WEST

Technical documentation

Simulation of a hydraulic cylinder drive

as part of the position controller software

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Electronics

CONTENTS

1 General information

These instructions describe the use of the module-internal simulation. It is to be understood as a supplement to the respective product documentation. The instructions given there for the safe use of the devices apply.

1.1 Symbols used

General note

Safety-relevant note

1.2 Imprint

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2 Introduction

The dynamic simulation of hydraulic systems is an established tool for the design engineer. There are numerous solutions on the market for pure offline simulation.

The controllers used in the model are generic. In the best case, coupling to real controllers in the form of an HIL (Hardware in the Loop) simulation is possible. The effort required for this is immense and not economical for most small to medium-sized projects.

However, the advantages of a full simulation are:

- Recognising design problems at an early stage
- Avoidance of functional risks
- Possibility to select more cost-effective components
- Simplest calculation of the system efficiency for a defined movement cycle, enabling comparison between different solutions
- Realistic test of the automation without a connected machine, shortening the commissioning phase
- Gain a deeper understanding of the physical interactions in the system
- Training opportunities

This is offset by the relatively high cost of model creation and parameterisation as well as the licence costs of the software used.

The solution described here avoids this by offering the possibility of a real physical simulation on the actual controller hardware. This is possible by limiting the complexity of the modelling and by using predefined (sub)systems.

3 The simulation model

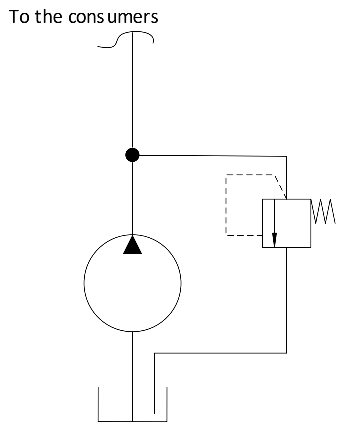
A simple system for electrohydraulic positioning of one or more axes consists of the elements considered in the following sections.

A pressure supply can supply several axes. The common pressure line is mapped by corresponding signal links between the submodels.

3.1 Pressure supply

There are different variants that can be selected via a parameter:

3.1.1 Constant pump, fixed speed, pressure relief valve (CDBV)

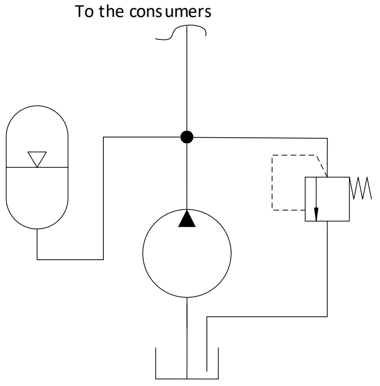


This variant of the pressure supply consists of a fixed displacement pump driven by a fixed-speed motor.

The combination is described by means of the nominal flow rate of the pump and pressure-dependent leakage.

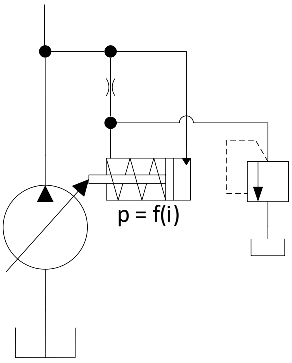
The pressure relief valve is modelled on the basis of its stationary behaviour and is characterised by opening pressure and characteristic curve gradient.

3.1.2 Constant pump, fixed speed, pressure relief valve, accumulator (CADBV)



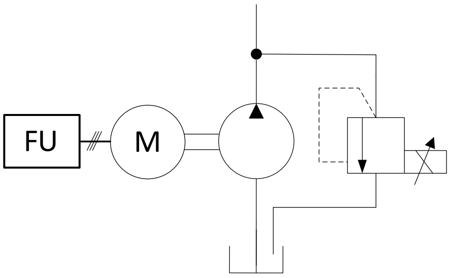
This variant also includes a hydraulic accumulator whose gas volume and preload pressure determine the behaviour.

