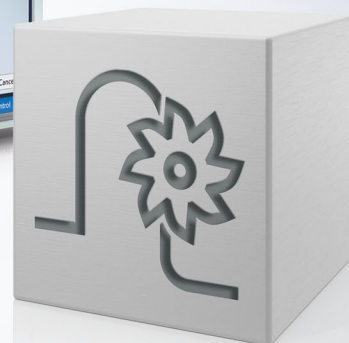
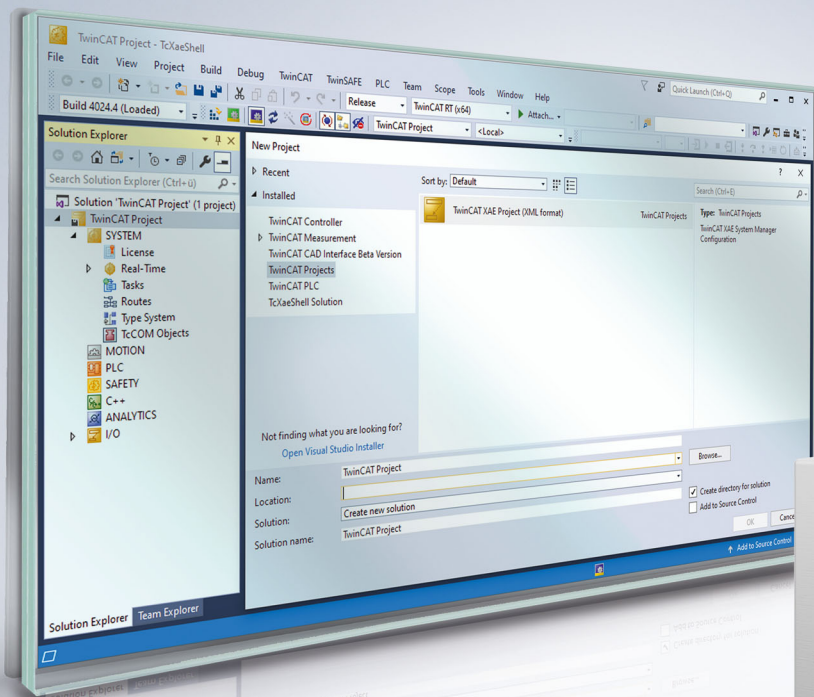


Functional description | EN

TF5200 | TwinCAT 3 CNC

Feedforward control



Notes on the documentation

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.

It is essential that the documentation and the following notes and explanations are followed when installing and commissioning the components.

It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

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

Disclaimer

The documentation has been prepared with care. The products described are, however, constantly under development.

We reserve the right to revise and change the documentation at any time and without prior announcement.

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EP1590927, EP1789857, EP1456722, EP2137893, DE102015105702

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General and safety instructions

Icons used and their meanings

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

Icons in explanatory text

1. Indicates an action.

⇒ Indicates an action statement.

DANGER

Acute danger to life!

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

CAUTION

Personal injury and damage to machines!


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

NOTICE

Restriction or error

This icon describes restrictions or warns of errors.

Tips and other notes

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

General example

Example that clarifies the text.

NC programming example

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

Specific version information


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

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1 Overview

Task

When an axis is interpolated, the real actual position of the axes at the interpolated set position takes place with a certain time delay due to the properties of the position control algorithms used and bus delays. The difference between command and actual position is referred to as position lag.

Path errors occur on curved paths due to position lag. This is the case in particular for a path compound with axes of different dynamics.

Position lag and therefore the path error can be minimised by using feedforward control.

Feedforward control by the controller compensates for position lag based on the current speed and acceleration. Feedforward control can be adapted to the machine dynamics and the required path accuracy by entering the appropriate parameters in the axis parameter lists [AXIS] and also in the NC program.

Effectiveness

Feedforward control is available for all axis and drive types [AXIS].

Programming

The feedforward control mode is selected in the NC program. Programming takes place using the modal commands **G135**, **G136** and **G137** [PROG].

Parameterisation

The parameter P-AXIS-00223 enables feedforward control for each axis or spindle. The required parameters are entered in the constant **V_SATZ_ANZ**. For other parameters see Chapter "[Parameters](#)". [[▶ 21](#)]

Mandatory note on references to other documents

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

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

2 Description

Principle

Position lag is caused by control system delay in speed, acceleration and jerk in the position controller with respect to the command variable calculated in the interpolator.

Feedforward control calculates the theoretical position lag to be set in the interpolator and which would result from the current speed, acceleration and jerk. From this, it calculates the command speed value $v_{Vorsteuerung}$ which is then added to the position controller output (see Fig. "Block diagram of conventional feedforward control"). This additional command value can be weighted with a factor.

The position lag expected from the axis speed Δs_v is obtained from the equation:

$$\Delta s_v = v/K_v$$

The position lag expected from constant acceleration Δs_a is obtained from:

$$\Delta s_a = a \cdot T_a / K_v$$

The position lag expected from constant jerk Δs_j results from:

$$\Delta s_j = j + T_a / K_v^2$$

Where T_a is the mechanical time constant of the drive.

Alternatively the command velocities and accelerations calculated in the CNC controller can be transferred as additive speed and torque command values to the drive controller and fed into the appropriate control loops as additive command values (see figure below).

