Technology Template “Hydraulics Characteristic”

Technology CPU

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SIMATIC
Technology Template "Hydraulics Characteristic"

Technology CPU

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1 Technology Template

1.1 Introduction

1.1.1 The technology template

A technology template is a software object or a code block with a defined interface that can be easily integrated into other software projects with little overhead and that performs a precisely defined technological task in these projects.

Using Technology CPU, the technology template described in this document helps you to automatically determine the behavior of controlled hydraulic systems and to provide the measured compensation characteristic as “cam disk” for the linearization of the control loop.

1.1.2 Main contents of this technology template

The following key elements are dealt with in this technology template:

- Automatic analysis of controlled hydraulic systems for the determination of the compensation characteristic
- Provision of the compensation characteristic of a controlled hydraulic system as “cam disk” for the linearization of the control loop
- Plausibility check of the determined compensation characteristic of the controlled hydraulic system
- Manual positioning of the hydraulic axis in JOG mode

1.1.3 Topics not covered by this application

This technology template does not include a description of …

- …the metrological method for the determination of the compensation characteristic of a controlled hydraulic system
- …the application and use of technology functions and technology objects with the technology CPU
- ...the programming of the technology CPU in STEP 7.

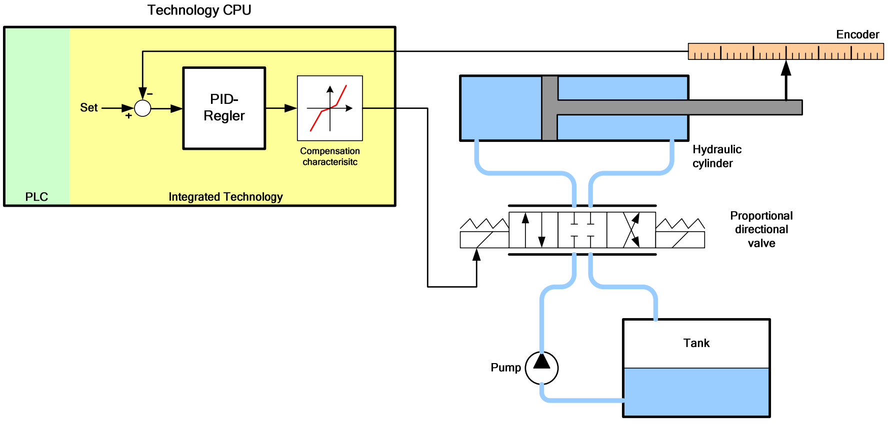
Basic knowledge of these topics is assumed.

1.2 Objective and purpose

1.2.1 Task definition

If a hydraulic axis is to be operated through the control loop of the technology CPU, it is necessary for optimal control that a compensation characteristic for the linearization of the non-linear behavior of the controlled hydraulic system is determined.

Figure 1-1 Control of a hydraulic axis

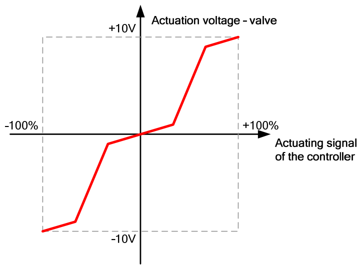


Generally, a hydraulic axis consists of a hydraulic cylinder, which is controlled via a proportional directional valve. The valve controls the flow/pressure of the hydraulic oil in the cylinder, which is provided via the pump. The valve is activated via the control output of the technology CPU.

The current position/current speed of the hydraulic cylinder is communicated to system control via a position measuring system (encoder). This actual value is fed back to the technology CPU and – together with the setpoint value – it is used as input parameter of the controller.

However, the controller of the technology CPU is designed for linear control system behavior, such as applies in the case of electrical axes. For optimal control of a hydraulic axis via technology CPU, a compensation characteristic required which maps the linear actuating signal of the controller onto the non-linear behavior of the hydraulic axis.

Figure 1-2 Compensation characteristic



1.2.2 Advantages

The use of a compensation characteristic in the control loop for a hydraulic axis of the technology CPU has the following advantages:

- **Enhancement of the control dynamics:**
  The control loop of the axis can be operated with a higher amplification factor, thus increasing the control stability of the circuit and reducing the positioning time of the hydraulic axis.
- **Increasing the positioning accuracy:**
  The positioning accuracy of the hydraulic axis is significantly increased when using the optimized control loop. Hence, the hydraulic axis can work faster and better for the implementation of the setpoint specifications of system control.

- **Applicability of pilot control:**
  The optimal use of the pilot control feature of requires a linear control system response. The application of pilot control is mainly required in the case of interpolating axes for the compensation of the tracking error.

The use of this technology template provides the user with the following advantages:

- **Simple determination of the compensation characteristic:**
  Via the technology template, the compensation characteristic of a hydraulic axis can be automatically determined by measuring the controlled hydraulic system and activated after the measurement.
- **Use within an application or as commissioning tool:**
  The technology template can either be used as commissioning tool for a one-time determination of the compensation characteristic or it can be embedded into an application for permanent use.
- **Simple activation of existing compensation characteristics:**
  If the compensation characteristic of a hydraulic axis has been determined and the measured values are provided in a data block, the compensation characteristic can be activated with these data via the technology template in a simple and efficient way, e.g. at each start of the technology CPU.

1.2.3 Restrictions

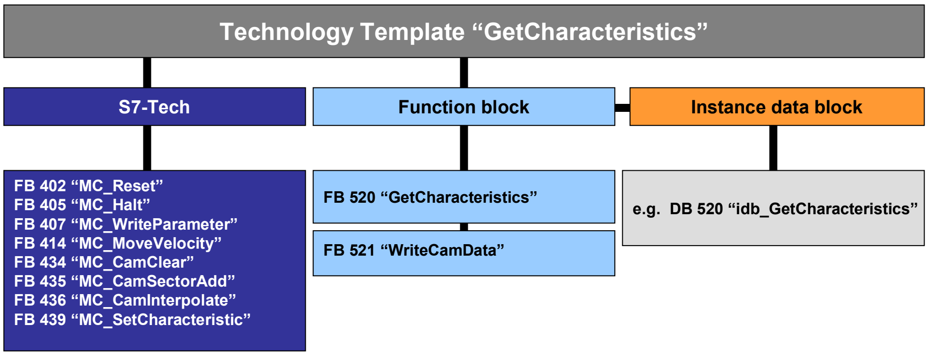
The following properties were not considered in the implementation of the technology template.

- **No monitoring of start position**
  The technology template does not monitor the start position of the hydraulic axis at the start of the analysis. The user must make sure that the cylinder is adequately positioned at the start of measurement. For this purpose, the technology template provides a function for the manual positioning of the hydraulic axis. The measurement is always taken in positive direction from the start position.
- **No optimization of the control parameters**
  The technology template does not perform an optimization of the control parameters in the control loop of the hydraulic axis. With the technology template, only the compensation characteristic for the activation of the hydraulic axis can be automatically determined in order to compensate for the non-linear behavior of the hydraulic axis in the control loop.

1.3 Components of the technology template

The technology template is a software package which contains all STEP 7 blocks required for the automatic measurement of the compensation characteristic of a hydraulic axis.

Figure 1-3 Components contained in the technology template



FB 520 "GetCharacteristics" contains the complete functionality for determining the compensation characteristic of a hydraulic axis. To do this, the function block performs measurements at the hydraulic axis in order to determine the compensation characteristic and saves this measured value in the instance data block of FB 520.

After the measurement has been completed, **FB 521 "WriteCamData"** transfers the determined compensation characteristic into a "cam disk" which can then be activated in the control loop in the technology CPU via technology function FB 439 "SetCharacteristics".

Note

Based on the complexity of the array accesses and administration processes to be performed in the function blocks, all mentioned function blocks of the technology template are created in SCL language.

The SCL sources of the function blocks of the technology template are not included in the available Step 7 projects.

1.4 Approved hardware and software

1.4.1 Hardware components

Table 1-1 Hardware components

Component	Qty.	MLFB/order number	Note
CPU 315T-2 DP	1	6ES7315-6TG10-0AB0 oder 6ES7315-6TH13-0AB0 as of firmware: Version: V2.6 / 4.1.1	The CPU executes the user program and the technological functions.
Micro Memory Card 8MB	1	6ES7953-8LP20-0AA0	The S7 program is stored on the MMC.

Table 1-2 Hardware components – Alternative 1

Component	Qty.	MLFB/order number	Note
CPU 317T-2 DP	1	6ES7317-6TJ10-0AB0 or 6ES7317-6TK13-0AB0 as of firmware: Version: V2.6 / 4.1.1	As an alternative to CPU 315T-2 DP at increased quantity framework
Micro Memory Card 8MB	1	6ES7953-8LP20-0AA0	The S7 program is stored on the MMC.

Table 1-3 Hardware components – Alternative 2

Component	Qty.	MLFB/order number	Note
CPU 317TF-2 DP	1	6ES7317-6TF14-0AB0 as of firmware: Version: V2.7 / 4.1.5	Failsafe technology CPU for simultaneous editing of technology program and safety program.
Micro Memory Card 8MB	1	6ES7953-8LP20-0AA0	The S7 program is stored on the MMC.

In addition to the technology CPU, the following hardware components are required for the application of the technology template:

Table 1-4 Additional hardware components

Component	Qty.	MLFB/order number	Note
Interface module IM174	1	6ES7174-0AA00-0AA0	Up to four analog drives can be activated via the interface module.

1.4.2 Software components

Standard software components

Table 1-5 Software components

Component	Qty.	MLFB/order number	Note
STEP 7	1	6ES7810-4CC10-0YA5 Version: V5.5 SP2	STEP 7 is the basic package for all optional software packages and used for programming the SIMATIC.
S7 Technology	1	6ES7864-1CC42-0YA5 Version: V4.2 SP1	Tool for parameterizing and programming the technology objects of the technology CPU

Software components required for the HMI user interface

Table 1-6 Software components

Component	Qty.	MLFB/order number	Note
WinCC flexible Runtime	1	6AV6613-1FA51-3CA0 Version: 2008 SP3	The Runtime software is required for operating the HMI user interface.
WinCC flexible	1	6AV6613-0AA51-3CA5 Version: 2008 SP3	The engineering software is required, if changes at the HMI user interface shall be performed or a new WinCC flexible Runtime shall be created.

Sample files and projects

The following list contains all files and archives used in this technology template.

Table 1-7 Files and STEP 7 archives of the technology template

Component	Note
27731588_CODE_GetCharacteristics_v421.zip	This STEP 7 archive contains only the blocks associated with the technology template for integration into a user program.
27731588_CPU315T_GetCharacteristics_EXP-S_v421.zip 27731588_CPU317T_GetCharacteristics_EXP-S_v421.zip	This STEP 7 archive contains all the blocks and an HMI user interface for the technology template. This project can be used directly as commissioning tool.
27731588_Template_GetCharacteristics_DOKU_v20_e.pdf	This document.

Required PLC-Open blocks from the “S7-Tech V4.2” library

The list contains all PLC-Open blocks from the “S7-Tech V4.2” library used for technology function calls in this technology template. The “S7 Tech V4.2” library is included in the “S7-Technology” software.

Table 1-8

PLC-Open blocks	Function
FB 402 “MC_Reset”	Acknowledging errors pending at an axis or a technology object.
FB 405 “MC_Halt”	Stopping axis movements

PLC-Open blocks	Function
FB 407 “MC_WriteParameter”	Writing system parameters to a technology object, e.g. setting the additional setpoint for an “AdditionalOutputValue” hydraulic valve.
FB 414 “MC_MoveVelocity”	Moving an axis via specification of rotational speed and switching the “Axis” technology object between speed-controlled and position-controlled mode.
FB 434 “MC_CamClear”	Deleting all existing interpolation points of a cam disk
FB 435 “MC_CamSectorAdd”	Adding new interpolation points to a cam disk.
FB 436 “MC_CamInterpolate”	Interpolation of a newly created cam disk to be used in the technology CPU.
FB 439 “MC_SetCharacteristics”	Activation of a valve characteristic for a Q-valve in the control loop of the technology CPU.

2 Basics

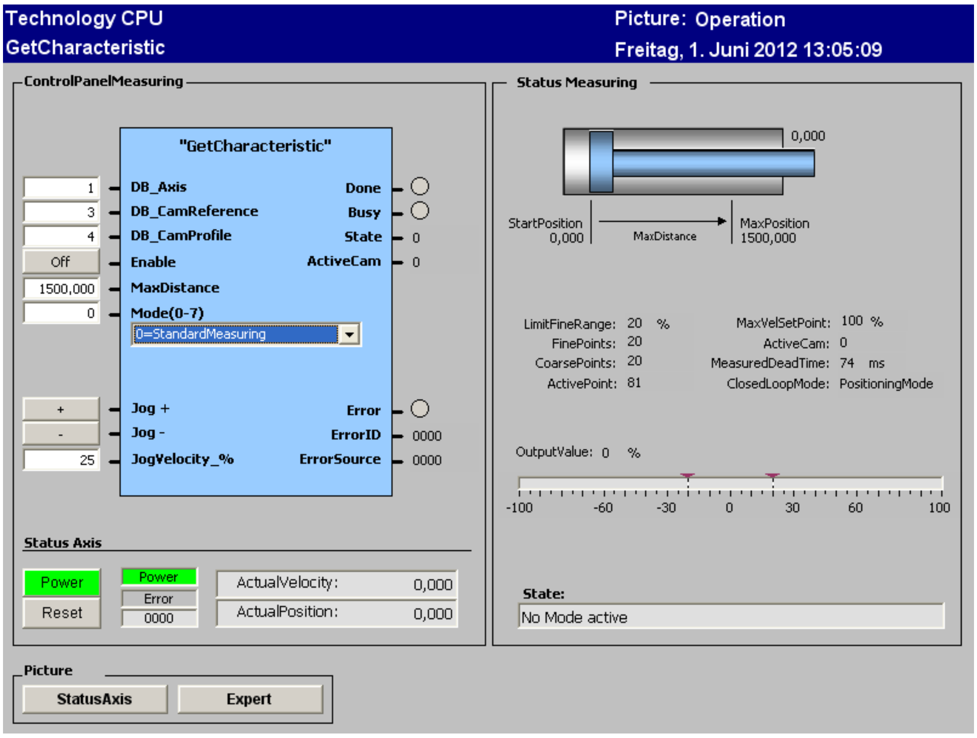
2.1 Application options of the technology template

2.1.1 Usage as commissioning tool

The technology template is loaded to a technology CPU as a separate application and it is only used for the determination of the compensation characteristic for a hydraulic axis.

The measured compensation characteristic can then be adopted in S7T-Config and be stored together with a STEP 7 project.

