



DOCUMENTATION ISG-kernel

Functional description Feedforward control

Short Description:
FCT-D2

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Preface

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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.

Further information

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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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

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". [▶ 22]

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 $v_{\text{Vorsteuerung}}$ 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:

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

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).

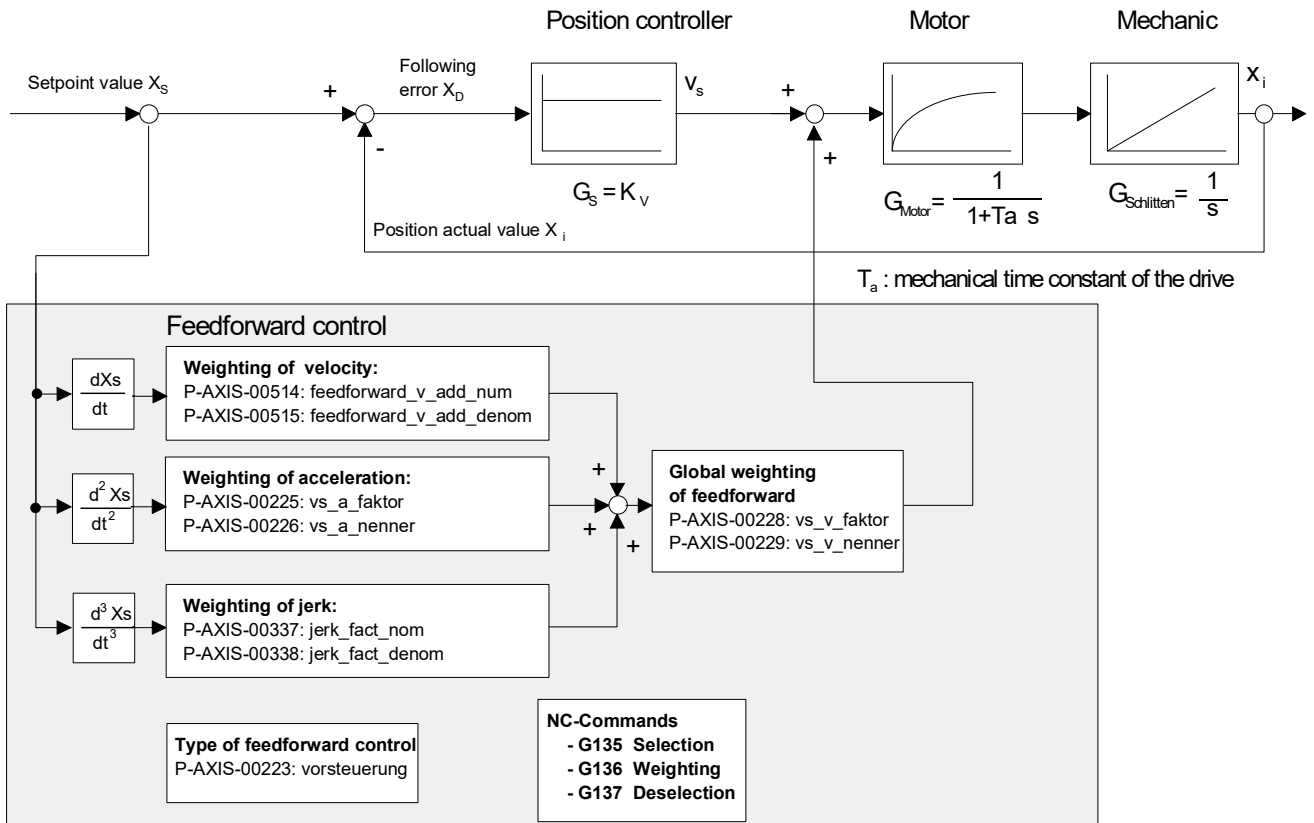


Fig. 1: Block diagram of conventional feedforward control

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.



