretical friction curve

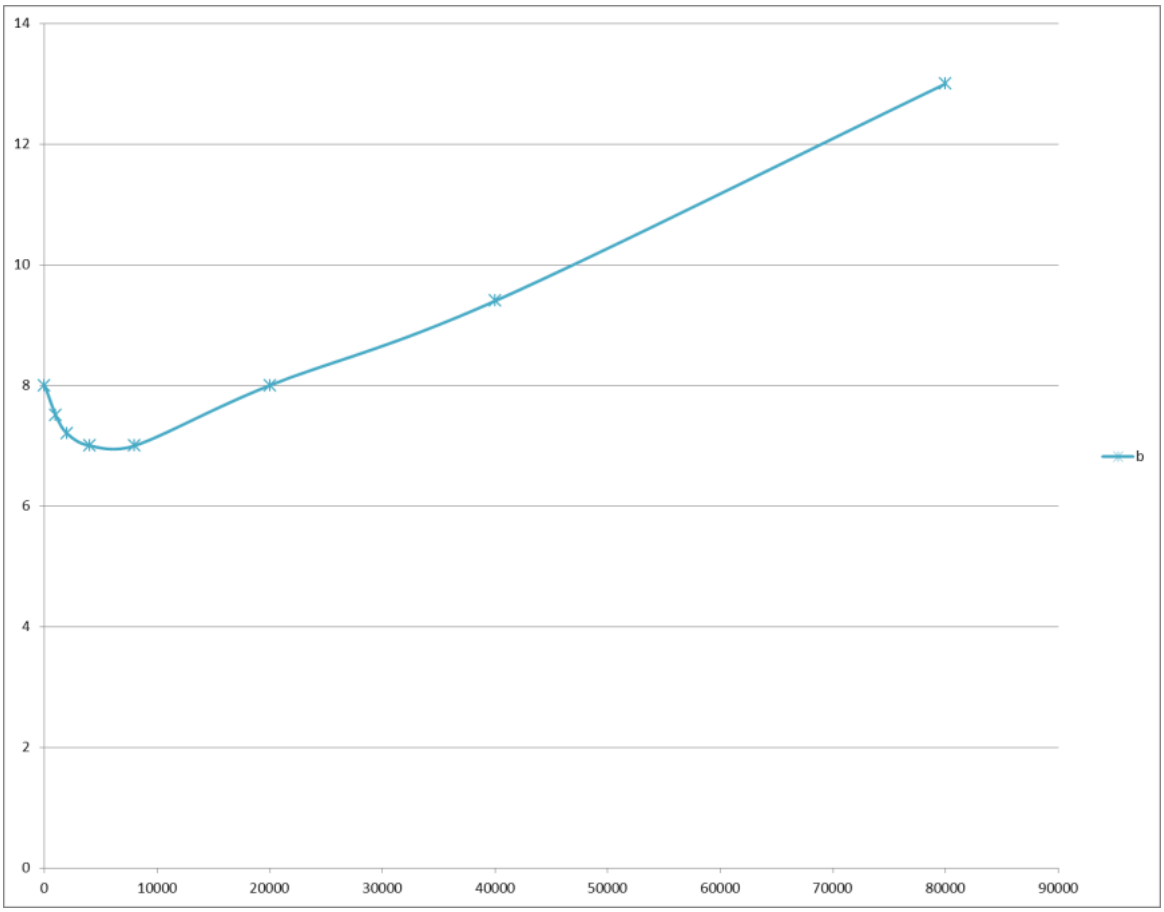


Fig. 16: Measured friction curve

4.5.1.1 Additive current dependent on velocity

Additive current

The purpose of friction compensation is to compensate actually existing friction torque by way of an additional torque. It acts in the form of speed-dependent feedforward control of the motor current.

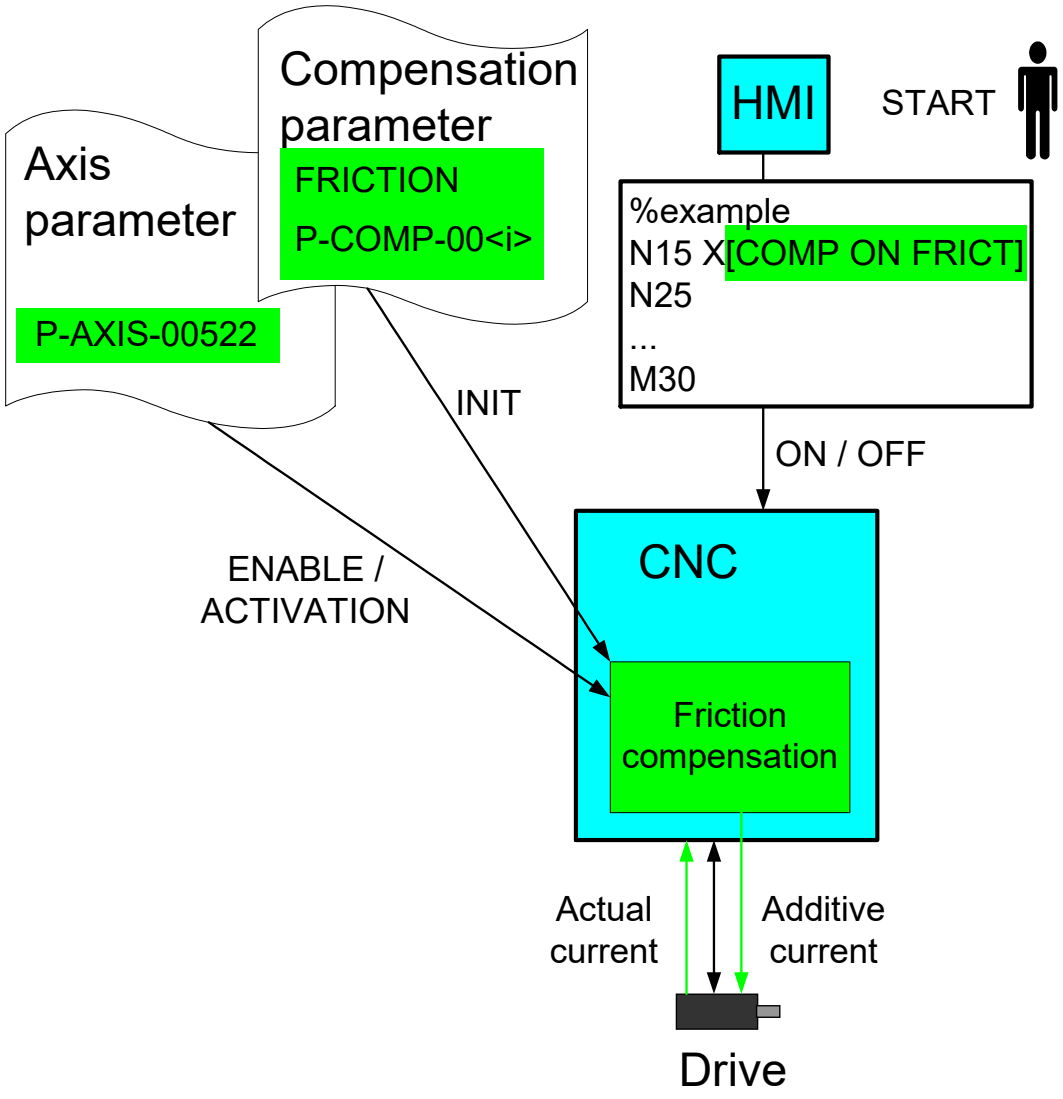


Fig. 17: Principle of friction compensation

Notice

It is basically sufficient to command a additive current to the drive on the setpoint side for friction compensation.

However, to determine the characteristic curve for the current and verify compensation, it is also necessary to read the actual current.

Effect

The algorithm compensates for friction during path motions (v≠0) by an additional motor current.

Control loop

The effect of friction compensation on closed-loop control is shown in the figure below.

