SIEMENS

Guide for Commissioning a Position-Controlled Drive

SIMATIC S7-1500, SINAMICS G120

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

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1 Task

1.1 Overview

Introduction

SIMATIC S7-1500 controllers support the connection of PROFIdrive-capable drives via PROFINET or PROFIBUS as positioning axis.

The present document will show with what measures the precision and performance of a position-controlled drive can be improved.

Overview of the automation task

The figure below provides an overview of the automation task.

Figure 1-1: Automation task

SINAMICS G120

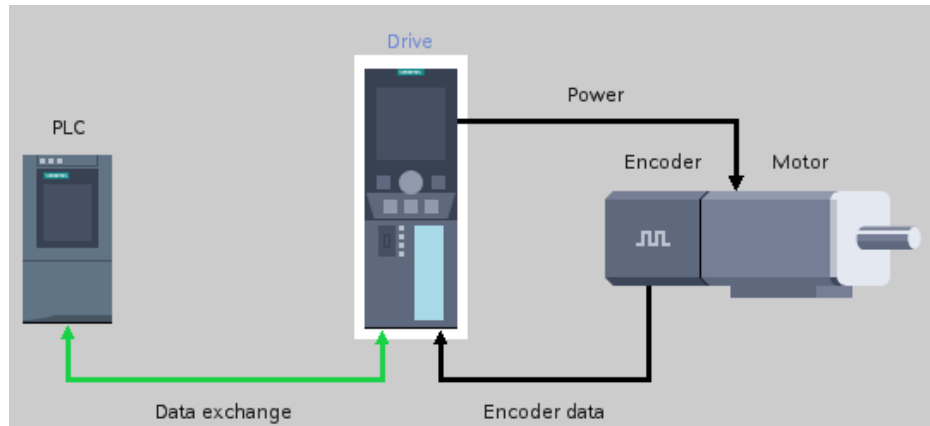SIMATIC S7-1500

PROFINET
PROFIBUS

Motor with speed encoder
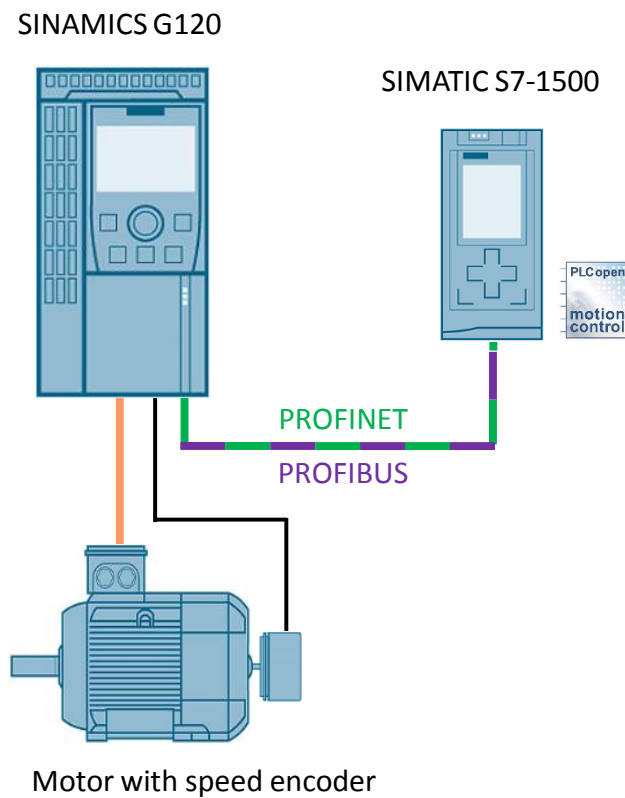
2 Solution

2.1 Overview

This present document explains in easy steps, how a position-controlled drive can be commissioned.

Figure 2-1: Configuring the drive

The approach is explained in the following subitems:

1. Commissioning the drive and optimizing the speed control
2. Commissioning the "Positioning axis" technology object and optimizing the position control

Commissioning the drive and technology object is only carried out with the TIA Portal (STEP 7 and Startdrive).

Advantages

The solution presented here, offers you the following advantages

- Time saving during commissioning
- High precision of the drive

Topics not covered in this application

This application does not contain a description of:

- Basic configuration and functioning of a drive
- Basic functions of the TIA Portal
- Description of the functionality of motion blocks

Assumed knowledge

Basic knowledge of drive technology as well as the TIA Portal is assumed.

2.2 Hardware and software components

2.2.1 Validity

This application is valid for

- TIA Portal (STEP 7 and Startdrive) V13 SP1 or higher
- SIMATIC S7-1500 controller
- SINAMICS G120 frequency converter

2.2.2 Components used

The recordings included in this document were created with the following components.

Hardware components

Table 2-1: Hardware components

Component	Qty	Article number	Note
CPU 1516-3 PN/DP	1	6ES7 516-3AN00-0AB0	As an alternative, a different motion-capable CPU can also be used.
SINAMICS G120 CU250S-2 PN	1	6SL3246-0BA22-1FA0	
SINAMICS PM240-2 IP20	1	6SL3210-1PB13-0ULx	
Asynchronous motor	1	1LA7060-4AB10-Z	Alternatively, another asynchronous motor can also be used.
HTL incremental encoder	1	6FX2001-4SB00	Alternatively, another incremental encoder with HTL signal can also be used.

Software components

Table 2-2: Software components

Component	Qty	Article number	Note
STEP 7 (TIA Portal) V13 SP1	1	6ES7882-1..03-..	
SINAMICS Startdrive V13 SP1	1	6SL3072-4DA02-0XG0	

Example files and projects

The following list includes all files and projects that are used in this example.

Table 2-3: Example files and projects

| Component	Note
109479977_Commissioning_a_Drive_v10_en.pdf	This document.

3 Mode of Operation

3.1 Sequence of commissioning

Commissioning the SINAMICS drive

The position-controlled drive is commissioned in two steps. First of all the drive has to be configured. In the process, the motor and encoder data is transferred to the drive. Afterwards there is the option to optimize the speed control located in the drive.

The job of a speed control in a drive is to track an actual speed value according to a setpoint speed as precisely as possible.

