SIEMENS
Ingenuity for life

SIMATIC S7-1500(T): Basics of axis control with technology objects and approach to axis optimization

TIA Portal V16 / SIMATIC S7-1500(T)

https://support.industry.siemens.com/cs/ww/en/view/109779884

Siemens Industry Online Support

This article is taken from the Siemens Industry Online Support. The terms of use stated there apply (https://new.siemens.com/global/en/general/terms-of-use.html).

Table of contents

1 Axis control ... 3

1.1 Introduction ... 3
1.2 Glossary ... 6
1.2.1 Speed precontrol kpc ... 6
1.2.2 Balancing filter ... 6
1.2.3 Position feedback control without DSC (in the controller) ... 7
1.2.4 Position feedback control with DSC (in the drive) ... 8
1.2.5 Following error ... 9
1.2.6 Position control difference / position control error ... 10
1.2.7 Difference between position setpoint and position actual value in the controller ... 11
1.2.8 Optimization and filter functions in the drive ... 11
1.2.9 Technology functions in the drive ... 11
1.3 Overview of axis closed-loop control types ... 12
1.3.1 Axis with precontrol and with DSC ... 12
1.3.2 Axis with precontrol but without DSC ... 13
1.3.3 Axis without precontrol but with DSC ... 14
1.3.4 Axis without precontrol and without DSC ... 15
1.4 Signal flow diagram of the TO axis ... 15

2 Procedure for optimizing axes ... 16

2.1 Requirements ... 16
2.2 Procedure for position control with DSC ... 17
2.3 Procedure for position control without DSC ... 19
2.4 Procedure in the form of a flowchart ... 23
2.5 Optimization of coupled or interpolated axes ... 24

3 Links and literature ... 25

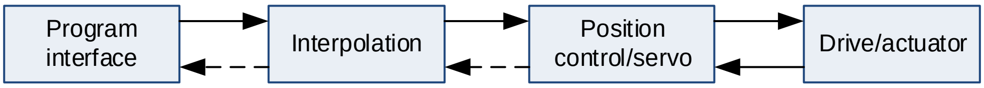
1 Axis control

1.1 Introduction

Technology objects in the SIMATIC S7-1500 are processed in the Motion Control application cycle. The application cycle is composed of required organization blocks (MC-Servo [OB91], MC-Interpolator [OB92]) and optional organization blocks, such as MC_PreServo, MC_PreInterpolator and the like.

In the Motion Control organization block MC-Interpolator, the Motion Control instructions are evaluated and the movement is orchestrated, while position control is carried out in MC-Servo.

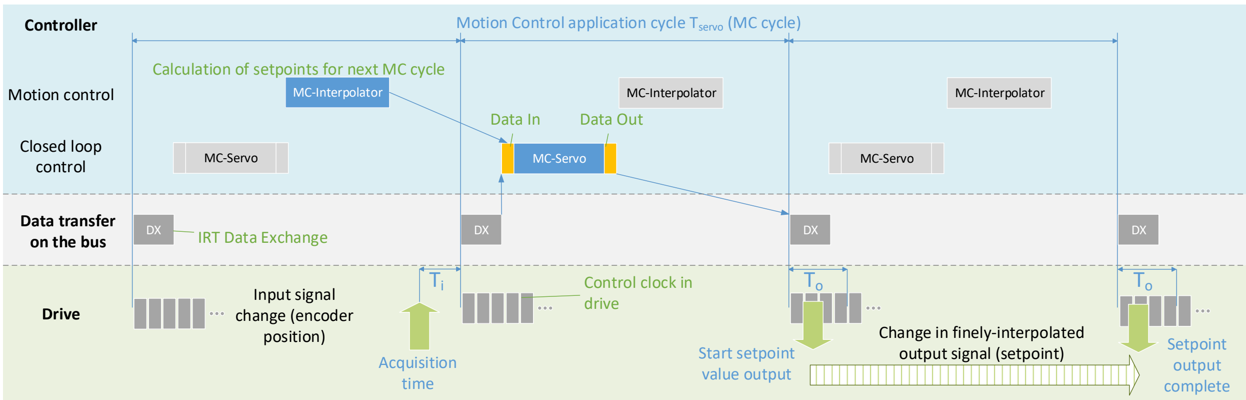
Figure 1-1 Application cycle sequence



Axis setpoint value calculation and output

The application clock limit is the beginning of the Motion Control application cycle (MC cycle). The target positions (reference variables) for the next MC cycle are calculated in the motion control in MC-Interpolator. In the next MC cycle, the position control for the axes and the speed setpoint for the associated drives are calculated in MC-Servo. At the end of MC-Servo (or MC_PostServo), the outputs are written to the drive (fine interpolation in the drive).

Figure 1-2 Axis setpoint value calculation and output



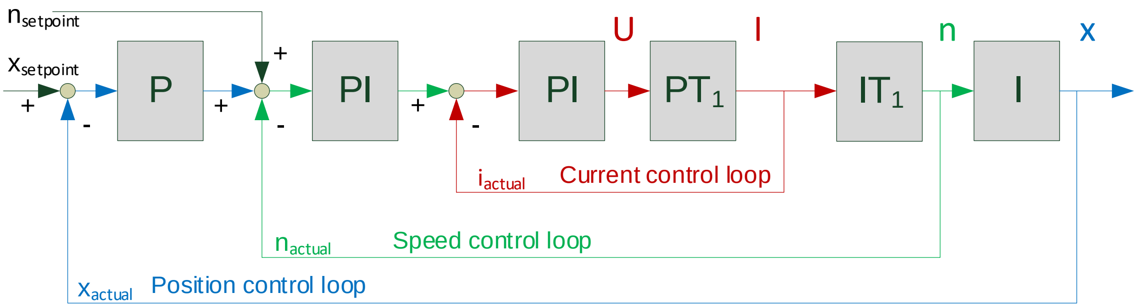
Calculation of actual value

The technological actual values of the technology object are formed in MC-Interpolator and provided to MC-Servo in the next cycle for position control.

Closed-loop control

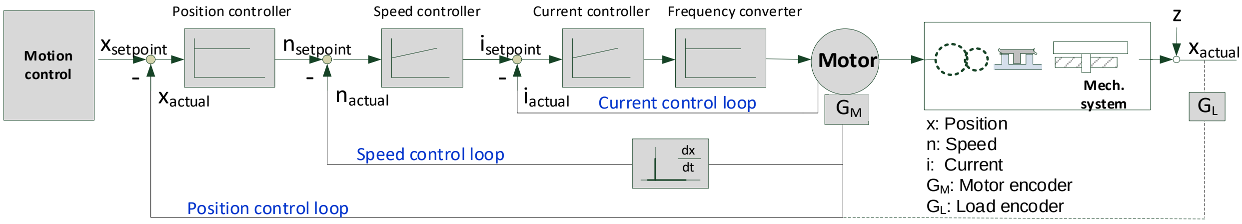
The block diagram in Figure 1-3 represents the feedback control flow of a position controller. The position controller is constructed in the form of a cascaded closed-loop feedback system. The innermost part of the feedback cascade is the current control loop, consisting of a PI and PT1 element; the next cascade is the speed control loop consisting of a PI and IT1 element, while the outermost cascade is a position control loop consisting of a P and I element.

Figure 1-3 Position controller block diagram



The technology object (TO) positioning and synchronization axis in the SIMATIC S7-1500 represents the axis in the controller. Together with the feedback control, the TO makes up the cascade closed-loop control in the drive. The closed-loop control circuit of the axis consists of a position controller, the speed- and current-controlled motor with motor encoder (for the position), and the coupled mechanical system of the machine (where applicable, with direct encoder). The current and speed feedback control circuit is located in the drive.