Figure 2-1 HMI user interface for usage as commissioning tool



Note This approach is mainly recommended for **individual projects** and **special purpose machines**.

2.1.2 Permanent usage in an application

The technology template is permanently integrated into a self-developed application.

The compensation characteristic of the hydraulic axis can be newly determined and activated at any point in time. For this purpose, the characteristic does not have to be stored in the STEP 7 project; instead, it can always be determined locally at the machine.

In this application case, the technology template additionally offers the possibility to determine and reactivate the compensation characteristic, e.g. at each start of the

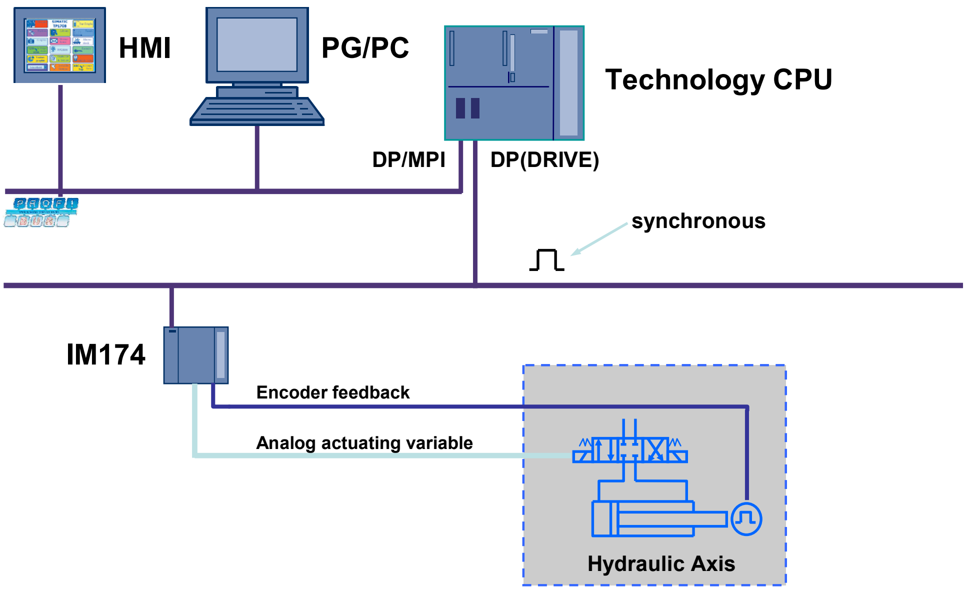
CPU, by means of the measured values stored in a data block. For this purpose, the measurement of the compensation characteristic has to be performed only once after loading the application to the CPU.

Note This approach is mainly recommended for **standard machines**.

2.2 Connecting a hydraulic axis

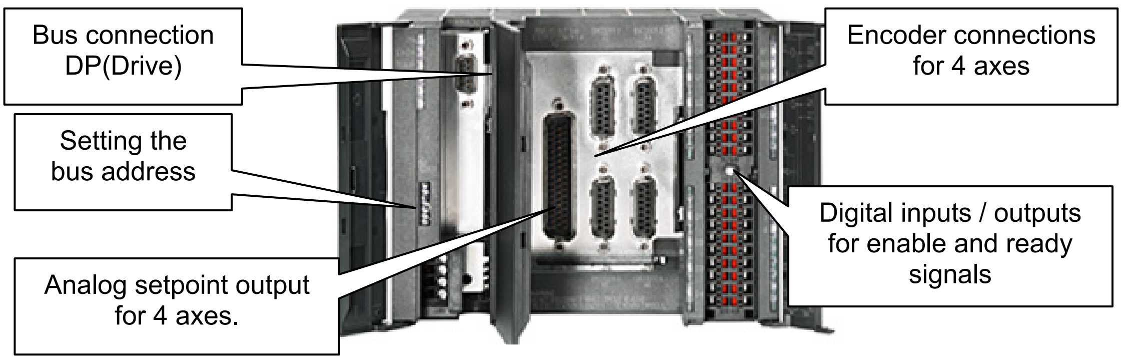
The connection of a hydraulic axis to the technology CPU is performed via interface module IM174.

Figure 2-2 Typical structure for controlling a hydraulic axis



The interface module is connected via the DP (Drive) connection of the technology CPU, and it provides the necessary interfaces for the output of an analog setpoint value to the hydraulic valve, and for reading the encoder signal of the hydraulic axis or the hydraulic cylinder.

Figure 2-3 Interfaces of IM174 for the activation of the hydraulic axes



3 Functional Mechanisms

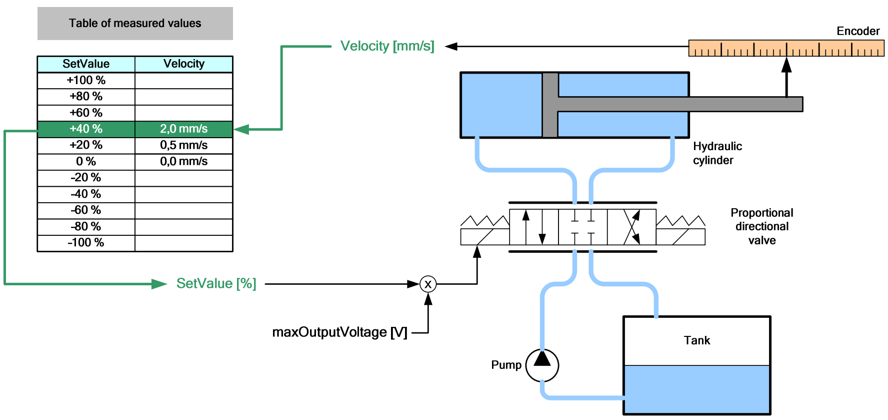
3.1 Measuring principle

The measuring principle of the technology template follows the recommendations of the manual on the S7 Technology (/5/) “Configuring Hydraulic Axes” for the determination of a valve characteristic as compensation characteristic of a hydraulic axis.

The valve of a hydraulic axis is activated via the output of an analog setpoint value. The resulting flow at the valve causes the hydraulic cylinder of the hydraulic axis to move. The velocity of this movement is determined via the encoder of the hydraulic axis and saved to the technology CPU.

This operation is automatically performed for several setpoint values. Thus, system control derives an allocation between the setpoint output and the resulting velocity of the hydraulic cylinder. Based on these measured values, the compensation characteristic of the hydraulic axis can be determined.

Figure 3-1 Measuring principle



3.2 Creating the compensation characteristic

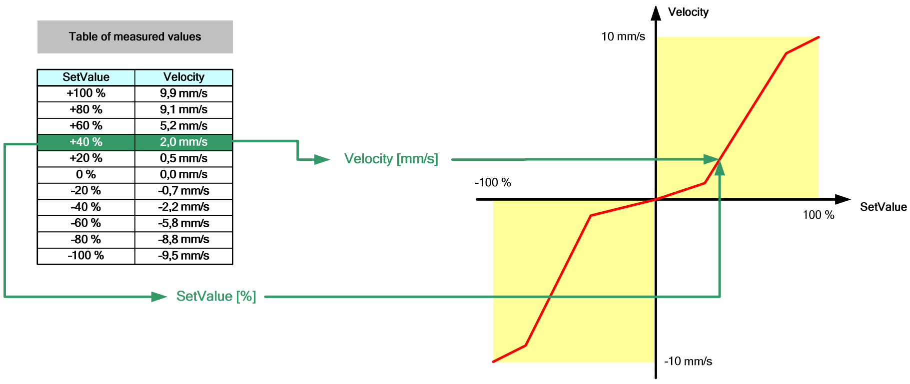
After all measured values have been determined for the output setpoint values, the compensation characteristic of the hydraulic axis can be identified by means of the specified table of measured values.

The compensation characteristic is stored in the technology CPU as technology object “cam disk”. The percentage setpoint value of the valve activation serves as input parameter of the cam disk and the resulting velocity of the hydraulic axis for the specified valve activation is allocated as output parameter.

Note

For the automatic determination of the characteristic, the creation and activation of the compensation characteristic is performed by the technology template without any further user intervention at the end of measurement.

Figure 3-2 Creating the compensation characteristic



3.3 Procedure for automatic measurement

3.3.1 Principle procedure

The complete automatic measurement of the compensation characteristic of a hydraulic axis is achieved via the output of specified setpoint values and the measurement of the resulting velocity of the hydraulic axis.

For this purpose, the output setpoint values are spread over the whole range of the actuating variable, which usually ranges from -100% to +100% or – in terms of voltage output – from -10V to +10V. The hydraulic axis is automatically repositioned to the start point of the measurement between the individual measurements.

3.3.2 Use of a reference characteristic

Since the compensation characteristic is not yet established before measuring the hydraulic axis, a reference characteristic is used for defining the output of the voltage values.

The technology template creates and activates a linear characteristic (straight line) as reference characteristic, which allows a direct allocation of the setpoint values to the voltage values.

Here is an example of the allocated voltage values:

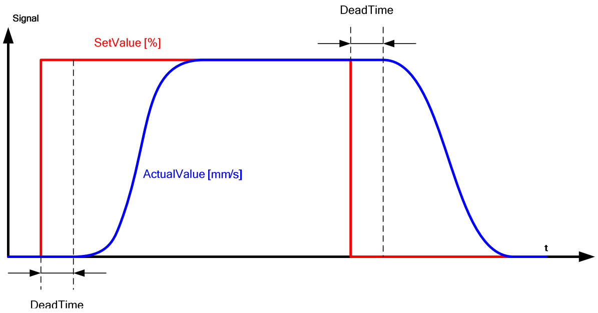
- 100% ⇨ 10.0V
- -100% ⇨ -10.0V
- 20% ⇨ 2.0V
- ...

3.3.3 Dead time determination of the hydraulic axis

Generally, a hydraulic axis is affected by a dead time period. It is defined as the time period that expires between the output of a setpoint value and the resulting movement of the axis.

In order to determine the velocities of the hydraulic axis correctly, the technology template performs a dead time determination before starting the measurements, which is taken into consideration when taking the measurements.

Figure 3-3 Dead time between the setpoint output and the movement of the hydraulic axis

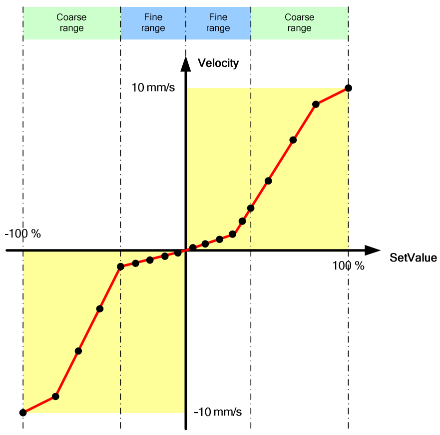


3.3.4 Increasing the accuracy in determining the characteristic

Two ranges for the measurement are defined in order to increase the accuracy when measuring the compensation characteristic:

- In the **fine range**, the characteristic has a small slope, wherefore the reaction of the hydraulic axis to changes in setpoint values are expected to be low. For this reason, the measurements are taken with a finer spacing of setpoint values in this area. The fine range should be limited by the setpoint value that induces a significant reaction of the hydraulic axis.
- In contrast, you can detect significant reactions of the hydraulic axis to the specified setpoint values in the **coarse range**. For this reason, a larger spacing of the setpoint values is allowed for measurement in this area.

Figure 3-4 Increasing the accuracy of the compensation characteristic



3.3.5 Measuring process of the technology template

This technology template performs the following steps for automatic measurement of the compensation characteristic of a hydraulic axis.

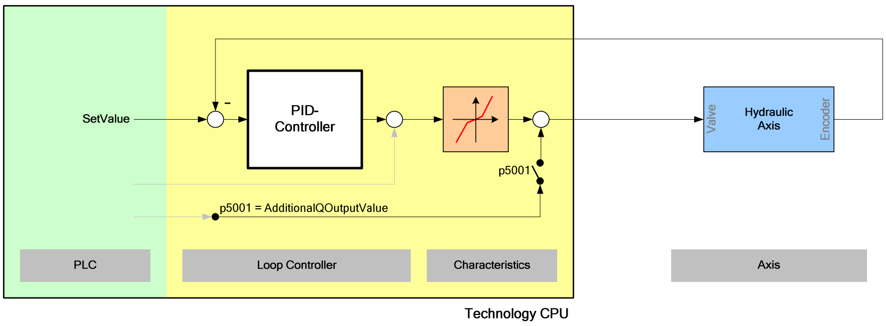
Table 3-1 Measuring operation of the technology template

No.	Step	Note
1.	Initialization of function block FB 520 “GetCharacteristics” of the technology template.	In this process, the linear characteristic is activated as reference characteristic and the technology object of the hydraulic axis is set to open-loop mode.
2.	Dead time determination of the hydraulic axis	Via the output of a setpoint step, the response time of the hydraulic axis up to the detection of a movement is measured by the CPU.
3.	Measurement of the compensation characteristic in the positive setpoint range of the hydraulic axis.	For each measurement, a defined setpoint value is output and – after the dead time and settling time have elapsed – the induced velocity of the axis is measured. After completion of each measurement, the axis is repositioned to the start position.
4.	Measurement of the compensation characteristic in the negative setpoint range of the hydraulic axis.	
5.	Writing and activating the measured compensation characteristic.	The compensation characteristic determined by means of the measurement is created and activated in the controller of the hydraulic axis.

3.4 Integrating the compensation characteristic

In the technology CPU, the compensation characteristic is integrated into the control loop directly after the controller and prior to the output of the setpoint value to the hydraulic axis.

Figure 3-5 Integration of the compensation characteristic into the control loop



Via compensation characteristic, the linear behavior of the controller is, in the technology CPU, adapted to the non-linear behavior of the hydraulic axis.

4 Configuration and Settings

4.1 Required technology objects

In order to operate the technology template, the following technology objects must be created in the technology CPU, be configured via S7T Config, and be interconnected.

- At least one hydraulic axis to be measured.
- At least two cam disks which are used in the measurement as compensation characteristic “CamProfile” and as reference characteristic “CamReference”.

Note

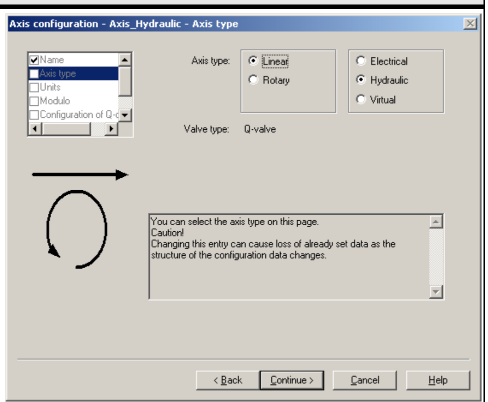
By reason of the operating principle, the technology template can only be used in connection with a hydraulic axis.