Figure 3-1: Controller in the drive
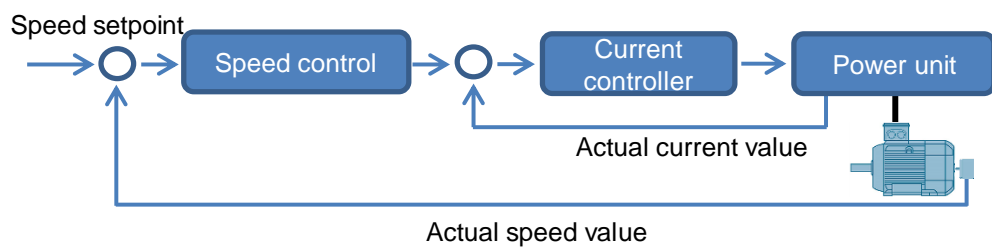
For the commissioning of the drive the following points are shown:

1. Checking speed and rotation direction
2. Optimizing speed control
3. detecting maximum acceleration

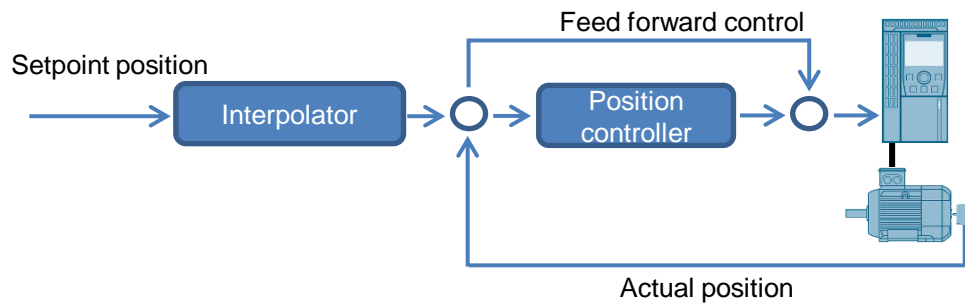### Commissioning the "positioning axis" technology object

After successful commissioning and optimization of the drive, it is then checked whether the required data can be correctly transferred from the drive to the controller. In the process, the configuration of the technology object is checked. Subsequently, the position controller is optimized.

A position controller is usually a P controller (less frequently a PI controller), which cyclically compares the internal position setpoint to the actual position of the encoder. The result of the setpoint/actual comparison is a signed differential value. The proportional gain of the position controller is known as the position loop gain or K_v factor. The output signal of the position controller is the setpoint speed value for the speed controller.

3.1 Sequence of commissioning

Figure 3-2: Controller in the technology object

For the commissioning of the technology object the following points are shown:

1. Checking settings of the position encoder
2. Checking speed normalization, counting direction and dynamic
3. Optimizing position controller
4. Optimizing feed forward control

3.2 Commissioning the drive

This chapter describes the commissioning of the SINAMICS drive.

Figure 3-3: Configuring the drive
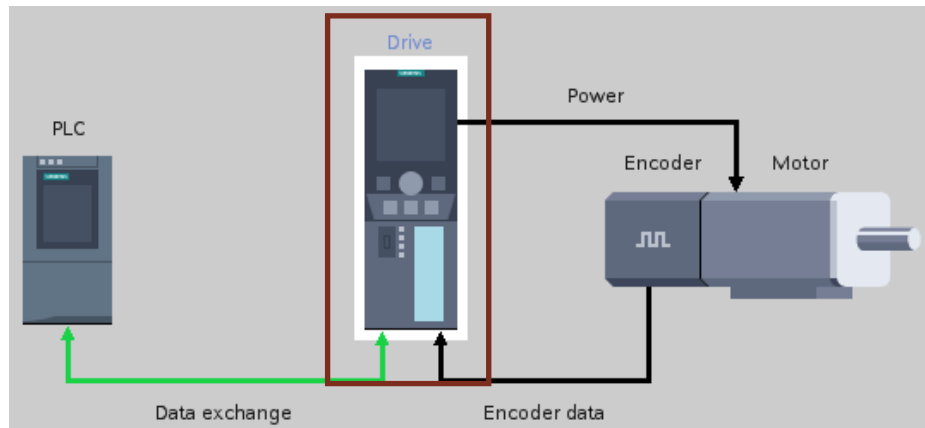
It is recommended to execute the commissioning wizard at the beginning of commissioning. Amongst others, the data of the motor and of the encoder is transferred to the drive. Furthermore, the ramp configuration of the drive (parameters p1120 and p1121) is specified.

Note	In the drive the ramps (p1120 and p1121) always have to be zero. Only for the optimization of the speed control, may it be necessary to configure an acceleration or deceleration ramp in the drive, in order to avoid mechanical damages on system components.

At the end of the commissioning wizard, the motor data identification (stationary measurement) has to be carried out.

⚠ WARNING	**Make sure that no persons or system components are endangered by the moving drive.** Take appropriate measures to prevent the drive from exceeding technical or mechanical limits, if required.

### 3.2.1 Checking speed, rotation direction and control direction

Once the commissioning wizard has run, speed, rotation direction and control direction have to be checked. To achieve this, the drive should first of all be moved at a low velocity setpoint. The control board of the drive can be used to operate it. The control board can be found in the TIA Portal in the "Commissioning" folder of the drive.

3.2 Commissioning the drive

Note	When the drive is first switched on, this can lead to uncontrolled movements. This can occur if, for example, the counting direction of the encoder and the rotation of the drive do not match.

Figure 3-4: Control board of the drive
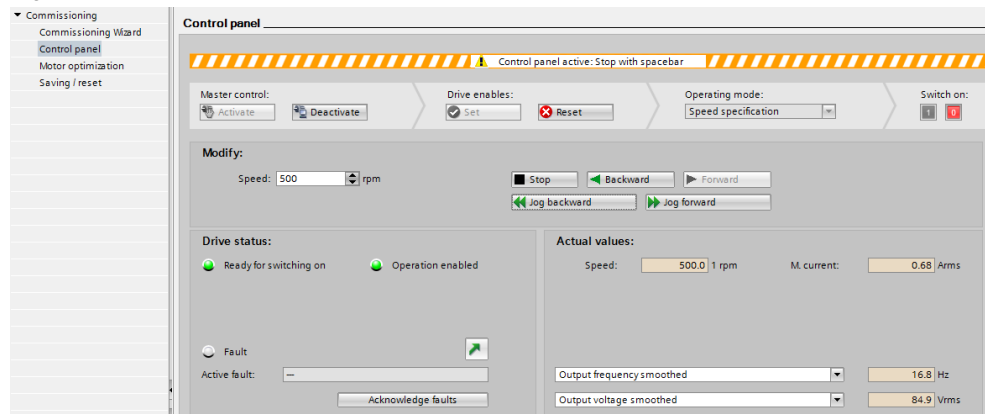
The current speed and rotation direction are displayed on the control board. These values have to match the behavior of the drive and have to be checked with an external measuring device.