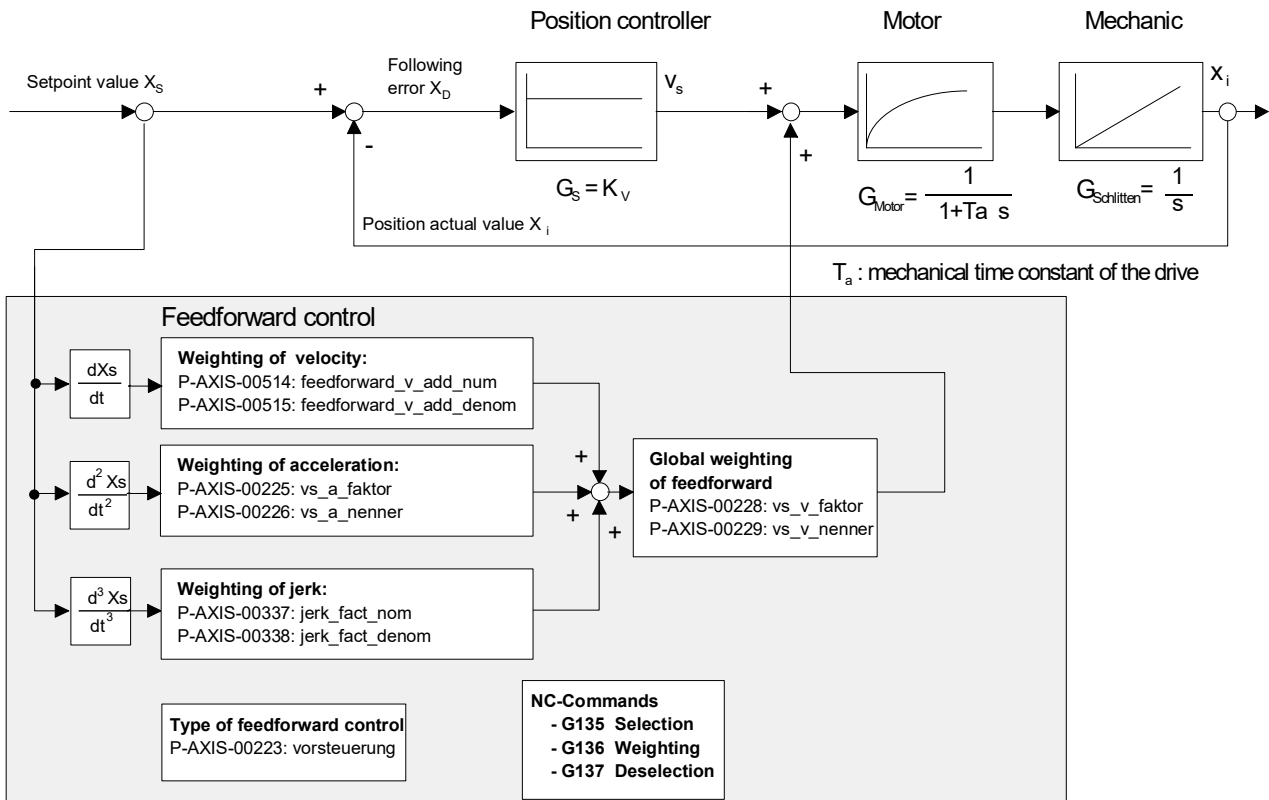


Fig. 1: Block diagram of conventional feedforward control

Feedforward control modes

Based on the cause of the position lag, the control system distinguishes between the following feedforward control modes

- Velocity feedforward control

- Acceleration feedforward control and
- Jerk feedforward control.

All feedforward control modes can be enabled or parameterised independently of one another.

Feedforward control for spindles

In the case of spindles, feedforward control is particularly necessary for thread tapping with endlessly rotating spindles since an ideal machining result is obtained by maintaining the specified command values with as few position lags as possible on both path axes and spindles.

Activation

The parameter P-AXIS-00223 enables feedforward control for each axis or spindle. When the corresponding bits are set, the feedforward control modes are selected and further control information is also activated. The feedforward control mode is selected in the NC program.

NOTICE

Note that the axes may overshoot when feedforward control is enabled.

Therefore, please be careful when parameterising feedforward control. Set the correct weighting factors in the axis parameter lists and in the NC program.

Weighting

The resulting feedforward control parameter can be weighted with 2 axis-specific factors. The parameters P-AXIS-00228 and P-AXIS-00229 weight the entire feedforward control process.

Weighting_{vorsteuerung} = P-AXIS-00228/P-AXIS-00229

Acceleration feedforward control can also be weighted by a real-time constant T_a which is defined by the parameters P-AXIS-00225 and P-AXIS-00226.

$T_a = P-AXIS-00225/P-AXIS-00226$

Jerk feedforward control can also be weighted by a factor

Weighting_{Ruckvorsteuerung} = P-AXIS-00337/P-AXIS-00338

which is defined from the parameters P-AXIS-00337 and P-AXIS-00338.



Empirically, the entire feedforward control can be weighted by a factor in the range of 0.7–1. At values >1 the axis is ahead of and the accuracy of the contour is falling off.