3.1.3 Ideal pressure-regulated pump (IDPMP)



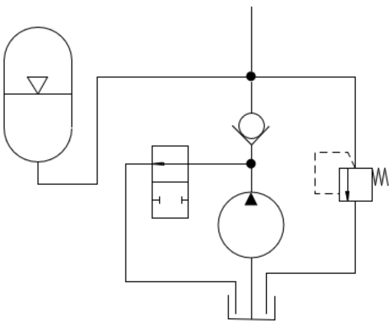
This variant can be represented in reality, for example, by a variable displacement pump with hydraulic-mechanical pressure control and an accumulator to cover peaks. The model has no dynamics. It guarantees a constant supply pressure at all times without load dependency.

3.1.4 Variable speed fixed displacement pump with proportional pressure relief valve (NPRDBV)



In contrast to the CDBV circuit, both the pump speed and the set pressure of the pressure relief valve are variable during runtime. Parameterisable speed ramps allow both relatively slow frequency converters or fast servomotors to be adjusted. The pressure relief valve is also described as a non-ideal element with regard to its stationary and dynamic behaviour.

3.1.5 Constant pump, fixed speed, pressure relief valve, accumulator charging circuit (ACHC)

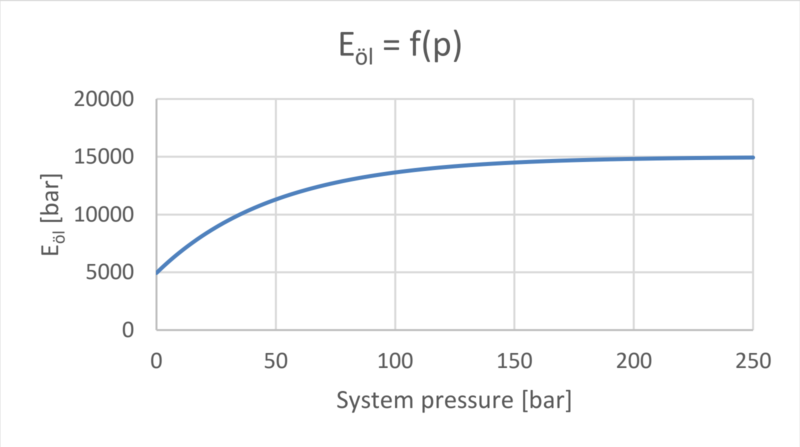


This circuit is similar to the CADBV variant, but has an accumulator charging circuit. This loads the accumulator at intervals. This is controlled via two pressure-dependent switching points. In the case of neutral circulation, the pump does not deliver anything into the pressure-side system so that all consumption is served from the accumulator.

In order to be able to simulate a certain pressure drop over time even when the appliance valves are closed, a pressure-proportional, permanent leakage can be set. This allows losses in the closed middle position of spool valves to be simulated.

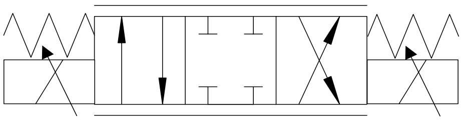
3.2 Oil

The pressure medium can either be idealised with a constant equivalent bulk modulus (fixed 14000 bar) or described with pressure dependence. The following relationship is defined:



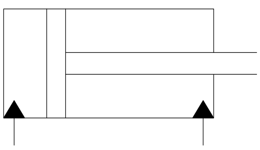
The use of this curve is particularly recommended when working with reduced supply pressure. By switching this model refinement on and off on a test basis, you can also test the influence of this property on the stability of the actuator.

3.3 Proportional valve



The behaviour of a 4/3 directional control valve with closed centre position, parameterisable overlap and dynamics is modelled. The nominal flow rates of the control edges can be specified individually. All parameters can be taken from the typical valve data sheets.