Afterwards the drive should be moved with the maximum required system speed. To do this, the speed has to be entered as setpoint specification in the control board.

⚠ CAUTION	**The maximum possible speed of a drive depends on its configuration and its use. This is why when determining the maximum speed, it needs be made sure that no damage can occur on the drive or system components when it is moved.**

3.2.2 Optimizing the speed control

automatic speed control optimization

At the beginning of the optimization of the speed control, the automatic speed control optimization (rotating measurement) has to be carried out. This can be triggered in "Commissioning" >> "Motor optimization".

Note	Before the automatic optimization of the speed control (rotating measurement) the motor data identification (stationary measurement) has to have been run without errors.

The result of the automatic optimization usually already delivers a sufficient control behavior of the drive. This can be easily checked by recording (trace) the actual speed value and the speed setpoint.

3.2 Commissioning the drive

Figure 3-5: well set speed control with step response

A well set speed control is characterized by:

- short attack time
- dynamic behavior
- low overshoot

manual optimization of the speed control

However, if the automatic speed control optimization does not lead to the desired result or if the automatic optimization is cancelled with an error, the speed control can also be optimized manually. In the process, both parameters that are responsible for the control behavior are set manually:

- Speed control P gain K_P
- Speed control reset time T_N

These parameters are set for manual optimization with SINAMICS Startdrive via the "Control type" function view.

Figure 3-6: "Control mode" function view

3.2 Commissioning the drive
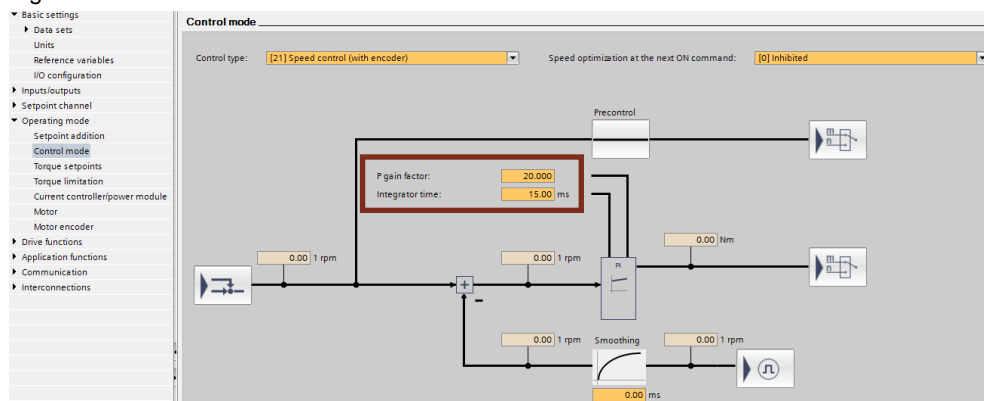
The approach for manual optimization of the speed control is as follows:

1. Establish an online connection to the drive.

2. Set the acceleration and deceleration times in the parameter view to zero, if this has not already happened when commissioning the drive (parameters p1120 and p1121).

3. Now set the feed forward control of the speed control to zero (parameter p1496)

4. Now specify a setpoint step of the speed via the control board and observe the course of the actual speed value with the help of a trace.

5. Optimize the speed control, by changing the parameter for the P gain K_P (p1460) and for the reset time T_N (p1462).

6. If the drive shows the desired behavior, optimization is finished. Leave the feed forward control (p1496) on 0%.

If the P gain K_P is too small and the reset time T_N is too large, the drive will display the following behavior:

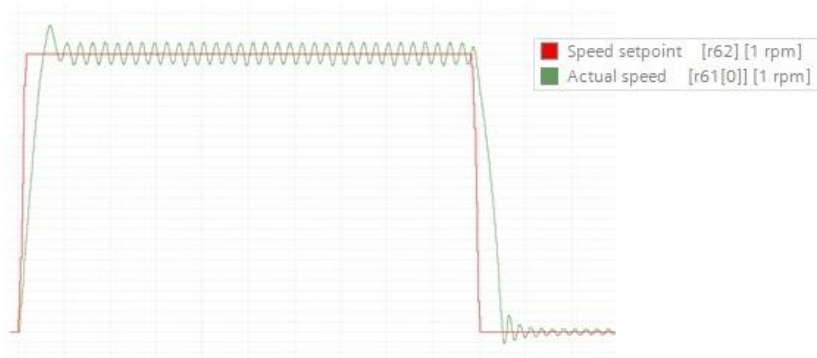Figure 3-7: Speed control with reset time being too big
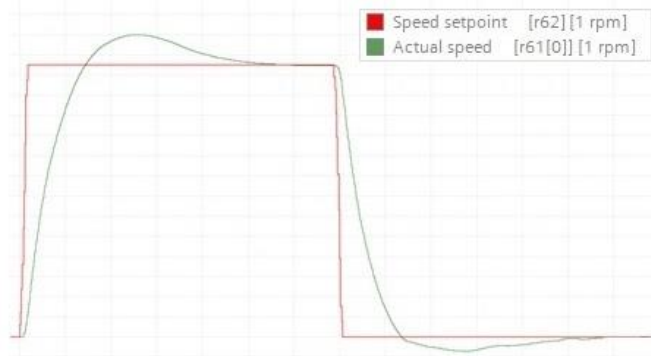
This control behavior has the following disadvantages:

- long attack time
- inert behavior
- long overshoot

If the P gain K_P is too large, the drive will display the following behavior:

Figure 3-8: Speed control with too large a proportional share

This control behavior has an undesired continuous speed oscillation.

3.2 Commissioning the drive

For the manual optimization of the speed control, the following parameters of a SINAMICS drive have to be influenced:

Table 3-1: required parameters of the drive

Meaning of the parameters	Parameter number
K_P for speed control with encoder	p1460
T_N for speed control with encoder	p1462
Ramp generator ramp-up time	p1120
Ramp generator ramp-down time	p1121
Feed forward control of the speed control	p1496

Note	The approach for manual optimization of the speed control is described in the operating instructions of the drive used. \5\

3.2.3 detecting maximum dynamic

After the optimization of the speed control, the maximum acceleration and the maximum deceleration of the drive have to be specified. To do this, the drive has to be moved via the Control board of the drive with maximum speed.

⚠ **CAUTION**	**The maximum possible speed of a drive depends on its configuration and its use. This is why when determining the maximum speed, it needs be made sure that no damage can occur on the drive or system components when it is moved.**

During the movement a trace has to be created. In it, the actual speed value and the setpoint speed are to be recorded.