Figure 1-4 Cascaded feedback control



There are two variants of the position feedback control (P control) of the outermost feedback control cascade:

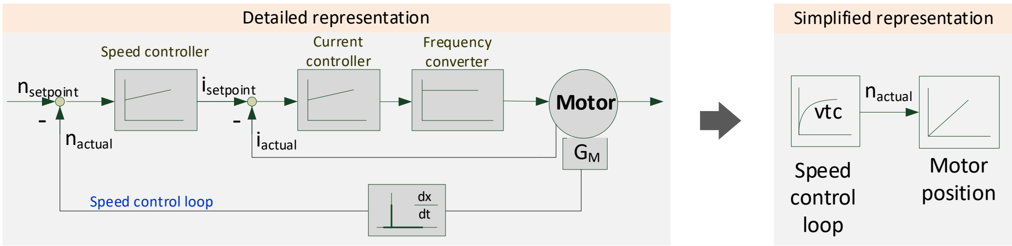
- Position control **in the controller** in the Motion Control application cycle (e.g. 4 ms)
- Position controller **in the drive,** for drives that support Dynamic Servo Control (DSC). For use with a SINAMICS drive, this is the default scenario, as the quicker feedback control clock in the drive (e.g. 125 µs) results in better control accuracy.

The dynamics of the position feedback control loop depend on the kv factor (<TO>.PositionControl.Kv), i.e. the proportional amplification of the position controller. The goal is to set this as high as possible.

Using the kv factor, the proportion of the control variable (proportion of the traverse speed, $n_{setpoint}$) is formed in the position controller based on the control difference ($x_{setpoint} – x_{actual}$), thereby adjusting for the position discrepancy and disturbance variables.

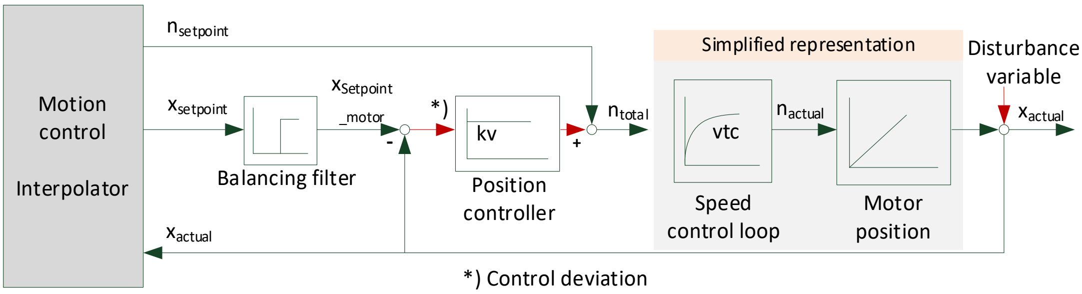
The figures below show a simplified version of the speed feedback control circuit from Figure 1-4 as follows:

Figure 1-5 Simplified speed control loop



The following representation of the feedback control structure will now serve as a basis for further explanations:

Figure 1-6 Simplified feedback control structure



Digital drive coupling

The coupling of drives and encoders via PROFIBUS DP and PROFINET IO is made possible with standardized PROFIdrive telegrams. Using these telegrams, setpoints and actual values as well as control and status words and other parameters can be transferred between the controller and the drive or encoder.

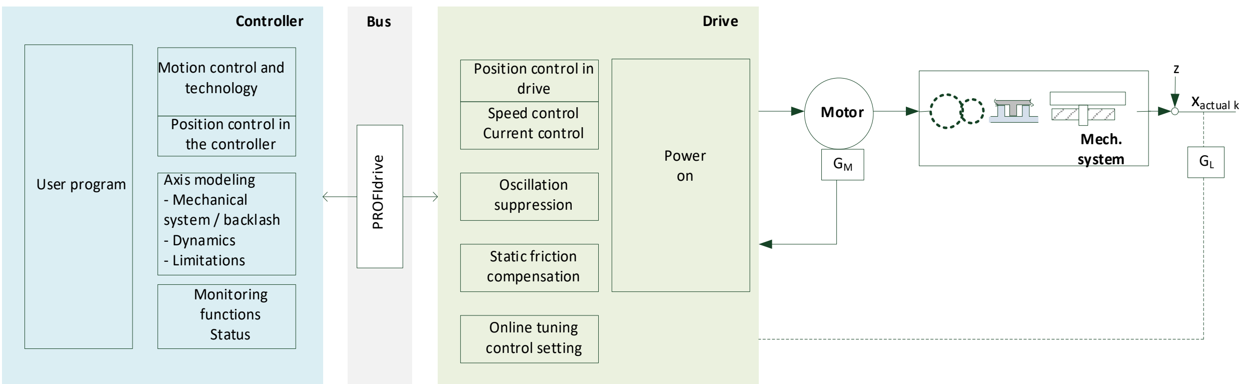
Note

Additional information is available in the FAQ "SIMATIC S7-1500(T): Drive Connection via PROFIdrive – Enables and General State Diagram".

https://support.industry.siemens.com/cs/ww/en/view/109770665

Components of the axis feedback control

The following figure shows the individual components of the axis feedback control, with the two variants "position control in the controller" and "position control in the drive" (DSC). Depending on the telegram type used and activated DSC, either the position control in the drive will be active; or in the controller.



1.2 Glossary

1.2.1 Speed precontrol kpc

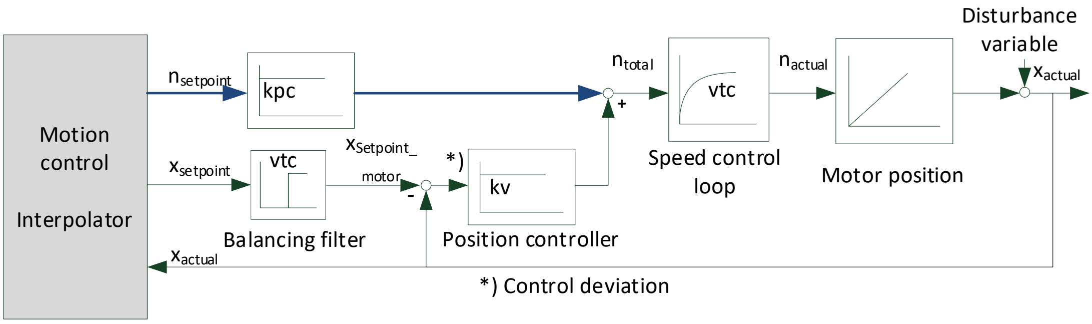
The setpoint control behavior of position feedback-controlled axes can be measurably improved by precontrol of the speed. Implementing precontrol minimizes following error and makes the position control more dynamic.

The speed from the reference variable calculation in MC-Interpolator is also fed into the speed controller as a precontrol value. The speed $n_{setpoint}$ is thereby specified to the speed controller directly as a setpoint value and does not have to be generated by the position controller.

The advantage of this is that the drive becomes more dynamic and the position controller now only compensates for disturbance variables.

For a digital drive coupling, the speed precontrol should be > 0% or 100%.

Using speed precontol the setpoint position for the position controller should be delayed in the controller via the balancing filter according to the process behavior of the axis.



1.2.2 Balancing filter

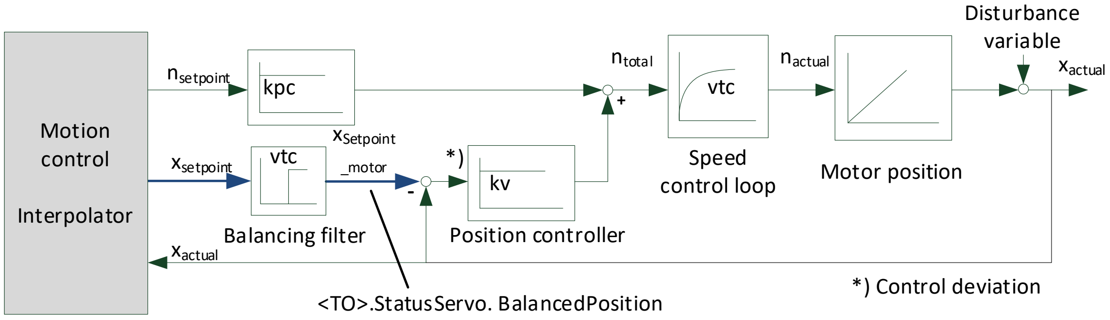
The balancing filter is a simplified model of the speed control loop. Before taking effect for the position control loop, the setpoint position is delayed in the balancing filter by the speed control loop substitute time vtc (<TO>.DynamicAxisModel.VelocityTimeConstant) so that the position controller does not counteract the precontrol effect. This prevents oversteering in the acceleration and deceleration phases, which would mainly manifest while positioning. When traversing with speed precontrol and an adequately configured balancing filter, the position controller mainly just corrects for the disturbance variables. The setpoint position after the balancing filter is displayed in <TO>.StatusServo.BalancedPosition.