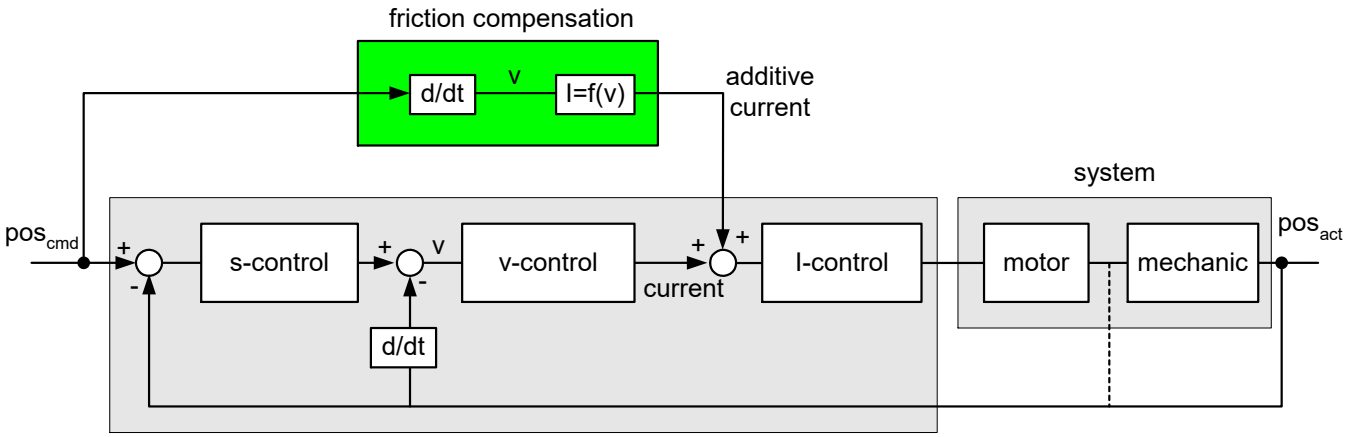


Fig. 18: Add friction compensation to the control loop of an axis

4.5.1.1.1 Reverse the motion direction

Reverse and weight the friction curve

In the Stribeck curve model, a jump in feedforward control current occurs in the axis reversal process (velocity zero crossing).

To prevent this discontinuity, the CNC monitors axis reversal. In this case, the friction model may be weighted before and after zero crossing.

- Before zero crossing: time [number of CNC cycles]
- After zero crossing: Path distance covered [0.1 µm]

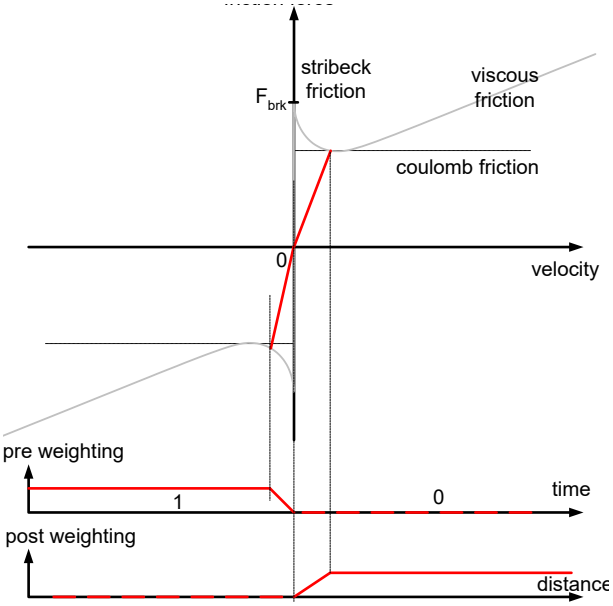


Fig. 19: Weight friction model before/after zero crossing, on reversal from negative to positive velocity

Notice

If no reversal takes place, i.e. the axis is only decelerated and continues in the same direction, the friction model is not weighted.

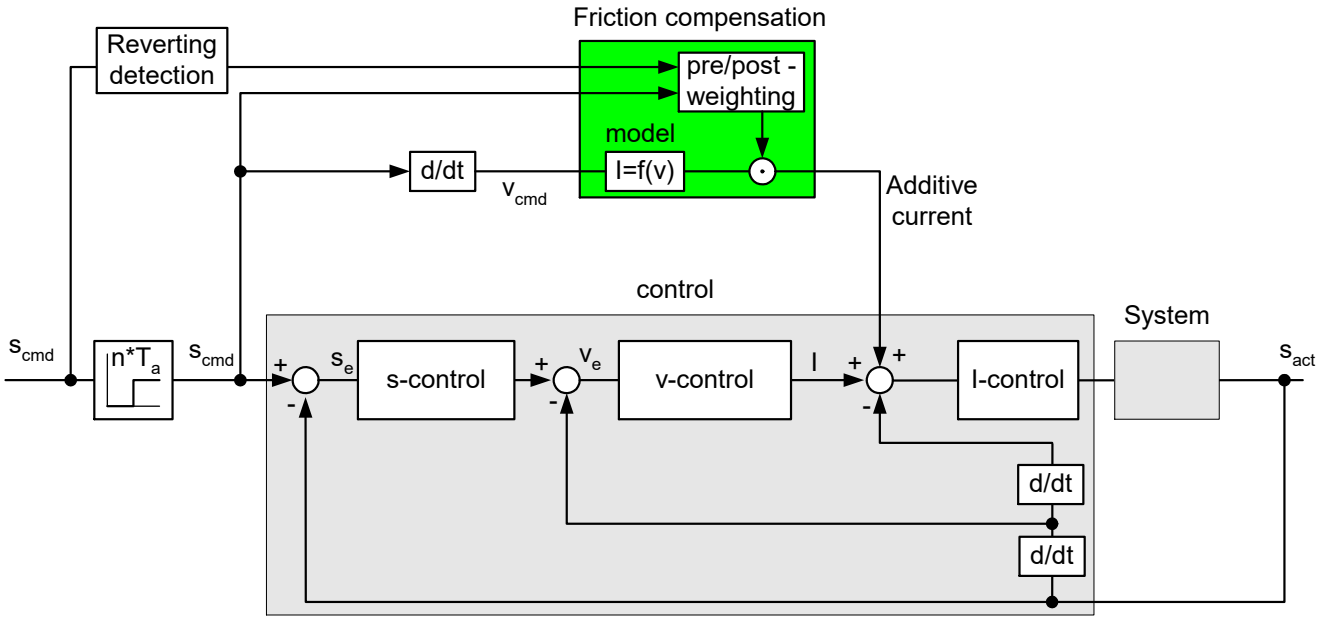


Fig. 20: Add friction compensation to the control loop of an axis

4.5.1.2 Parameterisation

Parameterise compensation values

The table for friction compensation must be programmed with ascending velocity and the velocity must be ≥ 0. This is checked when the list is downloaded list and, if applicable, the error message P-ERR-110591 is output.

As of CNC Build V3.1.3079.06, use P-COMP-00062 [▶ 89] to define a maximum number of table entries in the compensation value list. The entries actually used are defined in P-COMP-00042.

Friction compensation parameters are defined in the compensation value list:

- Maximum number of table entries P-COMP-00062 [▶ 89] as of Build V3.1.3079.06
- Friction compensation mode P-COMP-00041
- Number of table elements P-COMP-00042
- Current build-up after direction reversal P-COMP-00043
- Current decay before direction reversal P-COMP-00044
- Scaling factor for compensation values P-COMP-00045
- Table entries for velocity P-COMP-00046
- Table entries for current P-COMP-00047

Notice

Friction compensation is only active when the mode (P-COMP-00041) is assigned a value unequal to 0 and P-AXIS-00522 is set.

Only value 3 is permitted for P-COMP-00041

Programing Example

Parameterise friction compensation

```
frict_comp.mode                          3
frict_comp.table_entries                 3
frict_comp.position_delay                30
frict_comp.reversal_lookahead            4
frict_comp.scaling_factor                10
frict_comp.delay_cycles                  9

frict_comp.table[0].in                   0
frict_comp.table[0].out                  0
frict_comp.table[1].in                   316
frict_comp.table[1].out                  3722
frict_comp.table[2].in                   333
frict_comp.table[2].out                  3884
```

Parameter verification

A consistency check takes place when compensation parameters are adopted. If the parameters are not coherent, a related error message is output.