Figure 3-9: Trace to determine the maximum dynamic

3.2 Commissioning the drive

The maximum acceleration and the maximum deceleration are calculated according to the following formula:

$$Acceleration = \frac{Velocity\ change}{Period} = \frac{\Delta v}{\Delta t}$$

Calculation of the maximum acceleration

For the calculation of the maximum acceleration, the value of the velocity change has to be detected first. In the present example it is accelerated from standstill (speed equals zero) to the maximum speed. For this reason, the maximum speed of the velocity value corresponds to the calculation of the maximum acceleration.

As a second step the time has to be determined now in which the drive accelerates to the maximum speed. This period starts at the point where the acceleration starts on the drive (1) and ends when the drive reaches the setpoint of the maximum speed at a steady state (2).

Calculating the maximum deceleration

For the calculation of the maximum deceleration, the velocity change also hat to be detected. This is where the drive decelerates from its maximum speed to standstill (speed equals zero).

The period the drive requires for this, starts at the starting point of the deceleration (3) and ends when the drive has reached standstill (4).

Note	When calculating the acceleration or deceleration there may have to be a conversion of $\frac{Revolutions}{Seconds^2}$ to $\frac{Millimeters}{Seconds^2}$.

Example for calculating the maximum acceleration

The maximum speed of the drive is 1420 revolutions per minute. The drive reaches this speed in 0.52 seconds.

$$n_{max} = 1420\ \frac{1}{min} = 23.67\ \frac{1}{sec}$$

Thus, the maximum acceleration is calculated like this:

$$a_{max} = \frac{\Delta v}{\Delta t} = \frac{23.67\ 1/sec}{0.52\ sec} = 45.52\ \frac{1}{sec^2}$$
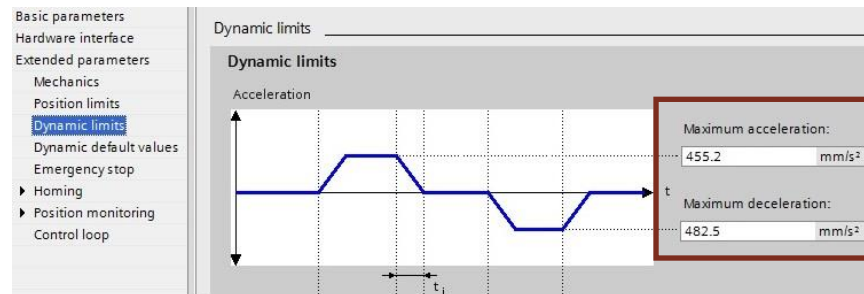
The load movement per motor revolution is 10 mm:

$$45.52\ \frac{1}{sec^2} * 10\ mm\ per\ revolution\ results\ in\ a_{max} = 455.2\ \frac{mm}{sec^2}$$

3.2 Commissioning the drive

The calculated values for the maximum acceleration and the maximum deceleration are to be entered in the dynamic limits of the technology object.
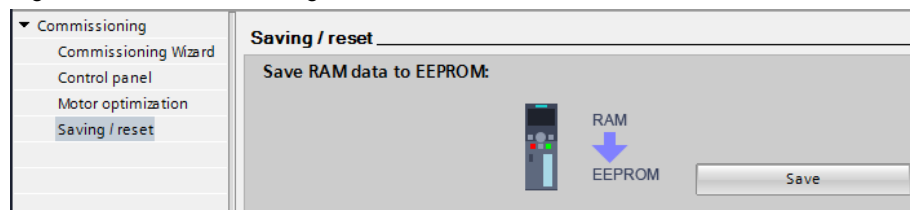
Figure 3-10: Dynamic limits of the technology object

Saving the settings

After commissioning the drive, the settings have to be saved. The following steps must be taken:

1. Save the settings of the drive in the EEPROM memory. This makes the settings available even after restarting the drive.

Figure 3-11: Save the settings

2. Disconnect online connection to the drive

3. Upload the drive settings into the TIA project

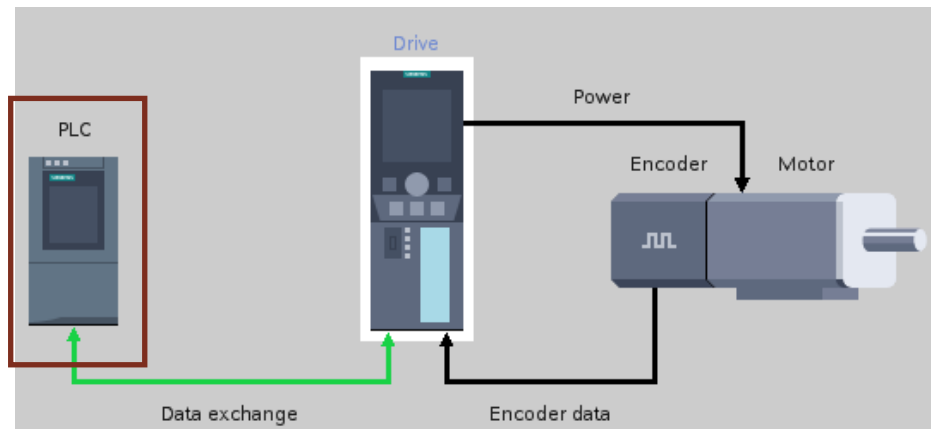Figure 3-12: Load the drive settings into the project

4. Save the TIA project

3.3 Commissioning the technology object

This chapter describes the points that are required to commission a position-controlled drive in the SIMATIC S7-1500 controller (PLC).

Figure 3-13: Configuring the drive

Here, the focus is on the following points:

- Checking position encoder setting
- Checking speed normalization, counting directions and dynamic
- Optimizing the position controller
- Optimizing the feed forward control

At this place it is assumed that a "Positioning Axis" technology object has been created and the basic configuration (selection encoder, drive etc.) has taken place.

Note	Application example \7\ shows how a position-controlled axis is created and the use of the required blocks.

3.3.1 Checking the position encoder setting

The data of the encoder has to be stored in the configuration of the technology object. This is where, among other information, the encoder type and "steps per revolution" is to be entered. If the encoder is directly connected to the SINAMICS drive, the values in the technology object have to match the ones of the drive parameter "PROFIdrive encoder format" (r979[2] to r979[5]).

