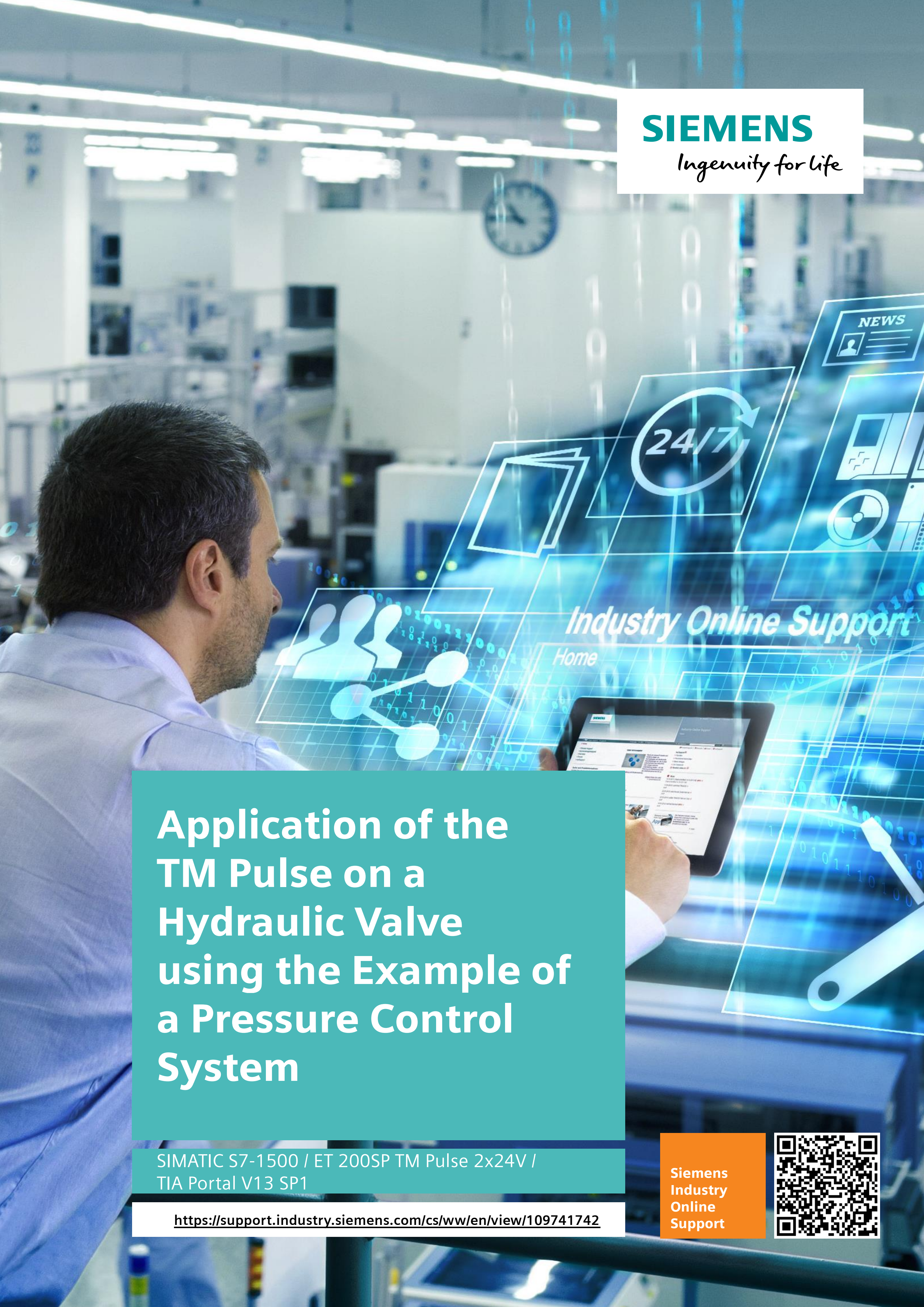

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Application of the TM Pulse on a Hydraulic Valve using the Example of a Pressure Control System

SIMATIC S7-1500 / ET 200SP TM Pulse 2x24V / TIA Portal V13 SP1

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1 Introduction

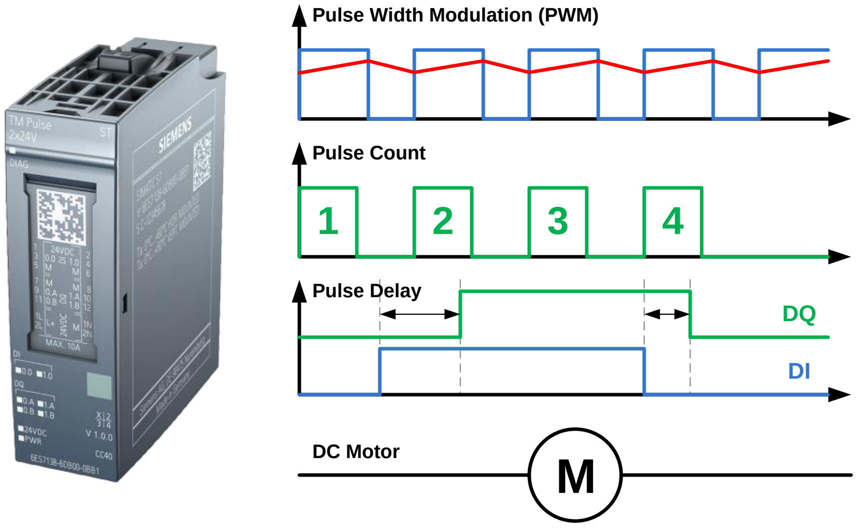
1.1 Overview

The TM Pulse 2x24V technology module provides the option to output pulses with a signal voltage of 24 Volt up to a rated current of 2 Ampere (two-channel) or 4 Ampere (single-channel). The signal pattern to be output can be flexibly adjusted, for example, to very precisely control switching valves, proportional valves, DC motors or other actuators. The maximum output frequency of the signal pulses is 100 kHz.

The TM Pulse 2x24V technology module offers a number of operating modes that provide different signal patterns:

- Pulse-width modulation
- Pulse chain or individual pulse
- On/off delay
- Direct current motor (brush type)

Figure 1-1 TM Pulse 2x24V technology module



The module has 2 channels that can be configured and controlled independent from each other. Each channel has a digital output (DQ) and a digital input (DI). The output can output frequencies of up to 100kHz. From 10 kHz to 100 kHz a current of maximum 100 mA is permitted. Up to 10kHz currents up to 2A can be output. Furthermore, the two channels can be combined into a single channel to output an output current of up to 4A at frequencies up to 10kHz. The input can be used as release signal of the pulse output.

Setting the basic function and the essential parameters of the TM Pulse 2x24V technology module in the hardware configuration of the TIA Portal. The setpoint is transferred cyclically by the user program to the TM Pulse 2x24 V during operation. Additional parameters can be changed cyclically or once by the user program.

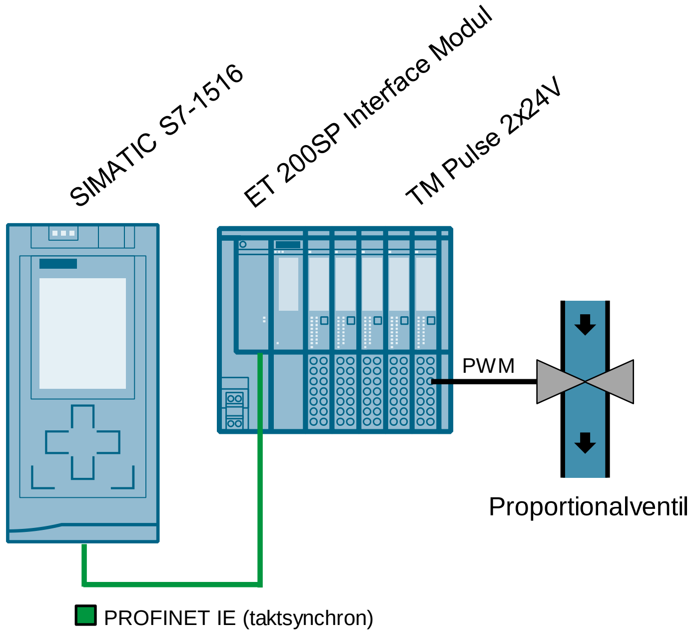
The TM Pulse 2x24V technology module has the following two integrated features for controlling proportional valves:

- Dithering
  Superimposition function of a dither signal on the PWM output to avoid sticky valves to improve the proportional valve control or the control behavior of the proportional valve.
- Unidirectional current control
  PID loop control for the proportional current control in pulse-width modulation (PWM) mode.

Overview of the automation task

The current application example describes the use of the TM Pulse 2x24V technology module on a hydraulic valve, using the example of pressure control on the hydraulic circle. A proportional valve is to be controlled via the TM Pulse 2x24V through which the pressure in a hydraulic system is to be held constant.

Figure 1-2 Schematic diagram of the automation task



The proportional valve of the hydraulic circle is controlled via the TM Pulse 2x24V with a controlled current via the pulse-width modulation (PWM) feature. The pressure control works in the user program of the SIMATIC S7-1516 CPU that generates the setpoint for the TM Pulse 2x24V current output.