Attention

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.

$$\text{Weighting}_{\text{vorsteuerung}} = \text{P-AXIS-00228/P-AXIS-00229}$$

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.

$$T_a = \text{P-AXIS-00225/P-AXIS-00226}$$

Jerk feedforward control can also be weighted by a factor

$$\text{Weighting}_{\text{Ruckvorsteuerung}} = \text{P-AXIS-00337/P-AXIS-00338}$$

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



Notice

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.

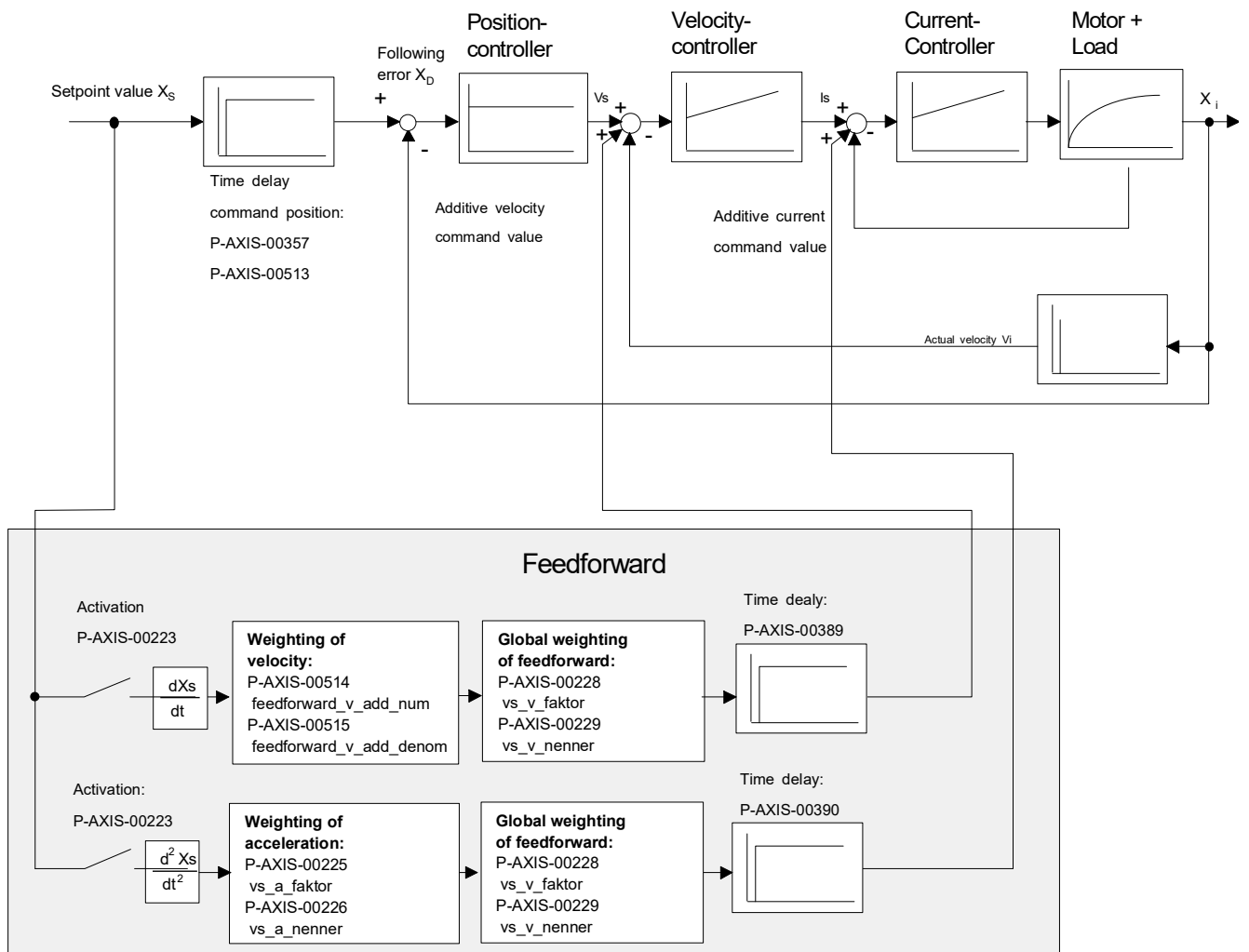


Fig. 2: Block diagram of feed forward control with additive setpoints

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).