In order to check whether the entered data matches that of the encoder used, the axis has to be moved mechanically by a certain distance. The shift then has to be determined by measuring it (e.g. with a caliper gauge). This shift of the axis has to match the change of the actual position.
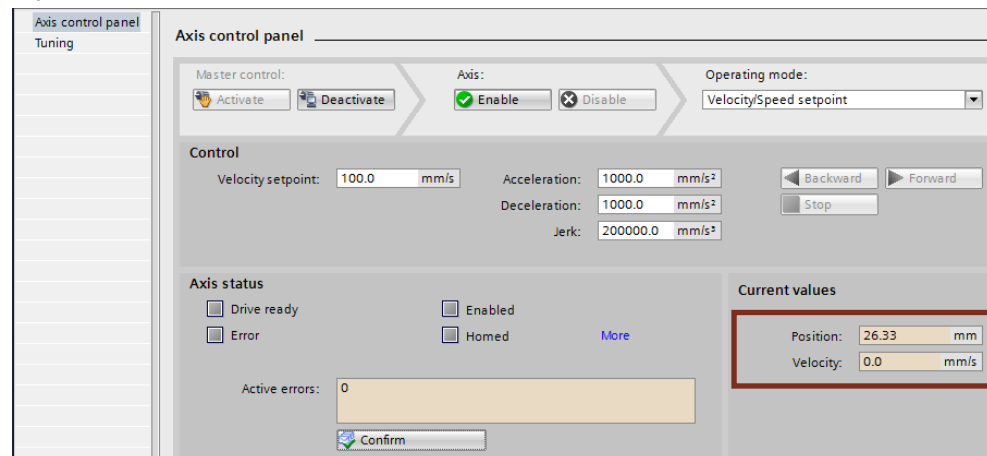
The actual position can be read online in the control board of the technology objet (axis control board).

3.3 Commissioning the technology object

Figure 3-14: Axis control board

If it is not possible to move the drive mechanically, the drive has to be moved with the help of the axis control board. To do this, a very low a velocity has to be selected because during the movement, the number of revolutions of the axis has to be determined.

When controlling the drive with the axis control board, the direction of rotation of the encoder can also be checked. Here, it has to be observed that when moving the axis in positive direction, the actual position is also increased.

If the position encoder delivers incorrect or no data, the following may have caused the error:

- Encoder not correctly connected to the drive
- Encoder or encoder cable defective
- Actual encoder value inverted
- Fine resolution of the encoder not correct

3.3.2 Checking of the speed normalization and traversing direction

In this step, speed normalization, counting direction and dynamic of the drive have to be checked. To do this, the following settings have to be made:

- Disabling the following error monitoring in the technology object
- Disabling the position monitoring (tolerance time to max.)
- Gain factor Kv = 0
- Feed forward control Kpc = 100%
- Moving the axis with maximum required speed

| ⚠ **CAUTION**	**The value for the maximum velocity has to be selected in a way to avoid damage on the drive or system components.**

3.3 Commissioning the technology object

The position controller has to be disabled at this point (Kv=0), so that the drive can only be moved "controlled". The specification of a speed setpoint takes place without position control action.

The controlled movement via the axis control board is not directly possible up to TIA version V13 SP1. This is why the settings of the gain factor and the feed forward control have to take place via the "control loop" operator screen of the technology object.

Figure 3-15: Control loop position controller
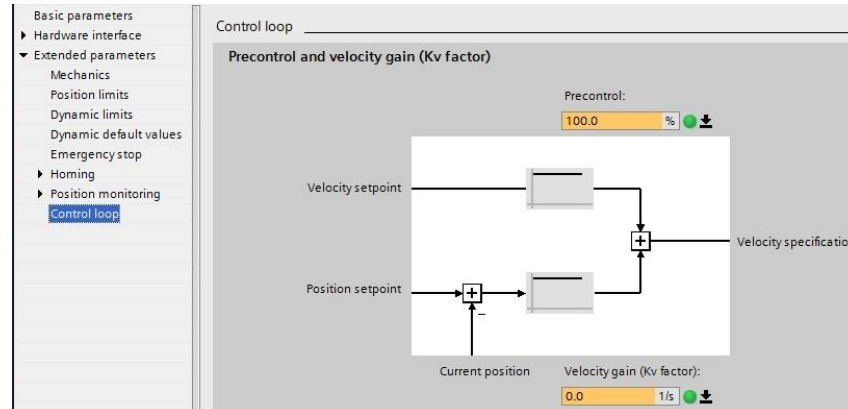
Moving the drive while checking the speed normalization and the counting direction can take place via the "Axis control board".

Before moving the drive it has to be checked whether the following parameters have the same values:

- The reference speed of the technology object has to match the reference speed of the drive (drive parameter p2000).

- The maximum speed of the technology object has to match the maximum speed of the drive (drive parameter p1082).

A trace has to be created in order to check the normalization, the counting direction and the dynamic of the drive. In it, the current velocity (ActualVelocity) and setpoint velocity profile (Velocity) has to be recorded. This is where the current velocity is to follow the course of the setpoint velocity profile as precisely as possible.

3.3 Commissioning the technology object

Figure 3-16: Checking the direction and value of the current velocity
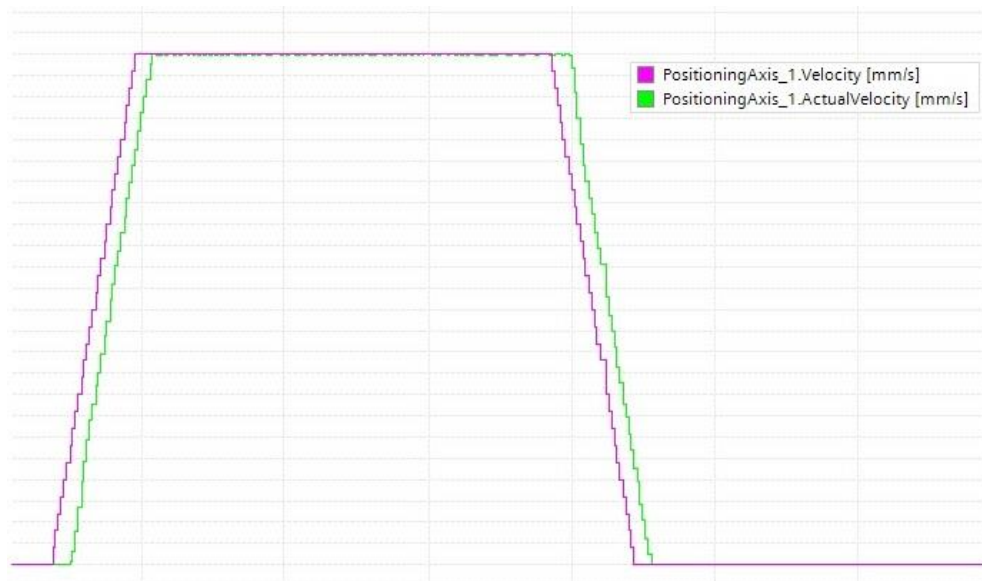
If the current velocity cannot follow the course of the setpoint velocity profile, this may have the following causes:

- Drive is moving to its current limits
- The limits in the technology object have been reached and have therefore been set too low

When the speed normalization and the counting direction is checked by evaluating the trace, and the desired (maximum) dynamic of the drive has been set, the positon controller can then be optimized. To do this, set the gain factor Kv to ten and disable the feed forward control (Kpc=0%). Re-enable the following error monitoring and position monitoring.