Advantages

The solution presented here, is characterized by the following advantages:

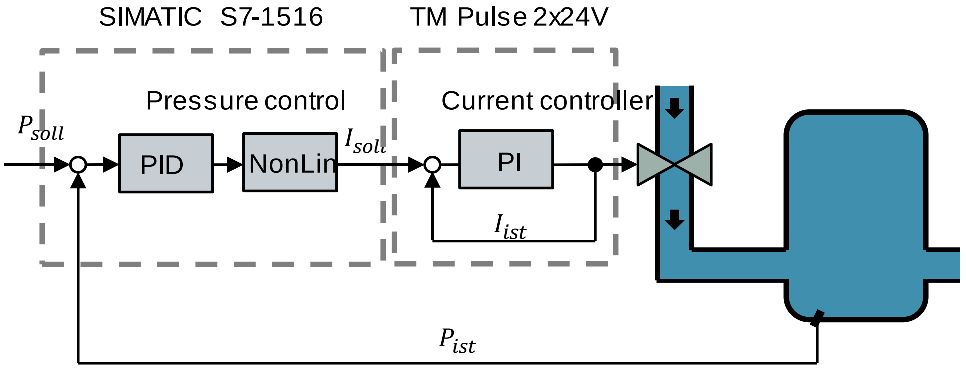
- The control of the proportional valve is exclusively via the TM Pulse 2x24V technology module. Therefore no additional control is required for the proportional valve.

- The TM Pulse 2x24V technology module offers the option to superimpose the corrective signal for the proportional valve with a dither frequency. This reduces the breakaway torque of the valve and therefore improves the control behavior of the proportional valve.

1.2 Mode of operation

The following graphic gives you a schematic overview of the method of functioning of the current application example.

Figure 1-3 Overview of the functioning of the application example



Together with the SIMATIC S7-1516 CPU and the TM Pulse 2x24V technology module the hydraulic systems forms a control loop that takes on the pressure control in the hydraulic system.

For this purpose, the SIMATIC S7-1516 CPU includes the "PID_Compact" software control (technology object) and a "NonLin" linearization block, which balances out a possible non-linearity of the proportional valve. The control system in the SIMATIC S7-1516 CPU generates the current setpoint from the current pressure of the hydraulic system for the TM Pulse 2x24V technology module.

In interaction with the integrated functions “current control" and “dithering" the TM Pulse 2x24V technology module takes on the control of the proportional valve that acts as actuator in the hydraulic system for pressure control. The TM Pulse 2x24V technology module works in the pulse-width modulation (PWM) mode. The communication between the SIMATIC S7-1516 CPU and the TM Pulse 2x24V technology module is via PROFINET in isochronous mode (IRT).

Note The “isochronous mode" system function improves the control properties of the system but is not an essential prerequisite for the operation. However, this example is based on this functionality.

Note The connection of pressure acquisition to the SIMATIC S7-1516 CPU it is not explicitly discussed in this application example since this can be done in different ways, for example, via an analog input module.

1.3 Components used

The application example was created and tested with the following components:

Hardware components

Table 1-1 Hardware components

Component	Number	Article number	Note
SIMATIC CPU S7-1516	1	6ES7 516-3AN00-0AB0	Firmware version: V1.8 or higher
Interface module IM 155-6 PN HF	1	6ES7 155-6AU00-0CN0	Firmware version: V3.3 or higher
TM Pulse 2x24V technology module	1	6ES7 138-6DB00-0BB1	Firmware version: V1.1 or higher

Software components

Table 1-2 Software components

Component	Number	Article number	Note
TIA Portal V13 SP1			
STEP 7 Professional	1	6ES7 822-1AE03-0YA5	Version: V13 SP1
HSP 0131 for ET200SP, TM Pulse	1		Download of the hardware support package (HSP) via the link listed in chapter 5.2 in \7\.
HSP 0157 for ET200SP, IM 155-6 PN HF	1		Download of the hardware support package (HSP) via the link listed in chapter 5.2 in \7\.

Notes on the support packages for the hardware catalog:

- HSP 0131:
  This support package is necessary to be able to use the TM Pulse 2x24V technology module in the TIA Portal V13 SP1.
- HSP 0157:
  This support package is required when the IM 155-6 PN HF interface module is to be used with firmware version V3.3 or higher in the TIA Portal V13 SP1. As of firmware version V3.x of the interface module it is possible to operate the TM Pulse 2x24V technology module without the intermediate base unit of the ET 200SP for a new load group (white coloring) directly on the right next to the IM 155-6 PN HF interface module.
  If an earlier firmware version is used, an additional module with white base unit for a new load group has to be used between the interface module and the TM Pulse 2x24V technology module.

Note The support packages mentioned for the hardware catalog (HSP) have to be installed for the use with this application example in the TIA Portal V13 SP1.

Note In later versions of the TIA Portal, the mentioned support packages for the hardware catalog (HSP) may already be integrated and do not have to be installed additionally.

Validity

This application is valid for…

- STEP 7 from V13 SP1 update 8 and higher
- SIMATIC S7-1500 CPUs as of firmware version V1.8.

Example files and projects

Table 1-3 Example files and projects

Component	Note
109741742_TMPulse_Hydraulic_ PressureControl_DOC_v10_en.pdf	This document
109741742_TMPulse_Hydraulic_ PressureControl_LIB_v10.zip	Library with the required function blocks to integrate the functionality in customized user programs.
109741742_TMPulse_Hydraulic_ PressureControl_PROG_v10.zip	Programming example to show the use of the function blocks in a user program including a simulation block for the simulation of the proportional valve. This makes it possible to operate the program example also without additional hydraulic components.

2 Engineering

2.1 Configuration

This chapter briefly describes and explains the configuration steps required for setting up a project for pressure control in a hydraulic system with the help of the TM Pulse 2x24V technology module.

Basic knowledge regarding the approach is assumed and can be found in the documents listed in links and literature (chapter 5.2) or the TIA Portal online help.

2.1.1 Prerequisites

To execute the displayed configuration steps, the following preconditions apply:

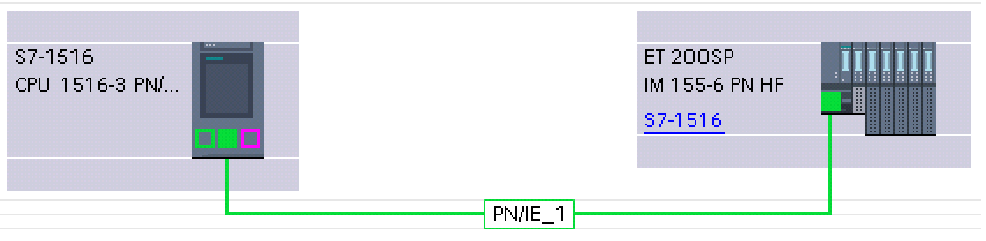
- HSP 0131 was installed in the TIA Portal.
- A new project was created in the TIA Portal.
- All hardware components listed in chapter 1.3 have been added to the project via the hardware configuration of TIA Portal.

2.1.2 Connecting the technology module to the CPU

The TM Pulse 2x24 V technology module is connected as distributed I/O ET 200SP to the SIMATIC CPU. To do this, an ET 200SP interface module (IM) is used here that supports the isochronous mode function via PROFINET.

For this purpose, the ET 200SP interface module (IM) is connected with the PROFINET input of the SIMATIC CPU in the network view of the TIA Portal via a PROFINET connection.

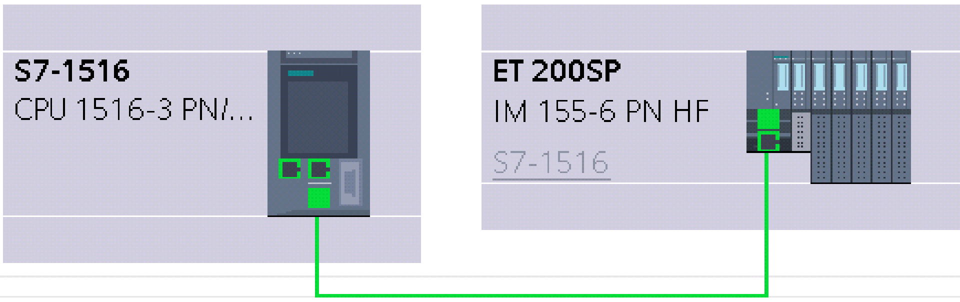
Figure 2-1 Network view of the application example



In addition, in order to be able to use the isochronous mode functionality, the topology of the PROFINET connection, through which the precise interconnection of the PROFINET inputs of the individual modules is defined, also has to be given to the TIA Portal.

Check the real interconnection of the PROFINET connection of the individual modules and then define the topology in the hardware configuration of the TIA Portal via drag-and-drop.