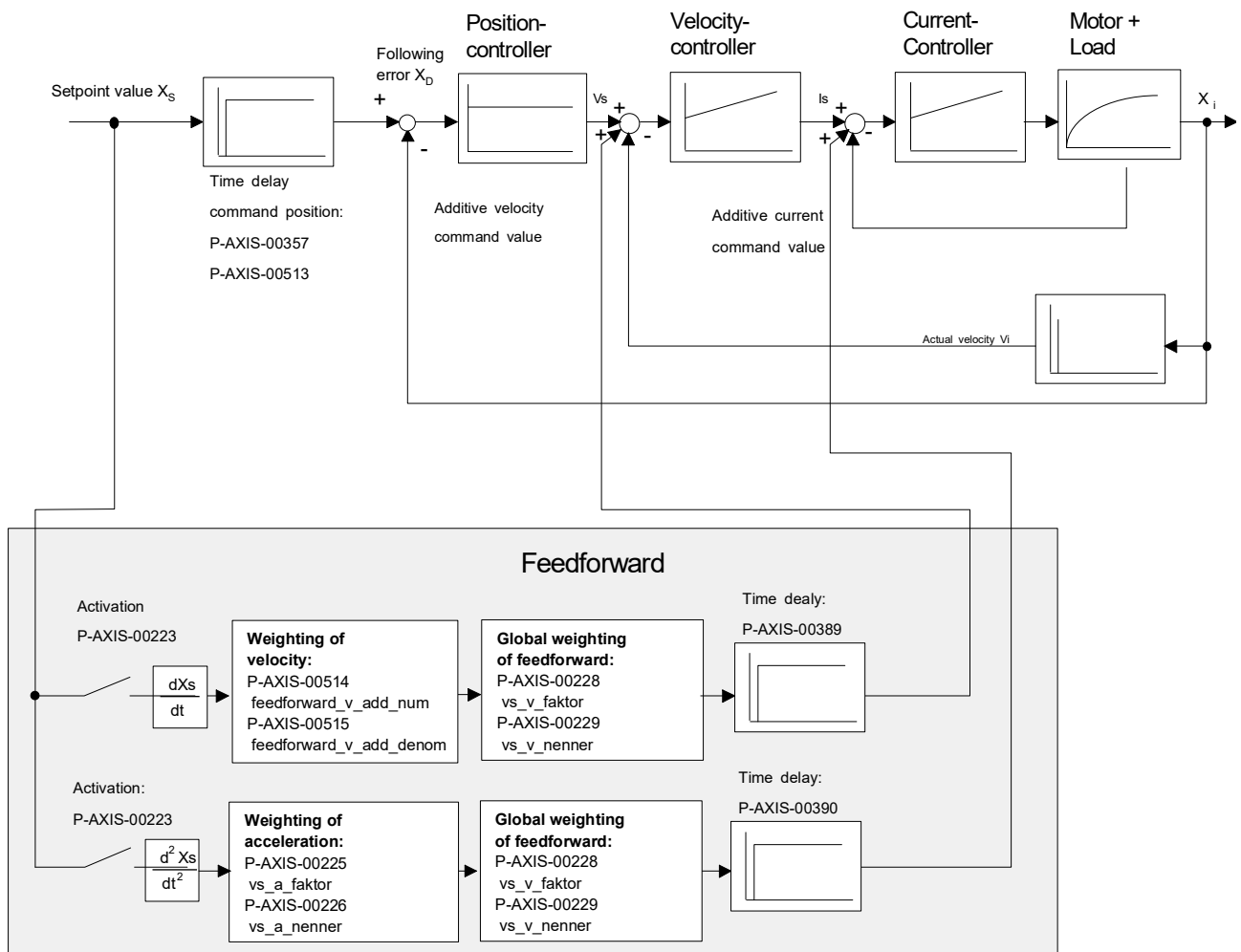


Fig. 2: Block diagram of feed forward control with additive setpoints

Parameterisation for PROFIdrive drives

PROFIdrive drives require the following additional parameters which must be set in the axis parameter lists:

- P-AXIS-00092: Position controller increments per revolution
- P-AXIS-00165: time offset of feedforward control parameters

With PROFIdrive drives, the parameter P-AXIS-00223 selects how to transfer the calculated feedforward control value to the drive:

- P-AXIS-00223, Bit 9 = 0: The feedforward control value is calculated in the control deviation (XERR – signal No. 25) as a position lag.
- P-AXIS-00223, Bit 9 = 1: The feedforward control value is included in the speed command value as a speed (NSOLL_B – signal No. 7).

NOTICE

SERCOS drives

With SERCOS drives, if feedforward control is to be implemented in the NC control system and not in the drive, the Kv factor in the axis parameter list must be set identical to the Kv factor of the SERCOS drive (IDN: (S-0-0104)).



With SERCOS drives, feedforward control is normally implemented in the drive itself and is set with the following parameters:

- IDN: S-0-0296: Velocity feed forward gain
- IDN: S-0-0348: Acceleration feedforward gain

3 Programming

Feedforward control is programmed in the NC program using the modal commands G135 , G136 and G137 [PROG].

Selecting feedforward control with G135

Feedforward control is explicitly deactivated every time the program is started. The axis group specific activation of feedforward control is programmed by the NC command G135 .

Weighting of feedforward control with G136

axis-specific, percentage weighting of the calculated feedforward control variables takes place with G136. It is limited to 100% for all axes. The weighting factors are reset to 100% after every program start. If feedforward control is activated or deactivated during the NC program, the weighting factors remain set to the values set by G136.

For axes with no G136 programmed, the weighting factor remains set to 100%.

It is also possible to enter the selection and weighting of feedforward control in a single block.

Deselecting feedforward control with G137

G137 deactivates axis group-specific feedforward control.

Deactivating individual axes

With axes for which no feedforward control is to be implemented after global selection with **G135**, a percentage weighting of 0% must be specified with **G136** .

Selecting and weighting feedforward control

```
G135          (Select feedforward control; weighting)
              (for all axes 100%)
G136 X80 Y95 Z0 (weighting; here, the Z axis)
              (has no feedforward control)
```

Parameterising spindles

Feedforward control for spindles is also programmed in the NC program using the modal commands G135 , G136 and G137 [PROG].

These commands permit the spindle-specific programming of feedforward control. The commands may not be used simultaneously with other spindle-specific commands.

Parameterising spindles

```
S[G135]           (Activate feedforward control for S)
S[G136=80]        (Define weighting in %)
S[G137]           (Deactivate feedforward control)
S2[G135 G136=90] ( at 90% weighting for S2)
S2[G136=0]        (Change weighting to 0%)
S1[G135]          (Activate with default weighting 100% for S1)
```

Delay

The calculation of feedforward values involves a delay of at least one cycle between the interpolator and the position controller.

NOTICE

Effects of delay on measurement run

In the worst case, an error may occur during measurement travel because the interpolator, which monitors the stroke of the block buffer between interpolator and position controller, ignores the distance components in the buffer.

This can be prevented by increasing the actual stroke of the measuring probe in the parameter P-AXIS-00086 (hub_messtaster).

Examples

The figures below show the measured position lags with and without speed and acceleration feedforward control for a simple path motion.

The figure below shows a clear position lag over the entire path motion.