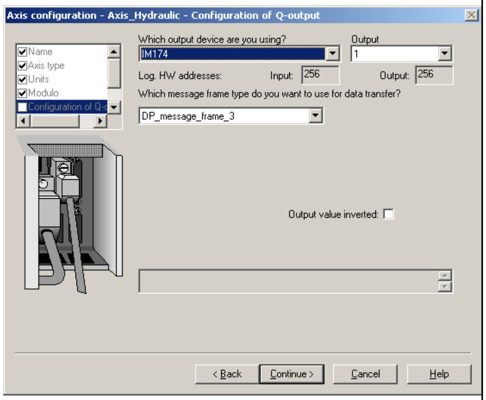
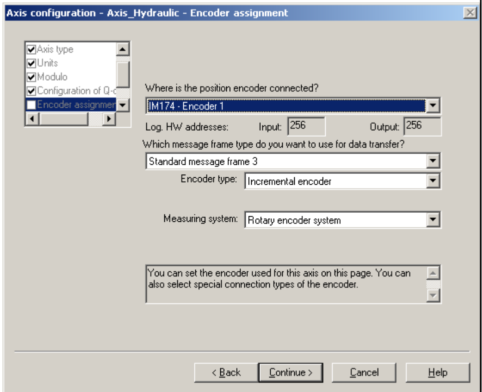
For using the template as demo system the example project of the technology templates is intended, which already contains all of the required axes, cam disks and parameterization to be able to test FB 520 “GetCharacteristics” on a technology CPU and an IM174.
However, since a linear correlation between setpoint and actual value of the virtual hydraulic axis applies for this parameterization, the characteristic curve determined by the technology template can only be a straight line.

4.2 Creating a hydraulic axis

Create a hydraulic axis in S7T-Config as before. In this documentation, only the points of interest relevant for creating the hydraulic axis shall be described.

Table 4-1 Points of interest relevant for the creation of a hydraulic axis

Characteristic feature	Note
Selection of axis type: Select “hydraulic” as axis type in the axis configuration wizard. **Note:** It is not possible to use the technology template in connection with a virtual axis because of axis control!	

Characteristic feature	Note
Configuration of setpoint output: Assign the setpoint output for the hydraulic axis to the appropriate module. In the hardware configuration for this documentation, the setpoint output is implemented via the IM174 interface module.	
Configuration of the actual value input: Assign the encoder signal of the hydraulic axis to the appropriate input module. In the hardware configuration for this documentation, the feedback of the encoder signal is implemented via the IM174 interface module as well.	

4.3 Creating the cam disks

Create two cam disks in S7T-Config. The first cam disk, “CamReference”, represents the reference cam disk for the automatic measurement of the compensation characteristic. The second cam disk, “CamProfile”, will contain the compensation characteristic determined in the automatic measurement and will be integrated into the control loop of the technology CPU.

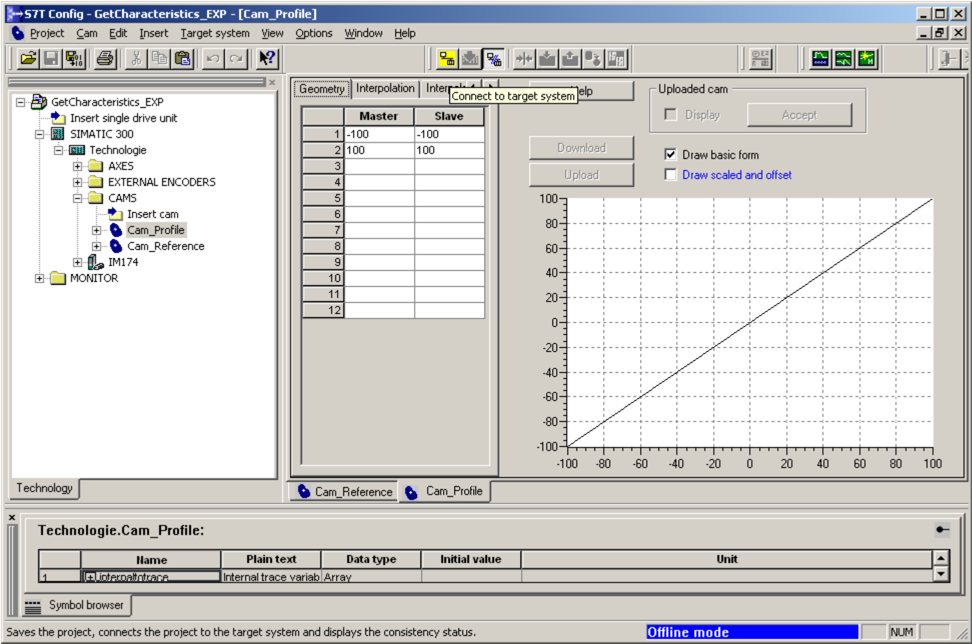
4.3.1 Creating the cam disks as “interpolation point table”

When creating the cam disk, select the “interpolation point table” and enter a straight line with the following interpolation points into the interpolation point table:

Table 4-2 Interpolation points for creating the straight line in the cam disks

No. / point	Master	Slave
1	-100	-100
2	100	100

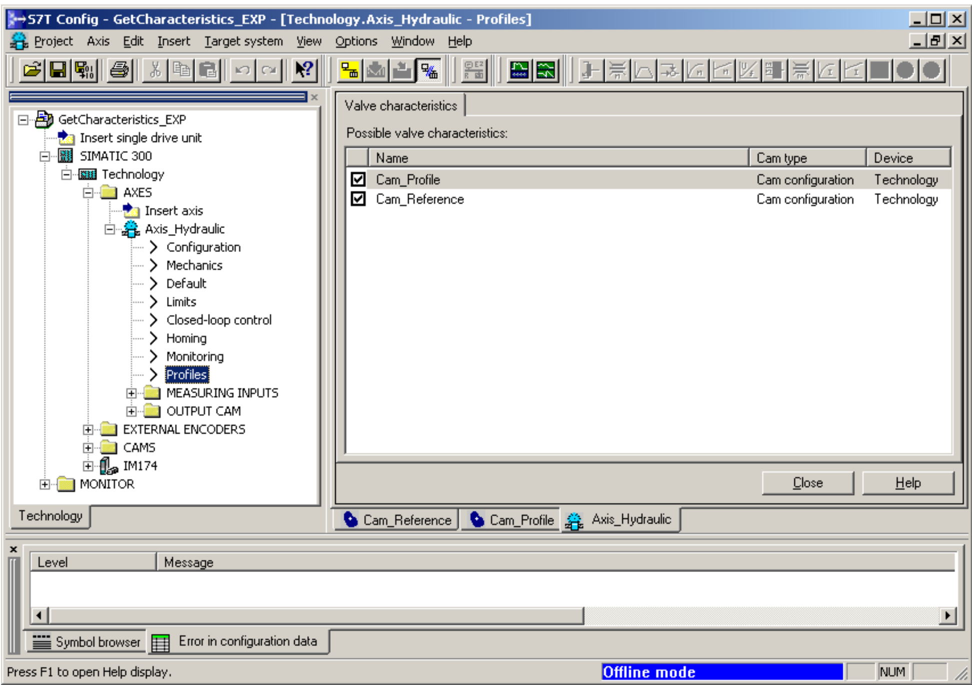
Figure 4-1 Creating the required cam disks as interpolation point table



4.3.2 Defining the cam disks as hydraulics characteristic

Define either of the two created cam disks as possible compensation characteristic of the created hydraulic axis.

Figure 4-2 Defining the cam disks as compensation characteristic



4.4 Creating the technology objects

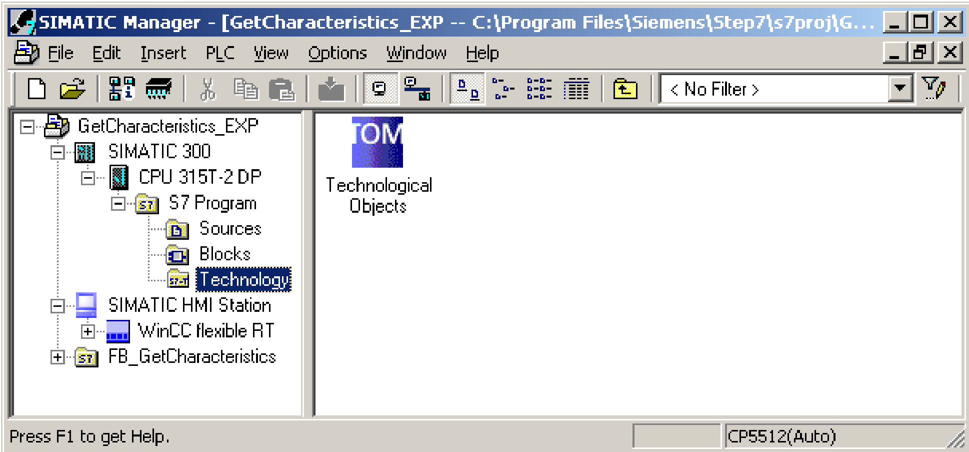
4.4.1 Save and compile the parameterization

After entering all the required settings in S7T-Config, save and compile the specified parameterization and close the S7T-Config software.

4.4.2 Creating the technology data blocks

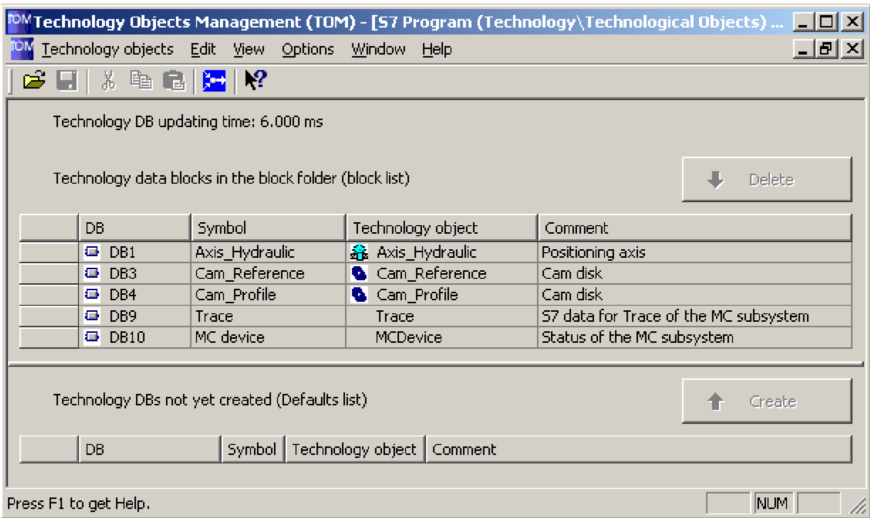
Open the Technology Objects Management via a double-click on the Technological Objects icon.

Figure 4-3 Open the Technology Objects Management



Check the suggested numbers of the technology data blocks and create the technology data blocks of the technology objects contained in the technology objects management by selecting the required objects and applying the "Create" button.

Figure 4-4 Creating the data blocks of the technology objects



5 Installation

5.1 Requirements

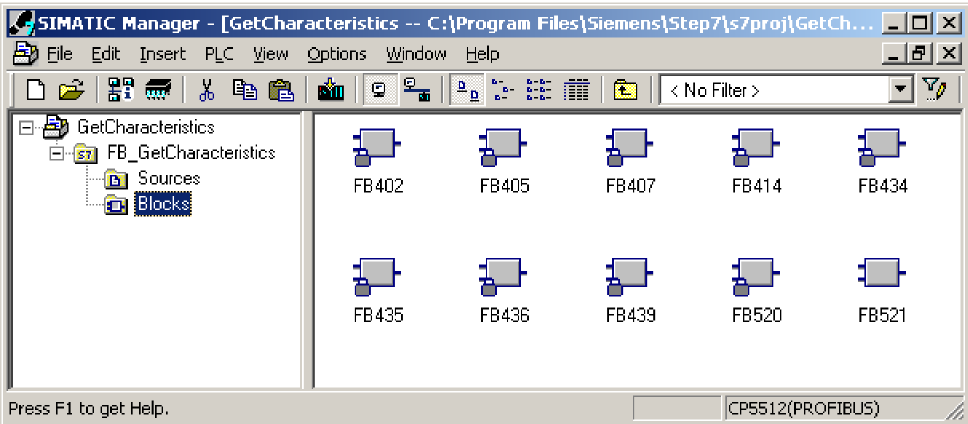
In order to use the technology template, the required technology objects, such as axes and cam disks, must have been created in the technology CPU via S7T Config.

Furthermore, the cam disks must have been assigned to the hydraulic axis as a possible compensation characteristic.

5.2 Retrieving the technology template

The technology template is delivered as STEP 7 archive. To be able to use the technology template, this archive first has to be retrieved using STEP 7.

Figure 5-1 Blocks of the technology template



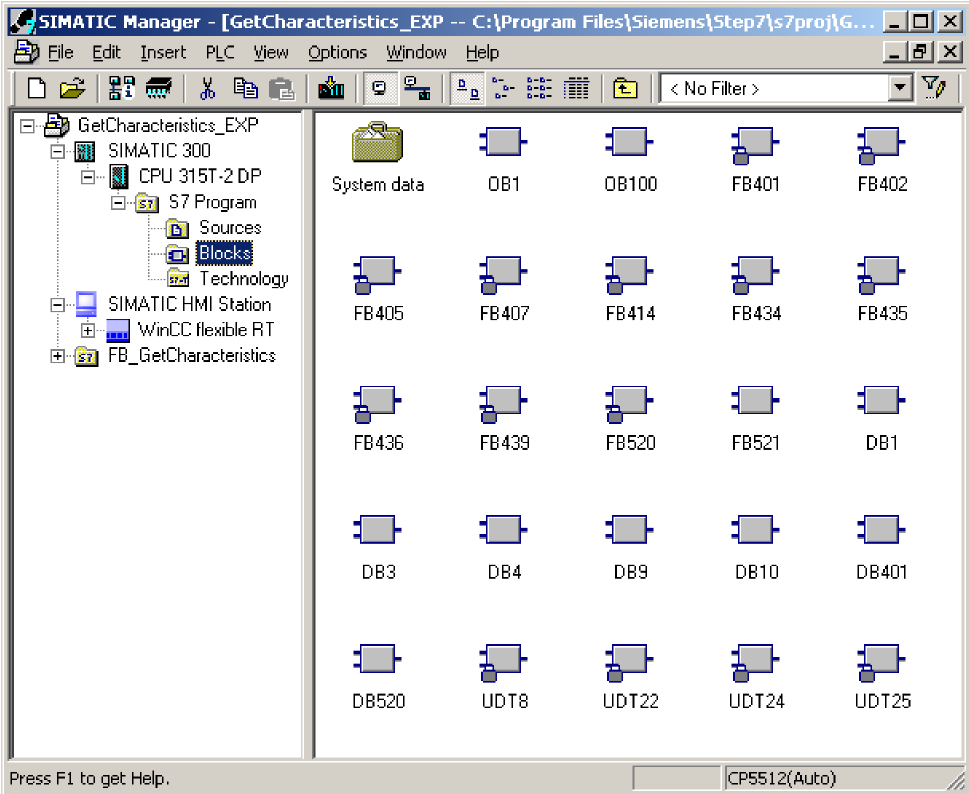
5.3 Integration into your application

5.3.1 Use of the technology template as commissioning tool

The example project of the technology template is particularly suited for the use of the technology template as commissioning tool. The example project represents an independent STEP7 project equipped with an HMI user interface via which all functions of the technology template can be operated and monitored.