With speed precontrol, the balancing filter must be set properly (see chapter 2).

If the balancing filter is programmed with the speed control loop substitute time vtc = 0.0 (default value), the axis can overshoot.

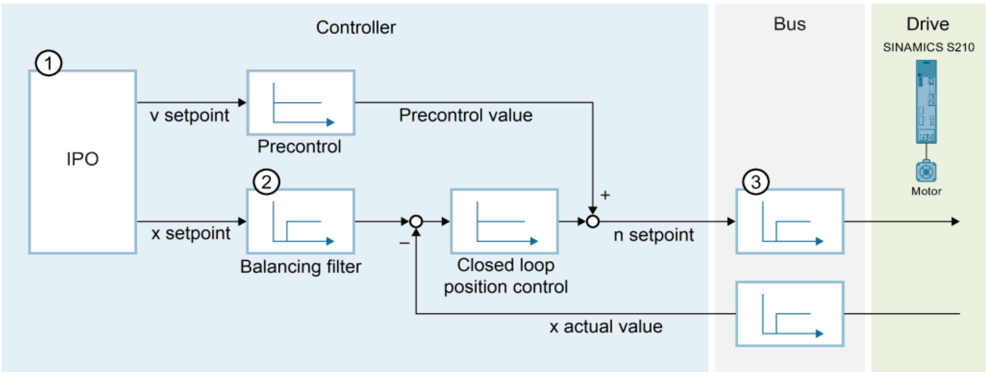
Note

> In the case of synchronized or interpolated axes, be sure that they are using the same speed control loop substitute time vtc. When their speed is the same, the axes will thus have the same following error.



1.2.3 Position feedback control without DSC (in the controller)

Figure 1-7 Control structure without DSC

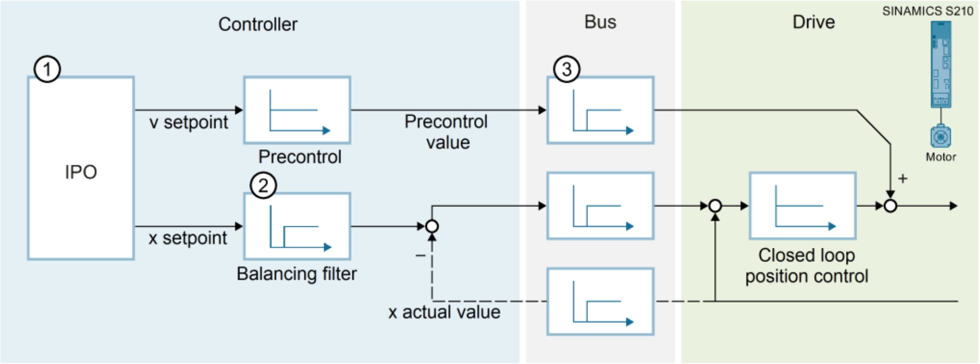


1. Interpolator with motion control
2. Internal account of signal travel times and RPM feedback loop substitute time
3. Controller-drive communication

In the case of position feedback control without DSC, position control is effected in the controller with the technology object in the Motion Control application cycle (e.g. 4 ms). At the drive, only the speed setpoint calculated by the controller is specified; and the speed and current feedback control are calculated. Position feedback control without DSC should only be used if the drive does not support DSC, for example simple drives or when using an analog setpoint interface. The control parameters can be found in the control panel with the trace function.

1.2.4 Position feedback control with DSC (in the drive)

Figure 1-8 Control structure with DSC



1. Interpolator with motion control
2. Internal account of signal travel times and RPM feedback loop substitute time
3. Controller-drive communication

In the case of position control with DSC, the position controller is located in the drive. Accordingly, it can be executed in the shorter position feedback circuit (e.g. 125 µs) for the drive cycle. This facilitates high position control gain (kv), and thus a high stiffness. The precontrol value for the speed, the kv factor and the control deviation/position deviation (XERR) are specified at the drive. A fine interpolation of the position setpoint value transmitted in the bus cycle (e.g. 2 ms) is carried out in the drive, before the position controller (e.g. in 125 µs). Optimization of the control parameters (kv and vtc) should be carried out under the limit conditions and with the drive methods, for example One Button Tuning (OBT).

DSC is automatically enabled if using the PROFIdrive telegrams 5, 6, 105 and 106. It is therefore a default setting with, for instance, the SINAMICS V90, S210 and S120 drives.

Position deviation XERR

To generate the position deviation XERR, in the controller the actual position is subtracted from the setpoint position. The same exact actual position is then added back to the transmitted XERR in the drive, so that the position controller in the drive works on the motor position setpoint value adjusted to the mechanical model and feedback control model (balancing filter).

The position controller in the drive therefore does not go to the technological position of the axis, but rather functionally to the adjusted position setpoint of the motor in accordance with the internal modeling.

Note

> For DSC the motor encoder (first encoder in the telegram) of the drive must be used as the first encoder for the technology object.
>
> Furthermore, if a load-side encoder and DSC is used, both motor **and** load-side encoder must be configured in the technological object.

1.2.5 Following error

The following error indicates by what amount the position actual value (x_{actual} from the motor encoder or load encoder) lags the position setpoint value, and always pertains to the active encoder. The following error is calculated in the controller in such a way that it matches the following error that actually exists at the drive. The currently calculated following error is displayed in the parameter <TO>.StatusPositioning.FollowingError.

The real following error is defined as the difference from the actual position at the axis encoder ($x_{actual\ k+1}$) to the time-based drive setpoint position ($x_{setpoint\ k}$), not the position difference between the actual and setpoint position at the TO present in the controller.

The transmission times of the setpoint value from the controller to the drive, and of the position actual value from the drive to the controller, as well as the cycle time, are already calculated out in the calculated following error. The calculated following error is therefore the same as the real following error.

To calculate the following error in the controller, the actual position that is currently in the controller is subtracted from the controller's setpoint position that is earlier by (delayed by) $T_{servo} + T_{dp} + T_o + T_i$.

The real following error is derived from the activated encoder (motor encoder or load-side encoder); it also takes into account the mechanics even if the motor-side encoder is active and pertains to the position of the axis.

The following error is particularly salient with position feedback control in the context of coupled axes. A calibration of the following error of the axes is particularly important with synchronous operation or interpolation. In that case, when they are at the same speed the axes should exhibit the same following error.

The following error entails the dynamic behavior of the axes (including drive and mechanical system) and is dependent on speed.

System with speed precontrol

The following formula applies for kpc = 100 % (z ≙ disturbance variable):

$$Following\ error = vtc \cdot v + z$$

The speed control loop substitute time is not made up by the closed-loop control. At a constant velocity, a constant following error will emerge; but oversteering is avoided at the axis.

Example: With vtc = 0.002 s and v = 1000 mm/s results a following error of 2 mm. When vtc=0.0, the following error is indeed calculated at 0 mm, but oversteering of the axis is the result.

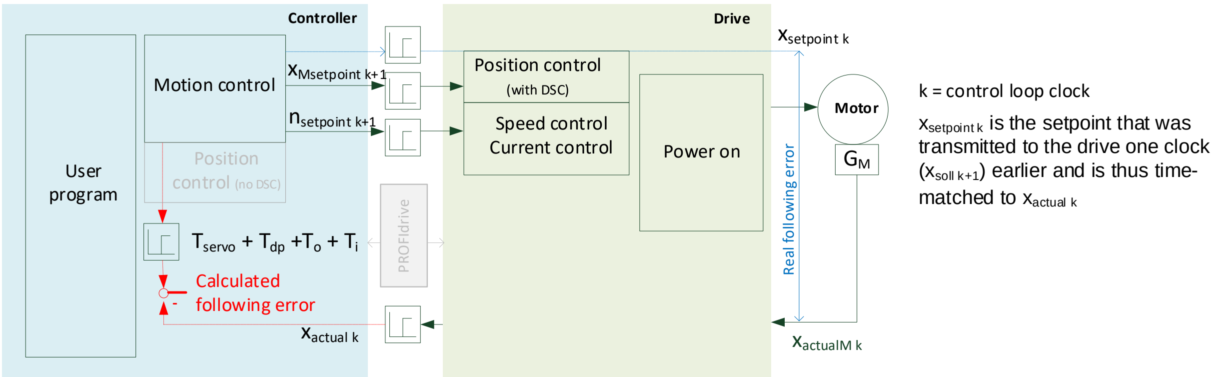
System without speed precontrol

The following formula applies for kpc = 0 % (z ≙ disturbance variable):

$$Following\ error = v \cdot \frac{1}{kv} + z$$

Example: With kv = 100 1/s and v = 1000 mm/s results in a following error of 10 mm.