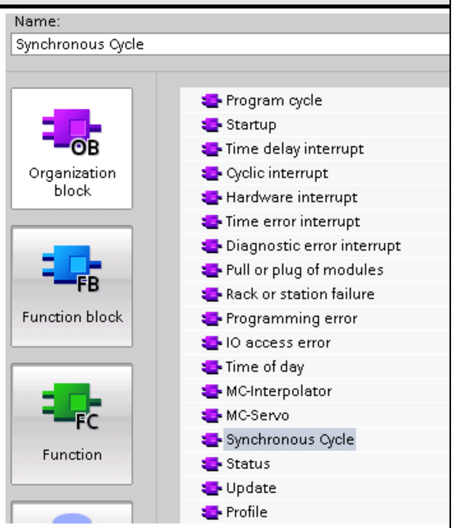
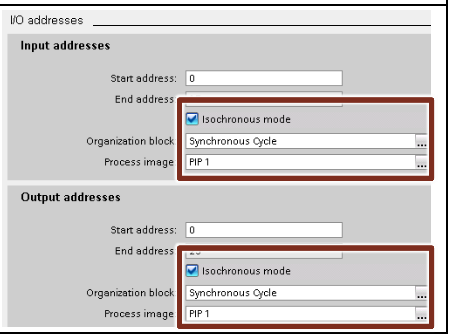
Figure 2-2 Topology of the application example

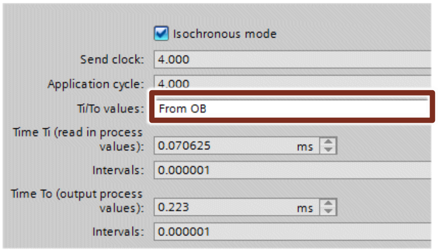


2.1.3 Setting the isochronous mode

Since the pressure control is operated in isochronous mode, the software also has to be configured accordingly, next to setting the hardware and the communication. This is why it is necessary to add an isochronous OB to the user project. This OB then executes the functions that are to be run in isochronous mode. The individual steps for creating this organization block are described in the following.

Table 2-1 Setting the isochronous mode

No.	Action	Remark
1.	Integrate an isochronous OB (Synchronous Cycle) in your user program.	
2.	Open the I/O address settings for the TM Pulse 2x24V technology module and enable the isochronous mode function for the inputs and outputs. Afterwards select the OB "Synchronous Cycle" for each input and output and set "PIP 1" for the partial process image.	

No.	Action	Remark
3.	Go to the settings for the isochronous mode of the ET 200SP head module. Here, for the Ti/To values make the setting "From OB". Thus, the time values for acquiring the input signals and outputting the output values are specified centrally from the organization block. **Note:** As soon as a module of the distributed I/O is set to isochronous mode, the appropriate head module is also automatically set to isochronous mode.	
4.	Now click on the PROFINET network in network view. The settings overview of the Sync domain is opened in the inspector window. This is where the SIMATIC S7-1516 CPU should be set as "Sync master" and ET 200SP as "Sync slave" with the RT class IRT.	

Further information on isochronous mode can be found in the application example "Isochronous mode with PROFINET - an example" listed in the “Links & Literature” (\5\).

2.2 Settings on the TM Pulse 2x24V technology module

2.2.1 General information

Settings on the TM Pulse 2x24V technology module can basically be made in three different ways:

- During the engineering phase in the device view of the technology module, in the hardware configuration of the TIA Portal.
- At runtime of the user program via data record 128 of the technology module. Thus, the module can be configured totally new at runtime. For more details, refer to the manual of the module.
- At runtime of the user program via the control interface of the technology module whilst using the SLOT parameters.

In the current example, the TM Pulse 2x24V technology module is preset via the hardware configuration of the TIA Portal. In the user program the channel configuration of the TM Pulse 2x24V is specified via data record 128 and individual parameter values of the module are changed via the SLOT parameters.

Note An explanation of the use of the control interface and the SLOT mechanism at runtime of the user program can be found in chapter 3.

2.2.2 Setting the operating mode

The TM Pulse 2x24V technology module offers the following operating modes in the hardware configuration of the TIA Portal.

- Pulse output (single pulse)
- Pulse-width modulation (PWM)
- Pulse chain
- On/off delay
- Frequency output
- Direct current motor

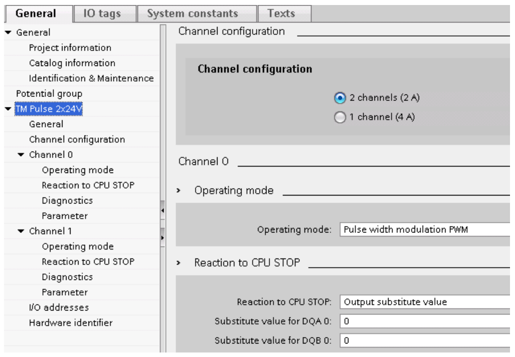
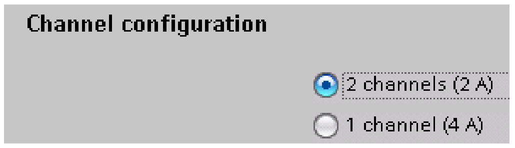
To control a proportional valve in order to realize pressure control in a hydraulic system, the pulse-width modulation (PWM) has to be set.

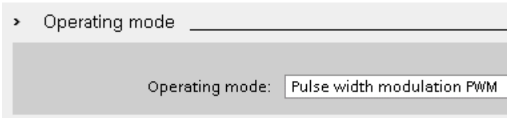
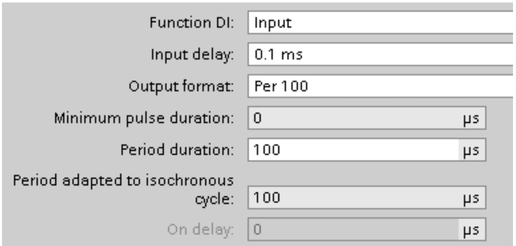
In the pulse-width modulation (PWM) mode of the TM Pulse 2x24V, the following additional functions can be enabled that are also required for the realization of controlling a proportional valve:

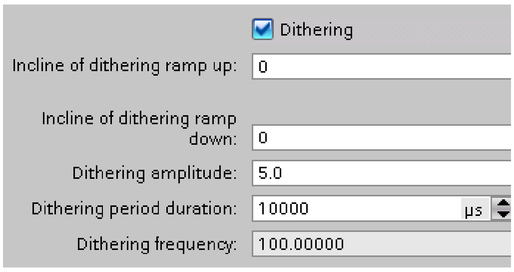
- Integrated current control
- "Dithering" function for the PWM output

The individual steps for setting the operating mode on the TM Pulse 2x24V technology module is briefly explained in the following table. Further information on the operating modes and the functions of TM Pulse 2x24V can be found in the manual of the TM Pulse 2x24V technology module.

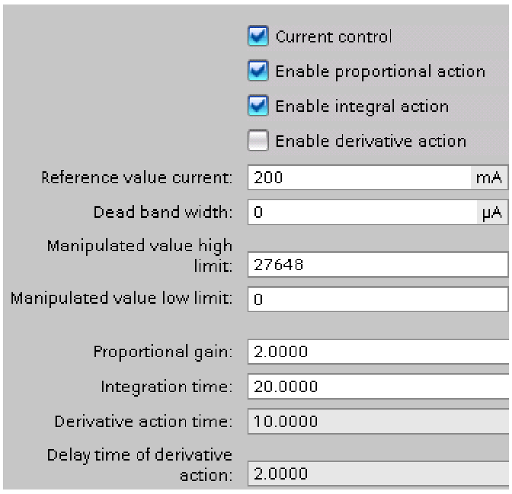
Table 2-2 Setting the operating mode

No.	Action	Remark
1.	Select the TM Pulse 2x24V technology module in the device view of the ET 200SP.	
2.	Select the properties tab in the inspector window.	
3.	Set the desired channel configuration. In the example program the TM Pulse 2x24V is configured with two channels. If only one channel is selected, the module can be operated with an increased output current.	

<table>
<tr><th>No.</th><th>Action</th><th>Remark</th></tr>
<tr><td>4.</td><td>Set the channel used to "Pulse width modulation PWM" operating mode.
In the example program both channels are set to this operating mode.</td><td>
</td></tr>
<tr><td>5.</td><td>Now make the following settings for all channels used of the TM Pulse 2x24V.</td><td></td></tr>
<tr><td>6.</td><td>Set the output format to 1/100 ("Per 100") and the period duration to 100 µs.
This value corresponds to a maximum PWM frequency of 10 kHz.</td><td>
</td></tr>
<tr><td>7.</td><td>Enable the dithering function.
As soon as the dithering function is enabled, additional properties of dithering can be set. These settings depend on the valve used and may possibly have to be optimized for real applications.

Note:
The dither period has to be an integer multiple of the period duration set.</td><td>
</td></tr>
<tr><td>8.</td><td>Enable the current control function.

Note:
As soon as the function is enabled, additional control parameters can be set. The values depend on the respective application.

Note:
The current reference value depends on the electric properties of the components used and may still have to be optimized for real applications.</td><td>
</td></tr>
</table>

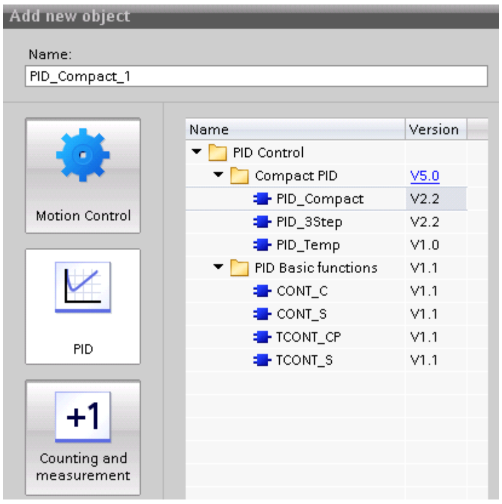
NOTICE	**The parameter values used for pulse-width modulation, dithering, and current control in this application example are customized to the simulation included and have to be adjusted or optimized for real applications on the components used.**

2.3 Creating the user program

2.3.1 Creating the “PID_Compact” software control

For the pressure control, a software control has to be added to the user program. To do this, the “PID_Compact” technology object in version 2.2 is used.