Note If you want to use the example project of the technology template as a commissioning tool, adapt the preset PROFIBUS addresses to the conditions of your system and adjust the provided technology objects.

Figure 5-2 Example project of the technology template



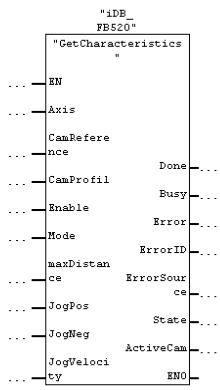
5.3.2 Permanent use of the technology template within an application

For permanent use of the technology template within your self-developed application, you should copy the complete S7 program folder **“FB_GetCharacteristics”** to the root directory of your project after extracting the STEP 7 archive to apply the required function blocks from there.

5.4 Calling FB 520 “GetCharacteristics”

5.4.1 Call function block in IL (Instruction List) and FBD (Function Block Diagram)

Table 5-1 Call of the function block of the technology template

<table>
<tr><th></th><th>STL</th><th>FBD</th></tr>
<tr><td>FB 520 “GetCharacteristics”</td><td><pre>CALL "GetCharacteristics" , "iDB_FB520"
 Axis   :=
 CamReference:=
 CamProfil   :=
 Enable   :=
 Mode   :=
 maxDistance :=
 JogPos   :=
 JogNeg   :=
 JogVelocity :=
 Done   :=
 Busy   :=
 Error   :=
 ErrorID   :=
 ErrorSource :=
 State   :=
 ActiveCam   :=</pre></td><td>
</td></tr>
</table>

The **FB 520 “GetCharacteristics”** block of the technology template can easily be called up in the application program of your STEP 7 project. The call has to be performed in a cyclically starting OB or FB block. Processing control by a timer interrupt (e.g. in OB 35) is not required, but possible.

5.4.2 Assigning the instance data blocks

The measured values for determining the compensation characteristic of a hydraulic axis are stored in the instance data block of **FB 520 “GetCharacteristics”**. After successful measurement, the measured values are copied to the cam disk defined at the “CamProfile” input.

- **Using the technology template as commissioning tool:**
  If the technology template is used as commissioning tool, you can define a separate “CamProfile” cam disk at the block input for each hydraulic axis to be measured, where the measured compensation characteristic will be copied to. After the compensation characteristic has been created, the measured values can be discarded or overwritten by the next measurement. In this application case, the allocation of one instance data block for a one-time call of function block FB 520 “GetCharacteristics” is sufficient.
- **Permanent use of the template in the user program:**
  If the technology template is to be used permanently within an application program, the use the technology template for creating the compensation characteristic at each start of the CPU is generally prevalent. For this purpose, the measured values for the creating the compensation characteristic must be provided in the data block. For this reason, a separate instance data block has to be created for each hydraulic axis for which the compensation characteristic is to be created at the start of the CPU so that there is a separate call of function block FB 520 “GetCharacteristics” block in the application program in each case.

5.5 Testing the functions of the technology template

A hydraulic axis and two cam disks have already been created in the example project for operating the technology template.

For testing the functions of the technology template the interface module IM174 is configured so that the technology template can be tested without connected hydraulic axes, only using a technology CPU and an IM174.

The IM174 is here configured as follows in order to simulate a connected hydraulic axis:

- The “Stepper” type has been selected as the “Drive Type”.
- The “Stepper” type has also been selected as the “Encoder Type”, which causes a direct feedback of the setpoint as the actual value. This creates a linear correlation between setpoint and actual value at the simulated “hydraulic axis”.

Note

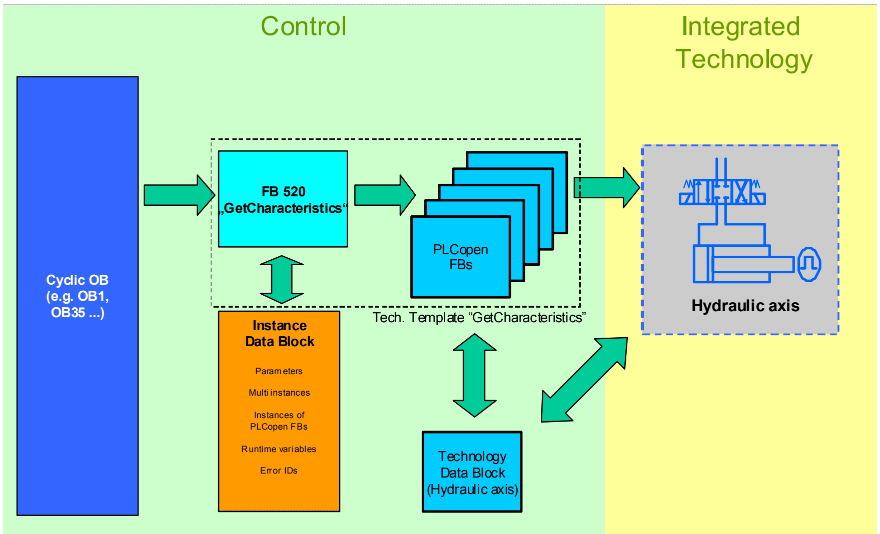
Due to the simulation of the hydraulic axis in IM174 the measured characteristic becomes a straight line.

6 Commissioning

6.1 Call environment

The **FB 520 “GetCharacteristics”** block of the technology template has to be called cyclically in the application program. For this purpose, the call can be performed directly in an OB block or within a cyclically processed FB block.

Figure 6-1 Call environment of the technology template



The technology object controlled by the FB 520 “GetCharacteristics” block is not allowed to be controlled by another part of the application program while FB 520 “GetCharacteristics” is active.

6.2 Interfaces

6.2.1 Structure of the interface

The interface of FB 520 “GetCharacteristics“ for controlling and configuring the functions of the technology template is divided into the following sections:

- **Block interface:**
  Input and output variables of FB 520 “GetCharacteristics”. In this section, the parameters for direct control of the desired function of the block are transmitted.
- **Expert parameters in the instance data block:**
  There is a special area of the instance data block of the FB 520 “GetCharacteristics” function block, where some parameters that control the algorithms used in the block can be changed. These parameters are preset and usually do not have to be changed by the user.

6.2.2 Block interface

In order to control the automatic measurement of the compensation characteristic of a hydraulic axis via **FB 520 "GetCharacteristics"**, the block is provided with the following interfaces:

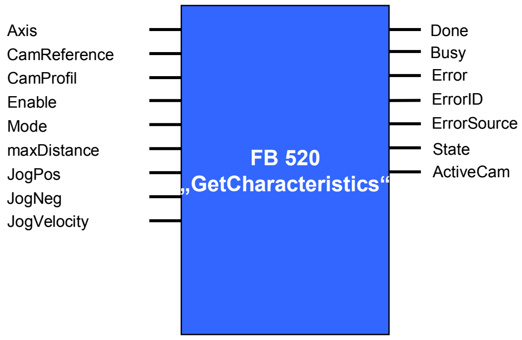


Table **6**-1 Block interfaces of FB 520 "GetCharacteristics"

Parameter	Data type	Initial value	Description
Input parameters			
Axis	INT	0	Number of the hydraulic axis to be automatically analyzed.
CamReference	INT	0	Number of the cam disk in which the reference characteristic is defined.
CamProfil	INT	0	Number of the cam disk in which the cam disk of the determined compensation characteristic is stored.
Enable	BOOL	False	The function selected via the mode input is started by a positive edge at this input. During an automatic analysis of a hydraulic axis, the measurement can be aborted by resetting the value at this input.
Mode	INT	0	Number of the operating mode that is started via the "Enable" input.
maxDistance	REAL	0.0	Maximum traversing distance of the cylinder from the start position, which is defined by the current position of the cylinder. The "maxDistance" variable determines the measuring range in positive direction from the start position. (see below)

Parameter	Data type	Initial value	Description
JogPos	BOOL	False	Manual positioning of the cylinder in positive direction.
JogNeg	BOOL	False	Manual positioning of the cylinder in negative direction.
JogVelocity	REAL	25.0	Percentage value of the maximum actuating variable for manual control of the cylinder in Jog mode.
Output parameters			
Done	BOOL	False	The block has finished processing. The steps of the selected operating mode have been successfully executed.
Busy	BOOL	False	The block is busy processing.
Error	BOOL	False	An error has occurred while processing the block. Further information on the localization of the error cause is provided via the ErrorID and ErrorSource outputs.
ErrorID	WORD	0	Error code of the block or of a technology function that has been called internally. In addition, it is possible to locate the error within the block via the ErrorSource output.
ErrorSource	WORD	0	Specification of an additional error code for localizing the error cause within the block.
State	INT	0	Output of the current operating state of the block (finite state machine)
ActiveCam	INT	0	Output of the cam disk currently used as compensation characteristic.

Note The automatic measurement of the compensation characteristic of the hydraulic axis can be terminated via the Enable input of the FB 520 “GetCharacteristics” block. However, the expiration of the dead time until a complete axis standstill is reached has to be taken into consideration when halting the hydraulic axis.

6.2.3 Expert parameters in the instance data block

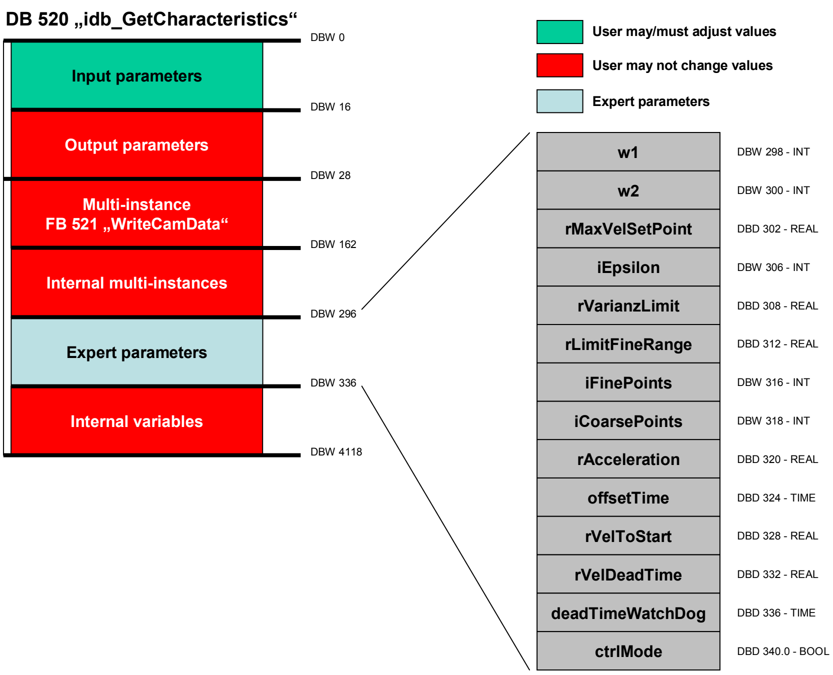
If required, it is possible to change the expert parameters for the direct control of the measuring algorithm via the instance data block of FB 520 “GetCharacteristics”.

Note

> The accuracy of the automatic determination of the compensation characteristic of a hydraulic axis depends on the settings of the expert parameters.
>
> The parameters are preset and usually they do not have to be changed. Before changing the expert parameters, you should be familiar with the function of these parameters.

The expert parameters are recorded in the instance data block of FB 520, starting from data word **DBW 298**.

Figure 6-2 Structure of the instance data block



The expert parameters for direct control of the measuring algorithm have the following function:

Table **6**-2: Expert parameter in the instance data block

Parameter	Data type	Initial value	Description
w1	INT	20	Window length for average value determination in the fine range and for dead time determination
w2	INT	30	Window length for average value determination in the coarse range
rMaxVelSetPoint	REAL	100	Maximum actuating setpoint for the measurement in percent.
iEpsilon	INT	1	Percentage threshold for acceptance of velocity in the

Parameter	Data type	Initial value	Description
			coarse area (stationary status of velocity)
rVarianzLimit	REAL	10.0	Variance limit for the detection of the axis movement during dead time determination
rLimitFineRange	REAL	20.0	Position for switch-over between fine range and coarse range during measurement.
iFinePoints	INT	20	Number of interpolation points for the measurement in the fine area.
iCoarsePoints	INT	20	Number of interpolation points for the measurement in the coarse area.
rAcceleration	REAL	500.0	Acceleration of the hydraulic axis in mm/s².
offsetTime	TIME	T#1000ms	Time offset for implementing the measurement, to which the dead time is added to form the measurement time (MeasureTime).
rVelToStart	REAL	30.0	Velocity in mm/s for moving the cylinder to the respective start position of the measurement.
rVelDeadTime	REAL	35.0	Velocity in mm/s used as setpoint output for dead time determination.
deadTimeWatchDog	TIME	T#5s	Monitoring time for the implementation of dead time determination.
ctrlMode	BOOL	TRUE	Defining the control mode of the axis after successfully performing a measurement of the compensation characteristic: FALSE : speed-controlled TRUE: position-controlled

6.2.4 Considering the geometric proportions of the hydraulic cylinder

The selection of the “start position” of the measurement and the setting of the “maxDistance” parameter serves for adjusting the measurement process to the geometric conditions of the hydraulic cylinder.

Starting position

The position of the axis where the hydraulic axis is located at the start of measurement (Enable = True) is used as **start position** for the measurement.