Attention

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).



Notice

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 the 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**.

With axes for which no **G136** was 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

In case of 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** .



Example

Selecting and weighting feedforward control

```
G135                (Select feedforward control; Weighting)
(100% for all axes)
G136 X80 Y95 Z0    (Weighting; In this case 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.



Example

Parameterising spindles

```

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

Delay

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



Attention

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.

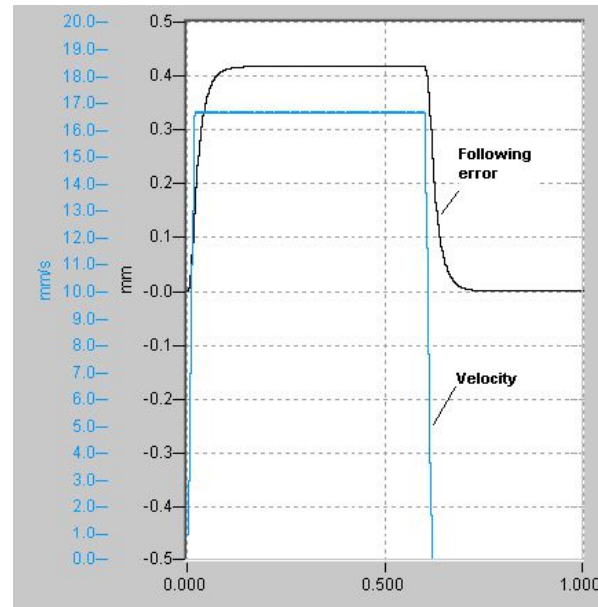


Fig. 3: Position lag without feedforward control

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).

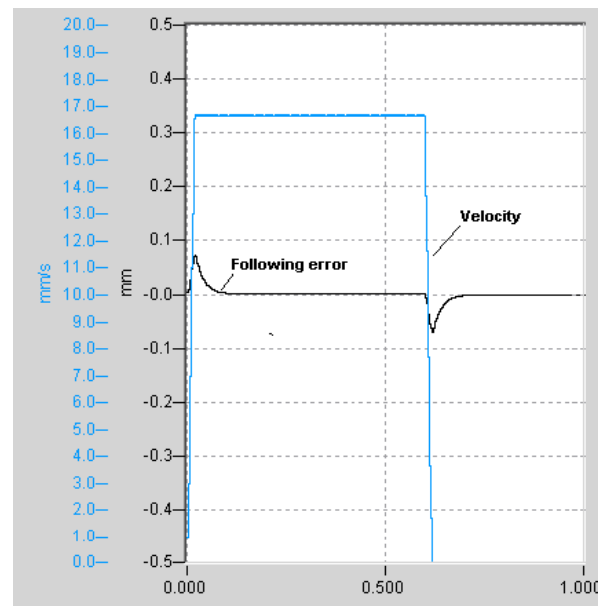


Fig. 4: Position lag with speed feedforward control

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

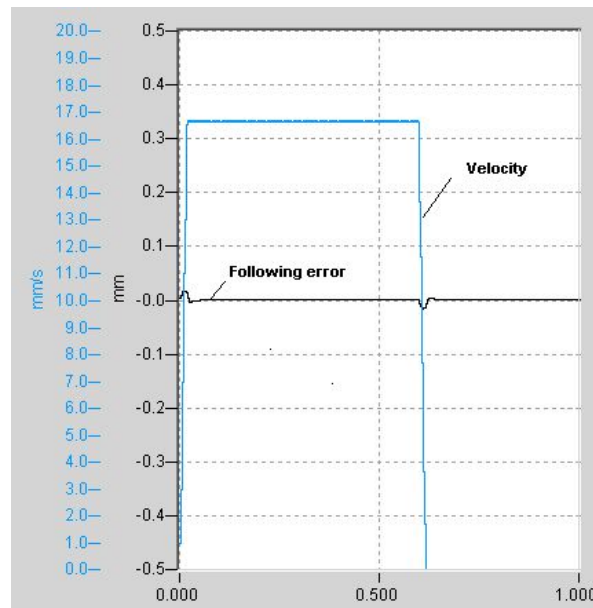


Fig. 5: Position lag with speed and acceleration feedforward control

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.