P-ERR-110591	Negative or non-ascending input values
P-ERR-110592	Unknown mode or no values specified

4.5.1.3 Select and deselect compensation

Activate/deactivate

By analogy to other compensations, compensation can be activated by a parameter in the axis list or additionally by an NC command.

Enable use/activate

Compensation can only be applied if the parameter P-AXIS-00522 is set (TRUE) in the parameter list and the compensation value list is parameterised.

Behaviour after start-up

When friction compensation is selected, it is active directly after controller start-up regardless of whether homing was executed.

Programming

In every case, compensation can also be activated or deactivated explicitly by the axis-specific COMP command in the NC program.

Attention

The COMP command is valid after program end. After activating or deactivating compensation, the operator must also explicitly deactivate or activate it at program end.

4.5.1.3.1 Programming

*<axis_name>***[COMP ON | OFF FRICT]**

<axis_name>	Name of the axis
COMP	Identifier to select/deselect axis-specific compensation. Must always be programmed as first keyword.
ON	Activates programmed compensation(s)
OFF	Deactivates programmed compensation(s)
FRICT	Keyword for friction compensation

Programing Example

Activates and deactivates friction compensation

```
N15 X[COMP ON FRICT] ;Activates X axis
N25 Y[COMP OFF FRICT] ;Deactivates Y axis
N35 X22 Y33 Z44
N45 X[COMP OFF FRICT] ;Deactivates X axis
N55 M30 ;Program end
```

Error message

If friction compensation must be activated with the COMP command but it was not activated by the parameter P-AXIS-00522, the error message P-ERR-70495 is output.

4.5.1.4 Special features of drive parameters

Drive telegram

The drive must be fitted with a torque interface to be able to use friction compensation.

SERCOS

The additive torque setpoint must be configured in the cyclic log.

- S-0-0084 Torque feedback value
- S-0-0081 Additive torque command value

CANopen

The related PDOs (process data objects) are similarly configured with CANopen.

- 6077 Torque actual value
- 60B2 Torque offset

4.5.2 Determine the parameters for the compensation value list

4.5.2.1 Determine parameters manually

Manual determination

Each of the compensation value list parameters can be determined “manually”.

To this end, the associated current (dig_drv.act_torque), e.g. in the scope, must be read off during a motion at constant speed. The motor current during a motion at constant speed is mapped in the figure below. It can be seen that the current is in the opposite direction to the speed.

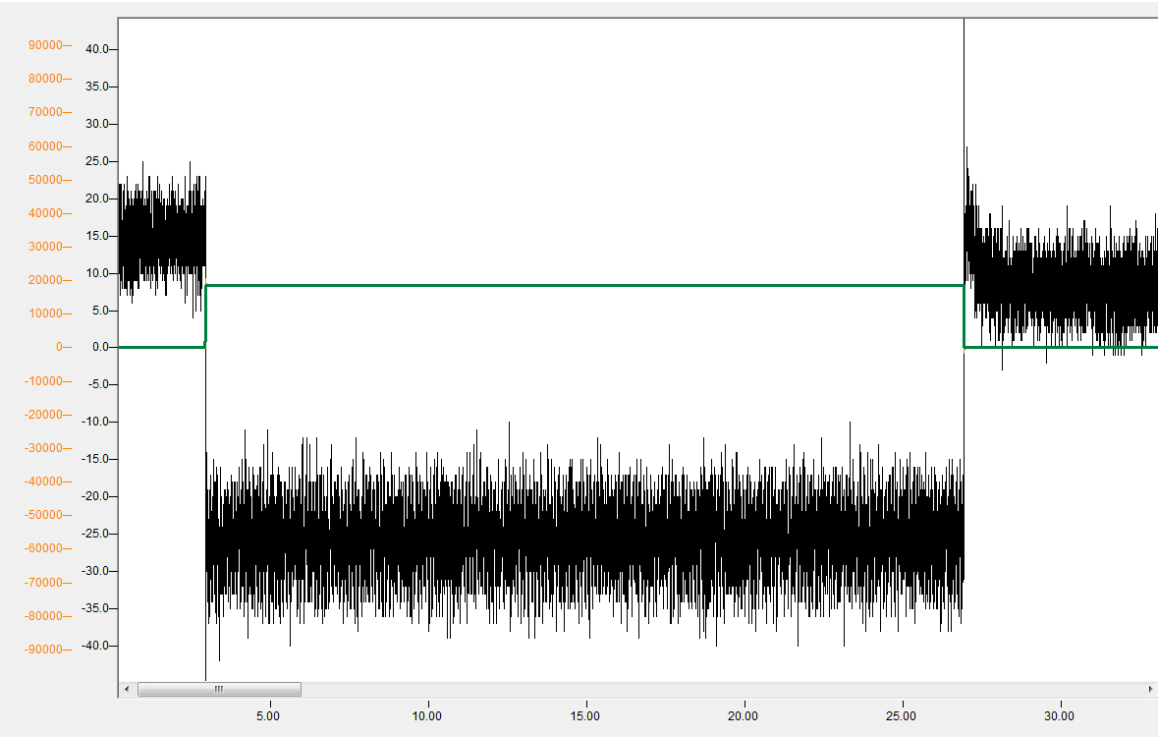


Fig. 21: Constant velocity (green) and associated current (black)

4.5.3 Effect of friction compensation

Friction compensation reduces position lag and axis backlash. This boosts accuracy. Furthermore, the speed controllers are relieved, as a result of which the dynamic parameters can be used to a greater extent without impairing the machining result.

The figure below shows the result of a circular transition test with compensation activated and deactivated. Without compensation (blue), clear peaks are visible at the quadrant transitions, which are reduced by compensation (red).

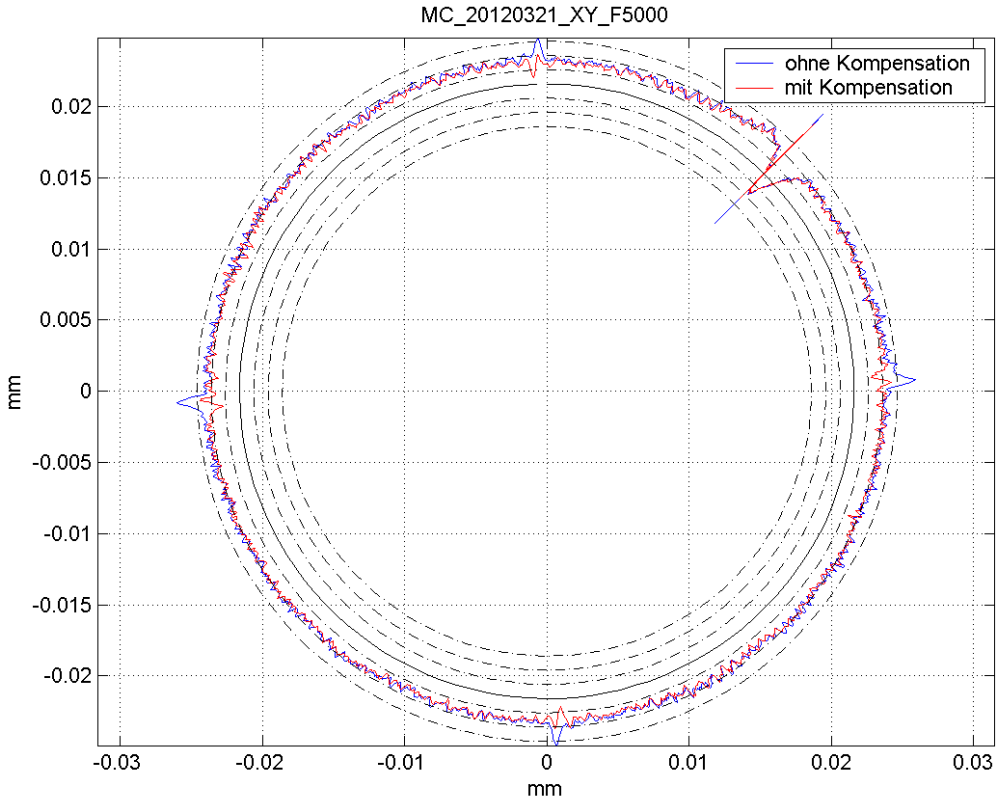


Fig. 22: Circular transition test with and without friction compensation

4.5.4 Parameter

4.5.4.1 Overview

4.5.4.1.1 Axis parameters

ID	Parameter	Description
P-AXIS-00522	lr_param.frict_comp	Activates and deactivates friction compensation