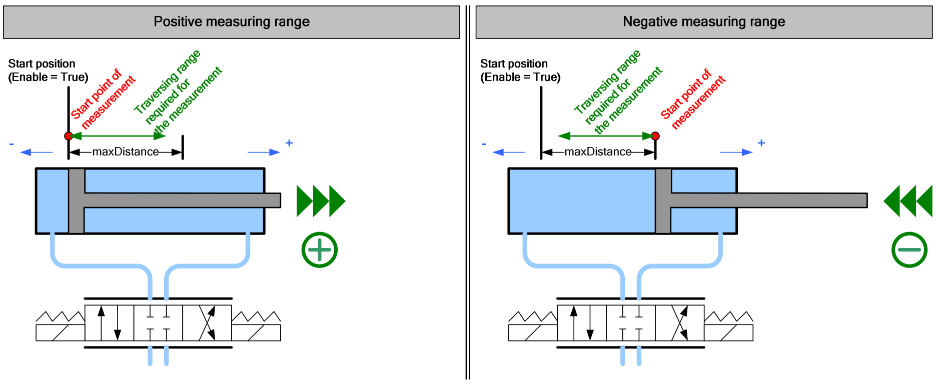
In order to select a suitable start position, you can move the hydraulic axis manually to the desired position via the **“JogPos”** and **“JogNeg”** inputs before starting the technology template. When selecting the start position, please take into account that the movements of the hydraulic cylinder will take place in positive direction from the start position during the measurement. You have to allow for a sufficient traversing range of the hydraulic cylinder in this area.

maxDistance

The “maxDistance” parameter implies two distinct specifications for the automatic measurement of the compensation characteristic by the technology template.

- For monitoring the movements of the hydraulic cylinder, the parameter defines the maximum admissible traversing range of the cylinder. Set the “maxDistance” parameter to a value that is a little greater than the traversing range of the cylinder required for the measurement.
- For the specification of the start point of the measurement in the negative measuring range, the parameter defines with reference to the start position the point to which the cylinder is positioned for the measurement in the negative range. In this case, the movements of the cylinder during the measurement will take place in negative direction.

Figure 6-3 Selection of the start position and setting of the “maxDistance” parameter



6.3 Warning messages and error messages

6.3.1 Indication of error events

If warnings or errors occur in the technology template, they are indicated at the block interface as follows:

- **“Error” output:**
  This output is set in the event of an error. The error cause can be read at the “ErrorID” and “ErrorSource” outputs.
- **“ErrorID” output:**
  Output of the error code associated with the error event or of a warning code.
- **“ErrorSource” output:**
  More detailed specification of the error code indicated at the “ErrorID” output for an easy localization of the cause of error.

Assignment of the error codes at the ErrorID output

The codes indicated at the “ErrorID” output can be assigned as follows:

- **Code 002x$_{HEX}$:**
  Warning message of a technology function that has been called in the technology template.

- **Code 008x$_{HEX}$:**
  Warning message of the FB 520 “GetCharacteristics” block which does not result from the use of a technology function.
- **Code 8xxx$_{HEX}$:**
  Error message of a technology function that has been called in the technology template.
- **Code 92xx$_{HEX}$:**
  Error message of the FB 520 “GetCharacteristics” block which does not result from the use of a technology function.

Assignment of the error codes at the ErrorSource output

Error messages with an ErrorSource code from 0001 to 0004 are caused within the FB 521 “WriteCamData” block.

All other error causes refer to the FB 520 “GetCharacteristics” block.

6.3.2 Warning and error codes at the “ErrorID” output

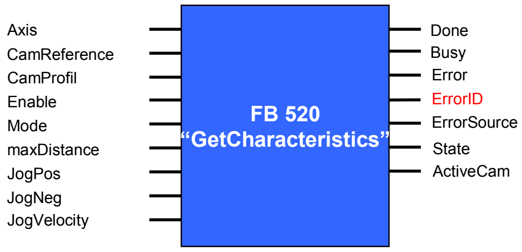


Table 6-3 Error codes at the “ErrorID” output

ErrorID [HEX]	Meaning	Note
0000	No error	
0080	Positive measuring range: The measuring range defined by the **maxDistance** parameter has been exceeded. The measurement is continued in the negative measuring range. Negative measuring range: The positioning during the measurement process has fallen short of the **start position** of the measurement. The measurement is concluded.	Set the **maxDistance** parameter in a way that the positioning of the cylinder required for the measurement can be effected within the specified measuring range.
0081	The measurement has been aborted by the user. Abortion in the positive coarse range: The measurement can be continued in the negative measuring range via Mode=1. Abortion in the negative measuring range: The measurement can be concluded by writing the cam disk via Mode=1.	If reasonable, remove the reason for aborting the measurement and repeat the measurement or continue or conclude the measurement via Mode=1.
0082	Manual positioning of the axis (JOG) only possible with Enable=False.	Reset the **Enable** input.

ErrorID [HEX]	Meaning	Note
9201	No axis number or invalid axis number specified.	Set the **Axis** parameter to a value > 0.
9202	No number or an invalid number has been specified for cam disk **CamReference** or **CamProfile**.	Set the **CamReference** and **CamProfile** parameters to a value > 0.
9203	Invalid mode selected	Set the **Mode** parameter to a value ranging from 0 to 5.
9204	Specification of maximum measuring range **maxDistance** too small.	Set the **maxDistance** parameter to a value > 0.
9205	No velocity or an invalid velocity has been specified for the JOG mode via **JogVelocity**.	The velocity in JOG mode must fulfill: 0 < **JogVelocity** ≤ 100
9206	Faulty parameterization of the expert parameter **rMaxVelSetPoint** for the maximum setpoint value of the measurement.	The maximum setpoint value must fulfill: 0 < **rMaxVelSetPoint** ≤ 100
9207	Faulty parameterization of the expert parameter **rVelToStart** for the axis velocity of start point positioning.	The velocity of start point positioning must fulfill: 0.0 < **rVelToStart** ≤ rMaxVelSetPoint
9208	Faulty parameterization of the expert parameter **rVelDeadTime** for the axis velocity of dead time determination.	The axis velocity of dead time determination must fulfill: 0.0 < **rVelDeadTime** ≤ rMaxVelSetPoint
9209	Faulty parameterization of expert parameter **w1** or **w2** for the window length of measuring value determination.	The window length must fulfill: 0 < **w1** ≤ 100 0 < **w2** ≤ 100
920A	The measurement has been aborted by the user in the positive fine range. The measurement cannot be continued in Mode=1.	If reasonable, adjust the parameterization and restart the measurement in **Mode=0**.
920B	The measured values stored in the instance data block of FB 520 have not been recorded for the cam disk with the number that is currently set via **CamProfile**. The cam disk cannot be written in **Mode=3**.	Set the **CamProfile** parameter to the correct cam disk number. The number must correspond to the **iDBNumber** in the instance data block.
920C	In the instance data block of FB 520 there are no measured values for writing the cam disk in **Mode=3**.	Perform a measurement in **Mode=0**.
920D	Time period for dead time determination exceeded.	Check enabling of valve and the axis movement or adjust the expert parameters in a suitable way: Increase **rVelDeadTime** or decrease **rVarianzLimit**.
920E	There have been too many measuring points parameterized in the fine and coarse range via the expert parameters **iFinePoints** and **iCoarsePoints**	The parameter sum must fulfill: Sum ≤ 100.

6.3.3 Warning and error codes at the “ErrorSource” output

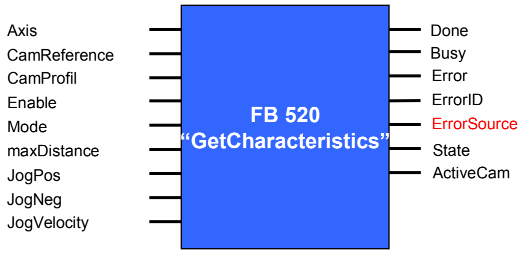


Table 6-4, Error codes at the “ErrorSource” output

Error Source [HEX]	Meaning	Note
0000	No error	
FB 521 “WriteCamData”		
0001	General error in writing the cam disk from the measuring values of the compensation characteristic.	
0002	Error in resetting the cam disk. The selected cam disk depends on the mode selection at FB 520.	FB 434 “MC_CamClear”
0003	Error in adding cam disk sectors. The selected cam disk depends on the mode selection at FB 520.	FB 435 “MC_CamSectorAdd”
0004	Error in interpolating the newly created cam disk. The selected cam disk depends on the mode selection at FB 520.	FB 436 “MC_CamInterpolate”
FB 520 “GetCharacteristics”		
0005	Error in activating the cam disk as compensation characteristic of the hydraulic axis. The selected cam disk depends on the mode selection at FB 520.	FB 439 “MC_SetCharacteristics”
0006	Error in the setpoint output for the hydraulic axis or in switchover from position-controlled mode to speed-controlled (open-loop) mode of the hydraulic axis.	FB 414 “MC_MoveVelocity”
0007	Error in halting the hydraulic axis by resetting the output setpoint value.	FB 405 “MC_Halt”
0008	Error in activating the superimposition of the actuating variable for the hydraulic axis in JOG mode via parameters p5000 or p5001.	FB 407 “MC_WriteParameter”
0009	Error in performing a reset of the hydraulic axis for confirmation of any pending errors.	FB 402 “MC_Reset”
FFFF	General error in the FB 520 “GetCharacteristics” block	

7 Operation

7.1 Operating modes of the technology template

7.1.1 Mode 0: Automatic measurement of the compensation characteristic

Via this mode, the compensation characteristic of a hydraulic axis is automatically determined.

The cam disk that is parameterized at the input of the “CamReference” block is preset wit a linear behavior (straight line) and then activated. The measurement of the compensation characteristic is performed. On completion of this operation, the determined compensation characteristic is created in the cam disk that is parameterized at the “CamProfile” input and this cam disk is activated as compensation characteristic.

7.1.2 Mode 1: Continue aborted measurement in the negative area

Via this mode, a measurement in mode 0 that has been aborted in the positive actuating range can be continued and completed in the negative actuating range.

An abortion of measurement can be necessary if there are vibrations of the hydraulic axis outside the desired traversing range.

If the measurement has subsequently to be aborted in the negative actuation range as well, you can perform a new call of the block in mode 1 to write the determined characteristic into the cam disk that is parameterized at the “CamProfile” input and then activate it.

Note The automatic measurement of the compensation characteristic of the hydraulic axis can be terminated via the Enable input of the FB 520 “GetCharacteristics” block.

7.1.3 Mode 2: Check determined compensation characteristic

Via this mode, the determined compensation characteristic can be checked for correctness. For this purpose, the measurement of mode 0 is performed with the compensation characteristic that is parameterized and activated at the “CamProfile” input. The characteristic measured in this process is saved to the cam disk that is parameterized at the “CamReference” input.

If the automatic measurement of the characteristic was successful, a linear graph (straight line) is stored in the reference characteristic after the check.

7.1.4 Mode 3: Create and activate the compensation characteristic anew

Via this mode, the compensation characteristic can be created and activated anew using measured values of an already determined compensation characteristic that are stored in the instance data block of FB 520 “GetCharacteristics”.

For instance, the measured values can be taken in a measurement during commissioning and then remanently stored in the instance data block of the technology template. In this case, the compensation characteristic can be created and activated anew from these data at each start of the CPU.

7.1.5 Mode 4: Activate reference cam disk

Via this mode, the reference characteristic that is parameterized at the "CamReference" input can be manually activated as compensation characteristic.

7.1.6 Mode 5: Activate compensation characteristic

Via this mode, the compensation characteristic parameterized at block input "CamProfile" can be manually activated as compensation characteristic.

7.1.7 Mode 6: Switch axis to speed-controlled mode

The hydraulic axis can be manually switched to speed-controlled mode via this mode.

In speed-controlled mode, a fixed setpoint value is output to the hydraulic axis which might cause a possible drift of the axis.

Note Via expert parameter "ctrlMode", and after completing an automatic measurement of the compensation characteristic, the hydraulic axis can be switched to speed-controlled or position-controlled mode.

7.1.8 Mode 7: Switch axis to position-controlled mode

The hydraulic axis can be manually switched to position-controlled mode via this mode.

In position-controlled mode, there is a controlled setpoint output to the hydraulic axis, which keeps the axis in position and avoids a drift of the axis. The precise position control of a hydraulic axis, however, is only possible by means of an exactly determined compensation characteristic in the control loop.

Note Via expert parameter "ctrlMode", and after completing an automatic measurement of the compensation characteristic, the hydraulic axis can be switched to speed-controlled or position-controlled mode.

7.2 Test of the technology template

For testing the technology template without connecting real axes it is recommended to use the example project for the technology template. Operating the technology template in this case only requires a technology CPU and the IM174 interface module.

For testing the technology template, load all parameterizations and Step7 blocks contained in the example project into the CPU without any modifications. Interface module IM174 of the example project has been parameterized so that testing the technology template is possible without real axes.

If necessary, only adjust the Profibus addresses in HW Config to the settings on your modules.

Note To operate the example project without real axes on the technology CPU and the IM174 interface module, which enables performing a complete analysis of the characteristic, we recommend setting the MaxDistance parameter of the technology template to value 1000.000.

The linear correlation between setpoint and actual value of the virtual axis yields a straight line as the measured characteristic.

Operating the HMI user interface for the test is described in chapter 7.4.

7.3 Use as commissioning tool

The example project for the technology template, which already contains all the blocks and the HMI user interface, is also suited to be used as commissioning tool. Enter your real existing hydraulic axis into the parameterization of the IM174 interface module. If necessary, adjust the addresses to the conditions of your system.

Note In contrast to the actual technology template, the enabling function for the hydraulic axis via technology function block FB 401 “MC_Power” is already contained in the example project.

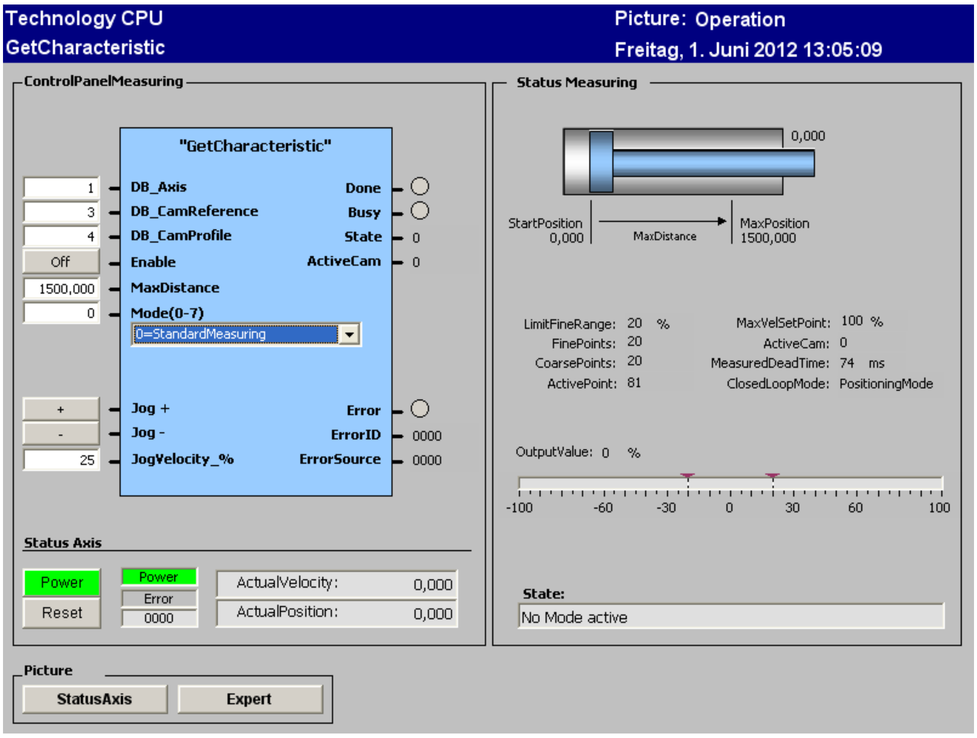
Operating the HMI user interface for using the technology template as commissioning tool is described in chapter 7.4.