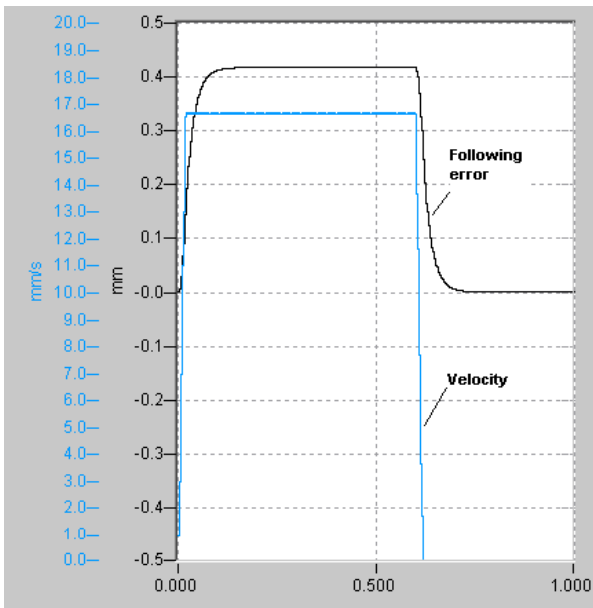


Fig. 3: Position lag without feedforward control

When speed feedforward control is activated, position lag peaks only occur in acceleration phases. Within the constant speed range, position lag is fully compensated by feedforward control (see figure below).

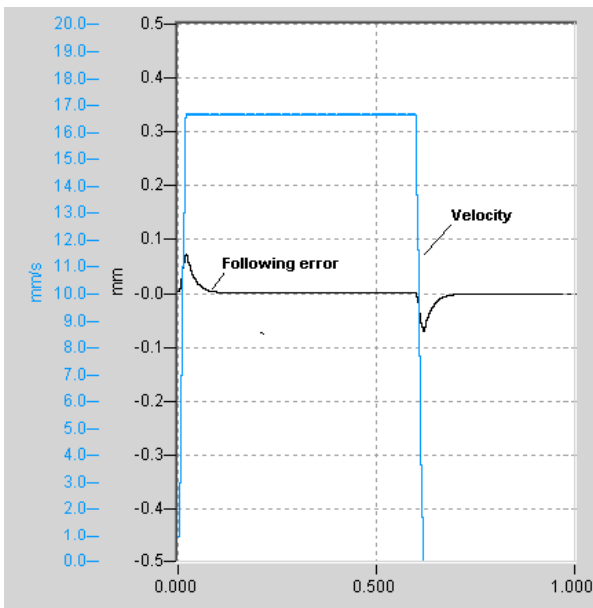


Fig. 4: Position lag with speed feedforward control

Position lag can be further reduced in acceleration phases by means of additional acceleration feedforward control (see figure below).

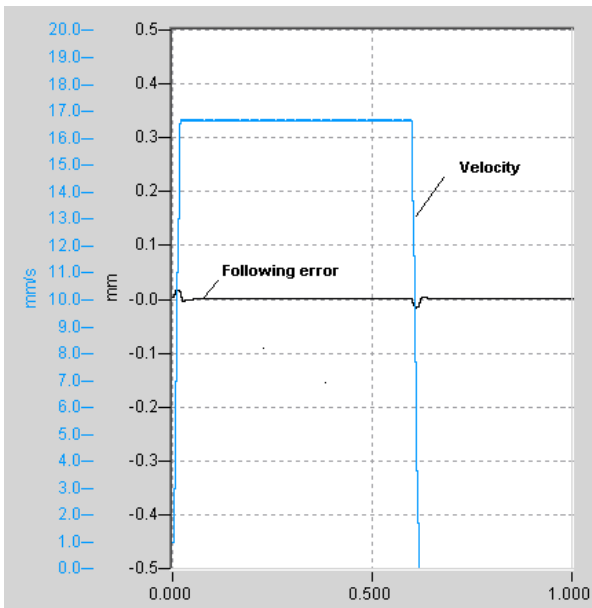


Fig. 5: Position lag with speed and acceleration feedforward control

4 Example: Parameterising feedforward control with additive command values

A number of settings are required to use speed feedforward control and acceleration feedforward control. The list below contains an overview of settings. They are explained in the sections.

Velocity feedforward control

The parameter P-AXIS-00223 first selects the

- conventional speed feedforward control (see also the block diagram “Block diagram of conventional feedforward control”) or
- outputs the speed feedforward control value as an additive command value (see also block diagram: "Block diagram of feed forward control with additive setpoints")
- Configure the additive command value in cyclic process data.

In both cases speed scaling follows as 2.Schritt in the following parameters:

- P-AXIS-00205
- P-AXIS-00206
- P-AXIS-00207

Then the weighting factors must be set by the parameters:

- P-AXIS-00228
- P-AXIS-00229

Acceleration feedforward control:

First select the following using P-AXIS-00223:

- Acceleration feedforward control
- output of acceleration feedforward control value

Then calculate the required motor torque. Configure the path resolution of the axis in:

- P-AXIS-00092
- P-AXIS-00233
- P-AXIS-00234
- P-AXIS-00362 and
- P-AXIS-00363

Then enter the total motor load in P-AXIS-00391 in the unit $\text{kg}\cdot\text{m}^2$

Calculate the required motor torque/current command value. Enter the nominal torque of the motor as a reference value for torque scaling in P-AXIS-00392

- Torque scaling factor in the parameters P-AXIS-00325 and P-AXIS-00326.
- The value for P-AXIS-00392 is contained in the motor data sheet.

Finally, enter the acceleration feedforward control delay related to the set position in the parameter P-AXIS-00390.

4.1 Velocity feedforward control

Configuration

To apply speed feedforward control, first configure speed feedforward control in P-AXIS-00223 and the output of the speed feedforward control value as an additive command value:


```

vorsteuer.vorsteuerung 0x101 #0x001: Activation velocity
                        feedforward
                        #0x100: Output as additive           velocity
command_value
    
```

Configure the additive speed command value in the cyclic process data.

i If the output of speed feedforward control is activated as an additive speed command value and no additive speed command value is configured in the cyclical process data, an error message P-ERR-70350 is output.

Speed scaling

Now only speed scaling needs to be parameterised. The parameters P-AXIS-00205, P-AXIS-00206 and P-AXIS-00207 are used for this.