4.5.4.1.2 Compensation values

ID	Parameter	Description
P-COMP-00041	Index of the incorrect interpolation point	Friction compensation mode
P-COMP-00042	frict_comp.table_entries	Number of elements in the compensation value table. Maximum of 20
P-COMP-00043	frict_comp.position_delay	Distance over which the motor current is built up during start-up.
P-COMP-00044	frict_comp.reversal_lookahead	Number of cycles during which the motor current is dissipated before a motion reversal.
P-COMP-00045	frict_comp.scaling_factor	Scaling factor for the entries in the compensation list
P-COMP-00046	frict_comp.table[i].in	Velocity
P-COMP-00047	frict_comp.table[i].out	Measured friction (motor current)
P-COMP-00058	frict_comp.delay_cycles	Delay in compensation values after reversal point in cycles
P-COMP-00062	frict_comp.max_points	Max. number of possible table entries

4.5.4.2 Description

4.5.4.2.1 Axis parameters

P-AXIS-00522	**Activation of friction compensation**	
Description	This parameter activates the friction compensation.	
Parameter	lr_param.frict_comp	
Data type	BOOLEAN	
Data range	0/1	
Axis types	T, R	
Dimension	T: ----	R: ----
Default value	0	
Drive types	SERCOS, CANopen	
Remarks	If friction compensation must be activated with the COMP command but it was not activated by the parameter P-AXIS-00522, the error message P-ERR-70495 is output.	

4.5.4.2.2 Compensation values

P-COMP-00041	**Friction compensation mode**	
Description	The parameter defines the operation mode for friction compensation. If the parameter is assigned the value 0, friction compensation is deactivated.	
Parameter	frict_comp.mode	
Data type	UNS16	
Data range	0: Deactivate friction compensation 3: Compensation with additive current taking into account the commanded speed	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks	To activate friction compensation, the mode must and P-AXIS-00522 must be set.	

P-COMP-00042	Number of elements in the compensation value table	
Description	This parameter defines the number of entries in the compensation table.	
Parameter	frict_comp.table_entries	
Data type	UNS16	
Data range	0 ≤ table_entries ≤ P-COMP-00062 [▶ 89]	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Remarks	P-COMP-00062 [▶ 89] is available as of Build V3.1.3079.06. The default upper limit is 20.	

P-COMP-00043	Delay value for current build-up	
Description	This parameter defines the delay value for current built-up at start-up. Its purpose is to prevent abrupt changes. Current build-up is linear.	
Parameter	frict_comp.position_delay	
Data type	SGN32	
Data range	0 ≤ position_delay ≤ 10	
Axis types	T, R, S	
Dimension	T: 0.1µm	R,S: 0.0001°
Default value	0	
Remarks		

P-COMP-00044	Reversal look ahead	
Description	This parameter defines the number of cycles over which the motor current decays before motion reversal.	
Parameter	frict_comp.reversal_lookahead	
Data type	UNS16	
Data range	0 ≤ reversal_lookahead ≤ 4	
Axis types	T, R, S	
Dimension	T: Cycles	R,S: Cycles
Default value	0	
Remarks		

P-COMP-00045	Scaling factor for compensation values	
Description	This parameter defines the scaling of all compensation values in the list.	
Parameter	frict_comp.scaling_factor	
Data type	SGN16	
Data range	MIN(SGN16) < scaling_factor < MAX(SGN16)	
Axis types	T, R, S	
Dimension	T: 0.1%	R,S: 0.1%
Default value	1000	
Remarks		

P-COMP-00046	Velocity input variable	
Description	This parameter defines the velocities for which the additional motor currents specified in P-COMP-00047 are to be output to the additive current interface. The values must be entered in ascending order.	
Parameter	frict_comp.table[i].in where i= P-COMP-00042	
Data type	SGN32	
Data range	0 < table[i].in < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: [µm/s]	R,S: [0.001°/s]
Default value	0	
Remarks		

P-COMP-00047	Measured friction (motor current) – output variable	
Description	This parameter defines the current which is to be additionally output at the additive current interface.	
Parameter	frict_comp.table[i].out where i= P-COMP-00042	
Data type	SGN32	
Data range	MIN(SGN32) < table[i].out < MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: *	R,S: *
Default value	0	
Remarks	* The dimension of the motor current depends on the internal data of the related drive. In CANopen and SERCOS, this value corresponds to the contents of the CNC object *dig_drv.act_torque*.	

P-COMP-00058	Delay time for compensation values	
Description	This parameter defines the delay time of all compensation values.	
Parameter	frict_comp.delay_cycles	
Data type	SGN16	
Data range	0 ≤ delay_cycles < 249	
Axis types	T, R, S	
Dimension	T: Cycles	R,S: Cycles
Default value	0	
Remarks		

P-COMP-00062	Maximum number of table entries for friction compensation	
Description	This friction compensation parameter (FCT-C25) saves the memory space required for a particular number of table entries. The size of the actually used compensation table is defined by `table_entries` (P-COMP-00042) and `table_entries` must be smaller than `max_points`.	
Parameter	frict_comp.max_points	
Data type	UNS32	
Data range	0 <= P-COMP-00062	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	20	
Remarks	The parameter value can no longer be changed after start-up or after lists are reloaded. Otherwise error ID 110641 is output. If P-COMP-00062 is not specified (or assigned the value 0), the default value is assigned to P-COMP-00062 for downward compatibility reasons. To avoid the default assignment, memory can be saved for an axis that does not use friction compensation by assigning the value 1 to P-COMP-00062. This parameter is available as of CNC Build V3.3079.06	

4.6 Crosstalk compensation

Crosstalk compensation is used to compensate for position errors caused by an acceleration in another axis.

Release Note

Functionality available as of CNC Build V3.1.3081.2 or V3.1.3108.4.

Compensation process

Crosstalk compensation is used to compensate an axis position depending on the acceleration of another axis.

The axis whose acceleration affects the compensation value is called the master axis. The axis for which compensation is active is called the slave axis.

A master axis can also be the salve axis of another master axis.

The axis whose position affects the compensation value is called the adaptation axis. Up to two adaptation axes can be specified.

Compensation can be configured direction-dependent.

Notice

The data for crosstalk compensation is specified in the compensation value list of the slave axis.