7.4 Operating the HMI user interface

7.4.1 Automatic measurement of the compensation characteristic

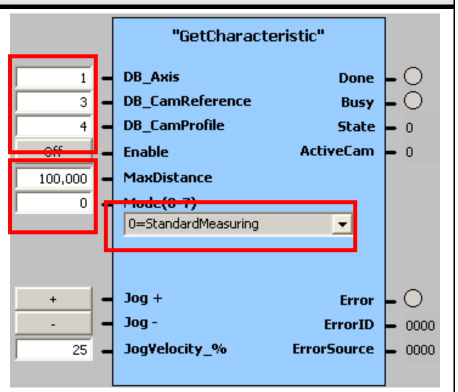
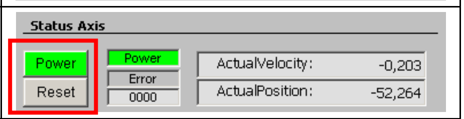
You can perform the automatic measurement of the compensation characteristic of a hydraulic axis via the “Operation” screen.

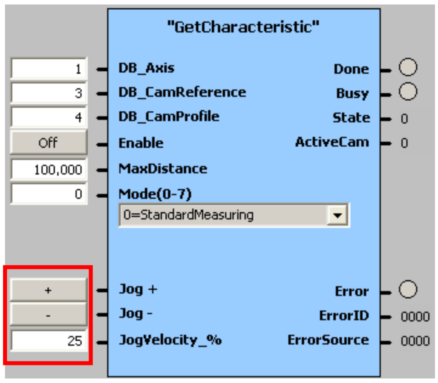
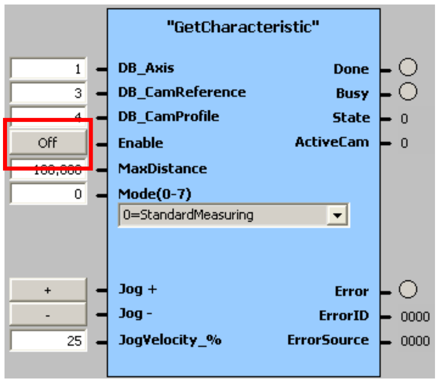
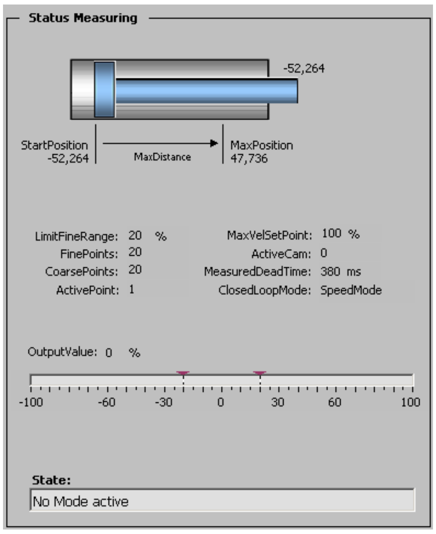
Figure 7-1 HMI screen for controlling the technology template



For performing the automatic measurement via the HMI user interface, proceed as follows:

Table 7-1 Performing an automatic measurement

No.	Action	Note
1.	Set the parameters of FB 520 “GetCharacteristics”. Specify the numbers of the desired **Axis** and of the **Cam disks**. Select the desired **Mode** and specify the maximum **Distance** for the measurement.	
2.	Enable the axis via the **Power** button and acknowledge any occurring errors via the **Reset** button.	

No.	Action	Note
3.	Move the hydraulic axis to the start position of the measurement by means of the **Jog+/Jog- direction keys**. Select a suitable **Velocity** for the manual positioning of the hydraulic axis, which is specified as percentage value based on the maximum actuating variable for the hydraulic valve.	
4.	Start the operation of the selected mode via the **Off** button at the Enable input of the block. **Note:** You should select mode 0, or mode 1 or 2 for the automatic measurement.	
5.	Monitor the measuring process via the status display.	

Note

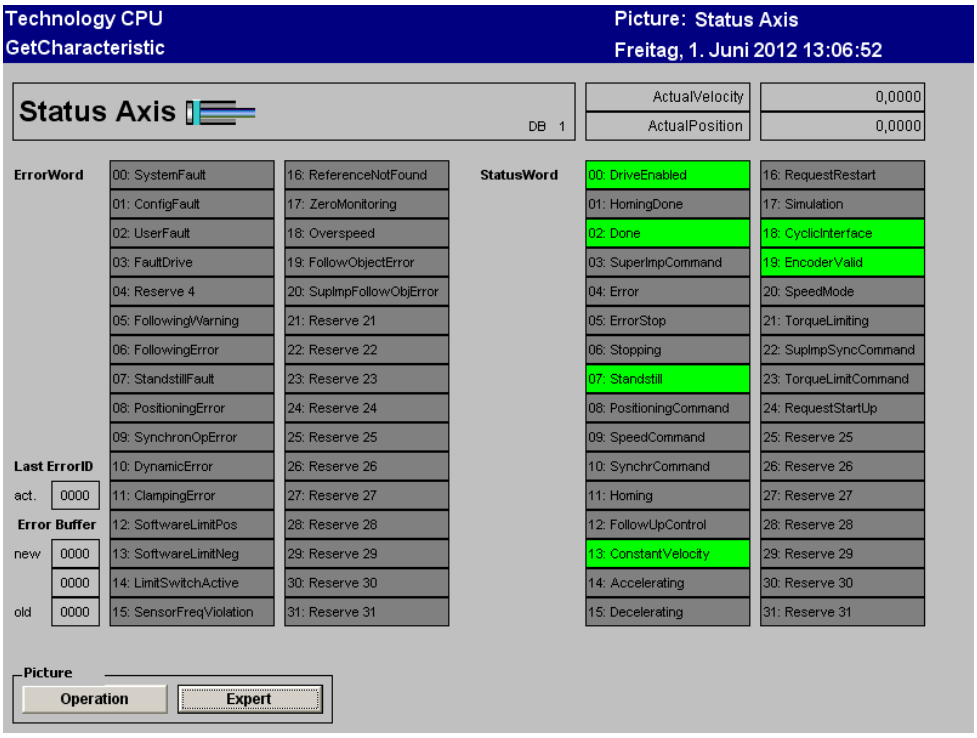
After the technology CPU is restarted and the hydraulic axis is enabled via the “Power” button, the axis might be in “closed-loop” mode. Thus, any occurring drift might trigger the standstill monitoring of the axis.

A one-time start of the measuring process, or executing mode 6, sets the status of the axis to open-loop mode (speed-controlled mode). In this mode, the standstill monitoring is no longer performed for the axis.

7.4.2 Check the axis status of the hydraulic axis

The current status of the hydraulic axis can be checked via the “Status axis” screen.

Figure 7-2 Display of the axis status



The status of the technology data block of the hydraulic axis is displayed in this screen. You can monitor any error conditions via the “ErrorWord” and the current axis status via the “StatusWord” of the axis. In addition to this, the screen displays the content of the error buffer of the last occurring error messages and the current position and speed of the axis.

7.4.3 Check and set the expert parameters

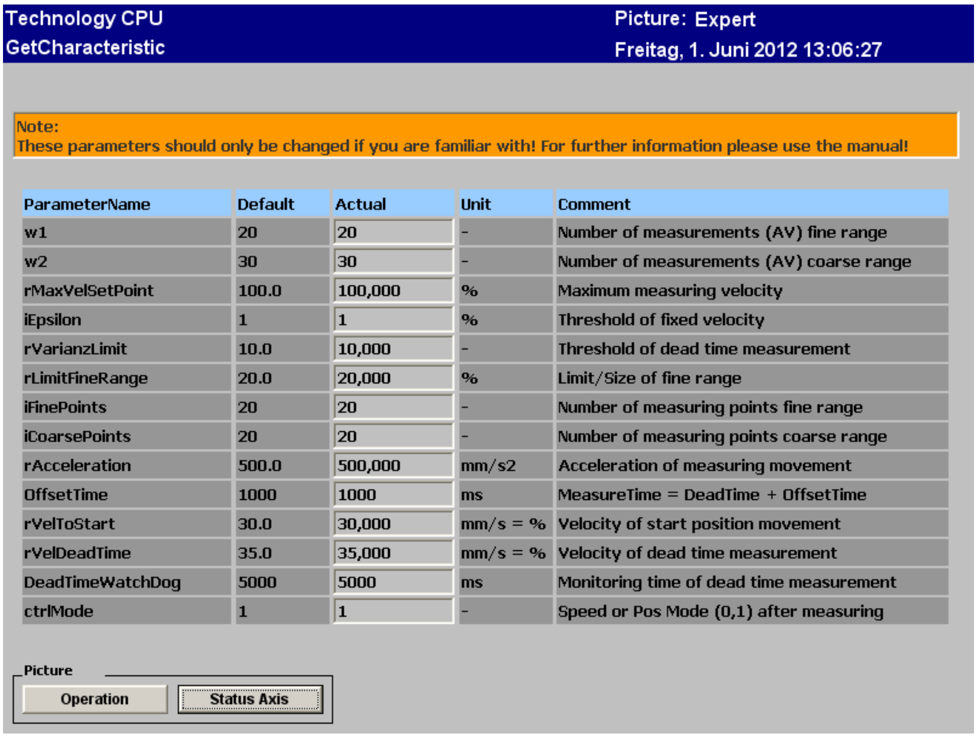
The settings of the expert parameters can be checked and changed via the “Expert” screen.

You can find a detailed description of the expert parameters in chapter 8.2 of this documentation.

Note

The parameters are preset and usually they do not have to be changed. Before changing the expert parameters, you should be familiar with the function of these parameters.

Figure 7-3 Overview of the expert parameters



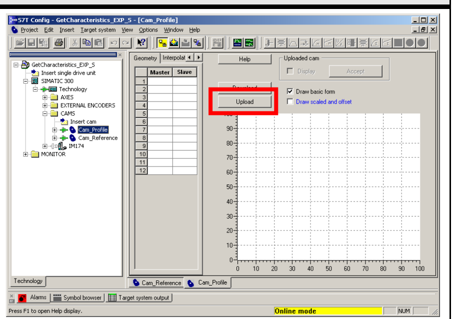
ParameterName	Default	Actual	Unit	Comment
w1	20	20	-	Number of measurements (AV) fine range
w2	30	30	-	Number of measurements (AV) coarse range
rMaxVelSetPoint	100.0	100,000	%	Maximum measuring velocity
iEpsilon	1	1	%	Threshold of fixed velocity
rVarianzLimit	10.0	10,000	-	Threshold of dead time measurement
rLimitFineRange	20.0	20,000	%	Limit/Size of fine range
iFinePoints	20	20	-	Number of measuring points fine range
iCoarsePoints	20	20	-	Number of measuring points coarse range
rAcceleration	500.0	500,000	mm/s2	Acceleration of measuring movement
OffsetTime	1000	1000	ms	MeasureTime = DeadTime + OffsetTime
rVelToStart	30.0	30,000	mm/s = %	Velocity of start position movement
rVelDeadTime	35.0	35,000	mm/s = %	Velocity of dead time measurement
DeadTimeWatchDog	5000	5000	ms	Monitoring time of dead time measurement
ctrlMode	1	1	-	Speed or Pos Mode (0,1) after measuring

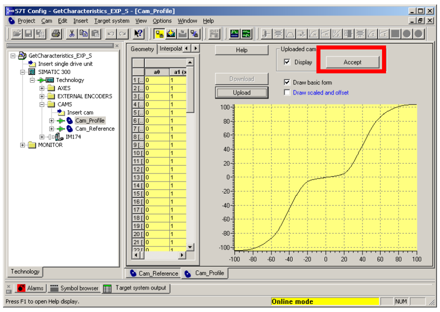
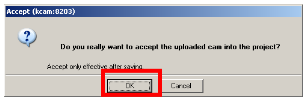
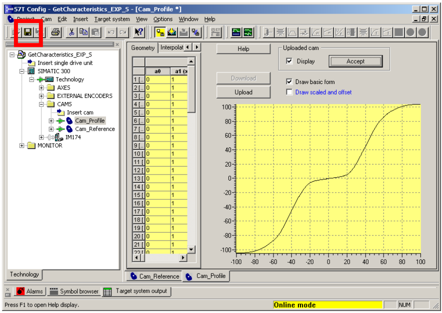
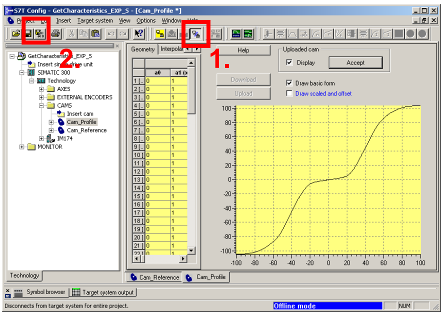
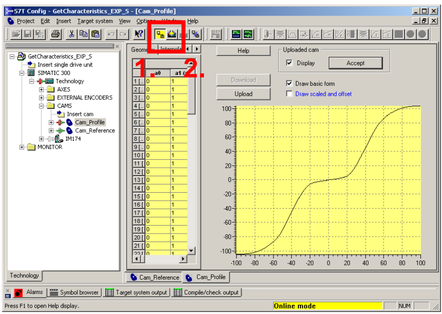
7.5 Adopting the measured characteristic in STEP 7

After the automatic measurement of the compensation characteristic of a hydraulic axis has been performed, the compensation characteristic is stored as cam disk in the main memory of the technology CPU. If you want to store the characteristic permanently as cam disk together with the STEP 7 project, it has to be read from the technology CPU to the programming device.