In the parameter P-AXIS-00205 enter the speed which is set for the axis taking into consideration all the transmission elements (e.g. gear ratio and spindle pitch) if a value of P-AXIS-00206 is output to the speed interface.

Enter the time base used at the speed interface in the parameter P-AXIS-00207.

Velocity feedforward control

A SERCOS drive which has a spindle pitch of 10 mm/rev and a default scaling for speed data (10⁻⁴ rpm), results in a translatory axis speed of 10 mm/min (10,000 * 10⁻⁴ rpm * 10 mm/rev) when the value 10,000 is output as the speed command value at the drive.

Therefore set the following values for the parameters P-AXIS-00205, P-AXIS-00206 and P-AXIS-00207:

```

antr.v_time_base      0      #Timebase per Minute
antr.v_reso_num       10000  #Outputvalue to drive
antr.v_reso_denom     10000  #Resulting axis velocity in      um/
v_time_base
    
```

If in addition a gear with a gear ratio of $i=3$ (n_{Motor}/n_{Last}) is considered, the translatory speed of the axis is reduced to 3.333 mm/min (10,000 * 10⁻⁴ rpm / i * 10 mm/rev) for the same output value. This results in the following values for P-AXIS-00206 and P-AXIS-00207:

```

antr.v_time_base      0      #Timebase per Minute
antr.v_reso_num       10000  #Outputvalue to drive
antr.v_reso_denom     3333   #Resulting axis velocity in      um/
v_time_base
    
```

In addition the output of the speed feedforward control value can be delayed in relation to the set position. This delay can be set by the parameter P-AXIS-00389.

i The maximum delay time that can be set is one position controller cycle. If a longer delay time is parameterised, the error message P-ERR-70349 is output and the delay time is set to 0.

The resulting parameter set is:

```

vorsteuer.vorsteuerung 0x101 #0x001: Activation velocity
                        feedforward
                        #0x100: Output as additive           velocity
command_value
vorsteuer.velocity_delay_time 150 # Delay velocity
                                feedforward against
                                position
                                # command value in us
antr.v_time_base      0      #Timebase per Minute
antr.v_reso_num       10000  #Outputvalue to drive
antr.v_reso_denom     3333   #Resulting axis velocity in      um/
v_time_base
    
```

4.2 Acceleration feedforward control

Configuration

To apply acceleration feedforward control, first configure acceleration feedforward control in P-AXIS-00223 and the output of the acceleration feedforward control value as an additive command value:

```
vorsteuer.vorsteuerung 0x202 #0x002: Activation accele-
                             ration feedforward
                             #0x200: Output as additive
                             torque command value
```

In addition configure the additive torque/current command value in the cyclic process data.



If the output of acceleration feedforward control is activated as an additive command value and no additive torque/current command value is configured in the cyclic process data, the error message ID 70351 is output.

Torque calculation

With acceleration feedforward control using an additive torque or current command value, the required motor torque is calculated by the equation below.

$$M = J_{\text{tot}} \cdot a$$

or

$$F = m_{\text{tot}} \cdot a$$

This torque is rescaled to the format used by the motor and then output to the drive.

Since specific knowledge of the mechanical structure of the axis is required to calculate angular acceleration, it is advisable to configure the path resolution of the axis by specifying the parameters P-AXIS-00092, P-AXIS-00233, P-AXIS-00234, and P-AXIS-00362 and P-AXIS-00363.

If a value unequal to 1 is assigned to one of the two parameters P-AXIS-00362 and P-AXIS-00363, the path resolution is calculated by the equation:

$$R = P - AXIS - 00092 * \frac{P - AXIS - 00234}{P - AXIS - 00233} * \frac{P - AXIS - 00363}{P - AXIS - 00362}$$

Parameter set

The following parameter set results for an axis with a motor encoder resolution of 2²⁰ increments per revolution, a gearbox ratio of 3 and a spindle pitch of 5 mm/rev:

```
antr.feed_const_num      50000      #feedconstant 5mm
                             per revolution
antr.feed_const_denom    1           #
getriebe[].incr_per_rev  1048576     #2**20 increments per
                             motor revolution
getriebe[].wegaufz       3           #gearbox ratio: input
                             revolutions
getriebe[].wegaufn       1           #gearbox ratio:
                             output revolutions
```

The total motor load (J_{tot}) is also required as a further parameter. J_{tot} is composed of the following:

- Total of motor moments of inertia and
- load torque referred to the motor shaft.

Enter the resulting value in the parameter P-AXIS-00391 in the unit kg*m².

```
getriebe[].load          0.48        #Total motor load
                             0.48 kg*m**2
```

The required motor torque can be calculated using the parameters now available. The following parameters are also required to calculate the torque/current command value output to the drive:

1. Motor nominal torque as reference value for torque scaling in P-AXIS-00392.
2. Torque scaling factor in the parameters P-AXIS-00325 and P-AXIS-00326.

The value for P-AXIS-00392 is contained in the motor data sheet:

```
antr.acc_reference_value 0.45        #stall torque in Nm
```

Enter the value which must be output as additive torque command value for the parameters P-AXIS-00325 and P-AXIS-00326 so that the motor outputs its nominal torque. This value depends on the torque scaling used in the drive.

For example, if a percentage weighting is used in 0.1% referred to the maximum current of the drive amplifier, the following results for a maximum current of 3.16 A and a nominal current of 1.58 A for the parameters P-AXIS-00325 and P-AXIS-00326:

$$P\text{-}AXIS\text{-}00325/P\text{-}AXIS\text{-}00326 = 1,58A/3,16A * 1000 = 500$$

The possible values for P-AXIS-00325 and P-AXIS-00326 would then be, for example:

```
antr.torque_scale_num    500
antr.torque_scale_denom  1
```

In addition, the output of the acceleration feedforward value can still be delayed in relation to the position command value; this delay can be set by the P-AXIS-00390 parameter.



The maximum delay time that can be set is one position controller cycle. If a longer delay time is parameterised, the error message ID 70348 is output and the delay time is set to 0.