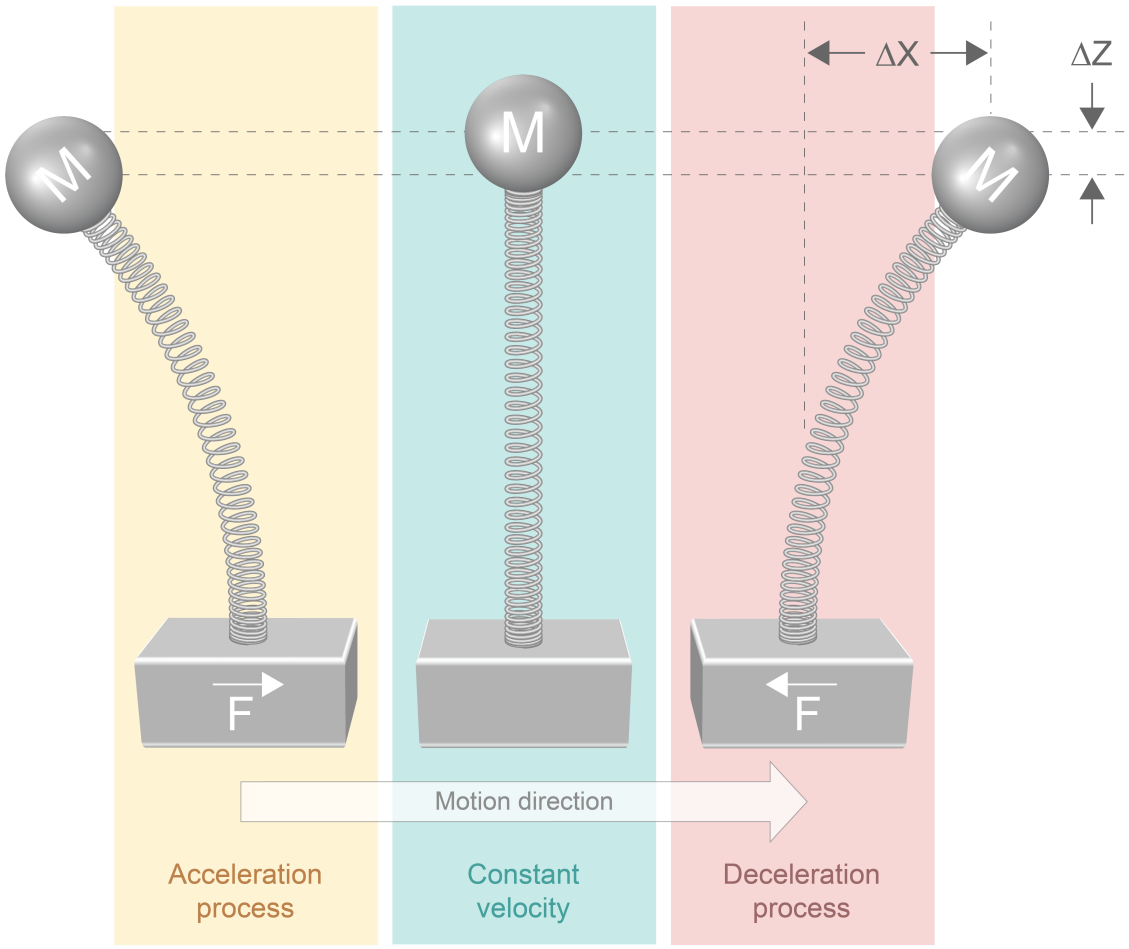


Fig. 23: Overview of crosstalk compensation

Properties

- A master axis has one or several slave axes.
- A slave has only one master axis.
- Crosstalk compensation can also be used for the master and slave axes of a gantry combination.
- A compensation value can be specified for each acceleration.
- Interpolation between accelerations is linear.
- Crosstalk compensation is available for all drive types.
- Compensations can only be viewed in the accelerations directly output to the drive (not in the normal display data) since compensation takes place outside normal calculations.

Effectiveness

Crosstalk compensation is only effective if all the following conditions are fulfilled:

- The function was activated for the slave axis.
- The compensation value list was provided.
- Master and slave axes include linear axes, rotary axes or spindles.

4.6.1 Overview

Activation

Crosstalk compensation is activated in the axis machine data record of the slave axis by P-AXIS-00789 [▶ 97] (lr_param.crosstalk).

Programing Example

Excerpt from the axis parameter list:

```
:
lr_param.crosstalk       1
:
```

Notice

Crosstalk compensation can also be used for a gantry axis group. A compensation value list must then be specified for each axis in the gantry combination (crosstalk compensation slave).

Compensation value lists can therefore have different settings for each gantry axis.

Activating/deactivating

Crosstalk compensation (ON if compensation is activated) can be switched on or off at any time when the slave axis is at standstill. The slave axis command positions displayed are offset with the offset values.

Filter:

These compensation values can be smoothed by using a sine-square filter. The parameter P-COMP-00064 [▶ 98] (n_cycles) switches the filter order to activate it.

Direction dependency of compensation

If position errors are dependent on the motion direction, compensation can be configured direction-dependent using the P-COMP-00084 [▶ 101] parameter.

Crosstalk compensation modes

Three modes are provided for crosstalk compensation.

Mode 1:

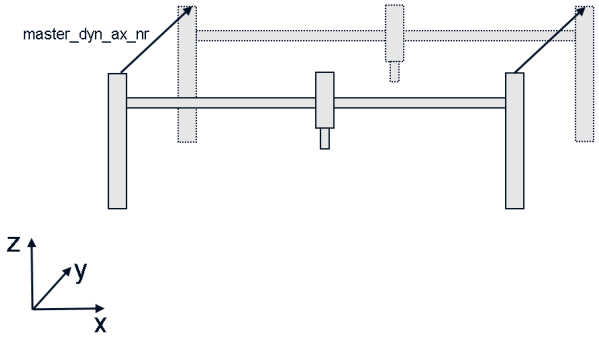


Fig. 24: Crosstalk compensation – Mode 1

An acceleration and the related compensation value are specified. With accelerations less than the specified values, the compensation value is linear interpolated.

Mode 2:

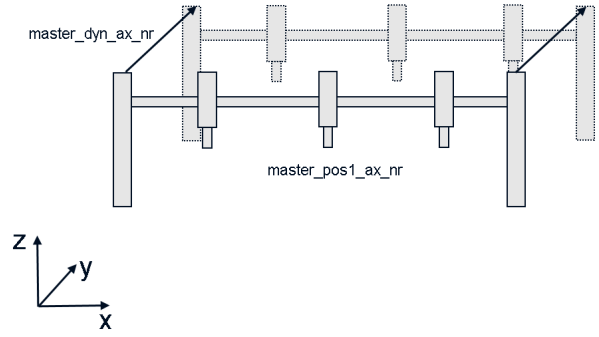


Fig. 25: Crosstalk compensation – Mode 2

Compensation is calculated using an adaptation axis which is obtained by the user conducting three measurement tests. The measurement tests are conducted at various positions on the adaptation axis. Compensation is then calculated using the position of the adaptation axis and the current acceleration.

Mode 3:

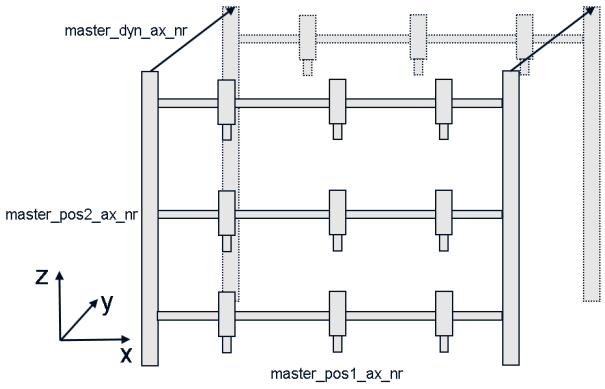


Fig. 26: Crosstalk compensation – Mode 3

Two adaptation axes can be specified. The user can enter up to 15 measurement tests in the compensation value list. Crosstalk compensation calculates compensation values using surface interpolation.

Here, please note that the measurements must cover the complete workspace. If this is not the case, incorrect compensation values can occur with positions outside the specified measuring range.

Management data of the crosstalk compensation list

General data of the list body is entered in the structure kw.crosstalk.*. It contains the following elements.

Management data elements

Variable name	Type	Meaning
mode	UNS08	Compensation mode
master_dyn_ax_nr	UNS16	Logical axis number of the master axis whose acceleration is used as the input variable of the compensation list.
master_pos1_ax_nr	UNS16	Logical axis number of the first adaptation axis.
master_pos2_ax_nr	UNS16	Logical axis number of second adaptation axis
n_cycles	UNS16	Number of cycles of the sine-square filter.
manual_activation	BOOLEAN	0: (Default) The CNC activates crosstalk compensation automatically as soon as the required preconditions are met.
max_points	UNS32	Number of measurement tests in the compensation value list.
acceleration	SGN32	Acceleration [mm/s²] in case of axis excursion.
deceleration	SGN32	Negative acceleration [mm/s²] in case of axis excursion.
velocity_dependent	BOOLEAN	Different compensation values for different motion directions.

Compensation values of crosstalk compensation

The corresponding compensation value of the slave axis is entered for each acceleration in the list **kw.crosstalk.table[i].***. The compensation list is valid for positive and negative directions of acceleration.