3.3.3 Optimizing the position controller

For a precise behavior of a position-controlled drive, the position controller has to be optimized.

manual optimization of the position controller

The quality of the position controller is checked comparing the setpoint velocity profile (Velocity) with the current velocity (ActualVelocity) of the technology object. This is where the current speed should follow the course of the setpoint speed profile as precisely as possible. An overshoot of the current speed is to be avoided when reaching the setpoint.

3.3 Commissioning the technology object

Figure 3-17: well set position controller
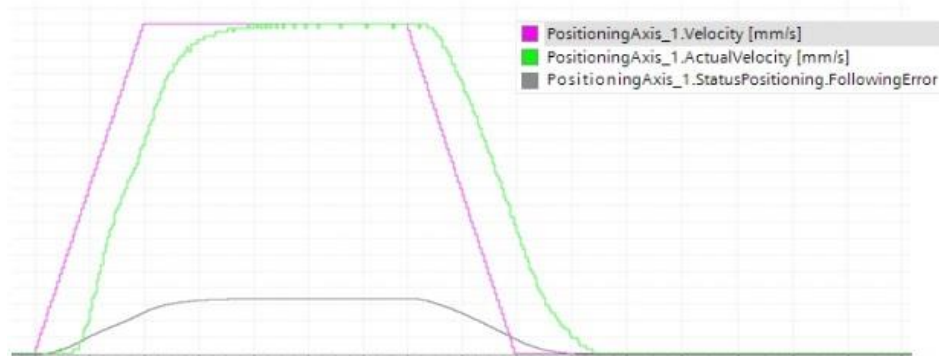
This control behavior is characterized by:

- short attack time
- dynamic behavior
- no overshoot

When optimizing the position controller, the ideal gain factor (Kv factor) has to be determined. This can be set in the "Control loop" screen.

During the optimization, as high a gain as possible is to be reached. A smaller gain results in a larger following error as well as more sluggish control behavior. The maximum attainable gain depends on the following factors:

- Mechanical stiffness
- Response time of the controlled system
- Size of the control cycle
- Type of drive connection (clock synchronous or non-clock synchronous)

The table below gives an idea of the size of the gain factor at very different operating conditions.

Table 3-2: Size of the gain factor

Gain factor	Mechanics	Type of drive	Control cycle
low (<15 1/s)	low stiffness	U/f, asynchronous motor, G120, hydraulic	low (>12 ms)
intermediate (>15 1/s)	intermediate stiffness	Vector with encoder	intermediate (<12 ms)
high (>30 1/s)	high stiffness	Servo, S120	high (<6 ms)

The optimization should be made with the following settings:

- Move with maximum required acceleration
- Move with 90% of the maximum required velocity (Velocity)
- Disabling the feed forward control (Kpc=0%)
- Start of the optimization with Kv=10

3.3 Commissioning the technology object

> ⚠️ **CAUTION**
>
> **The maximum acceleration and the maximum velocity have to be selected in a way so that no damage is caused on the drive or system components.**

Moving the drive while checking the optimization of the position control can take place via the "Axis control board". This is where values for the position controller can only be accepted online, if the control authority in the control board has been passed on.

Note If a function-capable motion program exists for controlling the position-controlled drive, the motion commands are to be started via this program.

If the gain factor has been set too low, the current velocity approaches the setpoint only slowly.

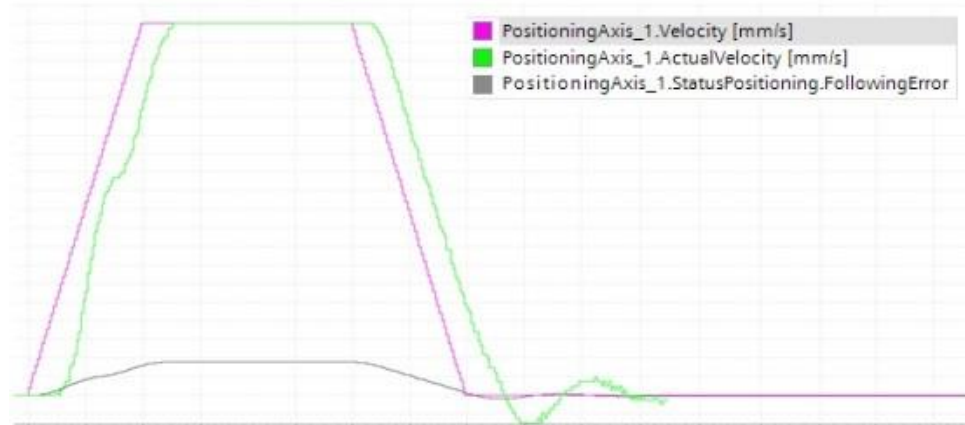Figure 3-18: Position controller with a gain factor that is too small
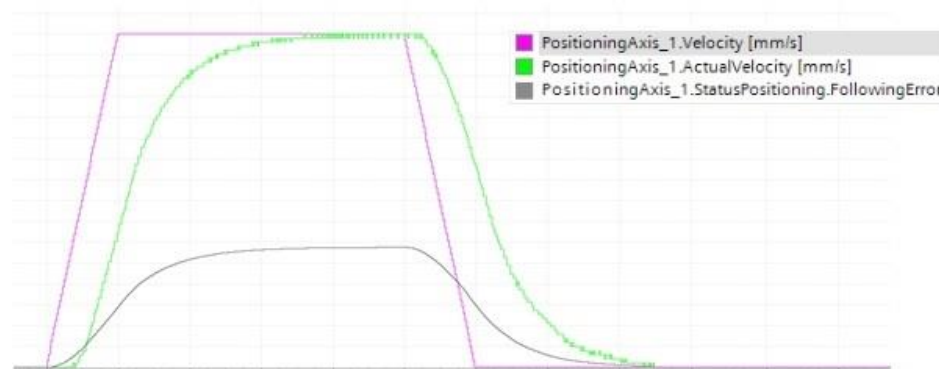
This control behavior has the following disadvantages:

- long attack time
- inert behavior
- large following error

3.3 Commissioning the technology object

If the gain factor has been set too high, there will be an overshoot of the current velocity.