The feedforward value to be output can be weighted by the parameters P-AXIS-00225 and P-AXIS-00226. In the following example the feedforward value is 1.2.

```
vorsteuer.vs_a_faktor    12        # Weighting acceleration feedforward numerator
vorsteuer.vs_a_nenner    10        # Weighting acceleration feedforward denominator
```

The resulting parameter set is:

```

vorsteuer.vorsteuerung 0x202 #0x002: Activation accele-
                             ration feedforward
                             #0x200: Output as additive
                             torque command value
antr.feed_const_num     50000 #feedconstant 5mm per
                             revolution
antr.feed_const_denom   1      #
getriebe[].incr_per_rev 1048576 #2**20 increments
                             per motor revolution
getriebe[].wegaufz      3      #gearbox ratio:
                             input revolutions
getriebe[].wegaufn      1      #gearbox ratio:
                             output revolutions
antr.acc_reference_value 0.45  #stall torque in Nm
antr.torque_scale_num   500
antr.torque_scale_denom 1
vorsteuer.acceleration_delay_time 150 # Delay accele-
                             ration feedforward
                             against
                             # position
                             command value in us
vorsteuer.vs_a_faktor   12     # Weighting acceleration
numerator                                     feedforward
vorsteuer.vs_a_nenner   10     # Weighting acceleration
denominator                                     feedforward

```

5 Parameter

5.1 Overview

Constant	Description	
V_SATZ_ANZ	Maximum number of buffered blocks	
ID	Parameter	Description
P-AXIS-00092	incr_per_rev	Position controller increments per revolution
P-AXIS-00165	shift_time	PROFIdrive: time offset of feedforward control parameters
P-AXIS-00205	v_reso_denom	Denominator, scaling factor for speed scaling
P-AXIS-00206	v_reso_num	Numerator, scaling factor for speed scaling
P-AXIS-00207	v_time_base	Time base for scaling factor for speed scaling
P-AXIS-00223	vorsteuerung	Feedforward control mode
P-AXIS-00225	vs_a_faktor	Substitute time constant for acceleration feedforward control, numerator
P-AXIS-00226	vs_a_nenner	Substitute time constant for acceleration feedforward control, denominator
P-AXIS-00228	vs_v_faktor	Weighting factor for feedforward control, numerator
P-AXIS-00229	vs_v_nenner	Weighting factor for feedforward control, denominator
P-AXIS-00325	torque_scale_num	Numerator, scaling factor, torque scaling
P-AXIS-00326	torque_scale_denom	Denominator, scaling factor, torque scaling
P-AXIS-00337	jerk_fact_num	Weighting factor for jerk feedforward control, numerator
P-AXIS-00338	jerk_fact_denom	Weighting factor for jerk feedforward control, denominator
P-AXIS-00389	velocity_delay_time	Delay time for speed feedforward control value
P-AXIS-00390	acceleration_delay_time	Delay time for acceleration feedforward control value
P-AXIS-00391	load	Motor load
P-AXIS-00392	acc_reference_value	Scaling factor to convert acceleration feedforward control values to motor format.

5.2 Description

P-AXIS-00092	Position controller increments per revolution	
Description	<p>This parameter contains the number of position controller increments per revolution of the motor axis.</p> <p>The internal value used in the CNC kernel (value after assessing the value transmitted in the bus telegram) is output with the parameters P-AXIS-00405 (SERCOS and CANopen drives), or P-AXIS-00065 (PROFIDRIVE drives). When this parameter is used, the parameters P-AXIS-00362/P-AXIS-00363 and P-AXIS-00511/P-AXIS-00512) must be used.</p>	
Parameter	getriebe[i].incr_per_rev	
Data type	UNS32	
Data range	$0 \leq \text{incr_per_rev} \leq \text{MAX}(\text{UNS32})$	
Axis types	T, R, S	
Dimension	T: Increments/ rev.	R,S: Increments/ rev.
Default value	1024	
Drive types	----	
Remarks	For possible applications, see. Settings of position scaling	

P-AXIS-00165	Time offset of feed forward control setpoints	
Description	<p>This parameter defines a time offset in NC cycles between the output of the setpoints and the output of the calculated feedforward control values. With a value > 0, the feedforward control values are output before the associated setpoint. This parameter optimises the behaviour of the feedforward control axis.</p>	
Parameter	vorsteuer.shift_time	
Data type	UNS16	
Data range	$0 \leq \text{shift_time} \leq 4$	
Axis types	T, R, S	
Dimension	T: Number of interpolation cycles	R,S: Number of interpolation cycles
Default value	3	
Drive types	Profidrive	
Remarks		

P-AXIS-00205	Normalisation of the velocity (denominator)	
Description	<p>The conversion factor of the set velocity to drive format is obtained by specifying the value output to the drive and the related path distance covered in the time specified in P-AXIS-00207.</p> <p>This parameter specifies the conversion factor numerator. (P-AXIS-00206 is the numerator)</p> <p>This parameter indicates the path covered in the time specified in P-AXIS-00207, provided the value in P-AXIS-00206 is output to the drive. The path is specified in 1 μm or 0.001°.</p>	
Parameter	antr.v_reso_denom	
Data type	UNS32	
Data range	$1 \leq \text{v_reso_denom} \leq \text{MAX}(\text{UNS32})$	
Axis types	T, R, S	
Dimension	T: 1 μm	R,S: 0,001°
Default value	36	
Drive types	All drive types	
Remarks		

P-AXIS-00206	Normalisation of command velocity (numerator)	
---------------------	--	--

Description	<p>The conversion factor of the command velocity to drive format is defined by specifying the value output to the drive and the related distance covered in the time specified in P-AXIS-00207 .</p> <p>This parameter specifies the conversion factor numerator. (P-AXIS-00205 is the denominator)</p> <p>The factor indicates the number of velocity increments output.</p>	
Parameter	antr.v_reso_num	
Data type	UNS32	
Data range	0 ≤ v_reso_num ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: increments	R,S: increments
Default value	1	
Drive types	All drive types	
Remarks		