Notice

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.



Example

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 $i=3$ ($n_{\text{Motor}}/n_{\text{Last}}$) 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.



Notice

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 acceleration feedforward
                                #0x200: Output as additive torque command value
```

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



Notice

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 2^{20} 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
  
```

A further parameter requires the total motor load (J_{tot}).

J_{tot} consists of:

- 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 $\text{kg}\cdot\text{m}^2$.

```

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:

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

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.



Notice

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 feed-
forward numerator
vorsteuer.vs_a_nenner     10  # Weighting acceleration feed-
forward 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
                             feedforward numerator
vorsteuer.vs_a_nenner     10     # Weighting acceleration
                             feedforward denominator

```

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 | feed forward | 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 | $1 \leq v_reso_denom \leq \text{MAX}(\text{UNS32})$ | |
| 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 | $0 \leq v_reso_num \leq \text{MAX}(\text{UNS32})$ | |
| 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 | 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. | |
| Parameter | antr.v_time_base | |
| Data type | UNS16 | |
| Data range | 0: per minute 1: per second 2: per sampling interval | |
| Axis types | T, R, S | |
| Dimension | T: ---- | R,S: ---- |
| Default value | 0 | |
| Drive types | SERCOS | |
| Remarks | | |

| | | | |
|---------------------|--|---|--------------|
| P-AXIS-00223 | Feedforward control mode | | |
| Description | This parameter specifies bit-coded which reference variables (velocity, acceleration and jerk) are to be active during feedforward control. | | |
| 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: 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 | |
| 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> $G_{Drive} = \frac{1}{1 + T_a * s} \quad \text{with} \quad T_a = \frac{P - AXIS - 00225}{P - AXIS - 00226}$ <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> $G_{Drive} = \frac{1}{1 + T_a * s} \quad \text{with} \quad T_a = \frac{P - AXIS - 00225}{P - AXIS - 00226}$ <p>P-AXIS-00225: time constant numerator.</p> | |
| Parameter | vorsteuer.vs_a_nenner | |
| Data type | SGN32 | |
| Data range | $0 \leq vs_a_nenner \leq \text{MAX}(\text{SGN32})$ | |
| 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 | $0 \leq vs_v_faktor \leq \text{MAX}(\text{SGN32})$ | |
| Axis types | T, R, S | |
| Dimension | T: ---- | R,S: ---- |
| Default value | 1 | |
| Drive types | ---- | |
| Remarks | <p>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> | |

| P-AXIS-00229 | Denominator weighting factor for feedforward control | |
|---------------|--|-----------|
| Description | This parameter describes the weighting factor for velocity and acceleration feedforward control. $Weighting_{feedforward\ control} = \frac{P - AXIS - 00228}{P - AXIS - 00229}$ | |
| Parameter | vorsteuer.vs_v_nenner | |
| Data type | SGN32 | |
| Data range | $0 \leq vs_v_nenner \leq MAX(SGN32)$ | |
| 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-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 | $0 < torque_scale_num < MAX(UNS32)$ | |
| 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 < torque_scale_denom < MAX(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 | |
| 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> $\text{jerk_fact} = \text{P-AXIS-00337} / \text{P-AXIS-00338} \quad [\triangleright 31]$ <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 ≤ jerk_fact_num ≤ MAX(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 < jerk_fact_denom ≤ MAX(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 ≤ velocity_delay_time < 6*interpolator cycle time | |
| Axis types | T, R, S | |
| Dimension | T: μs | R,S: μs |
| Default value | 0 | |
| Drive types | SERCOS, Profidrive, CANopen | |
| Remarks | <p>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.</p> | |

| 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 | $0 < \text{acceleration_delay_time} < 6 \cdot \text{Interpolator cycle time}$ | |
| 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: $\text{kg} \cdot \text{m}^2$ |
| 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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6 Appendix

6.1 Suggestions, corrections and the latest documentation

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