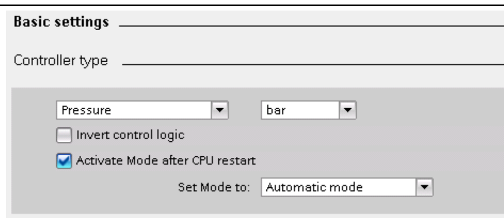
Table 2-3 Creating "PID_Compact" as technology object

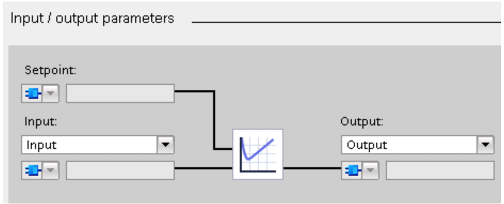
No.	Action	Remark
1.	Select the technology object folder in the project tree and add a new technology object.	
2.	Select the PID category and select PID_Compact in version V2.2. Enter a name for the technology object. Click on the OK button.	

2.3.2 Configuring the “PID_Compact” software control

The "PID_Compact" technology object is configured as follows for the use as control in the user program for pressure control.

Table 2-4 Configuring the "PID_Compact"

No.	Action	Remark
1.	Select the configuration item in the technology object of the "PID_Compact".	
2.	Select the basic settings and here, set the control type and the unit "bar". Then set the "Automatic mode" for the restart of the CPU	

No.	Action	Remark
3.	Set "Input" and "Output" at the input/output parameters of the control.	

The PID parameters are set during the optimization of the control. The steps necessary for the optimization are explained in chapter 3.4.3.

Alternatively, you can also enter the parameters of the control manually.

Note Before the active use of the program, the commissioning and optimization of the "PID_Compact" control has to be carried out. This can be done via the commissioning masks of the technology object.

Note In order to achieve a best possible control behavior it is recommended to, for example, carry out a new fine tuning of the control after changing the application cycle time.

2.3.3 Integrating the FB "ValveControl"

Once all prerequisites for the application have been created, the FB "ValveControl" can now also be integrated into the project from the library belonging to this application example.

The FB "ValveControl" is responsible for controlling the hydraulic valve via the TM Pulse 2x24V technology module. For each channel used of the TM Pulse 2x24V technology module an independent instance of FB "ValveControl" has to be crated in the user program.

It is sufficient here to integrate the FB "ValveControl" into the user project. For a detailed description of the integration of the FB "ValveControl", please refer to chapter 3.4.

2.3.4 OB "Synchronous Cycle"

Finally the function blocks of the application have to be called in the isochronous OB "Synchronous Cycle" of the controller. In order to be able to get consistent updates of the partial process image of the controller and an optimal behavior of the control, a certain call sequence of the blocks and of the additional functions in the OB has to be observed. For more detailed information, refer to \5\.

In the following, adding the system functions in accordance with the AEV model will be described:

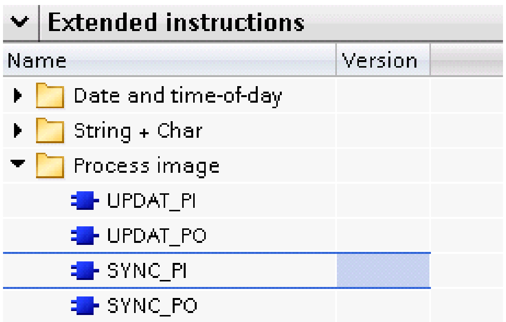
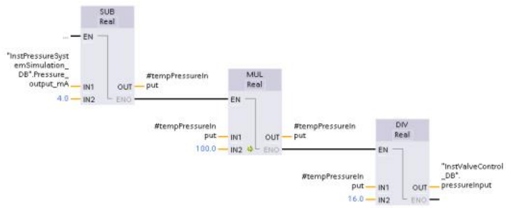
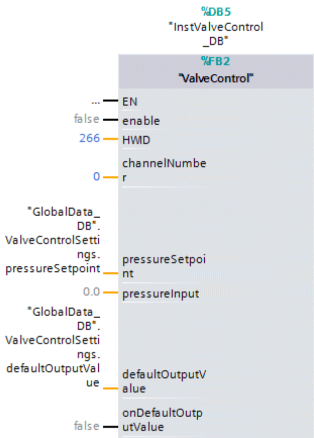
Note

There are two concepts regarding the update of the partial process images:

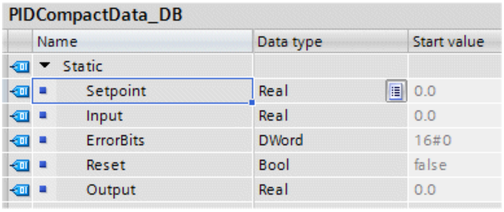
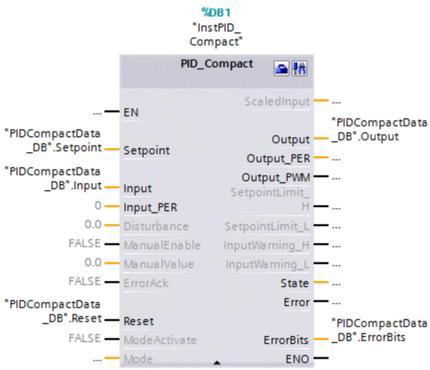
- the IPO model (input, process and output)
- the AEV model (output, input, process).

The IPO model should only be used when it is ensured that the runtime of the synchronous OB is always clearly shorter than the clocked communication network.
If cycle clock scaling is used between application cycle and bus cycle, in most cases this cannot be maintained. In this case the AEV-Modell should be used.

Table 2-5 Calling program blocks in OB

No.	Action	Remark
1.	Open the OB Synchronous Cycle and add the structure of the AEV model for updating the partial process images. To do this, place the SYNC_PO function into network 1 and the SYNC_PI function into network 2. **Note:** Both system functions can be found in the process image folder in the "Extended instructions" palette within the "Instructions" task card.	
2.	Network 3 is intended for a possible scaling of the currently acquired pressure that is provided to the control for pressure control in the following user program. This is where you add the required calculations for pressure scaling. There is an exemplary adaptation of the recorded pressure stored in the example program.	
3.	Add the call of the "ValveControl" function block into the fourth network. **Note:** In the current example the "GlobalData_DB" global data block is used for transferring the data to the inputs and outputs of the function blocks.	

<table>
<tr><th>No.</th><th>Action</th><th>Remark</th></tr>
<tr><td>4.</td><td>As global data storage for the control, add a data block of the "typeValveControlPidController" PLC data type into the project.

Note:
In the current example the "PIDCompactData_DB" global data block is used for this.</td><td>
PIDCompactData_DB<table><tr><th>Name</th><th>Data type</th><th>Start value</th></tr><tr><td>Static</td><td></td><td></td></tr><tr><td>Setpoint</td><td>Real</td><td>0.0</td></tr><tr><td>Input</td><td>Real</td><td>0.0</td></tr><tr><td>ErrorBits</td><td>DWord</td><td>16#0</td></tr><tr><td>Reset</td><td>Bool</td><td>false</td></tr><tr><td>Output</td><td>Real</td><td>0.0</td></tr></table></td></tr>
<tr><td>5.</td><td>Now add the function block of the "PID_Compact" control into the fifth network.
Interconnect the inputs and outputs of the block with the appropriate tags of the global data block of the "typeValveControlPidController" type.
In the current example the DB "PIDCompactData_DB" is used for this.</td><td></td></tr>
<tr><td>6.</td><td>Also interconnect the inputs and outputs of the "ValveControl" function block with the appropriate tags of the global data block of the "typeValveControlPidController" type.</td><td></td></tr>
</table>

Note

By using a reduction for the application cycle time of the synchronous cycle, the CPU can be relieved from strain. This usually does not have an influence on the control behavior of the pressure control.