3.4 Cylinder



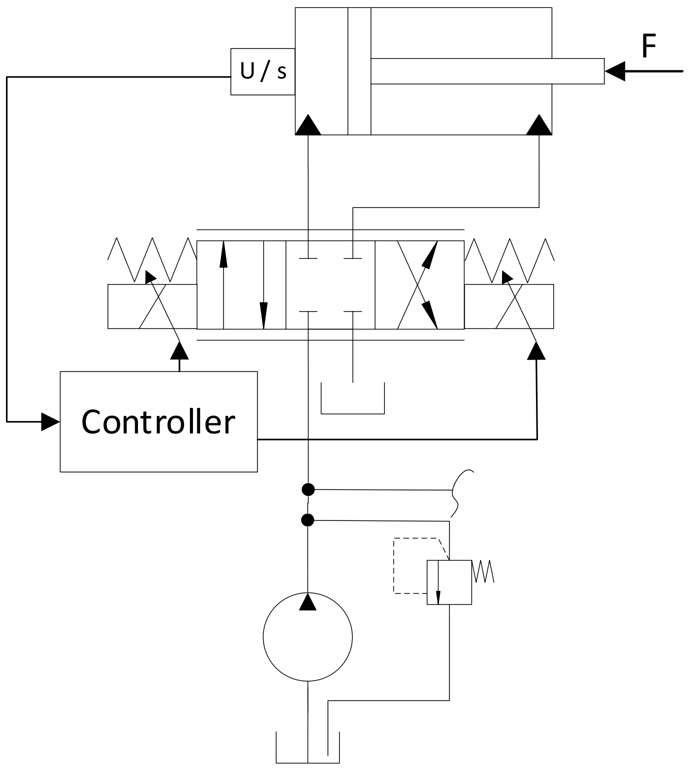
The model allows both synchronous and differential cylinders or plungers to be described through appropriate parameterisation.

The contained oil volume and its stroke dependency are taken into account in the equations of the pressure build-up. Static friction and viscous damping are also considered.

3.5 Load

It is possible to apply a constant load or specify two position-dependent curves for extension and retraction.

3.6 Typical overall model



In the simplest configuration, a cylinder drive with position controller can be simulated. The indicated connecting line on the pressure line symbolises the possibility of expanding to several axes that are fed by the same pressure supply.

4 Parameterisation

4.1 Parameter overview

All simulation parameters can be found in the "Simulation" group. This is a typical view of the parameter page in the WPC:

SIM	ON	Activate internal simulation
Simulation of the pressure supply		
VTYPE	NPRDBV	Type of the pressure supply
Q_PUMP	40,0	Nominal flow rate of the pump [l/min]
QVP	0,01	Pressure-dependent leakage [l/(min*bar)]
VHYD	5,0	Hydraulic dead volume [l]
EFP	OFF	The bulk modulus of the oil is pressure-dependent
PDBV	100,0	Nominal opening pressure of the relief valve [bar]
DPDBV	0,25	Characteristic curve slope [bar/(l/min)]
TNRAMP	1000	Time for speed change 0-100% [ms]
TDBV	0,08	Response time of the relief valve [s]
QNDBV	40,0	Flow corresponding to min. pressure [l/min]
PMIN	15,0	Minimum pressure relief valve [bar]
DBHYST	5,0	Characteristics hysteresis [% of PDBV]
Simulation of the direktional valve		
Q_PA	40,0	Nominal volume flow P->A [l/min]
Q_PB	40,0	Nominal volume flow P->B [l/min]
Q_AT	40,0	Nominal volume flow A->T [l/min]
Q_BT	40,0	Nominal volume flow B->T [l/min]
VOVL	0,0	Overlap [%]
VHYST	0,5	Hysteresis [%]
TSTP	20	Step response time [ms]
EIGENFV	35	Eigenfrequency of the valve [Hz]
Cylinder and pipes		
CYLDIAP	90,0	Piston diameter [mm]
CYLDIARA	0,0	Rod diameter A [mm]
CYLDIARB	40,0	Rod diameter B [mm]
CYLSTRK	0,1	Cylinder stroke 0.001m]
MOVMA	25,0	Moving mass [kg]
DVIS	100,0	Coefficient of viscous damping [Ns/m]
VTOTA	0,2	Dead volume side A [l]
VTOTB	0,2	Dead volume side B [l]
External and Internal Forces		
CCF	OFF	Load Curves
FHAFT	50,0	Static friction[N]
FLCONST	0,0	Constant load force against A [N]

4.2 *Pressure supply parameters*

Preliminary remark: Depending on the selection of the VTYPE parameter, only the parameters that are relevant for the selected type of pressure supply are displayed. The others can be ignored as they have no influence on the calculation.