Note Even a closed-loop controller with optimal settings will not produce a following error equal to zero.



1.2.6 Position control difference / position control error

The position control difference shows the effective position difference in the position controller between the position actual value and the position setpoint. It is displayed in the parameter <TO>.StatusServo.ControlDifference.

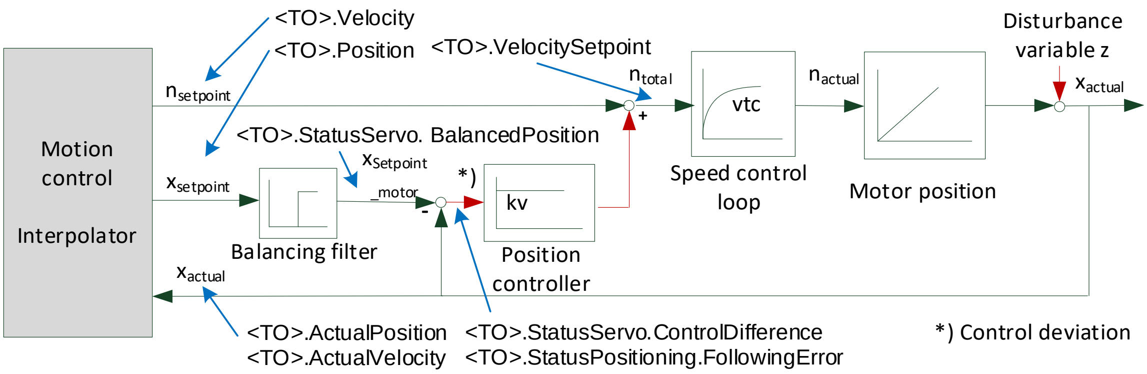
Position control error with DSC

The position control difference is the effective position difference in the DSC position controller; it is calculated as follows:

- **With precontrol**
  Difference in the actual position in the controller from the setpoint position delayed by the communication times T_i+T_o+T_{dp}+T_{servo} and the balancing filter vtc
- **Without precontrol**
  Difference in the actual position in the controller from the setpoint position delayed by the communication times T_i+T_o+T_{dp}+T_{servo}

Position control error without DSC

The position control difference is the effective position difference in the controller's position controller. It is calculated from the position difference between the position setpoint value and the position actual value. When precontrol is active, the setpoint position used for this purpose is the one behind the balancing filter.



1.2.7 Difference between position setpoint and position actual value in the controller

This difference calculated on an application basis from <TO>.Position and <TO>.ActualPosition is not meaningful for an evaluation of the position closed-loop control.

1.2.8 Optimization and filter functions in the drive

You can use the drive's optimization functions (such as One Button Tuning) and filter functions.

Note For more information on optimizing the drive refer to “Drive Optimization Guide”:

https://support.industry.siemens.com/cs/ww/en/view/60593549

1.2.9 Technology functions in the drive

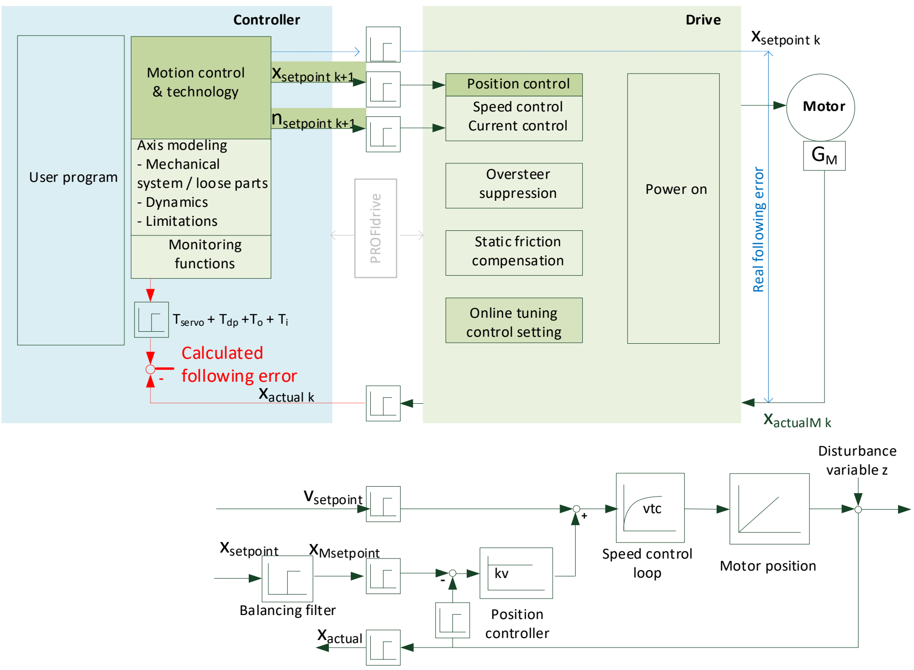
You can use technology functions of the drive (such as oscillation suppression, static friction compensation, hanging axis, etc.).

1.3 Overview of axis closed-loop control types

The following types of control types are possible:

- Axis with precontrol and with DSC
  Good control behavior, good disturbance variable attenuation and low following error. Typically, the best kind of closed-loop control.
- Axis with precontrol but without DSC
  Good control behavior, worse disturbance variable attenuation and low following error.
- Axis without precontrol but with DSC
  Worse master control behavior, good disturbance variable attenuation and larger following error.
- Axis without precontrol or DSC
  Worse master control behavior, worse disturbance variable attenuation and larger following error.

1.3.1 Axis with precontrol and with DSC



k = control loop clock

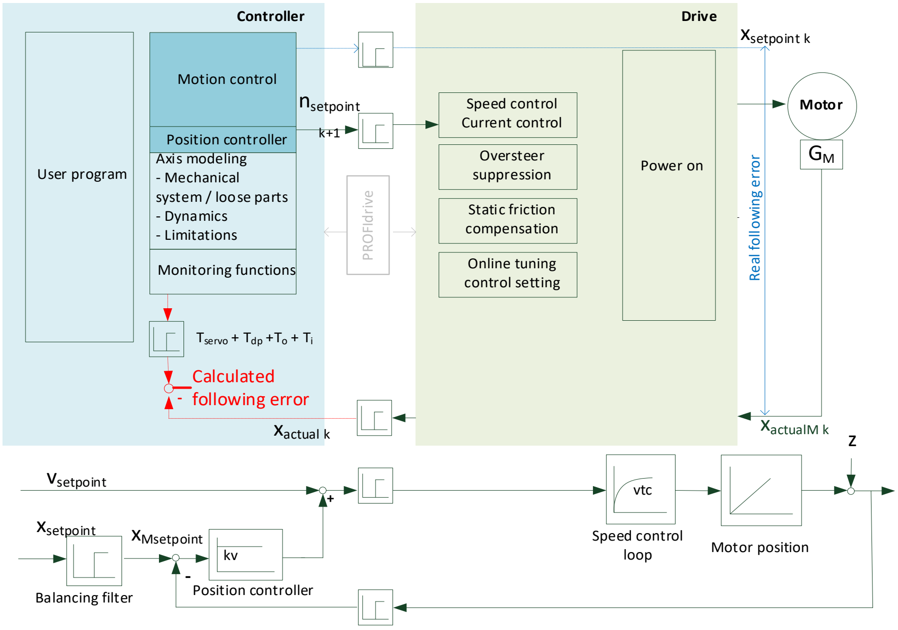
$x_{setpoint\,k}$ is the setpoint that was transmitted to the drive one clock ($x_{soll\,k+1}$) earlier and is thus time-matched to $x_{actual\,k}$

The position control error of the DSC position controller in the drive is shown in the controller in the parameter <TO>.StatusServo.ControlDifference. The balancing filter causes the delay by the speed control loop substitute time vtc. The position control error is the difference between the actual position in the controller and the setpoint position (delayed by T_i+T_o+T_{dp}+T_{servo}) after the balancing filter.