Figure 3-19: Position controller with a gain factor that is too high

Optimizing the position controller with the optimizing window in the TIA portal

With a pre-configured user interface the TIA Portal offers another option for optimizing the position controller. It can be found in the commissioning functions of the positioning axis.

Figure 3-20: User interface to optimize the position controller
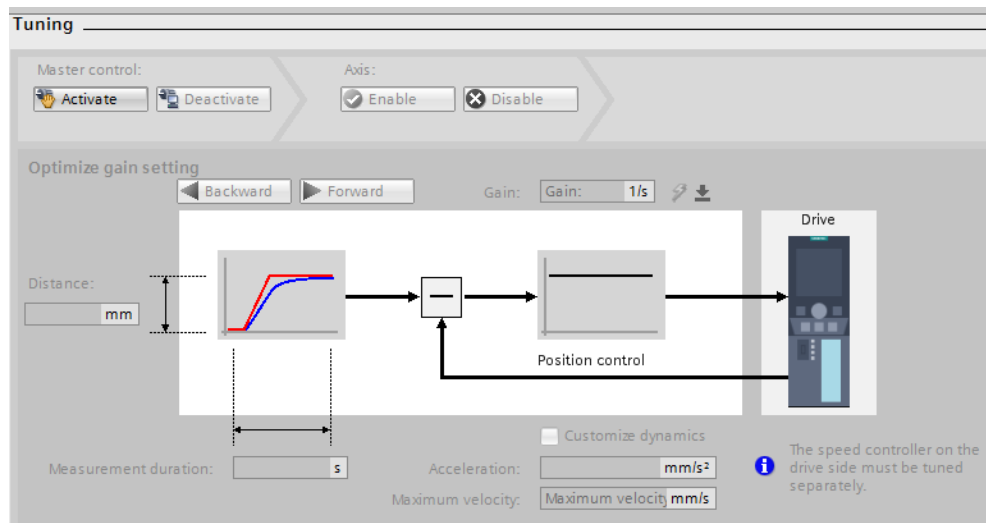
In this user interface, positioning movements can be executed with different Kv factors. The behavior of the drive can then be assessed with a trace.

Optimizing the position controller with the optimization window has the following advantages and disadvantages:

3.3 Commissioning the technology object

Table 3-3: Advantages and disadvantages of the optimization window

| Advantages	Disadvantages
Kv value can be set without having to give up control authority	Kv value has to be applied
The trace is started automatically	Setting options for the deceleration and the feed forward control are missing

Note	After the optimization the set values have to be saved offline.

3.3.4 Optimizing the feed forward control

An optimally set feed forward control increases the control dynamic and reduces the following error. The application advantage here is mainly all the dynamic positioning processes.

Analogous to the position control, the quality of the feed forward control can be checked by comparing the setpoint velocity profile (Velocity) and the current velocity (ActualVelocity) of the technology object. The following error is also to be recorded.

Figure 3-21: Feed forward control optimal
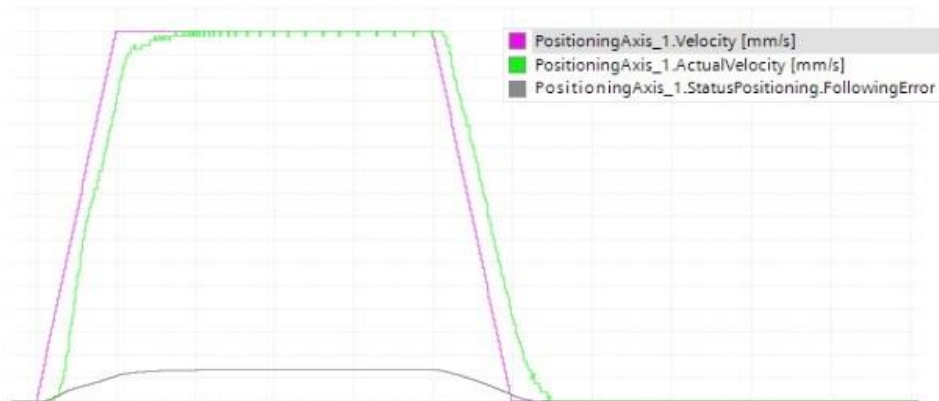
A well set feed forward control is characterized by:

- very short attack time
- dynamic behavior
- no overshoot

The aim of the optimization of the feed forward control is the determination of the ideal Kpc value. This can be set in the "Control loop" screen.

The optimization should be made with the following settings:

- Move with maximum required acceleration
- Move with 90% of the maximum required velocity (Velocity)
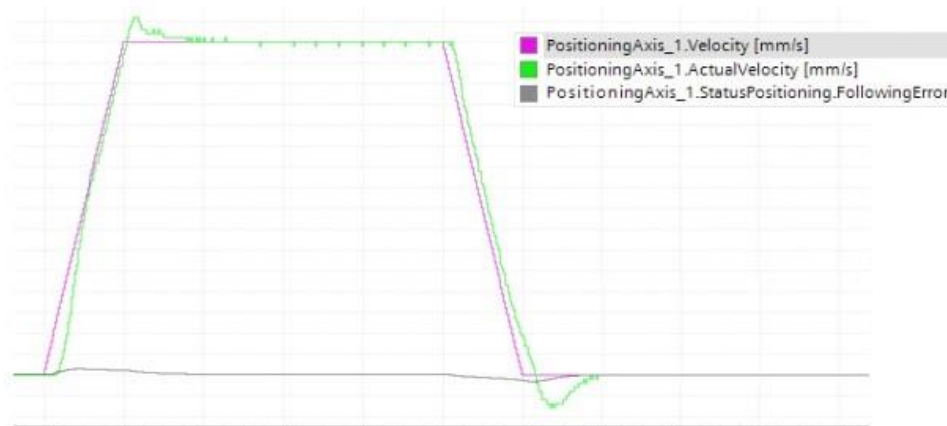- Optimizing feed forward control Kpc

3.3 Commissioning the technology object

<table>
<tr>
<td>⚠

CAUTION</td>
<td>**The maximum acceleration and the maximum velocity have to be selected in a way so that no damage is caused on the drive or system components.**</td>
</tr>
</table>

When using frequency converters of the SINAMICS G120 family, as well as for an analog or non-clock synchronous connection of the drives, the feed forward control should be reduced or switched off (Kpc=0%). Otherwise there could be overshoots

Figure 3-22: Feed forward control Kpc too high

If a feed forward control is too low, the drive will display the following behavior.