In order to store the measured compensation characteristic of a hydraulic axis as cam disk in a STEP 7 project, proceed as follows:

Table 7-2 Application of the characteristic/cam disk in the STEP 7 project

No.	Action	Note
1.	Open S7T Config, select the cam disk in which the compensation characteristic is contained and establish an online connection. Load the cam disk from the target device to the PG via the **Upload** button.	

No.	Action	Note
2.	Apply the cam disk loaded from the target device to your STEP 7 project via the **Accept** button.	
3.	Acknowledge the confirmation prompt via the **OK** button.	
4.	**Save** all changes in your STEP 7 project.	
5.	**Disconnect** the online connection to the target device and apply the cam disk to the offline project via **Save & Compile**.	
6.	Setup the **online connection** to the target device anew and **load** the project to the target device.	

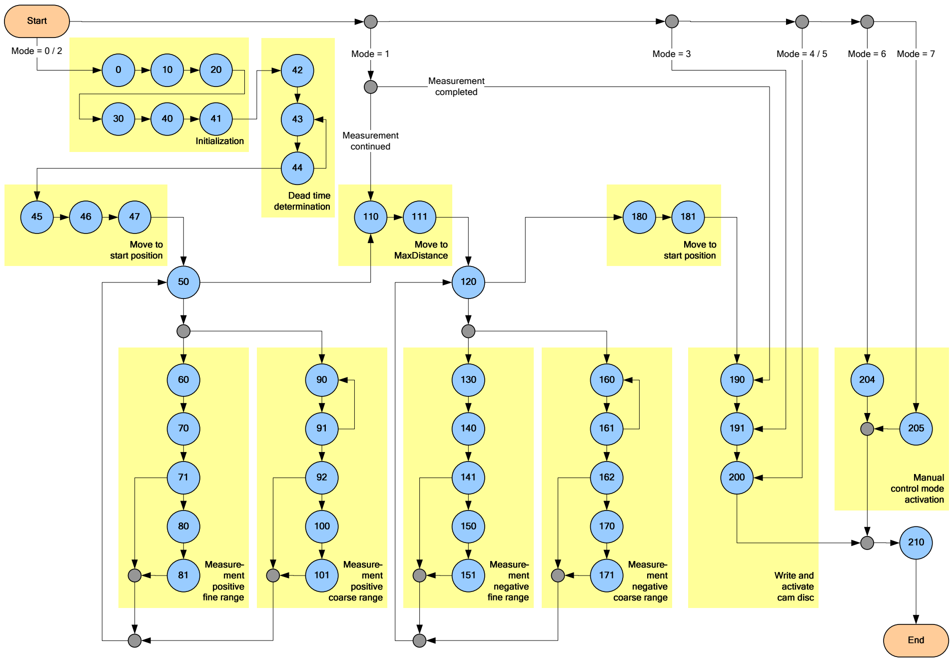
Note Not until the cam disk of the compensation characteristic is reloaded, it is permanently available in the load memory of the technology CPU so that it can be used at the next start of the CPU again.

8 Program Description

8.1 Describing the block statuses

In this chapter, the individual operating states of the FB 520 “GetCharacteristics” block shall be explained in detail. The current state of the block can be determined via the “State” output of the block.

Figure 8-1 Finite state machine of the FB 520 “GetCharacteristics” block



The individual states of the FB 520 “GetCharacteristics” block have the following function:

Table 8-1 Description of the states

State	Function	Active in mode							
Initialization									
0	Initialization of the block	0		2					
10	Acknowledgement of pending axis errors	0		2					
20	Activate CamProfile compensation characteristic in order to be able to set the CamReference reference characteristic	0		2					
30	Preset CamReference reference characteristic with linear characteristic (straight line)	0		2					
40	Activate CamReference reference characteristic as compensation characteristic for the measurement	0		2					
41	Acknowledgement of pending axis errors	0		2					

State	Function	Active in mode							
Dead time determination									
42	Output of the actuating variable for the hydraulic axis via the "MC_MoveVelocity" technology function	0		2					
43	Analysis of the resulting velocity of the hydraulic axis (calculation of moving average)	0		2					
44	Determination of the settled state of the resulting velocity (variance)	0		2					
Moving to start position (positive actuation range)									
45	Induce axis standstill taking account of the dead time and initiate the repositioning to start position.	0		2					
46	When the start position is reached, halt the axis via the "MC_Halt" technology function.	0		2					
47	Wait for expiration of the dead time for correct execution of the "MC_Halt" technology function.	0		2					
Measurement in the positive actuation range									
50	Management of the measurement in the positive actuation range. Distinction between positive fine range and coarse range.	0		2					
Measurement in the positive fine range									
60	Wait for the expiration of the measurement time (MeasureTime) that has been calculated in the dead time determination.	0		2					
70	Take measurements and calculate average value over window length w. Halt the axis via "MC_Halt" after completion of measurement.	0		2					
71	Wait for expiration of the dead time for correct execution of the "MC_Halt" technology function.	0		2					
80	Repositioning the axis to start position for taking the next measurement and halting the axis via "MC_Halt" when the start position is reached.	0		2					
81	Wait for expiration of the dead time for correct execution of the "MC_Halt" technology function.	0		2					
Measurement in the positive coarse range									
90	Take measurements with moving average determination.	0		2					
91	Analysis of the measured values for the detection of the settled state. When the settled state is reached, stop the axis via "MC_Halt".	0		2					
92	Wait for expiration of the dead time for correct execution of the "MC_Halt" technology function.	0		2					
100	Repositioning the axis to start position for taking the next measurement and halting the axis via "MC_Halt" when the start position is reached.	0		2					

State	Function	Active in mode							
101	Wait for expiration of the dead time for correct execution of the “MC_Halt” technology function.	0		2					
Moving to MaxDistance (negative actuation range)									
110	Initiate the positioning movement to maximum position (MaxPosition) and activate halt of axis when the maximum position is reached.	0	1	2					
111	Wait for expiration of the dead time for correct execution of the “MC_Halt” technology function.	0	1	2					
Measurement in the negative actuation range									
120	Management of the measurement in the negative actuation range. Distinction between negative fine range and coarse range.	0	1	2					
Measurement in the negative fine range									
130	Wait for the expiration of the measurement time (MeasureTime) that has been calculated in the dead time determination.	0	1	2					
140	Take measurements and calculate average value over window length w. Halt the axis via “MC_Halt” after completion of measurement.	0	1	2					
141	Wait for expiration of the dead time for correct execution of the “MC_Halt” technology function.	0	1	2					
150	Repositioning the axis to start position for taking the next measurement and halting the axis via “MC_Halt” when the start position is reached.	0	1	2					
151	Wait for expiration of the dead time for correct execution of the “MC_Halt” technology function.	0	1	2					
Measurement in the negative coarse range									
160	Take measurements with moving average determination.	0	1	2					
161	Analysis of the measured values for the detection of the settled state. When the settled state is reached, stop the axis via “MC_Halt”.	0	1	2					
162	Wait for expiration of the dead time for correct execution of the “MC_Halt” technology function.	0	1	2					
170	Repositioning the axis to start position for taking the next measurement and halting the axis via “MC_Halt” when the start position is reached.	0	1	2					
171	Wait for expiration of the dead time for correct execution of the “MC_Halt” technology function.	0	1	2					
Moving to start position (completion of measurement)									
180	Initiate the positioning movement to the start position (StartPosition) and activate halt of axis when the start position is reached.	0	1	2					

State	Function	Active in mode							
181	Wait for expiration of the dead time for correct execution of the “MC_Halt” technology function.	0	1	2					
Write and activate cam disk									
190	Determination of the maximum and minimum values of the measurements taken.	0	1	2					
191	Creating the cam disk from the measured values	0	1	2	3				
200	Activation of the cam disk as compensation characteristic in the controller of the hydraulic axis.	0	1	2	3	4	5		
Manual activation of the control mode									
204	Manual activation of the speed-controlled mode at the hydraulic axis via “MC_MoveVelocity”.							6	
205	Manual activation of the position-controlled mode at the hydraulic axis via “MC_MoveVelocity”.								7
Connecting the job processing									
210	Set the output variable of the block to display job processing.	0	1	2	3	4	5	6	7

8.2 Description of the expert parameters

If problems should arise in the automatic measurement of the compensation characteristic, it might be necessary to adjust the expert parameters of FB 520 “GetCharacteristics” in the instance data block.

Note

> The accuracy of the automatic determination of the compensation characteristic of a hydraulic axis depends on the settings of the expert parameters.
>
> The parameters are preset and usually they do not have to be changed. Before changing the expert parameters, you should be familiar with the function of these parameters.

8.2.1 Window length “w1”

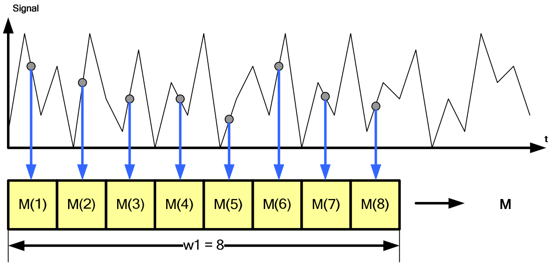
Presetting:	20 measurements

For measurement value determination in the fine range and for dead time determination of the hydraulic control system, the average value over the measured values is calculated in order to smooth out any distorted signals.

Window length “w1” defines the number of measured values used for the calculation of the average value.

For the setting of window length “w1”, the expected change of the measured values has to be considered. If too great a value is set for window length “w1”, rapid changes of measurement signals might be smoothed out too much by the average value determination so that they cannot be analyzed clearly.

Figure 8-2 Expert parameter – window length “w1”



Note

> Window length “w1” is valid for the fine range while window length “w2” is used for the coarse range. For a correct analysis of the hydraulic axis, the fine range has to be set in a way that only small changes of measurement signals take place in this range. Thus, the window length can be better adjusted to the measurement signals to be expected.

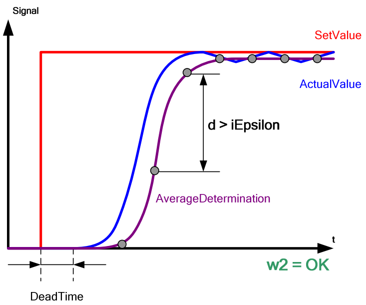
8.2.2 Window length “w2”

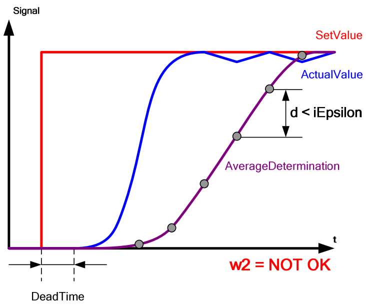
Presetting:	30 measurements

For measurement value determination in the coarse range, window length “w2” is used for average value calculation in order to smooth out any distorted signals.

In the coarse range, the end of an individual measurement is defined by the arrival at a stationary velocity, which is set via the expert parameter “iEpsilon”. If too great a value is set for window length "w2", the difference between the individual average values might be to low and the arrival at a stationary velocity is detected via “iEpsilon”. In this case, this measurement result would be distorted.

Figure 8-3 Expert parameter - window length “w2”





8.2.3 Maximum axis velocity “rMaxVelSetPoint”

Presetting:	100%

The maximum setpoint output for the measurement is determined via the “rMaxVelSetPoint” expert parameter

If the actuating variable exceeds the value set in this parameter, the measurement in this actuating range or the complete measuring process is terminated.

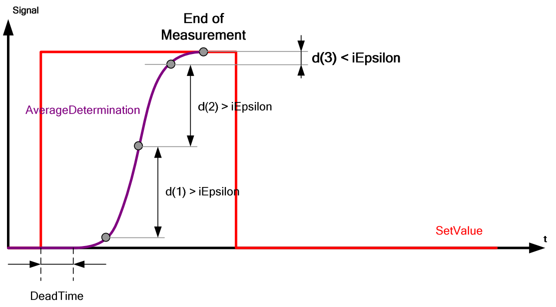
8.2.4 Decision threshold “iEpsilon”

Presetting:	1%

The decision threshold “iEpsilon” determines the change in percent of average values in the coarse range below which the velocity is considered to have settled to a stationary level and the individual measurement is finished.

For the setting of “iEpsilon”, you will have to take into consideration window length “w2” as well. The higher the value for window length “w2” is set, the more you should decrease the “iEpsilon” value.

Figure 8-4 Expert parameter - decision threshold “iEspilon“



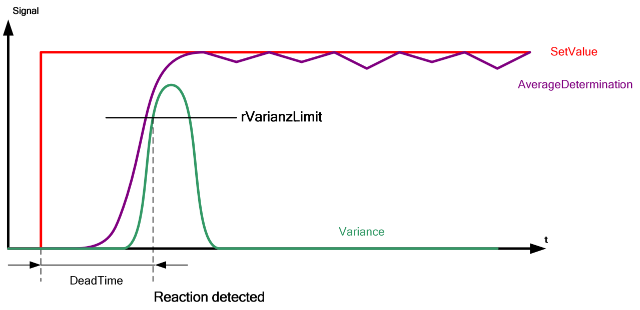
8.2.5 Decision threshold for the dead time determination “rVarianzLimit”

Presetting:	10

The variance of the average values is used for the determination of the dead time at the start of the automatic measurement of the hydraulic axis.

The response of the hydraulic axis to a setpoint step can be detected by the technology template via an increase of the variance. If the variance exceeds the threshold defined via “rVarianzLimit”, the response of the hydraulic axis to the setpoint step is detected and the dead time determined.

Figure 8-5 Expert parameter - decision threshold “rVarianzLimit“



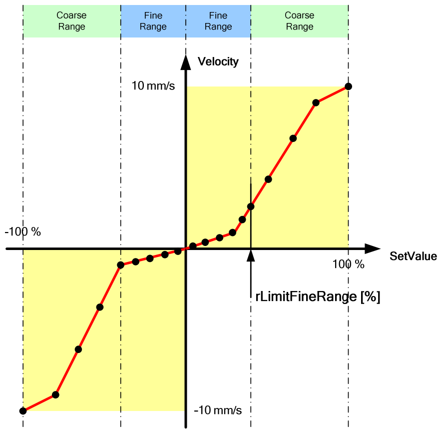
8.2.6 Limit between fine and coarse range "rLimitFineRange"

Presetting:	20%

The limit between fine and coarse range for measurement in the positive and negative measuring range is defined as percentage value via the expert parameter "rLimitFineRange".

In the fine and coarse range the measurement values are treated in a different way, wherefore these two ranges should be carefully and correctly separated when setting this parameter. Set the limit between fine and coarse range in a way as to ensure that you can already detect a significant movement of the hydraulic axis for the setpoint output defined via the "rLimitFineRange" parameter.