The following error pertains to the active encoder (motor-side or load-side encoder) and is determined by the speed control loop substitute time vtc times speed plus disturbance variables (with vtc = 0.001 s, for instance, v=1000 mm/s will produce a following error of 1 mm).

$$Following\ error = vtc \cdot v + z$$

1.3.2 Axis with precontrol but without DSC



k = control loop clock

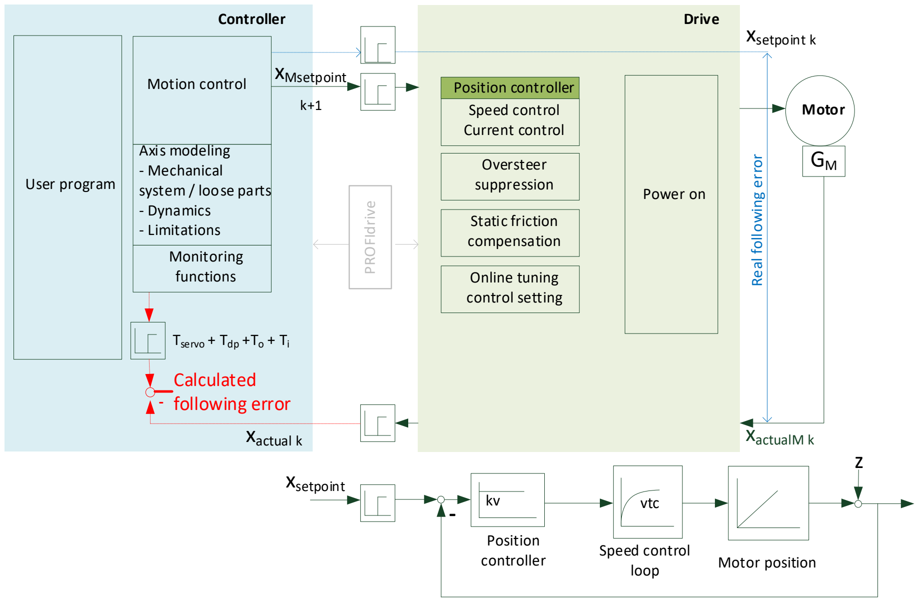
$x_{setpoint\ k}$ is the setpoint that was transmitted to the drive one clock ($x_{soll\ k+1}$) earlier and is thus time-matched to $x_{actual\ k}$

The position controller is run at the clock of the OB MC-Servo in the controller. For balancing, the system considers the delay by the speed control loop substitute time vtc and the communication times. The position control error is the difference between the actual position in the controller and the setpoint position (delayed by T_i+T_o+T_{dp}+T_{servo}) after the balancing filter.

The following error pertains to the active encoder (motor-side or load-side encoder) and is determined by the speed control loop substitute time vtc times speed plus disturbance variables (with vtc = 0.001 s, for instance, v=1000 mm/s will produce a following error of 1 mm).

$$Following\ error = vtc \cdot v + z$$

1.3.3 Axis without precontrol but with DSC



k = control loop clock

$x_{setpoint\ k}$ is the setpoint that was transmitted to the drive one clock ($x_{soll\ k+1}$) earlier and is thus time-matched to $x_{actual\ k}$

The position control error of the DSC position controller is shown in the controller in the parameter <TO>.StatusServo.ControlDifference. The position control error is the difference between the actual position in the controller and the setpoint position (delayed by T_i+T_o+T_{dp}+T_{servo}).

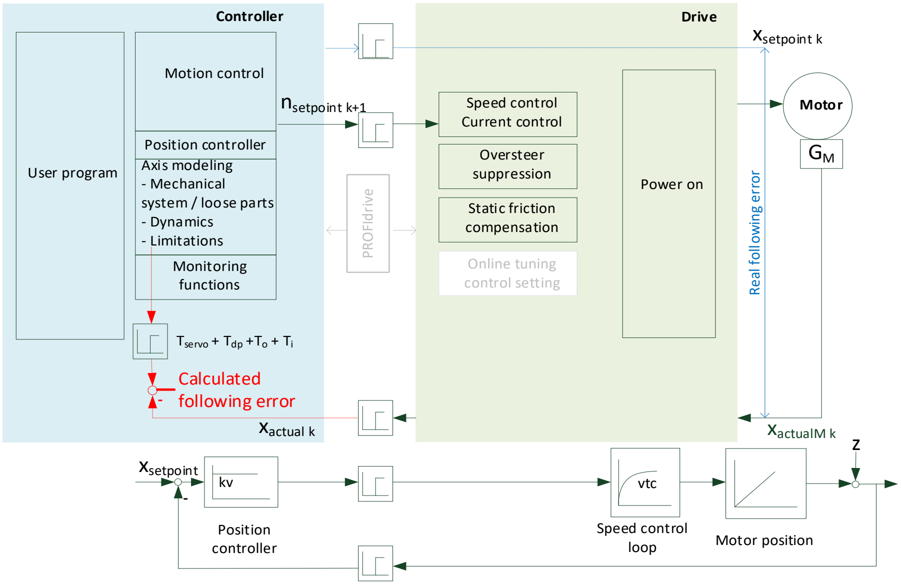
The following error is the difference between the actual position and the setpoint position at the drive (output); it is approximately equal to the control deviation of the DSC position controller in the drive.

For a constant traverse, the following error is determined by:

$$\Delta x \cdot kv = v$$

At a kv of 100 1/s at v=1000 mm/s, a following error of 10 mm will result.

1.3.4 Axis without precontrol and without DSC



k = control loop clock

$x_{setpoint\ k}$ is the setpoint that was transmitted to the drive one clock ($x_{soll\ k+1}$) earlier and is thus time-matched to $x_{actual\ k}$

The position controller is run at the clock of the OB MC-Servo in the controller. The position control error is the difference between the actual position and the setpoint position.

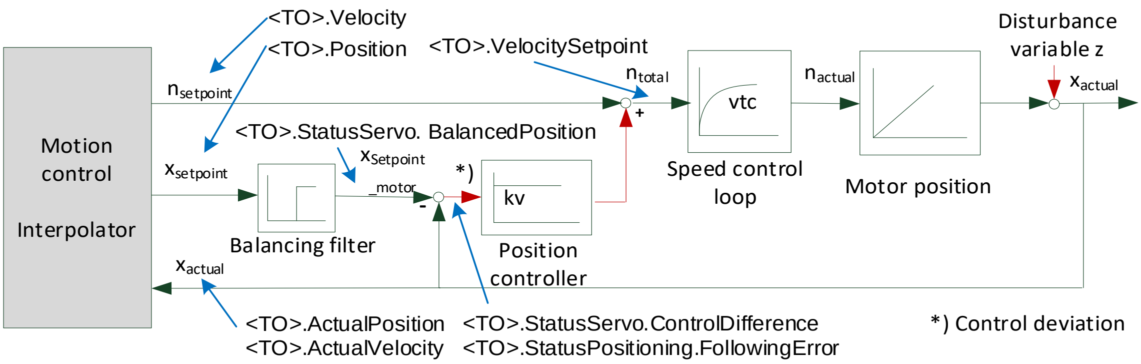
The following error is the difference between the actual position and the setpoint position at the drive (output); it is approximately equal to the control deviation of the controller.

For a constant traverse, the following error is determined by:

$$\Delta x \cdot kv = v$$

At a kv of 100 1/s at v=1000 mm/s, a following error of 10 mm will result.

1.4 Signal flow diagram of the TO axis



Note The control structure of the technology object for a positioning or synchronized axis, including TO tags, is shown in a detailed signal flow diagram:

https://support.industry.siemens.com/cs/ww/en/view/109770664

2 Procedure for optimizing axes

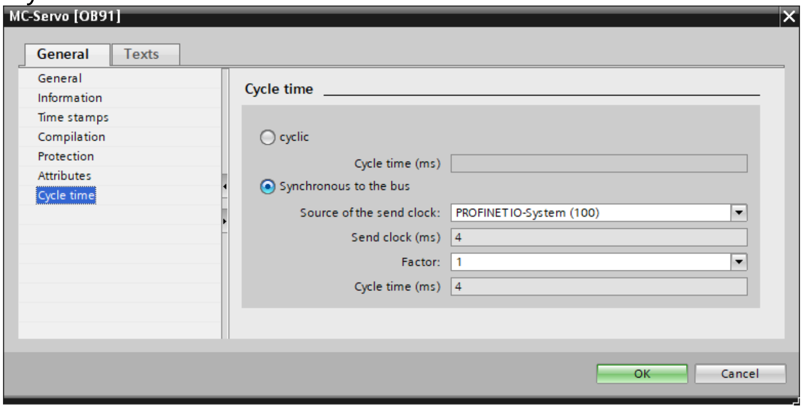
The goal of optimization is to attain optimal control behavior without oversteering.