4.2.1 SIM (activation of the internal simulation)

Command	Parameters	Unit	Group
SIM x	x= OFF|ON|EXT	-	**SIMULATION**

This command is used to activate the simulation if the "ON" or "EXT" setting is selected.

If you do not want to control any hardware outputs in this mode (the normal case), you should set ON. If EXT is selected, the assignments to the hardware outputs defined via the script will continue to be carried out. This mode, together with a corresponding script, is suitable for operating the device as a pure axis simulator, for example.

4.2.2 VTYPE (type of pressure supply)

Command	Parameters	Unit	Group
VTYPE x	x= CDBV|CADBV|IDPMP|NPRDBV|ACHC	-	**SIMULATION**

This command is used to select the type of pressure supply. See section 3.1.

4.2.3 QPUMP (nominal flow rate of the pump)

Command	Parameters	Unit	Group
QPUMP x	x= 0.0.. 10000.0	l/min	**SIMULATION**

This command is used to specify the nominal delivery rate of the pump. With the NPRDBV system, this corresponds to the flow rate at maximum speed. If the IDPMP system is selected, this parameter is not available as the flow rate is not limited.

4.2.4 QVP (pressure-dependent leakage)

Command	Parameters	Unit	Group
QVP x	x= 0.0.. 1000.0	ml/(min.*bar)	**SIMULATION**

The limited volumetric efficiency of the pump is defined by this specification. The parameter is also visible when VTYPE = IDPMP is selected. In this case, it is only used to calculate the power.

4.2.5 EFP (Bulk modulus of the oil depending on pressure)

Command	Parameters	Unit	Group
EFP x	x= OFF|ON	-	SIMULATION

As described in section 3.2, this setting can be used to determine whether a dependency of the oil compressibility on the pressure is taken into account. This is the case if the parameter is switched to ON. This setting relates to the entire model, i.e. the oil in the cylinder chambers is also calculated accordingly.

4.2.6 PDBV (nominal opening pressure of the pressure relief valve)

Command	Parameters	Unit	Group
PDBV x	x= 0.. 2000	bar	SIMULATION

This input determines the system pressure:

For the CDBV, CADBV and ACHC pressure supplies, it indicates the actual opening pressure of the fixed pressure relief valve.

The constant system pressure is defined here in the IDPMP system.

If the NPRDBV option is selected, this parameter specifies the maximum opening pressure of the pressure relief valve that is reached at 100% control. It is also the reference value for the valve hysteresis.

4.2.7 DPDBV (characteristic curve gradient of the pressure relief valve)

Command	Parameters	Unit	Group
DPDBV x	x= 0.01.. 200.0	bar/(l/min)	SIMULATION

A typical pressure relief valve has an approximately linear dependence of the pressure on the volume flow. This parameter is used to specify the gradient of this function. The parameter is not available for the IDPMP system.

4.2.8 VACC (gas volume of the accumulator)

Command	Parameters	Unit	Group
VACC x	x= 0.0.. 2000.0	l	SIMULATION

For the accumulator used in the CADBV and ACHC systems, the gas volume in the preloaded, non-pressurised state can be specified here. The higher the volume, the more oil can be absorbed.

4.2.9 PREP (preload pressure of the accumulator)

Command	Parameters	Unit	Group
PREP x	x= 0.0.. 2000.0	bar(g)	**SIMULATION**

For the accumulator used in the CADBV and ACHC systems, the preload pressure of the gas volume in the pre-loaded, non-oil-pressurised state can be specified here. Below this pressure, the accumulator does not absorb or release any oil. It should be noted that, like the other pressures, the value is actually specified as gauge pressure, i.e. the atmospheric pressure is still added during internal further calculation.

4.2.10 NPOL (polytropic exponent)

Command	Parameters	Unit	Group
NPOL x	x= 1.0.. 2.0	-	**SIMULATION**

Exponent for the polytropic change of state of the gas in the accumulator.

The preset value of 140, i.e. 1.4, corresponds to the isentropic change of state of a diatomic gas (e.g. N_2). The approach of this change of state leads to a conservative consideration. If the exponent is set to 1.0, this would correspond to an isothermal change of state in which more volume change is required for the same increase or decrease in pressure. This limiting case can be approximated for very slow processes.