Figure 8-6 Expert parameter – limit coarse/fine range "rLimitFineRange"



Note

> For setting the "rLimitFineRange" parameter, the percentage value of the actuating variable for which a significant movement of the hydraulic axis is detectable can be empirically determined via the JOG function of the technology template.

8.2.7 Measuring points in the fine range "iFinePoints"

Presetting:	20 measuring points

The number of measuring points in the fine range is determined via "iFinePoints". The determined number of measuring points is available for both the positive and the negative measuring range and the measuring points are equidistantly spread over the respective measuring range.

A high number of measuring points increases the measuring accuracy but prolongs the time period required for the measuring cycle.

The number of measuring points in the fine range and coarse range must meet the following requirement:

$$iFinePoints + iCoarsePoints \leq 100$$

8.2.8 Measuring points in the coarse range “iCoarsePoints”

Presetting:	20 measuring points

The number of measuring points in the coarse range is determined via “iCoarsePoints”. The determined number of measuring points is available for both the positive and the negative measuring range and the measuring points are equidistantly spread over the respective measuring range.

A high number of measuring points increases the measuring accuracy but prolongs the time period required for the measuring cycle.

The number of measuring points in the fine range and coarse range must meet the following requirement:

$$iFinePoints + iCoarsePoints \leq 100$$

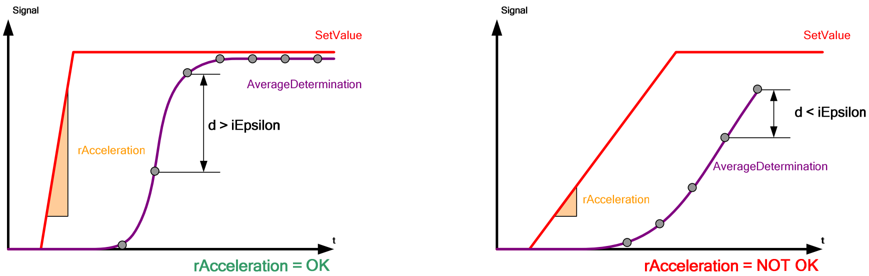
8.2.9 Acceleration “rAcceleration”

Presetting:	500 mm/s^2

The “rAcceleration” parameter defines the acceleration of the hydraulic axis. It is sent to the setpoint output for valve control via technology function block FB 414 “MC_MoveVelocity” and represents the increase of the setpoint signal.

When setting the acceleration – i.e. the slope of the setpoint signal – via “rAcceleration”, you will have to take into consideration the setting of expert parameter “iEpsilon” as well. The increase of the setpoint value per time should be set via the “rAcceleration” parameter that reaching the stationary velocity can still be certainly detected in the difference between average values evaluated via “iEpsilon”.

Figure 8-7 Expert parameter – acceleration “rAcceleration”



8.2.10 Measuring time offset “OffsetTime”

Presetting:	1000ms

The time period set in this parameter serves as an additional safeguard for correct measurement value determination and is added to the dead time measured by the block. The additional time period set in this parameter only affects the fine range of the measuring cycle.

The measurement time in the fine range is defined by:

$$MeasureTime = DeadTime + OffsetTime$$

Note	The higher the “OffsetTime” parameter is set, the more time is required for the measurement in the fine range.

8.2.11 Axis velocity for start point positioning “rVelToStart”

Presetting:	30mm/s = 30%

Used for the setting of the velocity of the hydraulic axis as percentage value of the actuating variable, which is used for the movement to start position in the positive measuring range and for the movement to “MaxPosition” and the repositioning to start position in the negative range.

The parameter can be set in the range 0…100% and should be determined in a way that the movement of the hydraulic axis to the desired positions can be performed within an acceptable time period.

The connection between set velocity and voltage output at the setpoint output is established via the reference characteristic during the measurement.

8.2.12 Axis velocity for dead time determination “rVelDeadTime”

Presetting:	35mm/s = 35%

Used for the setting in percent of the velocity or height of the setpoint step for the dead time determination.

The value of this parameter should be set in a higher actuating range so that a significant change of velocity can be detected for the hydraulic axis when the setpoint step is output. For this parameter, the setting of the expert parameter “rAcceleration”, which is responsible for the change of velocity - i.e. the slope of the setpoint step - has to be taken into consideration as well.

The parameter can be set in the range 0…100%.

8.2.13 Monitoring time for dead time determination “DeadTimeWatchDog”

Presetting:	5000ms

Monitoring time within which the block must conclude the dead time determination.

If the dead time cannot be determined within the period specified here, error message $920D_{Hex}$ is output. In this case, the following measures for solving this problem can be taken:

- Increase the setpoint step via “rVelDeadTime” parameter
- Increase “rAcceleration” parameter if the increase of the velocity for the setpoint step is set too low. If too low a value is set for the “rAcceleration” parameter, the increase per time of the setpoint value may be too slow for the response of the hydraulic axis to the setpoint output to be detected during dead time determination.
- Decrease the “rVarianzLimit” parameter if the limit for the detection of the response of the hydraulic axis to the setpoint step has been set too high.

8.2.14 Control mode of the axis after successful “ctrlMode” measurement

Presetting:	1

Presetting the control mode of the hydraulic axis after successfully performing a measurement and activating the determined compensation characteristic.

The parameter can be assigned with the following values:

- 0: speed-controlled operation
- 1: position-controlled operation

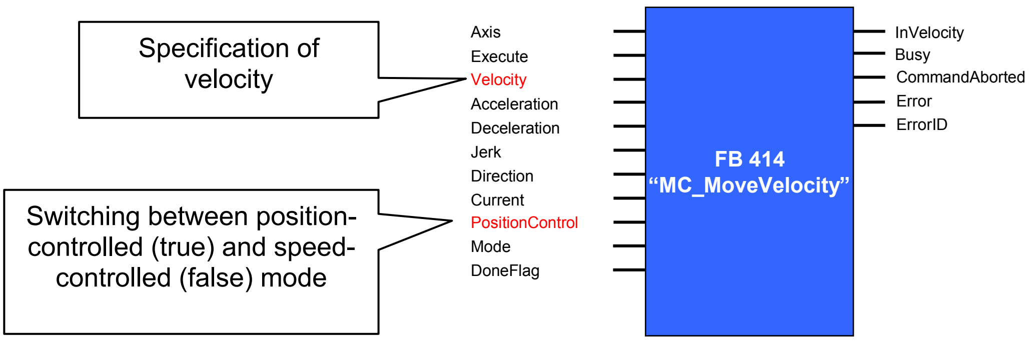
Note When selecting the speed-controlled operation, the hydraulic axis might produce drift, since in this operating mode a fixed setpoint is output to the axis and a possible drift cannot be compensated here.

9 Further Notes

9.1 Switching between speed control and position control

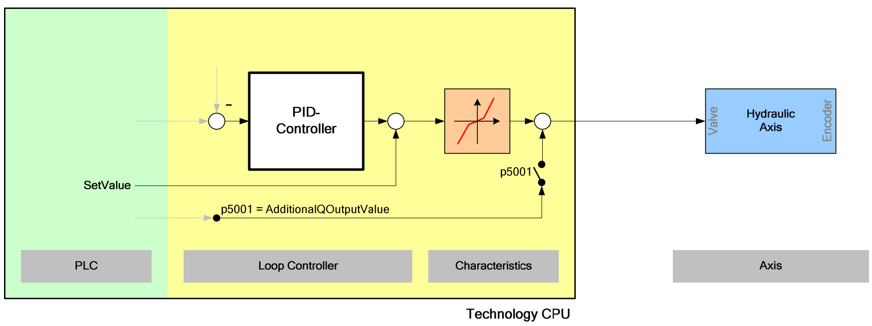
The technology object of the hydraulic axis can toggle between speed control and position control via technology function block FB 414 “MC_MoveVelocity”. For this purpose, you have to set the “PositionControl” input of the block to FALSE. To avoid the generation of any axis movements during the mode switch of the technology object, the block has to be called with Velocity = 0.0 in this case.

Figure 9-1 Selection of open-loop mode via FB 414 “MC_MoveVelocity”



If the technology object is set to open-loop mode, the setpoint specification takes place only behind the controller. However, the hydraulic axis is still controlled via the compensation characteristic. This means that closed-loop control is disabled.

Figure 9-2 Modification of the control loop in open-loop mode



Note The shown procedure of switching between speed control and position control could be used as background information. With the technology template you could manage the switching with mode 6 and mode 7 of the function block.

9.2 Setpoint limitation at the hydraulic axis

If a characteristic is allocated to the hydraulic axis while there are still no points created in the cam disk for the compensation characteristic, the setpoint output is permanently set to 0. In this case, error message 8020 “setpoint limitation active” is output at the technology data block.

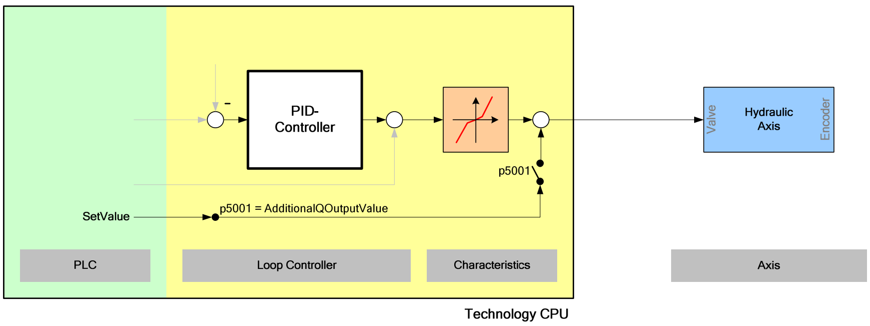
This problem can be solved by defining a linear characteristic (reference characteristic) for the direct transfer from the setpoint to an analog voltage output.

9.3 Direct output of a setpoint value

The direct output of a setpoint value for activating the hydraulic axis without applying the compensation characteristic can be performed by writing the p5000 parameter for superimposition of the actuation variable of the hydraulic axis.

The parameter is written by the technology template via technology function block FB 407 “MC_WriteParameter”.

Figure 9-3 Direct output of a voltage value



Note Before the superimposed output of the actuating variable for a hydraulic axis can be implemented via the p5000 parameter, the respective function must be activated via the p5001 parameter.

The direct output of a setpoint value is used in the technology template for positioning the hydraulic axis in JOG mode. This procedure has the advantage of a direct and defined output of a setpoint value even if no compensation characteristic has yet been activated.

10 Literature

10.1 Further literature

The following list is by no means complete and only provides a selection of appropriate sources.

Table 10-1 Bibliographic references

	Topic	Title
/1/	STEP 7	SIMATIC S7-300/400 Automatisieren mit STEP7 in AWL und SCL (Automating with STEP7 in STL and SCL) Author: Hans Berger Publicis MCD Verlag ISBN: 978-3-89578-397-5
/2/	STEP 7	SIMATIC – Programming with STEP 7 V5.4 Manual Edition 05 / 2010 Document ID: A5E02789665-01 Order number: 6ES7810-4CA10-8AW0 http://support.automation.siemens.com/WW/view/en/45531107
/3/	STEP 7	SIMATIC – System and standard functions for S7-300/400 Volume 1 and Volume 2 Reference manual Edition 05 / 2010 Document ID: A5E02789975-01 Order number: 6ES7810-4CA10-8AW1 http://support.automation.siemens.com/WW/view/en/44240604
/4/	Technology CPU	SIMATIC – S7-300 CPU 31xT Device Manual Issue 07/2010 Document ID: A5E01672598-02 http://support.automation.siemens.com/WW/view/en/21362915
/5/	Technology CPU	SIMATIC - Engineering Tools S7-Technology Function Manual Edition 10/2010 Document ID: A5E00251797-07 http://support.automation.siemens.com/WW/view/en/48353024
/6/	Technology CPU	SIMATIC – Dec. I/O PROFIBUS module IM 174 Device Manual Edition 09/2011 Document ID: A5E00859728-04 http://support.automation.siemens.com/WW/view/en/35014863

10.2 Internet links

The following list is by no means complete and only provides a selection of appropriate sources.

Table 10-2 Internet links

	Topic	Title
\1\	Reference to the document	http://support.automation.siemens.com/WW/view/en/27731588
\2\	Siemens Industry Online Support	http://support.automation.siemens.com
\3\	Technology Template	Technology CPUs: Tech. Template "Move_Jog" http://support.automation.siemens.com/WW/view/en/21365191 Technology CPUs: Tech. Template "flying shears" http://support.automation.siemens.com/WW/view/en/21062270 Technology CPUs: Tech. Template "cross cutter“ http://support.automation.siemens.com/WW/view/en/31073433 Technology CPUs: Tech. Template "Error Messages" http://support.automation.siemens.com/WW/view/en/21402122 Technology CPUs: Tech. Template "MotionList Basic“ http://support.automation.siemens.com/WW/view/en/59259273
\4\	Technology FAQ	How can I display a cam disc of the technology CPU on the HMI using WinCC flexible? http://support.automation.siemens.com/WW/view/en/26680228 How can a simple palletizer be realized with a technology CPU and FB 488 “MC_MovePath”? http://support.automation.siemens.com/WW/view/en/48206063 Which safety functions can be used with the interpolation at the fail-safe technology CPU? http://support.automation.siemens.com/WW/view/en/48205978 How can you create a cam during runtime that is based on line segments (interpolation point table) and that connects these segments by continuous transitions? http://support.automation.siemens.com/WW/view/en/35690077 Which versions of the S7 Technology option package are available and which SINAMICS S120 drive firmware can you use with which of these versions? http://support.automation.siemens.com/WW/view/en/31051715 Which options exist for reading hardware limit switch signals into a technology CPU? http://support.automation.siemens.com/WW/view/en/25545745 How can a SINAMICS "Active Line Modul" (ALM) be controlled via DP-Drive PROFIBUS? http://support.automation.siemens.com/WW/view/en/25543996 Which encoders can be used for the technology CPUs? http://support.automation.siemens.com/WW/view/en/25544321
\5\	Application & Tools	Technology CPUs: Parameterization of the “Gear Synchronization” Technology Function (SyncOp Guide) http://support.automation.siemens.com/WW/view/en/23577545 Technology CPUs: Flying shears with print-mark synchronization based on gear synchronism http://support.automation.siemens.com/WW/view/en/21063352 Technology CPU 317TF-2 DP: example for evaluation of the safety functions used in an application. http://support.automation.siemens.com/WW/view/en/47393794 Technology CPUs: "Kinematics Simulation Center" - Connecting the Simulation Software to a Technology CPU Interface http://support.automation.siemens.com/WW/view/en/58260820

11 History

Table 11-1

Version	Date	Revisions
V1.0	11/2008	First issue
V2.0	05/2012	Layout adjustment of the documentation. Integrating the functional expansion of the technology template into the documentation.