P-AXIS-00207	Time base for normalisation of velocity	
Description	<p>The time base for adapting the velocity interface to the unit used in the drive can be specified as value per minute, second or sampling interval. If normalisation per sampling interval is selected, the output value changes proportionally depending on the CNC cycle time at constant velocity. This may be essential depending on the drive.</p>	
Parameter	antr.v_time_base	
Data type	UNS16	
Data range	<p>0: per minute</p> <p>1: per second</p> <p>2: per sampling interval</p>	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Drive types	SERCOS	
Remarks		

P-AXIS-00223	Feedforward control mode	
Description	<p>This parameter specifies bit-coded which reference variables (velocity, acceleration and jerk) are to be active during feedforward control.</p>	
Parameter	vorsteuer.vorsteuerung (feedforward)	
Data type	STRING	

Data range	Flag	Meaning	Value
	NONE	No feedforward control	0x0000
	VEL	Velocity feedforward control	0x0001
	ACC	Acceleration feedforward control	0x0002
	JERK	Jerk feedforward control	0x0004
	ADD_VEL	Velocity feedforward control by output of an additive velocity command value () PROFIdrive: In PROFIdrive telegram 5, the calculated feedforward control value is calculated as the velocity in the velocity command value (NSOLL_B - Signal No.7); as opposed to VEL, the feedforward value is calculated here as a position lag in the control deviation ((XERR - Signal No.25).	0x0101
	ADD_ACC	Acceleration feedforward control by output of an additive torque/current command value	0x0202
	ADD_JERK	Jerk feedforward control by output of an additive torque/current command value	0x0804
Axis types	T, R, S		
Dimension	T: ----	R,S: ----	
Default value	NONE		
Drive types	----		
Remarks	<p>This function is available for all types of axes and types of drives. Jerk feedforward is only available when a jerk-limited velocity profile is used. For details on defining the acceleration profile, see P-CHAN-00071 and [PROG// Command #SLOPE [TYPE...]].</p> <p>The specification of values by codes is possible as of CNC Builds</p> <ul style="list-style-type: none"> • V2.11.2034.6 • V2.11.2808.03 • V3.1.3065.04 and • V3.1.3102.00 <p>.</p> <p>Examples:</p> <p>Velocity and acceleration feedforward control: vorsteuer.vorsteuerung VEL ACC</p> <p>Velocity and acceleration feedforward control by additive command values: vorsteuer.vorsteuerung (feedforward) ADD_VEL ADD_ACC</p> <p>In previous CNC Builds values had to be specified bit-coded for the UNS16 variable. Default value: 0</p>		

P-AXIS-00225	Numerator equivalent time constant for feedforward control of acceleration
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Description	<p>The acceleration command variable is weighted by the mechanical time constant of the drive.</p> <p>The drive is modelled here as a first-order time delay element (see figure of the conventional feedforward control).</p> <p>The following transfer function in the Laplace range is obtained:</p> $G_{Drive} = \frac{1}{1 + T_{\alpha} * s} \quad \text{with} \quad T_{\alpha} = \frac{P - AXIS - 00225}{P - AXIS - 00226}$ <p>P-AXIS-00226: time constant denominator.</p>	
Parameter	vorsteuer.vs_a_faktor	
Data type	SGN32	
Data range	0 ≤ vs_a_faktor ≤ MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: μs	R,S: μs
Default value	1	
Drive types	----	
Remarks		

P-AXIS-00226	Denominator equivalent time constant for feedforward control of acceleration	
Description	<p>The acceleration command variable is weighted by the mechanical time constant of the drive.</p> <p>The drive is modelled here as a first-order time delay element (see figure of the conventional feedforward control]).</p> <p>In the Laplace range the following transfer function is obtained</p> $G_{Drive} = \frac{1}{1 + T_{\alpha} * s} \quad \text{with} \quad T_{\alpha} = \frac{P - AXIS - 00225}{P - AXIS - 00226}$ <p>P-AXIS-00225: time constant numerator.</p>	
Parameter	vorsteuer.vs_a_nenner	
Data type	SGN32	
Data range	0 ≤ vs_a_nenner ≤ MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	1	
Drive types	----	
Remarks		

P-AXIS-00228	Numerator weighting factor for feedforward control	
Description	<p>This parameter describes the weighting factor for velocity and acceleration feedforward control.</p> $Weighting_{feedforward\ control} = \frac{P - AXIS - 00228}{P - AXIS - 00229}$	
Parameter	vorsteuer.vs_v_faktor	
Data type	SGN32	
Data range	0 ≤ vs_v_faktor ≤ MAX(SGN32)	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----

Default value	1
Drive types	----
Remarks	We know from experience that the weighting factor should be in the range of 0.7 - 1. At values >1 the axis leads and impairs contour accuracy.

P-AXIS-00229	Denominator weighting factor for feedforward control
Description	This parameter describes the weighting factor for velocity and acceleration feedforward control. $\text{Weighting}_{\text{feedforward control}} = \frac{\text{P-AXIS-00228}}{\text{P-AXIS-00229}}$
Parameter	vorsteuer.vs_v_nenner
Data type	SGN32
Data range	$0 \leq \text{vs_v_nenner} \leq \text{MAX}(\text{SGN32})$
Axis types	T, R, S
Dimension	T: ---- R,S: ----
Default value	1
Drive types	----
Remarks	We know from experience that the weighting factor should be in the range of 0.7 - 1. At values >1 the axis leads and impairs contour accuracy.