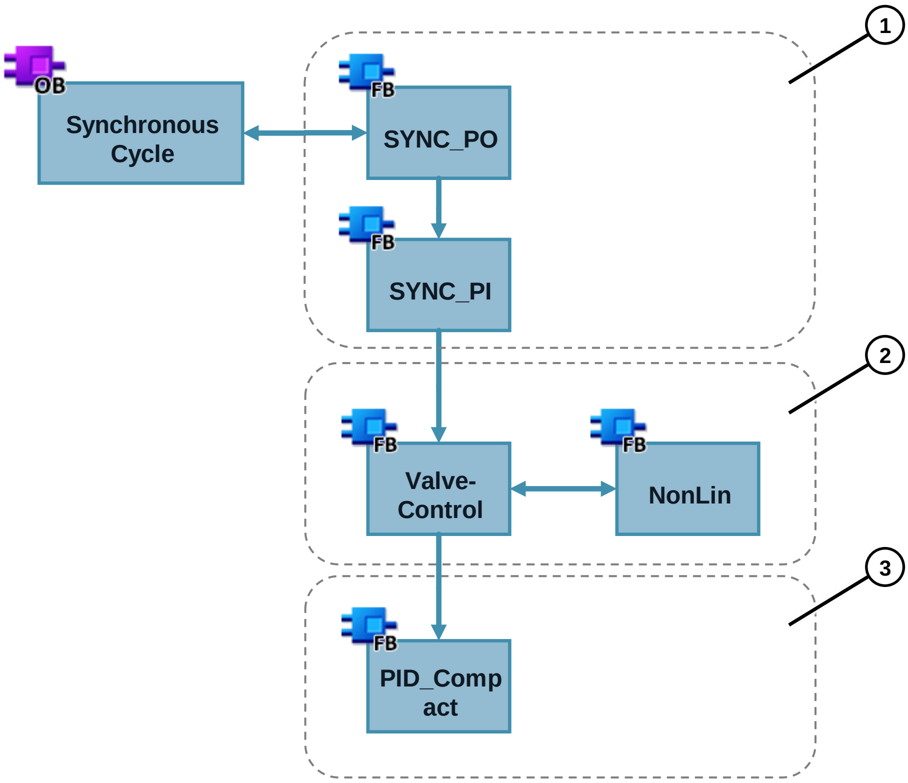
2.3.5 Program overview

Once the individual configuration steps have been executed, the following call structure for the OB Synchronous Cycle is the result.

Table 2-6 Legend

No.	Description
1.	Updating the partial process image of the controller Updating the outputs by writing the output tags via the "SYNC_PO" function and reading the current status of the inputs via the "SYNC_PI" function.
2.	Calling the function block for valve control Linearization of the setpoint via the "NonLin" function block that contains the characteristic. Data exchange with the "PID_Compact" control via the "PIDCompactData_DB" global data block.
3.	Calling the control for pressure control.

Figure 2-3 Program overview



3 "ValveControl" Function Block

3.1 Interface description

3.1.1 Interface of the FB "ValveControl"

The "ValveControl" function block that takes on the control of the hydraulic valve via the TM Pulse 2x24V technology module has the following interface:

Figure 3-1 Interface of the FB "ValveControl"

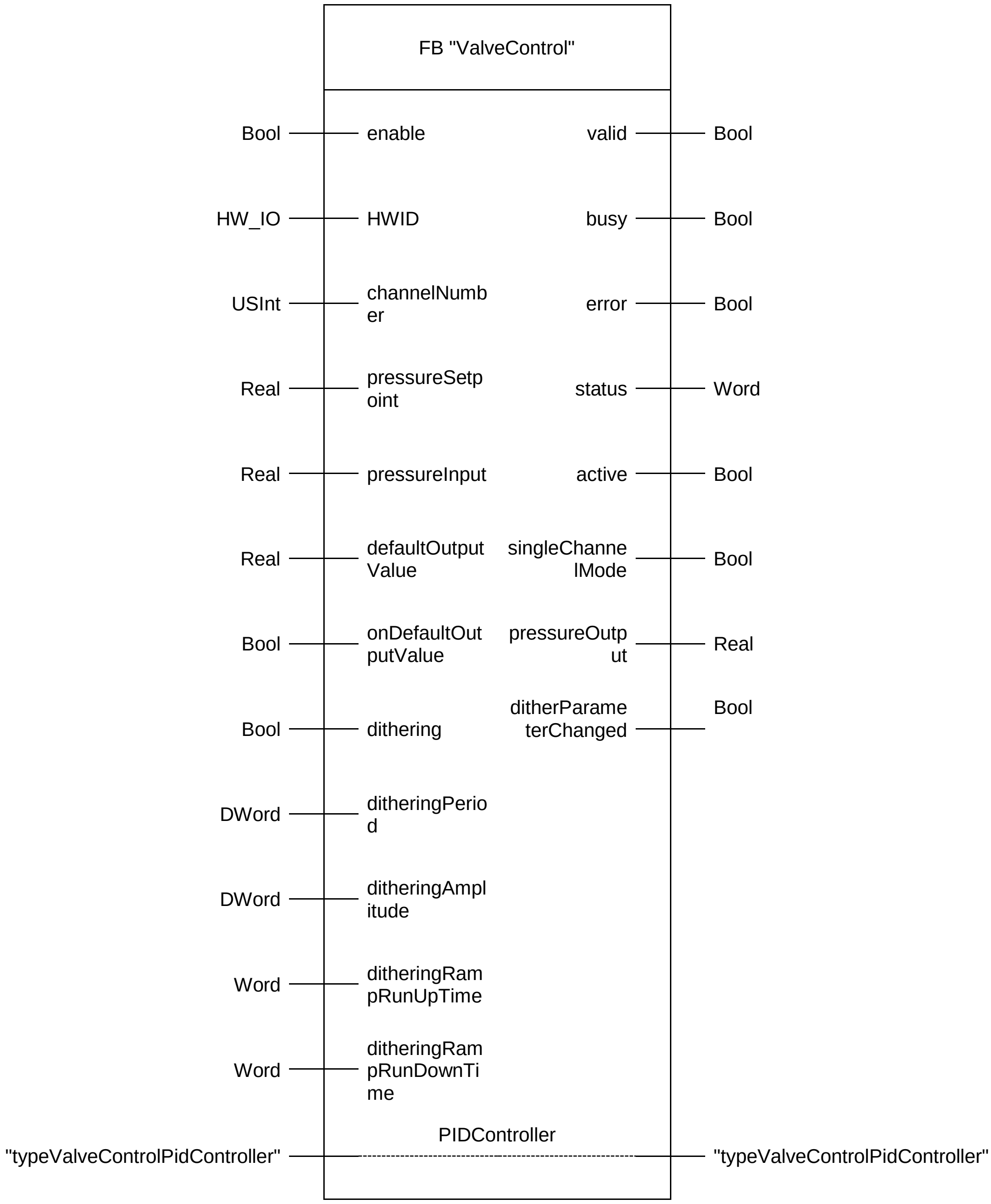


Table 3-1: Parameters of "ValveControl"

Name	P type	Data type	Comment
enable	IN	Bool	Processing the block is enabled via this input. If the input is reset, processing of the block is interrupted and the control signal of the valve is reset. This closes the valve.
HWID	IN	HW_IO	Hardware ID of the TM Pulse 2x24V technology module that is used for valve control.
channelNumber	IN	USInt	Number of the channel of the TM Pulse 2x24V technology module that is connected with the hydraulic valve. Possible values: 0, 1
pressureSetpoint	IN	Real	Setpoint of the pressure control to which the hydraulic system is to be controlled.
pressureInput	IN	Real	Current pressure of the hydraulic system that is returned from the sensor to the hydraulic system.
defaultOutputValue	IN	Real	Substitute output value of the function block as setpoint for the pressure control that can be enabled via the "onDefaultOutputValue" input.
onDefaultOutputValue	IN	Bool	Enabling the substitute output value of the function block for pressure control.
Dithering	IN	Bool	Enabling the dithering function in order to improve the control behavior of the valve piston of the hydraulic valve by superimposing a vibration in the output signal of the TM Pulse 2x24V technology module.
ditheringPeriod	IN	Dword	Setting the period duration in micro seconds for the superimposed dither signal. The permitted range is between (4 x PWM period) and 100,000 µs. **Note:** Set the period duration to an integer multiple of the application cycle in order to achieve a best-possible result.
ditheringAmplitude	IN	Dword	Setting the amplitude of the superimposed dither signal in relation to the period duration of the output signal.

Name	P type	Data type	Comment
ditheringRampRunUp Time	IN	Word	Definition of the dither ramp-up time. This parameter defines the increase of the dither signals after the activation of the dither function in milliseconds. The permitted range of the ramp-up and ramp-down time is 0 to 30,000ms.
ditheringRampRunDo wnTime	IN	Word	Definition of the dither ramp-down time. This parameter defines the decrease of the dither signal after the deactivation of the dither function in milliseconds. The permitted range of the ramp-up and ramp-down time is 0 to 30,000ms.
valid	OUT	Bool	This output is set to TRUE if valid signals are pending on the block outputs.
busy	OUT	Bool	This output is set to TRUE if the block works without error.
error	OUT	Bool	This output is set to TRUE if an error has occurred while processing the block. Refer to the status output on the “status” output for more information about the cause of the error.
status	OUT	Word	This output supplies additional information on the current status of the block or cause of error.
active	OUT	Bool	This output is set to TRUE if the TM Pulse 2x24V technology module is controlled by the block.
pressureOutput	OUT	Real	The setpoint calculated by the block for the pressure control. The output value is for information only. Transferring the setpoint of the PID_Compact control is via the "PIDController” input/output.
singleChannelMode	OUT	Bool	This output is set to TRUE if the TM Pulse 2x24V technology module is operated in single channel mode. On the channelNumber input the value has to be specified with 0 in this operating mode. The outputs for channel 0 and 1 of the TM Pulse 2x24V module can be connected in parallel, in order to increase the output current of the technology module to 4A.

Name	P type	Data type	Comment
ditherParameterChanged	OUT	Bool	This output is set to TRUE if all dither parameters to be changed have been successfully transferred to the TM Pulse 2x24V.
PIDController	IN_OUT	"typeValveControlPidController"	The data exchange between the function block and the PID_Compact control takes place via this block input/output.