4.2.11 TNRAMP (time for speed change)

Command	Parameters	Unit	Group
TNRAMP x	x= 0.. 100000	ms	**SIMULATION**

The pump drive of the NPRDBV system has limited dynamics. Conventional inverters contain a ramp function for the speed setpoint, which can be used to define this within certain limits. In addition, there is of course a physical limit, as an acceleration torque is required. You should therefore either enter the set ramp time or, if this is relatively short, the actual realisable acceleration time for a speed change from 0-100%.

4.2.12 TDBV (response time of the pressure relief valve)

Command	Parameters	Unit	Group
TDBV x	x= 1.. 100000	ms	**SIMULATION**

The control behaviour of the proportional pressure relief valve in the NPRDBV system is approximated by a PT1 element. Its time constant is specified at this point.

4.2.13 QNDBV (quantity for minimum pressure specification pressure relief valve)

Command	Parameters	Unit	Group
QNDBV x	x= 1.. 100000	l/min	SIMULATION

The proportional pressure relief valves in the NPRDBV system have a volume-dependent pressure drop even when not actuated. The associated flow characteristic curve is defined by a point (quantity / pressure).

4.2.14 PMIN (minimum pressure pressure relief valve)

Command	Parameters	Unit	Group
PMIN x	x= 0.0.. 2000.0	bar	SIMULATION

Pressure specification for the flow characteristic curve, see above.

4.2.15 DBHYST (characteristic hysteresis)

Command	Parameters	Unit	Group
DBHYST x	x= 0.01.. 1000.0	%	SIMULATION

The resulting pressure at the proportional - pressure relief valve is a function of control and volume flow. If only the relationship p=f(i) (with i = solenoid current) is considered, i.e. the volume is kept constant, a characteristic curve is obtained that shows this relationship. The control pressure characteristic curve usually has a significant hysteresis, which is specified in the data sheet in relation to the maximum pressure. This value must be entered here.

4.2.16 PSTOP / PSTART (switching points for accumulator charging circuit)

Command	Parameters	Unit	Group
PSTOP x PSTART x	x= 0.0.. 2000.0	bar	SIMULATION

These parameters are only relevant for the ACHC supply system (with accumulator charging circuit).

The pressure PSTOP corresponds to the upper switching point of the charging circuit. If it is exceeded, charging of the accumulator is ended and the neutral circulation of the pump is activated and/or its drive is switched off. The non-return valve to the accumulator and system closes. As soon as the pressure has fallen below PSTART, the accumulator is charged again. This is therefore a 2-point controller with presettable hysteresis. To ensure proper function, always set PSTOP > PSTART.

4.2.17 QLEAK (pressure-dependent system leakage)

Command	Parameters	Unit	Group
QLEAK x	x= 0.0.. 1000.0	ml/(min.*bar)	**SIMULATION**

When using an accumulator charging circuit, it is very important to take into account the leakage quantities that occur during periods without pump delivery. These are generally losses that can occur in the shut-off center position of spool valves.

In contrast to the pump leakage, which is specified with the parameter "QVP", this quantity is also present when the pump is not delivering into the system.

4.3 Parameters of the directional control valve

4.3.1 Q_PA / Q_PB / Q_AT / Q_BT (nominal volume flows)

Command	Parameters	Unit	Group
Q_.. x	x= 0.0.. 10000.0	l/min	**SIMULATION**

For each of the four control edges of the directional control valve, the flow rate at full opening and a defined pressure difference of 35 bar (per edge) is specified at this point. Valves with short-circuited consumer connections are usually measured so that this corresponds to a total pressure of 70 bar with an identical pressure drop at the inlet and outlet edges.

If the data sheet specification refers to a different differential pressure, it must be converted:

$$Q_E = Q_D \cdot \sqrt{\frac{35\,bar}{\Delta p_D}}$$

where Q_E is the quantity to be entered, Q_D is the quantity specified in the data sheet and Δp_D is the pressure difference at <u>one</u> control edge of the data sheet specification.

4.3.2 VOVL (overlap)

Command	Parameters	Unit	Group
VOVL x	x= 0.0.. 100.0	%	SIMULATION

This parameter specifies the (positive) overlap of the directional control valve. This is symmetrical on both sides.