Compensation value list

Variable name	type	Meaning
position[i].ax_1	SGN64	Position of the first adaptation axis with acceleration test i
position[i].ax_2	SGN64	Position of the second adaptation axis with acceleration test i
position[i].correction_accelerate_dir_pos	SGN64	Compensation value for acceleration in positive motion direction
position[i].correction_decelerate_dir_pos	SGN64	Compensation value for deceleration in positive motion direction

position[i].correction_accelerate_dir_neg	SGN64	Compensation value for acceleration in negative motion direction
position[i].correction_decelerate_dir_neg	SGN64	Compensation value for deceleration in negative motion direction

4.6.2 Parameter

4.6.2.1 Overview

ID	Parameter	Description
P-AXIS-00789	lr_param. crosstalk	Activate crosstalk compensation

ID	Parameter	Description
P-COMP-00063	kw.crosstalk.master_ax_nr	Logical axis number of the master axis
P-COMP-00064	kw.crosstalk.n_cycles	Number of cycles for ‘smooth switching’
P-COMP-00065	kw.crosstalk.last_index	Last index of compensation value list
P-COMP-00066	kw.crosstalk.table[i].acceleration	Accelerations of the master axis
P-COMP-00067	kw.crosstalk.table[i].correction	Compensation values for the slave axis
P-COMP-00080	kw.crosstalk.master_pos1_ax_nr	Logical axis number of the first adaptation axis
P-COMP-00081	kw.crosstalk.master_pos2_ax_nr	Logical axis number of the second adaptation axis
P-COMP-00082	kw.crosstalk.mode	Crosstalk compensation mode
P-COMP-00083	kw.crosstalk.max_points	Number of measurement tests in the compensation value list
P-COMP-00084	kw.crosstalk.velocity_dependent	Different compensation values for different motion directions
P-COMP-00085	kw.crosstalk.position[i].ax_1	Position of the first adaptation axis with acceleration test i
P-COMP-00086	kw.crosstalk.position[i].ax_2	Position of the second adaptation axis with acceleration test i
P-COMP-00087	kw.crosstalk.position[i].correction_accelerate_dir_pos	Compensation value for acceleration in positive motion direction
P-COMP-00088	kw.crosstalk.position[i].correction_accelerate_dir_neg	Compensation value for acceleration in negative motion direction
P-COMP-00089	kw.crosstalk.position[i].correction_decelerate_dir_pos	Compensation value for deceleration in positive motion direction
P-COMP-00090	kw.crosstalk.position[i].correction_decelerate_dir_neg	Compensation value for deceleration in negative motion direction

4.6.2.2 Description

Axis parameter

P-AXIS-00789	Activate crosstalk compensation	
Description	This parameter activates the crosstalk compensation function.	
Parameter	lr_param.crosstalk	
Data type	BOOLEAN	
Data range	0/1	
Axis types	T	
Dimension	T: ----	
Default value	0	
Drive types		
Remarks	Parameter available as of CNC Build V3.1.3079.32 and higher	

Compensation parameters

P-COMP-00063	Logical axis number of the master axis	
Description	This parameter determines the logical number of the master axis whose acceleration is used as the input variable of the compensation value list of the slave axis.	
Parameter	kw.crosstalk.master_dyn_ax_nr	
Data type	UNS16	
Data range	1 ≤ P-COMP-00063 ≤ MAX (UNS16)	
Axis types	T	
Dimension	T: ----	R,S: -
Default value	0	
Remarks	Parameter available as of CNC Build V3.1.3081.2 or V3.1.3108.4.	

P-COMP-00064	Number of cycles for ‘smooth switching’	
Description	This parameter determines the number of cycles for which crosstalk compensation is coupled/decoupled softly.	
Parameter	kw.crosstalk.n_cycles	
Data type	UNS16	
Data range	0 ≤ P-COMP-00064 ≤ 20 (maximum number of cycles above which coupling or decoupling is to occur)	
Axis types	T, R, S	
Dimension	T: ----	R, S: -
Default value	0	
Remarks	Parameter available as of CNC Build V3.1.3079.32	

P-COMP-00066	Accelerations of the master axis	
Description	This parameter defines the acceleration of the master axis requiring a compensation of the slave axis.	
Parameter	kw.crosstalk.acceleration	
Data type	SGN32	
Data range	0 < P-COMP-00066 < MAX(SGN32)	
Axis types	T	
Dimension	T: [mm/s²]	R,S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00067	Negative acceleration of the master axis	
Description	This parameter defines the negative acceleration of the master axis which must be used to compensate the slave axis.	
Parameter	kw.crosstalk.deceleration	
Data type	SGN32	
Data range	MIN(SGN32) ≤ P-COMP-00067 < 0	
Axis types	T	
Dimension	T: [mm/s²]	R,S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00065	Manual activation of crosstalk compensation	
Description	The CNC activates crosstalk compensation automatically if it is selected in the axis parameters (P-AXIS-00789 [▶ 97]) and the required preconditions are met. If the parameter P-COMP-00065 is set to 1, crosstalk compensation must be explicitly activated by an NC command. [PROG// Selecting/deselecting axis compensations in the NC program (COMP)] Compensation is deactivated at the end of the NC program, when the CNC is reset or when the compensating axis is released.	
Parameter	kw.crosstalk.manual_activation	
Data type	BOOLEAN	
Data range	0: Automatic activation 1: Explicit activation in NC program	
Axis types	T	
Dimension	T: ----	R, S: -
Default value	0	
Remarks	Parameter available as of CNC Build V3.1.3081.2 or V3.1.3108.4.	

P-COMP-00080	Logical axis number of the first adaptation axis	
Description	This parameter defines the logical axis number of the first adaptation axis. The position of the adaptation axis influences compensation in Modes 2 and 3 (P-COMP-00082 [▶ 100]).	
Parameter	kw.crosstalk.master_pos1_ax_nr	
Data type	UNS16	
Data range	0 < P-COMP-00080 < MAX(UNS16)	
Axis types	T	
Dimension	T: ----	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00081	Logical axis number of the second adaptation axis	
Description	This parameter defines the logical axis number of the second adaptation axis. The position of the adaptation axis influences compensation in Mode 3 (P-COMP-00082 [▶ 100]).	
Parameter	kw.crosstalk.master_pos2_ax_nr	
Data type	UNS16	
Data range	0 < P-COMP-00081 < MAX(UNS16)	
Axis types	T	
Dimension	T: ----	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00082	Crosstalk compensation mode	
Description	This parameter specifies the compensation mode.	
Parameter	kw.crosstalk.mode	
Data type	UNS08	
Data range	1 …3	
Axis types	T	
Dimension	T: ----	R, S: -
Default value	1	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00083	Number of measurement tests in the compensation value list	
Description	This parameter sets the number of measurement tests specified in the compensation value list.	
Parameter	kw.crosstalk.max_points	
Data type	UNS32	
Data range	0 ≤ P-COMP-00083 < 15	
Axis types	T	
Dimension	T: ----	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00084	Different compensation values for different motion directions	
Description	This parameter sets whether a compensation should use different compensation values for different motion directions.	
Parameter	kw.crosstalk.velocity_dependent	
Data type	BOOLEAN	
Data range	0 / 1	
Axis types	T	
Dimension	T: ----	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00085	Position of the first adaptation axis with acceleration test	
Description	This parameter specifies the position of the first adaptation axis for the ith acceleration test.	
Parameter	kw.crosstalk.position[i].ax_1	
Data type	SGN64	
Data range	MIN(SGN64) ≤ P-COMP-00085 < MAX(SGN64)	
Axis types	T	
Dimension	T: [0.1 µm]	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00086	Position of the second adaptation axis with acceleration test	
Description	This parameter specifies the position of the second adaptation axis for the ith acceleration test.	
Parameter	kw.crosstalk.position[i].ax_2	
Data type	SGN64	
Data range	MIN(SGN64) ≤ P-COMP-00086 < MAX(SGN64)	
Axis types	T	
Dimension	T: [0.1 µm]	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00087	Compensation value for acceleration in positive motion direction	
Description	Compensation value at position i for acceleration in positive motion direction.	
Parameter	kw.crosstalk.position[i].correction_accelerate_dir_pos	
Data type	SGN64	
Data range	MIN(SGN64) ≤ P-COMP-00087 < MAX(SGN64)	
Axis types	T	
Dimension	T: [0.1 µm]	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00088	Compensation value for acceleration in negative motion direction	
Description	Compensation value at position i for acceleration in negative motion direction.	
Parameter	kw.crosstalk.position[i].correction_accelerate_dir_neg	
Data type	SGN64	
Data range	MIN(SGN64) ≤ P-COMP-00088 < MAX(SGN64)	
Axis types	T	
Dimension	T: [0.1 µm]	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4 This parameter is only active if P-COMP-00084 [▶ 101] is activated.	