3.1.2 PLC data type "typeValveControlPidController"

The data exchange between the "ValveControl" function block and the actual "PID_Compact" control is via the "PIDController" input/output of the "ValveControl" function block. For this data area an independent PLC data type is defined that is made up as follows.

Table 3-2 Data type "typeValveControlPidController"

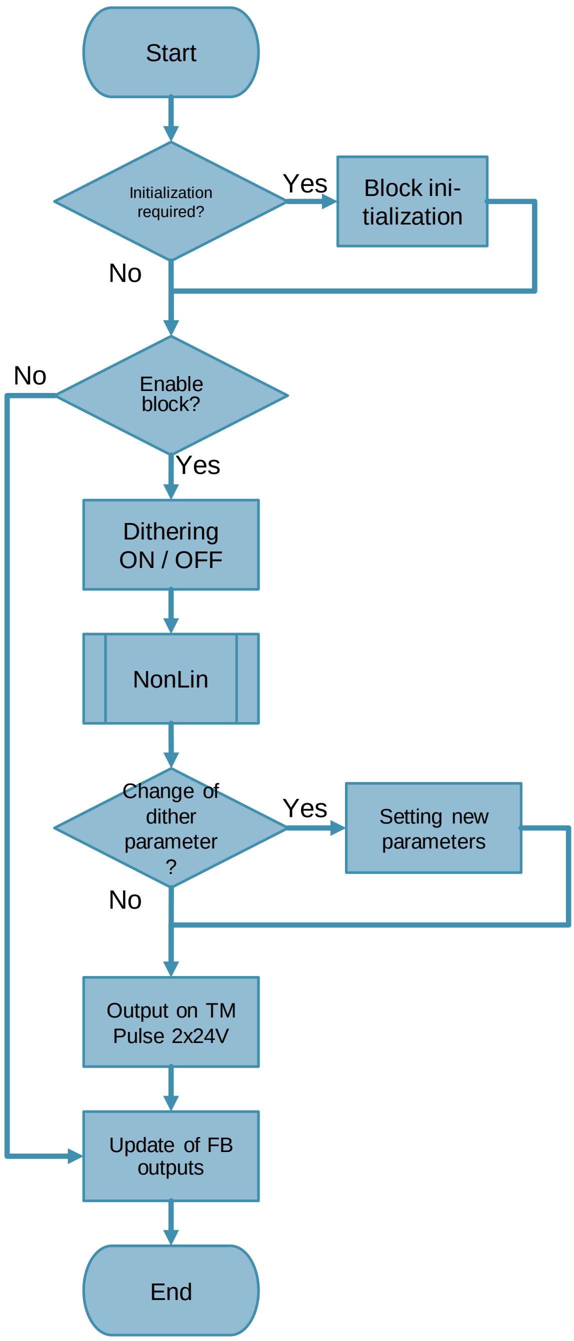
Identifier	Data type	Start value	Meaning
Setpoint	Real	0.0	The setpoint provided for pressure control via the "PID_Compact" control.
Input	Real	0.0	Current pressure of the hydraulic system that is returned from the sensor of the hydraulic system and is transferred to the "PID_Compact" control block here.
ErrorBits	DWord	16#0	Feedback signal of the "PID_Compact" control block that provides further information in the event of an error. **Note:** More information on the cause of the error can be found in the documentation of the "PID_Compact" control block or the technology object.
Reset	Bool	False	If the signal is set to TRUE the "PID_Compact" control block is reset.
Output	Real	0.0	Output value of the "PID_Compact" control block for pressure control.

3.2 Functioning of the FB "ValveControl"

3.2.1 Overview

The following figure shows the functional sequence of the FB "ValveControl". For reasons of clarity, error handling and stopping the control within the function block was not shown.

Figure 3-2 Simplified program workflow of the FB "ValveControl"



3.2.2 Characteristic linearization via FB "NonLin"

Usually the volume current of a proportional valve and the control current of the valve have a nonlinear relation. However, to be able to use the valve for the control, the valve characteristic has to be linearized. This is achieved by FB "NonLin".

For this purpose, the FB "NonLin" contains a linearization characteristic (compensation characteristic) that is defined via interpolation points, which balances out the nonlinear behavior of the proportional valve for the control system. The pressure or volume current output via the proportional valve is displayed as function of the control current of the valve in this characteristic. The interpolation points of the characteristic have to be stored in ascending order in FB "NonLin".

Within the "ValveControl" function block, the output value of the "PID_Compact" control for controlling the valve is transferred to FB “NonLin”, which then compensates the nonlinear valve behavior via the contained linearization characteristic of the valve and returns the necessary current setpoint for the required pressure. This current setpoint can be transferred to the TM Pulse 2x24V as control variable.

Note The TM Pulse 2x24V technology module also provides the resulting, measured current for controlling the valve via the feedback interface. This value could, for example, be used for measuring the valve in the commissioning phase.

3.3 Output of the valve control variable via TM Pulse 2x24V

3.3.1 Data exchange using the TM Pulse 2x24V

The behavior of a channel of the technology module can be influenced through the user program via the control interface of the TM Pulse 2x24V. In the "ValveControl" function block the interface is used for the following actions:

- Transfer of the control variable for the proportional valve
- Enabling the dither signal
- Setting the technology module parameters

The start address of the control interface of the technology module can be specified, with the help of the hardware ID (HWID) using the RD_ADDR command at runtime of the user program.

The setpoint current for the valve control is transferred cyclically to the TM Pulse 2x24V as OUTPUT_VALUE via the first four bytes of the control interface. However, in the PWM operating mode only the two low-order bytes of the interface are used.

The dither function for the control variable output can be enabled and disabled via bit 5 in byte 9 of the control interface of the technology module.

Other settings in TM Pulse 2x24V can also be made at runtime via the SLOT parameters of the control interface of the technology module.

Table 3-3 Control interface of TM Pulse 2x24V for one channel

Byte	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00	OUTPUT_VALUE							
01								
02								
03								
04	SLOT							
05								
06								
07								
08	Reserved			MODE_ SLOT	LD_SLOT			
09	Reserv ed	Reserv ed	DITHE R	SET_ DQB	SET_ DQA	Reserv ed	TM_ CTRL_ DQ	SW_ EN ABLE
10	Reserved							RES_ ER ROR
11	Reserved							

3.3.2 Configuring the TM Pulse 2x24V via SLOT parameters

To configure the TM Pulse 2x24V via the SLOT parameters at runtime of the user program, the bytes 4 to 7 and byte 8 of the control interface have to be used. Different individual parameters of the TM Pulse 2x24V can be updated via these parameters or the permanent update of one parameter of the TM Pulse 2x24V is made possible.

Table 3-4 The SLOT parameters of the control interface of the TM Pulse 2x24V

Value	Meaning
MODE_SLOT (Byte 8, bit 4)	MODE_SLOT specifies whether an individual (MODE_SLOT = 0) or a cyclic (MODE_SLOT = 1) update of a parameter is to be carried out. In the current application example MODE_SLOT = 0 is used.
LD_SLOT (Byte 8, bit 3 to 0)	The value in LD_SLOT specifies what properties of the behavior of TM Pulse 2x24V are to be changed. The properties depend on the selected operating mode: 0000 = no action (0) 0001 = period duration (1) 0010 = on delay (2) 0011 = switch-off delay (3) 0100 = switch-on duration (4) 0101 = dither ramp (5) 0110 = dither amplitude (6) 0111 = dither period (7)

Value	Meaning
	For the parameter values used in FB "ValveControl", respective constants are created.
SLOT (Byte 4 to 7)	The value written in SLOT is interpreted depending on MODE_SLOT and LD_SLOT. Through the SLOT value, for example, the period duration in the PWM operating mode or the dither amplitude can be changed.

The "ValveControl" function block does not use the SLOT parameters for permanent update of the dithering parameters. The following parameters are written via the control interface if there is a change of the FB "ValveControl" input parameters:

- Dither amplitude
  Assignment of the amplitude ratio in mil values. The permissible value range is between 0 and 500‰. If the dither amplitude is, for example, set to value 100‰ and the switch-on period in the PWM operating mode is set to 50%, the effective switch-on duration of the signal varies periodically between 40% and 60%.
- Dither period
  Period duration of the dither signal in micro seconds. The permissible value range of the dither period is between (4xPWM period) and 100,000 µs, whereby the dither period always has to be selected larger 2ms.
- Dither ramp (including ramp-up and ramp-down time)
  The dither ramp parameter consists of two data words. The low word stands for the dither ramp-up time, the high word for the dither ramp-down time.

Note If the PWM period is changed in running operation with the help of the SLOT mechanism so that the dither period becomes smaller than (4 x PWM period), the dither function is disabled and the STS_DITHER = 0 feedback bit until a valid combination of dither and PWM period is assigned.

Note Set the dither period to an even integer multiple of the application cycle to achieve a best possible result.

3.4 Integrating FB "ValveControl"

The following section explains how you can integrate the FB "ValveControl" quickly and easily into a separate user project.