If the drive supports DSC, this type of axis/drive control should be used, as it allows for significantly better control accuracy.

2.1 Requirements

Before the actual axis optimization is carried out, please check the following:

- **Application cycle synchronous to the bus**
  Check whether the application cycle, where the organization blocks for MC-Servo [OB91] and MC-Interpolator [OB92] are called, is set as "synchronous to the bus":



- **Drive and encoder connection**
  The reference values for the drive and encoder connection in the controller and in the drive/encoder must be configured identically. If applying the drive and encoder parameters automatically, this is guaranteed.
  To test, traverse the drive with the drive control panel, or move it yourself as far as possible and compare the actual position of the TO in the trace with the real position.
- **Direction of rotation**
  Setpoints and actual values must match the direction of rotation.

Note

You can find detailed commissioning instructions in the guide "SINAMICS G: Guide for Commissioning a Position-Controlled Drive":

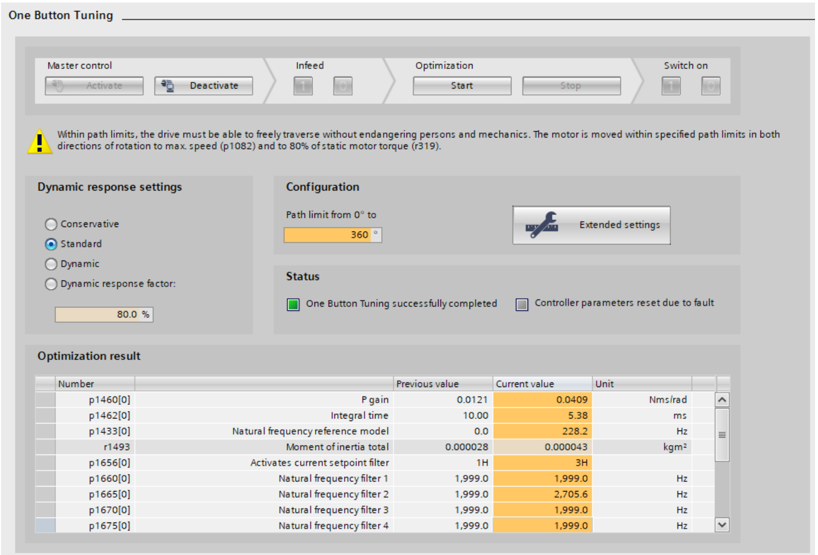
https://support.industry.siemens.com/cs/ww/en/view/109479977

2.2 Procedure for position control with DSC

Table 2-1 Procedure for position control with DSC

<table>
<tr><th>No.</th><th>Action</th></tr>
<tr><td>1.</td><td>The drive is connected clock-synchronized via a PROFIdrive telegram with DSC (telegram 5, 6, 105 or 106).</td></tr>
<tr><td>2.</td><td>

Use automatic control optimization with "One Button Tuning" in the drive



With SINAMICS S210 and S120 drives, you can use editors in Startdrive to perform automatic control optimization. Open the "Commissioning" → "One Button Tuning" for the drive object.

In the process of this optimization, not only the settings of the speed and current feedback loop controls are determined, but also the maximum possible gain (kv factor), which is based on the programmed speed feedback loop control clock, of the DSC position controller (r5276) and the speed control loop substitute time vtc (r5277).

The mechanical drive is calibrated with the help of short test signals. In this way, the feedback control system's parameters can be optimally adjusted to suit the present mechanical system.

Caution: Depending on setting (p5301), the drive will be accelerated with a significant moment! Caution with linked mechanical system!

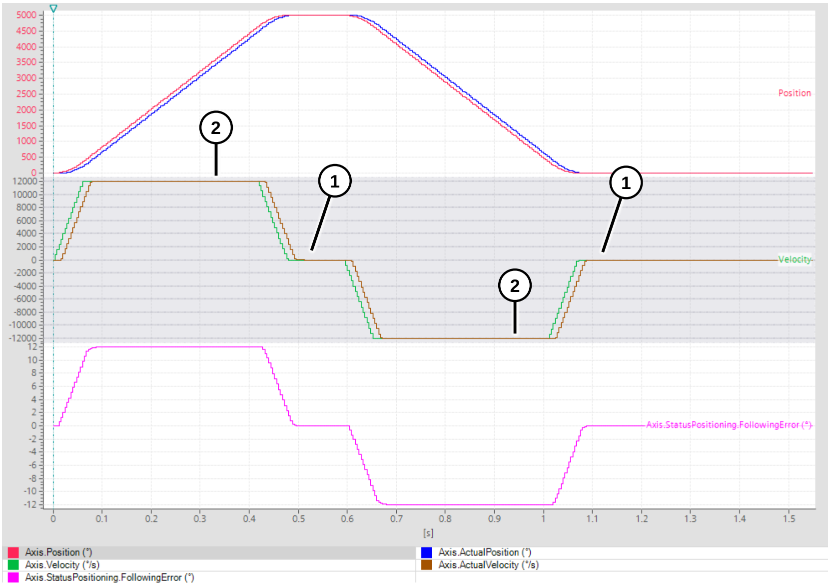
The drive saves the status of the optimization and the values that you find.

For detailed information, see the function manual drive functions SINAMICS S120 (\4\) and SINAMICS S210 (\5\).
</td></tr>
</table>

<table>
<tr><th>No.</th><th>Action</th></tr>
<tr><td>3.</td><td>
Apply the parameters to the axis configuration of the TO
Once the control parameters have been determined with the help of "One Button Tuning", they can be applied to the technology object from parameters r5276 (kv factor) and r5277 (vtc).
<table>
<tr><td>p5275[0]</td><td>Online / One Button Tuning dynamic response time constant</td><td>7.5</td><td>ms</td></tr>
<tr><td>r5276[0]</td><td>Online / One Button Tuning maximum Kv factor estimated</td><td>10.58</td><td>1000 rpm</td></tr>
<tr><td>r5277[0]</td><td>Online/One Button Tuning precontrol symmetrizing time esti...</td><td>0.98</td><td>ms</td></tr>
<tr><td>p5280[0]</td><td>Current setpoint filter adaptation configuration</td><td>[0] Inactive</td><td></td></tr>
</table>
Here, due to the different units, the values will need to be converted for use in the TO.
kv: TO in 1/s and OBT in 1000/min → $kv_{TO} = kv_{OBT} \cdot \frac{1000}{60}$
vtc: TO in s and OBT in ms → $vtc_{TO} = \frac{vtc_{OBT}}{1000}$

Additionally, for the kv factor of the TO, only a maximum of 50% of the deter-mined theoretical maximum kv should be applied. If the settings in the drive change, another OBT optimization and synchronization in the TO should be performed.
</td></tr>
<tr><td>4.</td><td>
Record trace
Use the trace function to record the following TO parameters
• <TO>.Position
• <TO>.ActualPosition
• <TO>.Velocity
• <TO>.ActualVelocity
• <TO>.StatusPositioning.FollowingError
• Optional: <TO>.StatusTorqueData.ActualTorque

Because the setpoint and actual values are being recorded, select the OB MC-Servo as the recording clock of the trace. After MC-Servo processes, the new setpoint values will be available, which match chronologically with the actual values of MC-Interpolator from the previous clock.
If the axis is operated with 100% speed precontrol and the speed control loop substitute time vtc is configured correctly, the control error (<TO>.StatusServo.ControlDifference) in the steady-state condition must be zero on average during the constant motion phase.
If speed precontrol is not in effect, the control error in the steady-state condition is calculated as follows:
Control error = setpoint speed / kv
If another control error results, then the interface between the controller and the drive has been configured improperly. One common cause is the divergent configuration of the reference values for drive and encoder connection in the controller and the drive (if data adaption was not used).
</td></tr>
</table>

No.	Action
5.	**Evaluation of trace** (also see \6\) When modifying the kv-factor, pay attention to the following properties of the curve: • The curve shows a short settling time. • The curve does not exhibit a motion reversal of the actual position. (1) • When arriving at the setpoint position, only a small oversteer occurs, if any. (1) • The trend shows a stable response overall (no oscillation in the curve). (2) 
6.	If you are not yet satisfied with the optimization result, please consult the procedures for optimizing kv and vtc in chapter 2.3.