4.3.3 VHYST (valve hysteresis)

Command	Parameters	Unit	Group
VHYST x	x= 0.0.. 100.0	%	SIMULATION

This parameter specifies the hysteresis of the directional control valve.

4.3.4 TSTP (step response time)

Command	Parameters	Unit	Group
TSTP x	x= 0.. 1000	ms	SIMULATION

The step response time of the valve (data sheet specification) must be entered here. Sometimes this must be read from a diagram.

4.3.5 EIGENFV (natural frequency of the valve)

Command	Parameters	Unit	Group
EIGENFV x	x= 1.. 1000	Hz	SIMULATION

The natural frequency of the valve is specified here, which is either listed directly in the data sheet or can be taken from a body diagram. The frequency at which the phase shift is -90° must be determined there.

In the case of directly controlled valves, this is usually not specified either, only the step response time. The natural frequency should then be entered according to the rule of thumb $f_0\ [\mathrm{Hz}] \approx 740\ /\ T_{Step}\ [\mathrm{ms}]$ should be entered.

4.4 Cylinder parameters

4.4.1 CYLDIAP (piston diameter)

Command	Parameters	Unit	Group
CYLDIAP x	x= 0.1.. 1000.0	mm	**SIMULATION**

4.4.2 CYLDIARA (rod diameter A)

Command	Parameters	Unit	Group
CYLDIARA x	x= 0.0.. 1000.0	mm	**SIMULATION**

If there is a rod on side "A", its diameter must be specified here, otherwise 0 mm.

4.4.3 CYLDIARB (rod diameter B)

Command	Parameters	Unit	Group
CYLDIARB x	x= 0.0.. 1000.0	mm	**SIMULATION**

If there is a rod on side "B", its diameter must be specified here, otherwise 0 mm.
To simulate a plunger cylinder, the rod diameter can be set equal to the piston diameter.

4.4.4 CYLSTRK (cylinder stroke)

Command	Parameters	Unit	Group
CYLSTRK x	x= 1.. 10000	mm	**SIMULATION**

4.4.5 MOVMA (moving mass)

Command	Parameters	Unit	Group
MOVMA x	x= 1.. 10000	kg	**SIMULATION**

The moving mass includes the piston, the piston rod and the parts to be driven. If there is a mechanical transmission (e.g. by a lever), a mass reduced to the piston must be determined and specified here. This information is not used to determine a weight force, see below.

4.4.6 DVIS (viscous damping coefficient)

Command	Parameters	Unit	Group
DVIS x	x= 10.. 10000	Ns/m	SIMULATION

This coefficient indicates the proportion of the frictional forces that is proportional to the speed. This causes damping of the cylinder.

4.4.7 VTOTA / VTOTB (dead volume side A/B)

Command	Parameters	Unit	Group
VTOTA/B x	x= 0.2.. 100.0	l	SIMULATION

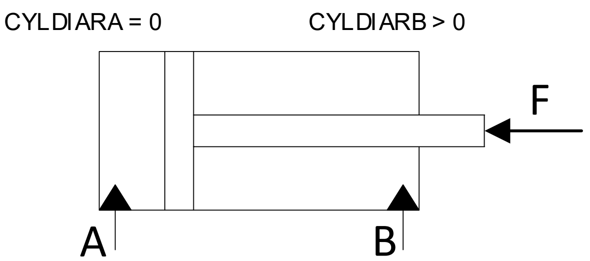
Dead volume of the oil on side A / B of the cylinder and the connected line up to the valve. If hoses are used, their elasticity must be taken into account by applying a surcharge factor (e.g. 2.5 for the oil volume within the hose).

4.5 Load force parameters

Basically, this refers to any force acting on the cylinder, with the exception of viscous damping (see above). This also includes the weight force. If a load is not moved purely horizontally, this must be taken into account accordingly.

Sign convention:

A force against "A" is regarded as positive. So when this cylinder extends (x rises, oil flows into its port A), work is performed against the force F:



In the case of a negative force, the piston rod in this example would be subjected to tensile stress.

4.5.1 CCF (force curves)

Command	Parameters	Unit	Group
CCF x	x= OFF|ON	-	**SIMULATION**

If "ON" is selected here, the load force is defined separately for extension and retraction depending on the stroke. "OFF" means that only a constant load force (+ direction-dependent friction) can be specified.