3.4.1 Prerequisites

The following prerequisites have to be fulfilled before the start of the described integration of the FB "ValveControl" into a separate user project:

- The hardware has been configured as described.
- The isochronous communication was configured

Note The “isochronous mode" system function improves the control properties of the system but is not an essential prerequisite for the operation. However, this example is based on this functionality.

If the "isochronous mode" is not to be used, control loop blocks should be called in a cycle interrupt OB.

3.4.2 Adding into the user program

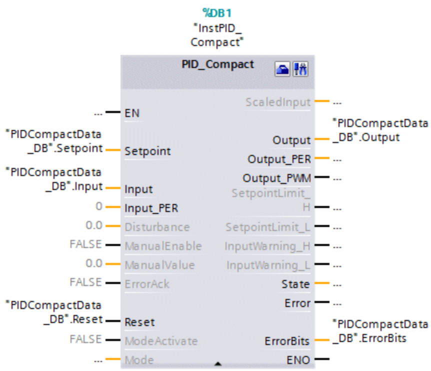
The "ValveControl" function block can be added in a user program as follows:

Table 3-5 Transferring the blocks from the global library

No.	Action	Remark
1.	Open the global library of the application example. It includes all necessary function blocks and data types.	
2.	Copy all data types from the global library to your user project.	This is where the PLC datatypes folder can be accepted in your user project using drag-and-drop.
3.	Copy all function blocks from the global library to your user project.	This is where the “Program blocks” folder can be accepted in your user project using drag-and-drop.

Now the transferred function blocks have to be interconnected with the "PID_Compact" technology object and the block inputs and outputs have to be supplied with the appropriate values.

Table 3-6 Connection FB ValveControl and PID_Compact

No.	Action	Remark
1.	Create a global data block of data type "typeValveControlPidController".	The data exchange between the FB "ValveControl" and the "PID_Compact" technology object is performed via this data block.
2.	Interconnect the inputs and outputs of the "PID_Compact" with the data block tags.	
3.	Interconnect the inputs and outputs of the FB "ValveControl" with the data block tags.	

3.4.3 Optimizing the pressure control

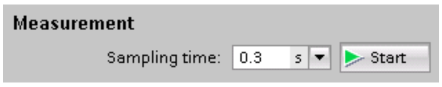
There are configuring and commissioning interfaces available for the "PID_Compact" technology object in the TIA Portal that can be used for the commissioning and optimization of the control.

The following prerequisites have to be met for the optimization of the "PID_Compact" technology object:

- The PID_Compact is in “Manual”, “Inactive” or “Automatic” mode.
- A setpoint is specified manually within the configured limits via the FB "ValveControl".

Now automatic pretuning can be carried out for the control, and afterwards fine tuning.

Table 3-7 Optimizing the control for pressure control

No.	Action	Remark
1.	Open the commissioning mask of the "PID_Compact" control.	
2.	Select a suitable sampling time and click on "Start".	
3.	Select pretuning and click “Start”. If pretuning does not start, an error will be output in the status area tuning.	
4.	Once pretuning has been completed, select fine tuning and click on "Start".	

Note

Apart from the automatic tuning of the control parameters, they can also be specified manually. This procedure is described in the documentation of "PID_Compact".

3.5 Error handling

If an error occurred when processing the "ValveControl" block, it will be shown on the "error" output of the block. In addition the "status" output includes further notes on the reason for the error, which are listed in the table below.

Table 3-8 Possible values for the status output of the FB "ValveControl"

Status	Description
16#7000	The function block is ready for operation or is currently executed.
16#8600	The "PID_Compact" technology object is in error status. More information regarding the cause of the error can be found in the "errorBits" output of "PID_Compact" and the documentation of the technology object.
16#8700	When calling the RD_ADDR system function an error occurred. More information regarding the cause of the error can be found in the feedback value of the system function in the instance data block and the documentation.
16#8701	An incorrect value was specified on the "channelNumber" input. Please check the value entered there.
16#8702	When checking the data record 128 to determine the operating mode (2A/4A mode) of the technology module, an error occurred. More information regarding the cause of the error can be found in the statRDRECStatus static tag of the function block and the TIA Portal online help for the RDREC function.
16#8703	An error occurred during the plausibility check for the channel number specified on the channelNumber block input and the configuration of TM Pulse 2x24V for the single or two channel operation (2A/4A mode). Please check the configuration of TM Pulse 2x24V or the setting on the channelNumber input of the block.
16#8704	One of the specified dithering parameter was invalid and could not be transferred to the TM Pulse 2x24V. Check all specified parameters and if required correct the specifications made.

If the "ValveControl" block is in error state, the control variable output via the TM Pulse 2x24V is set to 0.

Once the cause of the error has been removed, the "ValveControl" block can be started again via a rising edge on the "enable" input. Here, a reset is performed on the "PID_Compact" technology object.

4 Valuable Information

4.1 Dithering

The dithering function causes a mechanical vibration in a proportional valve when the desired valve position is controlled with current from the PWM output of the TM Pulse 2x24V. The vibration is induced because the target current for the valve coil is superimposed by a dither current fluctuation.

The dither vibration improves precision and linearity of proportional control valves by minimizing problems caused through static friction and hysteresis in the valve control via the superimposed vibrations on the valve piston:

- Static friction is avoided in piston movement.
- The stick-slip effects are minimized.
- The sticking of the valve piston caused by residuals from the medium is stopped.

The parameters for the setting of the dithering signal in TM Pulse 2x24V are:

- Dither amplitude
- Dither period
- Dither frequency
- Dither ramp (ramp-up and ramp-down time)

The optimum values for these parameters depend on the respective application.

Figure 4-1 Example: No dithering

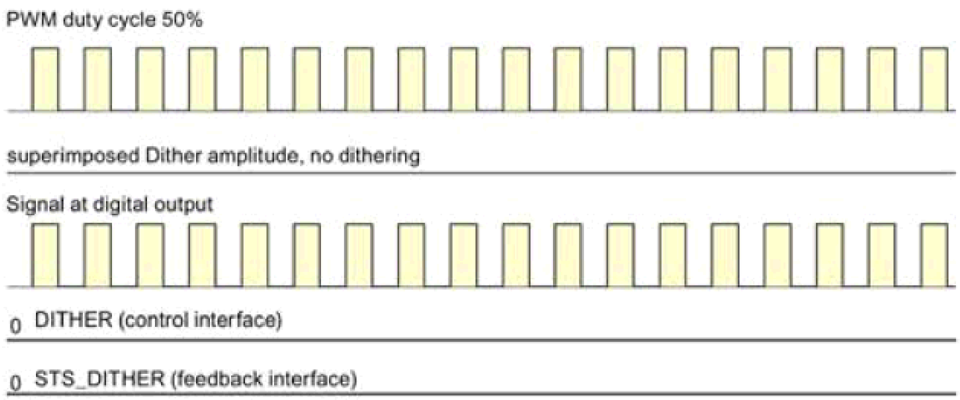
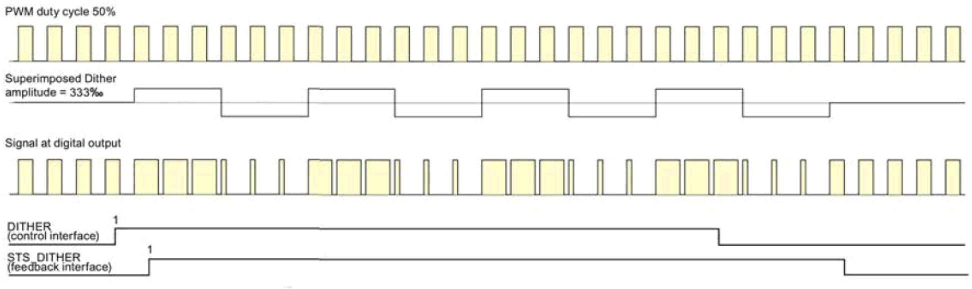


Figure 4-2 Dithering active (dither period = 6 x PWM period, dither ramp = 0)



4.2 Simulation of proportional valve

In the current example program a simulation of a proportional valve was used for test purposes. This makes it possible to test the user program already during the development and without the hardware setup of the hydraulic system.

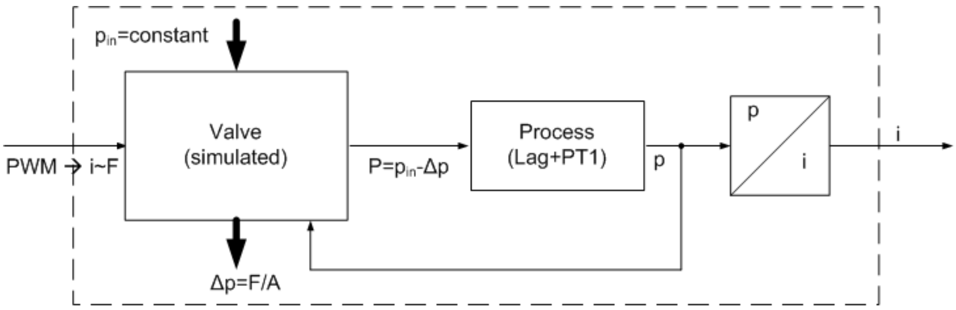
The advantages of using such a simulation are:

- Independence from the hardware of the system to be controlled
- Time and costs savings by testability of the software during development

The LSim block library offers different function blocks to illustrate a simulated controlled system in the user program. The individual blocks of the library can be made up to the desired controlled system.