2.3 Procedure for position control without DSC

Before optimizing the position controller, the speed and current closed-loop controls in the drive must be set (see Requirements, chapter 2.1). If available, use "One Button Tuning" in the drive to do this.

With SINAMICS S210 and S120 drives, you can use editors in Startdrive to perform automatic control optimization. The settings of the speed and current controls will be determined in the process of this optimization.

SINAMICS S210 and S120 support position control without DSC. If DSC is available in the drive, this function should be used because it allows a much better control accuracy to be attained.

Drives that do not support DSC may offer functions for an optimization (which may also be automatic) of the speed and current controls.

For the first strategy listed above, (high dynamics for continuous movements), this optimization already delivers excellent results.

The optimization of the position controller for movements without oversteer is described below.

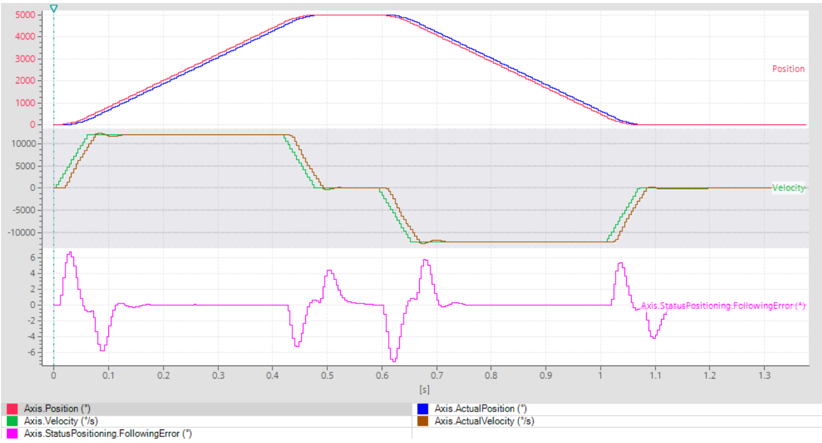
Table 2-2 Procedure for position control without DSC

<table>
<tr><th>No.</th><th>Action</th></tr>
<tr><td>1.</td><td>First disable speed precontrol and balancing filter at the TO axis (<TO>.PositionControl.Kpc=0.0 and <TO>.DynamicAxisModel.VelocityTimeConstant=0.0).
<table>
<tr><th colspan="5">Axis</th></tr>
<tr><th></th><th>Name</th><th>Data type</th><th>Start value</th><th>Monitor value</th></tr>
<tr><td>23</td><td>▼ PositionControl</td><td>TO_Struct_Position...</td><td></td><td></td></tr>
<tr><td>24</td><td>Kv</td><td>LReal</td><td>10.0</td><td>10.0</td></tr>
<tr><td>25</td><td>Kpc</td><td>LReal</td><td>100.0</td><td>0.0</td></tr>
<tr><td>26</td><td>EnableDSC</td><td>Bool</td><td>false</td><td>FALSE</td></tr>
<tr><td>27</td><td>SmoothingTimeByChangeDifference</td><td>LReal</td><td>0.0</td><td>0.0</td></tr>
<tr><td>28</td><td>InitialOperativeSensor</td><td>UDInt</td><td>1</td><td>1</td></tr>
<tr><td>29</td><td>▶ ControlDifferenceQuantization</td><td>TO_Struct_Position...</td><td></td><td></td></tr>
<tr><td>30</td><td>▼ DynamicAxisModel</td><td>TO_Struct_Dynami...</td><td></td><td></td></tr>
<tr><td>31</td><td>VelocityTimeConstant</td><td>LReal</td><td>0.0</td><td>0.0</td></tr>
<tr><td>32</td><td>AdditionalPositionTimeConstant</td><td>LReal</td><td>0.0</td><td>0.0</td></tr>
</table>
</td></tr>
<tr><td>2.</td><td>Position the axis cyclically with high deceleration rate and trapezoidal speed profile (Jerk = 0.0); record the signals of the axis in the trace (see 3.). The traversing profile can, for example, be generated with relative positioning in both directions using the Motion Control instruction MC_MoveRelative. Make sure that the axis reaches the constant velocity phase during this operation. You must also select the deceleration such that the current or torque in the drive is not limited. To do this, the actual torque of the axis in the parameter <TO>.StatusTorqueData.ActualTorque can also be recorded by using telegram 750.</td></tr>
<tr><td>3.</td><td>Record trace
Use the trace function to record the following TO parameters

<TO>.Position
<TO>.ActualPosition
<TO>.Velocity
<TO>.ActualVelocity
<TO>.StatusPositioning.FollowingError
Optional: <TO>.StatusTorqueData.ActualTorque

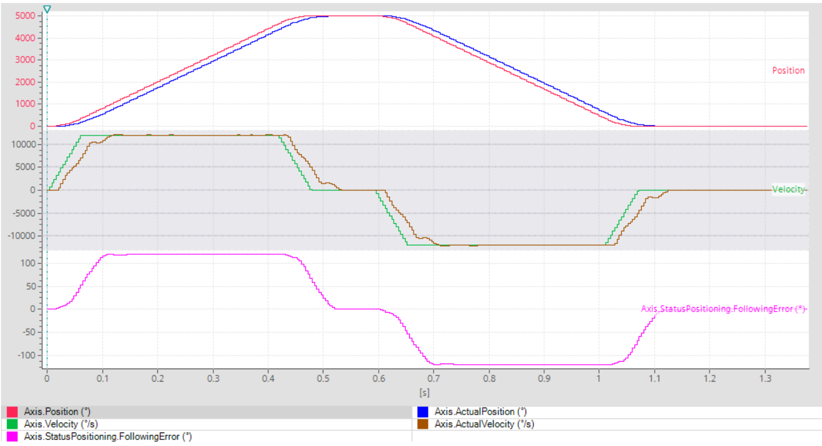
Because the setpoint and actual values are being recorded, select the OB MC-Servo as the recording clock of the trace. After MC-Servo processes, the new setpoint values will be available, which match chronologically with the actual values of MC-Interpolator from the previous clock.
At 0% speed precontrol, the control error in steady-state condition is calculated as follows: Control error = setpoint speed / kv.
If another control error results, then the interface between the controller and the drive has been configured improperly. One common cause is the divergent configuration of the reference values for drive and encoder connection in the controller and the drive (if automatic apply was not used).</td></tr>
<tr><td>4.</td><td>Starting with kv = 10, keep increasing the gain factor in small steps as long as the speed actual value and the position actual value do not oversteer (or only slightly oversteer) while approaching the target position. Deduct 10% from this maximum Kv value and make this setting on the target device.</td></tr>
<tr><td>5.</td><td>To set the speed precontrol, activate it at the TO axis by setting the parameter <TO>.PositionControl.Kpc = 100.0.
When speed precontrol is used, the entry behavior during positioning and the control error in the acceleration and deceleration phases are influenced by the time constant of the balancing filter (vtc).</td></tr>
<tr><td>6.</td><td>Next, cyclically position the axis with high deceleration and record the position control difference in the trace. Make sure that the axis reaches the constant velocity phase during this operation. You must also select the deceleration such that the current or torque in the drive is not limited.</td></tr>
</table>

<table>
<tr><th>No.</th><th>Action</th></tr>
<tr><td>7.</td><td>Beginning with 0.0 ms, increase the time constant of the balancing filter (<TO>.DynamicAxisModel.VelocityTimeConstant) in steps, for instance by 1 ms, until the axis reaches the target position without oversteer or understeer.
You may want to allow a small overshoot/undershoot upon entry in the target position to enable a faster settling behavior.</td></tr>
<tr><td>8.</td><td>If the time constant is too low, the delay of the position setpoint value is too low. The position controller also compensates for the existing control difference for the purpose of precontrol. Overshoot will occur during the acceleration and deceleration phases.