P-COMP-00089	Compensation value for deceleration in positive motion direction	
Description	Compensation value at position i for deceleration in positive motion direction.	
Parameter	kw.crosstalk.position[i].correction_decelerate_dir_pos	
Data type	This parameter is only active if P-COMP-00084 is activated.	
Data range	MIN(SGN64) ≤ P-COMP-00089 < MAX(SGN64)	
Axis types	T	
Dimension	T: [0.1 µm]	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4	

P-COMP-00090	Compensation value for deceleration in negative motion direction	
Description	Compensation value at position i for deceleration in negative motion direction.	
Parameter	kw.crosstalk.position[i].correction_decelerate_dir_neg	
Data type	SGN64	
Data range	MIN(SGN64) ≤ P-COMP-00090 < MAX(SGN64)	
Axis types	T	
Dimension	T: [0.1 µm]	R, S: -
Default value	0	
Remarks	Parameter available as of V3.1.3081.2 and V3.1.3108.4 This parameter is only active if P-COMP-00084 [▶ 101] is activated.	

4.6.2.3 CNC objects

Name	CROSSTALK::activated		
Description	This object reads whether crosstalk compensation is activated by P-AXIS-00789 [▶ 97] .		
Task	GEO (Port 551)		
Index group	0x120300	Index offset	0x<A_{ID}>01F4
Data type	BOOLEAN	Length	1
Attributes	read	Unit	[-]
Remarks	Available as of CNC Build V3.1.3079.32		

Name	CROSSTALK::actual_offset		
Description	This object reads the current effective offset of crosstalk compensation.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>01F7
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks	Available as of CNC Build V3.1.3079.32		

Name	CROSSTALK::delta_offset		
Description	This object reads the change in compensation value in the current crosstalk compensation cycle.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>01F6
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks	Available as of CNC Build V3.1.3079.32		

Name	CROSSTALK::end_offset		
Description	This object reads the compensation value of crosstalk compensation at the current position without filters.		
Task	GEO (Port 551)		
Index group	0x120300	**Index offset**	0x<A_{ID}>01F8
Data type	SGN32	**Length**	4
Attributes	read	**Unit**	[Incr.]
Remarks	Available as of CNC Build V3.1.3079.32		

4.6.3 Example of a compensation value list

Example

Crosstalk compensation with Mode 1

```
# ****************************************
# Axis compensation data for Z axis
# ****************************************

kopf.achs_nr                        3
kopf.log_achs_name                  Z
```

```
kw.crosstalk.mode                    1

kw.crosstalk.master_dyn_ax_nr        1 /*Logical axis number of the master
axis */
kw.crosstalk.velocity_dependent      TRUE
#
kw.crosstalk.acceleration            10000 ( mm/s^2)
kw.crosstalk.deceleration           -10000 ( mm/s^2)
kw.crosstalk.position[0].correction_accelerate_dir_pos  25 (0.1 um)
Kw.crosstalk.position[0].correction_decelerate_dir_pos 25
Kw.crosstalk.position[0].correction_accelerate_dir_neg 50
kw.crosstalk.position[0].correction_decelerate_dir_neg  50
```

Example

Crosstalk compensation with Mode 2

```
# ***************************************
# Axis compensation data for Z axis
# ***************************************

kopf.achs_nr                         3
kopf.log_achs_name                   Z
kw.crosstalk.mode                    2

kw.crosstalk.master_dyn_ax_nr        1 /*Logical axis number of the master
axis */
kw.crosstalk.velocity_dependent      TRUE
#
kw.crosstalk.acceleration            1000 ( mm/s^2 )
kw.crosstalk.deceleration           -1000 ( mm/s^2 )
kw.crosstalk.position[0].ax_1        0    (0.1 um )
kw.crosstalk.position[0].correction_accelerate_dir_pos  50 (0.1 um)
Kw.crosstalk.position[0].correction_decelerate_dir_pos 50
Kw.crosstalk.position[0].correction_accelerate_dir_neg 60
kw.crosstalk.position[0].correction_decelerate_dir_neg  60
kw.crosstalk.position[1].ax_1        1000    (0.1 um)
kw.crosstalk.position[1].correction_accelerate_dir_pos  70 (0.1 um)
Kw.crosstalk.position[1].correction_decelerate_dir_pos 70
Kw.crosstalk.position[1].correction_accelerate_dir_neg 80
kw.crosstalk.position[1].correction_decelerate_dir_neg  80
kw.crosstalk.position[2].ax_1        2000    ( 0.1 um)
kw.crosstalk.position[2].correction_accelerate_dir_pos  50 (0.1 um)
kw.crosstalk.position[2].correction_decelerate_dir_pos 50
Kw.crosstalk.position[2].correction_accelerate_dir_neg 60
kw.crosstalk.position[2].correction_decelerate_dir_neg  60
```

Example

Crosstalk compensation with Mode 3 with 9 measuring points

```
# ************************************
# Axis compensation data for Z axis
# ************************************

kopf.achs_nr                          3
kopf.log_achs_name                    Z
kw.crosstalk.mode                     3

kw.crosstalk.master_dyn_ax_nr      2 ( Logical axis number of the master
axis )


kw.crosstalk.master_pos1_ax_nr 1 ( Logical axis number of the first ad-
aptation axis )
kw.crosstalk.master_pos2_ax_nr      3 ( Logical axis number of the
second adaptation axis )
kw.crosstalk.max_points             9 ( Number of measuring points)
kw.crosstalk.velocity_dependent     TRUE
#
kw.crosstalk.acceleration_pos       1000 ( mm/s^2 )
kw.crosstalk.acceleration_neg      -1000 ( mm/s^2 )
kw.crosstalk.position[0].ax_1       0    ( 0.1 um)
kw.crosstalk.position[0].ax_2       0    ( 0.1 um)
kw.crosstalk.position[0].acc_pos_vel_pos_correction  60 ( 0.1 um )
kw.crosstalk.position[0].acc_pos_vel_neg_correction  60
kw.crosstalk.position[0].acc_neg_vel_pos_correction  70
kw.crosstalk.position[0].acc_neg_vel_neg_correction  70
#…

#…
kw.crosstalk.position[8].ax_1       3000 ( 0.1 um )
kw.crosstalk.position[8].ax_2       3000 ( 0.1 um )
kw.crosstalk.position[8].acc_pos_vel_pos_correction  50 ( 0.1 um )
kw.crosstalk.position[8].acc_pos_vel_neg_correction  50
kw.crosstalk.position[8].acc_neg_vel_pos_correction  60
kw.crosstalk.position[8].acc_neg_vel_neg_correction  60
```

4.6.4 Error messages

Errors in the configuration of crosstalk compensation result in deactivation of the function for the affected axis and to the output of an error message or warning message.

Overview of error messages:

- ID 70622
- ID 70625
- ID 70626
- ID 70627
- ID 70629
- ID 70631
- ID 70632
- ID 70657
- ID 70658
- ID 70659
- ID 70660

5 Other configuration options for axis compensation

5.1 Selecting/deselecting axis compensation in the NC program

Notice

Axis compensations switched off by the COMP command has a global NC program effect, i.e. compensations are not automatically activated at program end. They must be switched back on explicitly using the COMP command in the subsequent NC program.