P-AXIS-00325	Numerator scaling factor for torque
Description	Numerator of the scaling factor for the commanded torque to the drive. The factor is specified as a quotient. This quotient is the value which must be output to the motor to reach the nominal torque.
Parameter	antr.torque_scale_num
Data type	UNS32
Data range	$0 < \text{torque_scale_num} < \text{MAX}(\text{UNS32})$
Axis types	T, R, S
Dimension	T: ---- R,S: ----
Default value	1
Drive types	SERCOS, Lightbus,CANopen
Remarks	

P-AXIS-00326	Denominator scaling factor for torque
Description	Denominator of the scaling factor for the commanded torque to the drive. The factor is specified as a quotient. This quotient is the value which must be output to the motor to reach the nominal torque.
Parameter	antr.torque_scale_denom
Data type	UNS32
Data range	$1 < \text{torque_scale_denom} < \text{MAX}(\text{UNS32})$
Axis types	T, R, S
Dimension	T: ---- R,S: ----
Default value	1
Drive types	SERCOS, Lightbus,CANopen
Remarks	If the value 0 is set for P-AXIS-00326, an error message with the ID number P-ERR-110465 is output and the internal scaling factor is set to 0 In this case no output of the additive torque command value to the drive is sent.

P-AXIS-00337	Numerator of scaling factor for jerk feedforward
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Description	<p>This parameter specifies the numerator of the scaling factor for jerk feedforward control. The scaling factor for jerk feedforward control is defined as:</p> $\text{jerk_fact} = \text{P-AXIS-00337} / \text{P-AXIS-00338} \quad [\rightarrow 27]$ <p>The output of the jerk feedforward control command value to the drive must be activated by setting bit 0x04 in axis parameter P-AXIS-00223 .</p>	
Parameter	vorsteuer.jerk_fact_num	
Data type	UNS32	
Data range	$0 \leq \text{jerk_fact_num} \leq \text{MAX}(\text{UNS32})$	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	1	
Drive types	----	
Remarks	<p>Jerk feedforward control is only possible if a jerk-limited acceleration profile is used. For non jerk-limited acceleration profiles a jerk command value of 0 is output.</p> <p>For details on defining the acceleration profile, see P-CHAN-00071 and [PROG// Command #SLOPE [TYPE...]].</p>	

P-AXIS-00338	Denominator of scaling factor for jerk feedforward	
Description	<p>This parameter specifies the denominator of the scaling factor for jerk feedforward control. The scaling factor for jerk feedforward control is defined as:</p> $\text{jerk_fact} = \text{P-AXIS-00337} / \text{P-AXIS-00338}$ <p>The output of the jerk feedforward control command value to the drive must be activated by setting bit 0x04 in axis parameter P-AXIS-00223 .</p>	
Parameter	vorsteuer.jerk_fact_denom	
Data type	UNS32	
Data range	$0 < \text{jerk_fact_denom} \leq \text{MAX}(\text{UNS32})$	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	100	
Drive types	----	
Remarks	<p>Jerk feedforward control is only possible if a jerk-limited acceleration profile is used. For non jerk limited acceleration profiles a jerk command value of 0 is output.</p> <p>For details on defining the acceleration profile, see P-CHAN-00071 and [PROG// Command #SLOPE [TYPE...]].</p> <p>A value of 0 is inadmissible for this parameter. If this value is specified nevertheless, an error message with error code 110473 is output and the value is corrected to the default (100).</p>	

P-AXIS-00389	Delay time for velocity feedforward	
Description	<p>If velocity feedforward control via an additive velocity command value is activated, this parameter can delay the output of the velocity feedforward control value with respect to the command position.</p> <p>The delay time unit is in μs. Maximum delay is six interpolator cycles.</p>	
Parameter	vorsteuer.velocity_delay_time	
Data type	UNS16	
Data range	$0 \leq \text{velocity_delay_time} < 6 \cdot \text{interpolator cycle time}$	
Axis types	T, R, S	
Dimension	T: μs	R,S: μs
Default value	0	
Drive types	SERCOS, Profidrive, CANopen	

Remarks	If the permitted value of P-AXIS-00389 is exceeded, the error message P-ERR-70349 is output and P-AXIS-00389 is corrected to 0.
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P-AXIS-00390	Delay time for acceleration feedforward
Description	If acceleration feedforward control via an additive torque command value is activated, this parameter delays the output of the acceleration feedforward control value with respect to the command position. The delay time unit is in μs . Maximum delay is six interpolator cycles.
Parameter	vorsteuer.acceleration_delay_time
Data type	UNS16
Data range	$0 < \text{acceleration_delay_time} < 6 * \text{Interpolator cycle time}$
Axis types	T, R, S
Dimension	T: μs R,S: μs
Default value	0
Drive types	SERCOS, Lightbus, Profidrive, CANopen
Remarks	If the permitted value of P-AXIS-00390 is exceeded, the error message P-ERR-70348 is output and P-AXIS-00390 is corrected to 0.

P-AXIS-00391	Load inertia
Description	To set up acceleration feedforward with additive torque command value, the total load inertia of the motor must be configured here. The total load inertia is the inertia of the motor itself and the inertia of the load related to the motor shaft. In case of a translatory moved axis, the moved masses must be converted to an equivalent inertia related to the motor shaft.
Parameter	getriebe[i].load
Data type	REAL64
Data range	$0 \leq \text{load} \leq \text{MAX}(\text{REAL64})$
Axis types	T, R, S
Dimension	T: kg R,S: $\text{kg} * \text{m}^2$
Default value	1.000000e-006
Drive types	SERCOS
Remarks	

P-AXIS-00392	Reference value for converting torque values to the motor format.
Description	This parameter is used for the scaling of the additive torque command if acceleration feedforward control is used with additive command values. The motor stall torque must be entered.
Parameter	antr.acc_reference_value
Data type	REAL64
Data range	$0 \leq \text{acc_reference_value} \leq \text{MAX}(\text{REAL64})$
Axis types	T, R, S
Dimension	T: N R,S: Nm
Default value	1
Drive types	SERCOS, CANopen
Remarks	

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Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

Huelshorstweg 20
33415 Verl
Germany

Phone: +49 5246 963-0
e-mail: info@beckhoff.com
web: www.beckhoff.com

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More Information:
www.beckhoff.com/TF5200

Beckhoff Automation GmbH & Co. KG
Hülshorstweg 20
33415 Verl
Germany
Phone: +49 5246 9630
info@beckhoff.com
www.beckhoff.com