Figure 3-23: Feed forward control Kpc too low
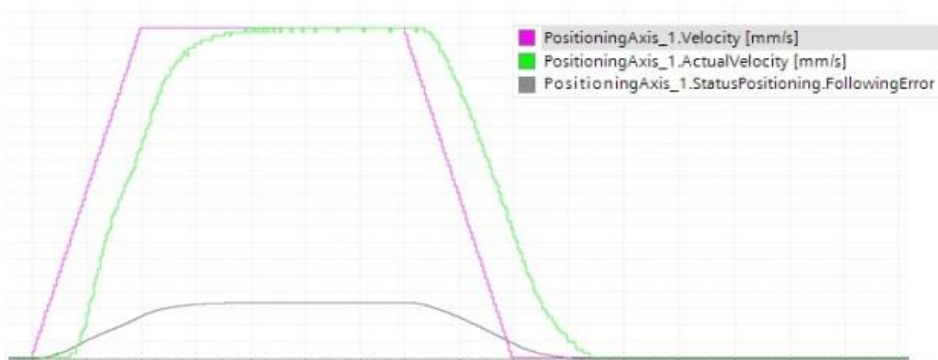
This control behavior has the following disadvantages:

- larger following error
- longer attack time

Moving the drive while checking the optimization of the feed forward control can take place via the "Axis control board".

3.4 Summary of commissioning

Commissioning of a position-controlled drive is summarized as follows.

Commissioning the drive

Table 3-4: Steps for commissioning the drive

Step	Task
1.	Run the commissioning wizard with final automatic motor data calculation
2.	Check speed and rotation direction
3.	Optimize speed control
4.	detect maximum dynamic of the drive

Commissioning the technology object

Table 3-5: Steps for commissioning the technology object

Step	Task
1.	Check position encoder setting
2.	Check speed normalization, counting direction and dynamic
3.	Optimize position controller
4.	Optimize feed forward control

3.5 Information for the processing of faster motion sequences

For some applications, a high dynamic behavior of the drive is desired. This means that a drive, once it has reached it setpoint position, should start with the next positioning job as fast as possible.

If the drive is to respond as quickly as possible to a new positioning command, the "minimum dwell time in the positioning window" has to be set to zero seconds.

Figure 3-24: Setting the dwell time
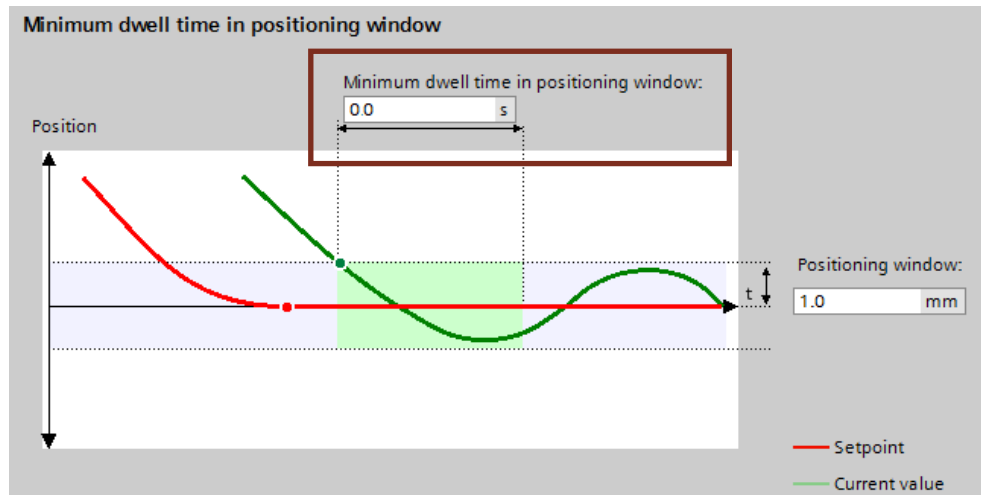
4 Links & Literature

Table 4-1

	Topic	Title
\1\	Siemens Industry Online Support	https://support.industry.siemens.com
\2\	Download page of the entry	https://support.industry.siemens.com/cs/ww/en/view/10947 9977
\3\	STEP 7 V13	Updates for TIAP V13 http://support.industry.siemens.com/cs/document/90466591
\4\	Startdrive V13 Download page	http://support.industry.siemens.com/cs/document/68034568
\5\	SINAMICS G120 with CU240 B/E-2 manuals	Operating Instructions: http://support.industry.siemens.com/cs/document/94020562 List manual (parameters and error list): http://support.industry.siemens.com/cs/document/99683523
	SINAMICS G120 with CU250S-2 manuals	Operating Instructions: http://support.industry.siemens.com/cs/document/94020554 List manual (parameters and error list): http://support.industry.siemens.com/cs/document/99683818
	SINAMICS G120C Manuals	Operating Instructions: http://support.industry.siemens.com/cs/document/99710404 List manual (parameters and error list): http://support.industry.siemens.com/cs/document/99683780
	SINAMICS G120D with CU240D-2 manuals	Operating Instructions: http://support.industry.siemens.com/cs/document/99711357 List manual (parameters and error list):http://support.industry.siemens.com/cs/document/99684194
	SINAMICS G120D with CU 250D-2 manuals	Operating Instructions: http://support.industry.siemens.com/cs/document/99721485 List manual (parameters and error list): http://support.industry.siemens.com/cs/document/99684194
	SINAMICS S120 Manuals	Manual: http://support.industry.siemens.com/cs/document/109478725 List manual (parameters and error list): http://support.industry.siemens.com/cs/document/33974002
\6\	SIMATIC S7-1500	SIMATIC S7-1500 Automation System: http://support.industry.siemens.com/cs/document/59191792 Function Manual SIMATIC S7-1500 Motion Control: http://support.industry.siemens.com/cs/document/99005173
\7\	Positioning a G120 with S7-1500	Application Example: http://support.industry.siemens.com/cs/ww/en/view/81666970

5 History

Table 5-1

Version	Date	Modifications
V1.0	02/2016	First version