If the time constant is too high, the delay of the position setpoint value is too large. The control difference between setpoint and actual value will be negative. The position control will work against the precontrol.

A slow convergence into the end position will be visible in the trace recording.
If the optimum time constant has been chosen, the control difference will be 0.



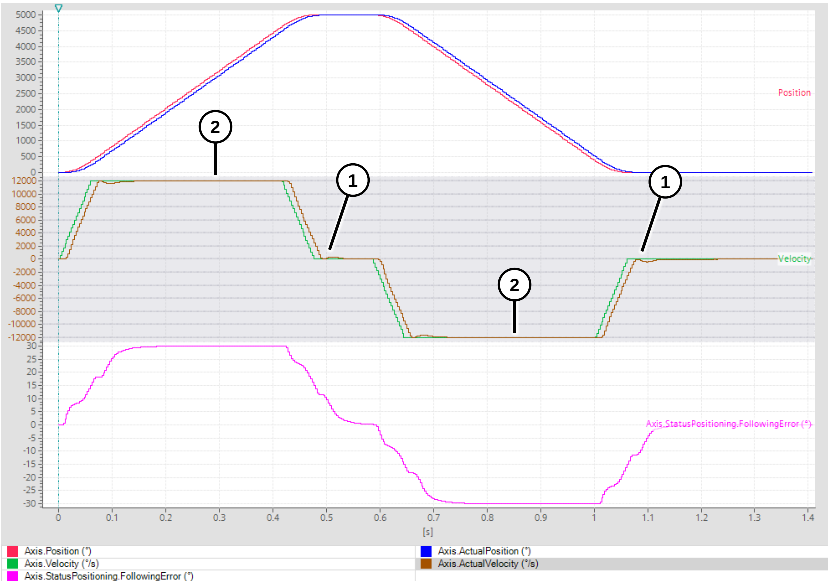
</td></tr>
<tr><td>9.</td><td>Depending on the application, the values will have to be modified to suit the goal of optimization:
• Optimization for following error
vtc as close to 0 as possible → oversteer behavior
• Optimization for no overshoot
configure vtc → following error occurs</td></tr>
</table>

<table>
<tr><th>No.</th><th>Action</th></tr>
<tr><td>10.</td><td>

Evaluation of trace logging (see also \6\)

When modifying kv and vtc, pay attention to the following properties of the graph:

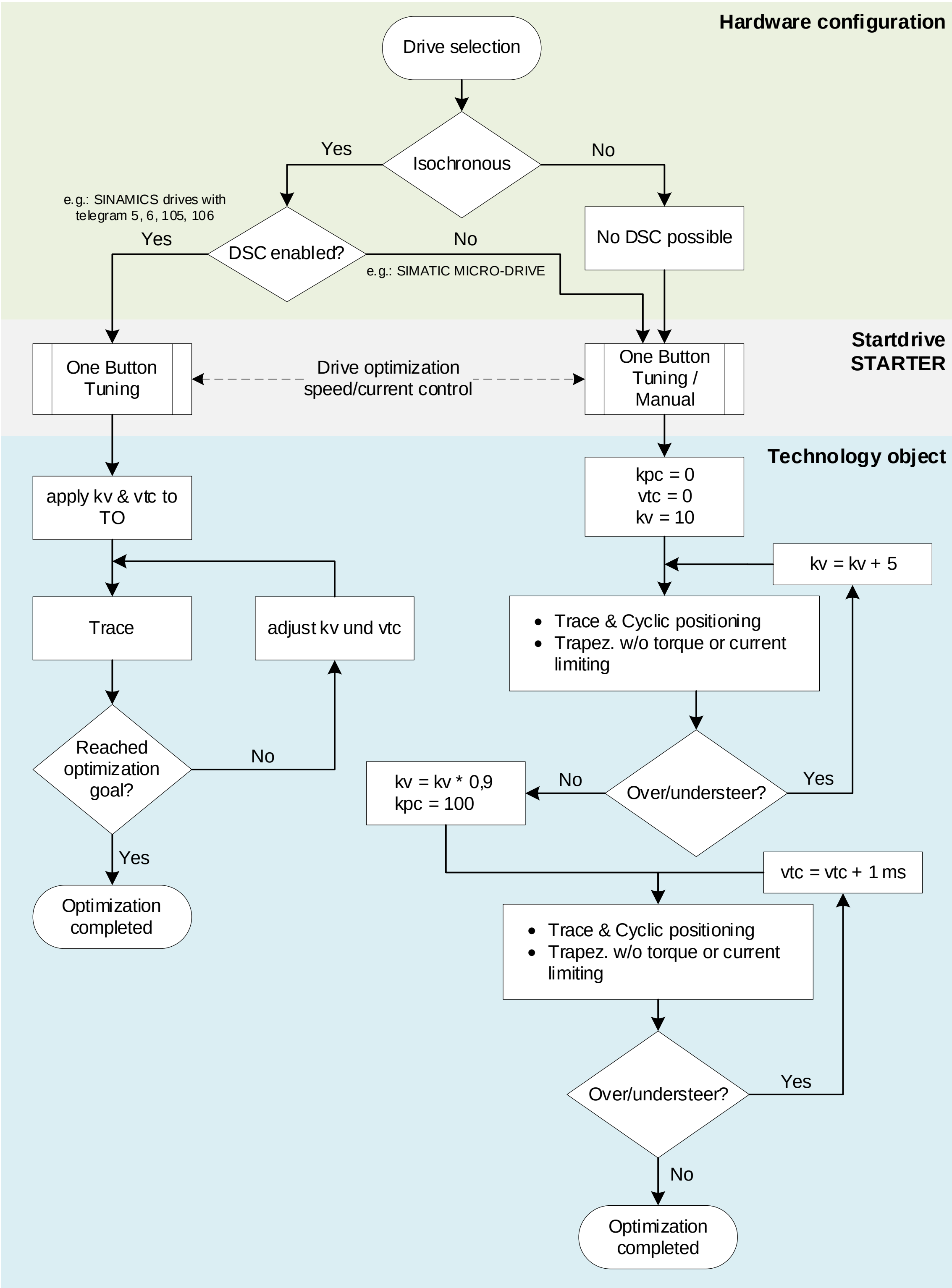
- The curve shows a short settling time.
- The curve does not exhibit a motion reversal of the actual position. (1)
- No oversteer occurs when approaching the setpoint position. This especially visible in the actual velocity. (1)
- The trend shows a stable response overall (no oscillation in the curve). (2)



</td></tr>
</table>

2.4 Procedure in the form of a flowchart

Figure 2-1 Flowchart



2.5 Optimization of coupled or interpolated axes

Ordinarily, axes which operate highly independently of one another will be optimized independently, too.

Only in special cases, such as with a highly dynamic interaction of the overall system, can a dynamic adjustment be undertaken in addition to the actual optimization of the individual axes.

For example, this is the case if a sheet of material must be accelerated by multiple axes. If these axes exhibit differing dynamic behavior, the tension in the web would not be constant between the segments.

In coupled axes it is important that the following error in the axes involved is nearly identical. Therefore, when using precontrol, make sure that the axes use the same speed control loop substitute time vtc. The axes involved in a machine often have differing mechanical properties. For this reason, the speed and position controllers of the individual axes cannot be optimized "equally well". The result is that one of the axes is more dynamic than the others.

3 Links and literature

Table 3-1:

No.	Subject
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to the article page of the FAQ https://support.industry.siemens.com/cs/ww/en/view/109779884
\3\	SIMATIC S7-1500(T): Signal flow diagram of the technology object axis https://support.industry.siemens.com/cs/ww/en/view/109770664
\4\	SINAMICS S120 Function Manual Drive Functions https://support.industry.siemens.com/cs/ww/en/view/109754299
\5\	SINAMICS S210/SIMOTICS S-1FK2 https://support.industry.siemens.com/cs/ww/en/view/109771824
\6\	SIMATIC S7-1500(T) Axis functions V5.0 in TIA Portal V16 Chapter: Optimizing position controllers https://support.industry.siemens.com/cs/ww/en/view/109766462/107864306699
\7\	SIMATIC S7-1500(T): Drive Connection via PROFIdrive – Enables and General State Diagram https://support.industry.siemens.com/cs/ww/en/view/109770665
\8\	Drive Optimization Guide https://support.industry.siemens.com/cs/ww/en/view/60593549