In order to simulate the behavior of the proportional valve a ValveSimulation function block was written. The "LSim_PT1" block follows after the simulated valve and after the "LSim_Lagging" block in order to reproduce the setting of the pressure in the system. The following figure shows the schematic configuration of the simulation.

Figure 4-3 Systemic configuration of the simulation



It is assumed that a valve has a constant input pressure of 100 bar, therefore a pressure between 0 and 100 bar can be set in the hydraulic system. The output pressure of the valve corresponds to the system pressure to be controlled.

The valve is structured in a way that the input pressure gets straight into the system or is used to overcome a spring force.

$$F_{on} = F_{System} + \Delta F_{Spring\ force}$$

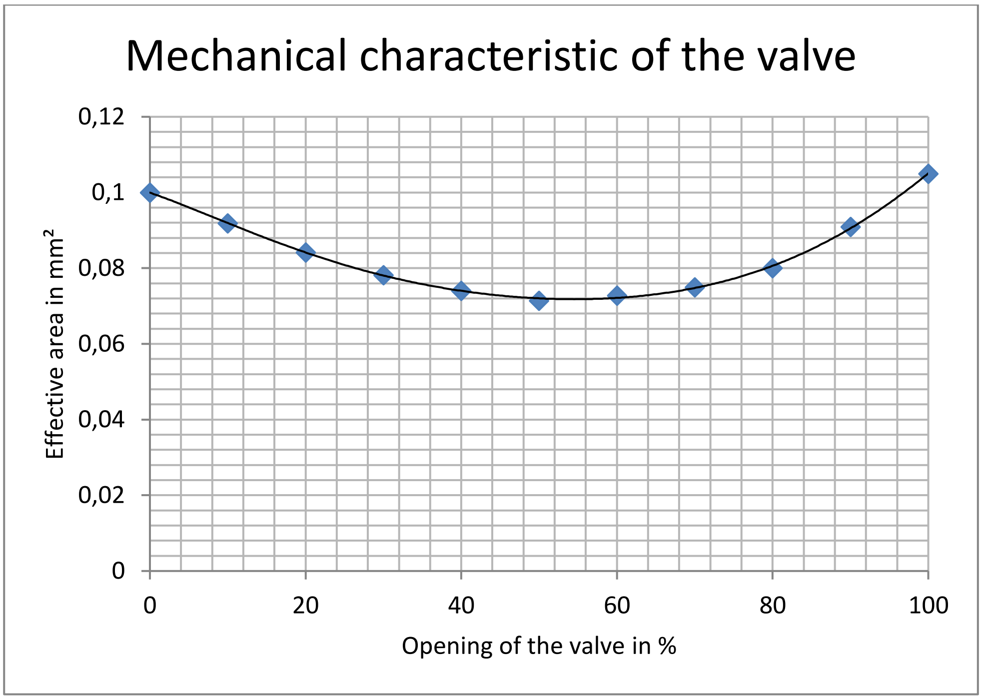
When the valve opens, the effective area changes, which is needed to overcome the spring force.

$$\Delta p = \frac{Force}{Area}$$

This area has a nonlinear behavior.

The ValveSimulation block has the two inputs DQA and nDQA. If a 1 is pending on DQA, the valve opens, otherwise it closes. How much it opens or closes per cycle depends on the calculated increment. In accordance with the characteristic, the effective area then changes, which applies the required spring force F, using the Δp differential pressure. The illustrated characteristic is normally not available to the user of a valve, and only presents the basics of the valve simulation.

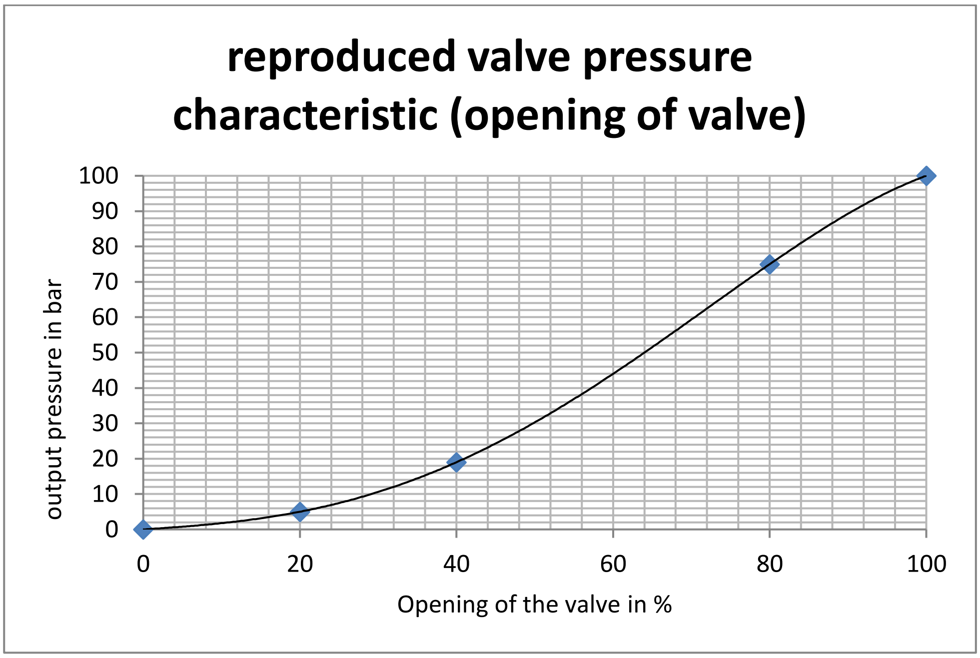
Figure 4-4 Mechanical characteristic of a valve



The output pressure of the valve is, as already mentioned, calculated via force/area (simulated). Since the user does not have this information, the following diagram was used instead.

As of now we are only interested in the pending output pressure when a certain setpoint is to be applied to the valve. The dependence of the output pressure from the setpoint, can usually be viewed in the data sheet.

Figure 4-5 Valve characteristic of the pressure



To be able to illustrate this characteristic, the SimulationValve block uses FB NonLin.

Apart from DQA and nDQA, the block has other parameters for the valve simulation. The following table describes the parameters and their function.

Table 4-1 Description of the simulation parameters to be set

Parameter	Data type	Comment
TransitTime	Real	The time the valve needs to go from closed to completely open.
Pressure_input	Real	Input pressure of the valve
DQA	Bool	If a 1 is pending here, the valve opens. Otherwise it closes.
DQA_n	Bool	Negation of DQA
Cycle	Real	This parameter corresponds to the application cycle of the organization block in which the simulation is called.

NOTICE **The simulation of a proportional valve realized here only presents an approximation to the behavior to the behavior of such a valve and does not claim to be correct or complete.**

5 Appendix

5.1 Service and Support

Industry Online Support

Do you have any questions or need support?

Siemens Industry Online Support offers access to our entire service and support know-how as well as to our services.

Siemens Industry Online Support is the central address for information on our products, solutions and services.

Product information, manuals, downloads, FAQs and application examples – all information is accessible with just a few mouse clicks at https://support.industry.siemens.com/.

Technical Support

Siemens Industry's Technical Support offers quick and competent support regarding all technical queries with numerous tailor-made offers – from basic support to individual support contracts.

Please address your requests to the Technical Support via the web form: www.siemens.en/industry/supportrequest.

Service offer

Our service offer comprises, among other things, the following services:

- Product Training
- Plant Data Services
- Spare Parts Services
- Repair Services
- Field & Maintenance Services
- Retrofit & Modernization Services
- Service Programs & Agreements

Detailed information on our service offer is available in the Service Catalog: https://support.industry.siemens.com/cs/sc

Industry Online Support app

Thanks to the "Siemens Industry Online Support" app, you will get optimum support even when you are on the move. The app is available for Apple iOS, Android and Windows Phone.
https://support.industry.siemens.com/cs/en/en/sc/2067

5.2 Links and Literature

Table 5-1

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to this entry: https://support.industry.siemens.com/cs/ww/en/view/109741742
\3\	SIMATIC PROFINET System Description System Manual Edition: 03/2012 https://support.industry.siemens.com/cs/en/en/view/19292127 Chapter: Isochronous mode https://support.industry.siemens.com/cs/en/en/view/19292127/36668171019
\4\	Closed-Loop Control with PID_Compact V2.2 Application example Edition: 03/2016 https://support.industry.siemens.com/cs/ww/en/view/79047707
\5\	Isochronous mode - An example FAQ Edition: 10/2015 https://support.industry.siemens.com/cs/ww/en/view/109480489
\6\	SIMATIC ET 200SP Technology module TM Pulse 2x24V Manual Edition: 09/2015 Document ID: A5E35061195-AA https://support.industry.siemens.com/cs/ww/en/view/109478710
\7\	Support packages for the hardware catalog in TIA Portal (HSP) HSP 0131: SIMATIC ET 200SP, TM Pulse (6ES7138-6DB00-0BB1) HSP 0157: SIMATIC ET 200SP, IM 155-6 PN HF (6ES7 155-6AU00-0CN0) Download https://support.industry.siemens.com/cs/ww/en/view/72341852

5.3 Change documentation

Table 5-2

Version	Date	Modifications
V1.0	05/2017	First version