Syntax:

<axis_name> **[COMP** [[**ON** | **OFF** [**BACKLASH CROSS PLANE LEAD TEMP FRICT CROSSTALK**]] | **OFF_ALL**]

[**NO_MOVE**] { \ } **]**

<axis_name>	Name of the axis
COMP	Identifier to select/deselect axis-specific compensation. Must always be programmed as the first keyword.
ON	Activates programmed compensation(s)
OFF	Deactivates programmed compensation(s)
BACKLASH	Keyword for backlash compensation [as of Build V3.1.3081.05]
CROSS	Keyword for cross compensation
PLANE	Keyword for plane compensation
LEAD	Keyword for spindle leadscrew error compensation
TEMP	Keyword for temperature compensation
FRICT	Keyword for friction compensation [as of Build V2.11.2022.05]
CROSSTALK	Keyword for crosstalk compensation [as of Build V3.1.3079.32]
OFF_ALL	Switch off all active compensations. No further compensation keywords may be programmed after the keyword.
NO_MOVE	By default the position offset occurring when axis compensations are switched on/off is executed before NC program processing is continued. The keyword NO_MOVE suppresses this motion. The channel is initialised with the changed axis position. The position offset is only executed at the next axis motion programmed in the NC program.
\	Separator ("backslash") for clear programming of the command over multiple lines.

Programing Example

Axis-specific programming

```
;Deactivate cross and plane compensation in the X axis
N10 X[COMP OFF CROSS PLANE
;Compensation programming of multiple axes in an NC block
N50 X[COMP OFF CROSS] Y[COMP ON LEAD TEMP]
;Deactivate all compensations in the Z axis
N100 Z[COMP OFF_ALL]
;Deactivate all compensations of the Y axis without axis motion
N200 Y[COMP OFF_ALL NO_MOVE]
```

5.2 Checking the states of axis compensation in the NC program

V.A variables

The following V.A. variables can be used to check from the NC program whether a compensation programmable via the COMP command is initialised or already active for a specific axis and the value of the compensation..

Notice

Read access to the variables with the identifier L_{Flush} causes flushing of the NC channel.

For example, flushing the NC channel can result in the error ID 20651 if tool radius compensation (G41/G42) is active.

Check for initialisation

CROSS_COMP_INIT.X	Is cross compensation initialised for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
PLANE_COMP_INIT.X	Is plane compensation initialised for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
LEAD_COMP_INIT.X	Is leadscrew error compensation activated for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
TEMP_COMP_INIT.X	Is temperature compensation initialised for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
FRICT_COMP_INIT.X	Is friction compensation initialised for the axis? If yes, then 1	Boolean	0, 1	L_{Flush}
CROSSTALK_COMP_INIT.X	Is crosstalk compensation initialised for the axis? If yes, then 1	Boolean	0, 1	L_{Flush}

Check for activation

CROSS_COMP_ACT-IVE.X	Is cross compensation active for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
PLANE_COMP_ACT-IVE.X	Is plane compensation active for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
LEAD_COMP_ACT-IVE.X	Is leadscrew error compensation active for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
TEMP_COMP_ACT-IVE.X	Is temperature compensation active for the axis? If yes, then 1	Boolean	0 , 1	L_{Flush}
FRICT_COMP_ACT-IVE.X	Is friction compensation active for the axis? If yes, then 1	Boolean	0, 1	L_{Flush}
CROSSTALK_COMP_ACTIVE.X	Is crosstalk compensation active for the axis? If yes, then 1	Boolean	0, 1	L_{Flush}
BACK-LASH_COMP_ACT-IVE.X	Is backlash compensation active for the axis? If so, then 1 **[as of V3.1.3081.05]**	Boolean	0, 1	L_{Flush}

Read current compensation values:

As of CNC Build **V2.11.2810** the following V.A. variables of the current compensation values are available.				
LEAD_COMP_CURR.X	Current compensation value of LSEC for the axis	Real	[mm, inch]	L_{Flush}
CROSS_COMP_CURR.X	Current compensation value of cross compensation for the axis	Real	[mm, inch]	L_{Flush}
PLANE_COMP_CURR.X	Current compensation value of plane compensation for the axis	Real	[mm, inch]	L_{Flush}
TEMP_COMP_CURR.X	Current compensation value of temperature compensation for the axis	Real	[mm, inch]	L_{Flush}
FRICT_COMP_CURR.X	Current compensation value of friction compensation for the axis	Real	[mm, inch]	L_{Flush}
CROSSTALK_COMP_CURR.X	Current compensation value of crosstalk compensation for the axis	Real	[mm, inch]	L_{Flush}
BACK-LASH_COMP_CURR.X	Current compensation value of backlash compensation for the axis **[as of V3.1.3081.05]**	Real	[mm, inch]	L_{Flush}

Programing Example

Check the states of the axis compensation

```
N010 G74 X1 Y2 Z3
N020 $IF V.A.CROSS_COMP_INIT.X != TRUE
N030 #MSG ["Cross_Comp for X not init."]
N040 $ENDIF
N050 $IF V.A.TEMP_COMP_INIT.X != TRUE
N060 #MSG ["Temp_Comp for X not init."]
N070 $ENDIF
N080 X [ COMP ON CROSS TEMP ]
N090 $IF V.A.CROSS_COMP_ACTIVE[0] != TRUE
N100 #MSG ["Cross_Comp for X not active"]
N110 $ENDIF
N120 $IF V.A.TEMP_COMP_ACTIVE[0] != TRUE
N130 #MSG ["Temp_Comp for X not active"]
N140 $ENDIF
N150 ...
```

5.3 Monitoring of effectiveness of axis compensations in automatic mode

Some axis compensations must fulfil certain preconditions before they can be active. To ensure that the selected axis compensations are operative in automatic mode, the required compensations for processing the NC program can be specified bit-encoded in the parameter 'lr_param.prog_movement_requires_compensations' (see P-AXIS-00465).

The CNC then outputs the error message P-ERR-70435 if the axis is moved in automatic mode and the specified axis compensations are not active. However, in manual mode or during homing [FCT-M1//Description], the axis can be moved without compensations.

For example, this monitoring function may be practical to prevent the production of an inaccurate workpiece if there are errors in the compensation table.

Prerequisites

The following conditions exist for the effectiveness of axis compensations:

1. The compensation table may contain no errors, see [COMP].
2. The axis must be referenced for spindle leadscrew error compensation and temperature compensation.
3. The master axes must be referenced for cross and plane compensation..
4. The drive releases must be set for cross and plane compensation before NC program start.

Activating the monitoring function in the axis parameter list

Variable name	Type	Meaning
lr_param.prog_movement_requires_compensations	UNS32	Bit-encoded specification of the required compensations

Notice

The CNC only generates error messages for compensations which are also enabled in the axis parameter list.

Bit encoding

The table below contains the bit encoding for axis compensations. The bit identifier can also be used to specify the required compensations:

Bit	Identifier	Axis compensation
0x1	BACKLASH	Backlash compensation
0x2	LEAD	Leadscrew error compensation
0x4	TEMP	Temperature compensation
0x8	CROSS	Cross compensation
0x10	PLANE	Plane compensation

Example

Monitoring the effectiveness of axis compensations in automatic mode

The following entry is required in the axis parameter list to monitor spindle leadscrew error compensation and cross compensation:

lr_param.prog_movement_requires_compensations LEAD | CROSS

The two compensations must be selected so that the CNC outputs an error message in automatic mode when the conditions are no longer met.

lr_param.ssfk 1

lr_param.crosscomp 1

6 Appendix

6.1 Suggestions, corrections and the latest documentation

Did you find any errors? Do you have any suggestions or constructive criticism? Then please contact us at documentation@isg-stuttgart.de.

The latest documentation is posted in our Online Help (DE/EN):

QR code link: https://www.isg-stuttgart.de/documentation-kernel/

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Notice

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Email: documentation@isg-stuttgart.de

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P-COMP-00028 67
P-COMP-00029 36
P-COMP-00030 52
P-COMP-00032 53
P-COMP-00033 53
P-COMP-00041 86
P-COMP-00042 87
P-COMP-00043 87
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P-COMP-00046 88
P-COMP-00047 88
P-COMP-00057 68
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P-COMP-00081 100
P-COMP-00082 100
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P-COMP-00084 101
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P-COMP-00086 102
P-COMP-00087 102
P-COMP-00088 102
P-COMP-00089 103
P-COMP-00090 103
Positive backlash 9

ISG Industrielle Steuerungstechnik GmbH
STEP, Gropiusplatz 10
D-70563 Stuttgart

www.isg-stuttgart.de
support@isg-stuttgart.de