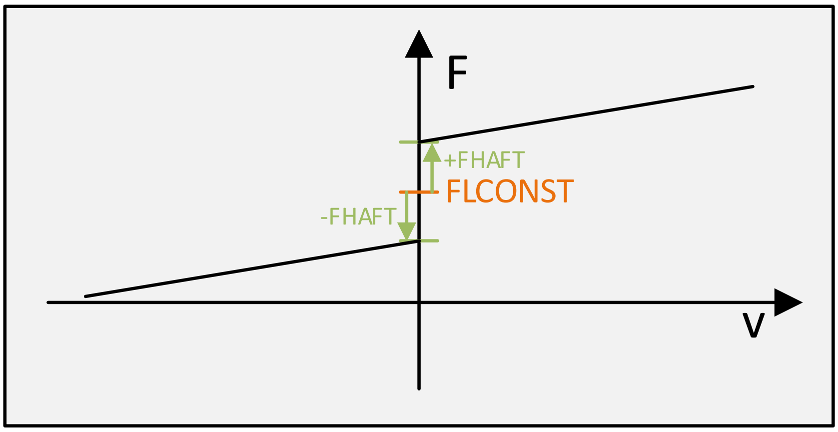
4.5.2 FHAFT (direction-dependent frictional force)

Command	Parameters	Unit	Group
FHAFT x	x= 10.. 10000000	N	**SIMULATION** **CCF = OFF**

4.5.3 FLCONST (constant load force against A)

Command	Parameters	Unit	Group
FLCONST x	x= -10000000.. 10000000	N	**SIMULATION** **CCF = OFF**

On the effect of the forces FHAFT and FLCONST:



If the speed is positive, FHAFT is added to FLCONST; if the speed is negative, it is subtracted. The further gradient of the counterforce results from the viscous damping.

4.5.4 FNORM (standardised maximum force)

Command	Parameters	Unit	Group
FNORM x	x= -10000000.. 10000000	N	**SIMULATION** **CCF = ON**

4.5.5 CCFLE / CCFLR (force curves)

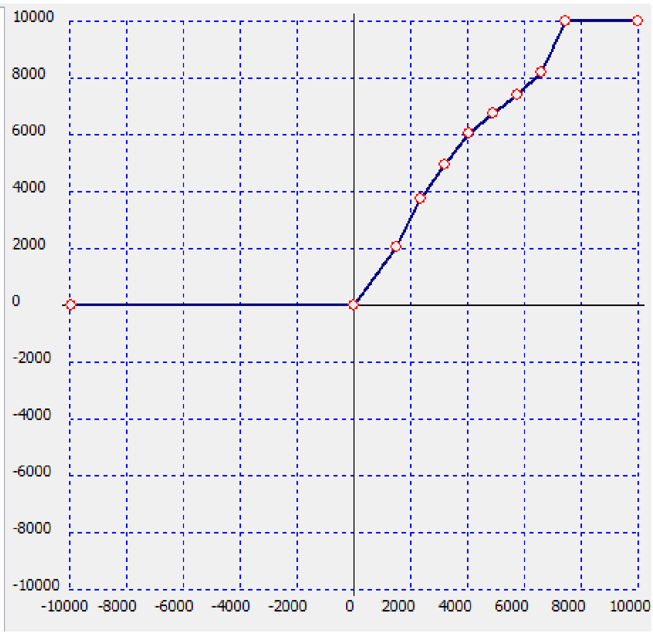
Command	Parameters	Unit	Group
CCFLE/CCFLR :I X Y	i= -10... 10 x= -10000... 10000 y= -10000... 10000	- 0,01 % 0,01 %	**SIMULATION** **CCF = ON**

Force curves can be entered as curves at this point. The X-axis corresponds to the standardised stroke, the Y-axis to a standardised force.

The curve is always in the first or second quadrant. Negative strokes do not occur, which is why the corresponding Y coordinates are set to "0".

The output is calculated using linear interpolation: **y=(x-x1)*(y1-y0)/(x1-x0)+y1**.

Command	X-Value	Y-Value
CC:10	10000	10000
CC:9	7474	10000
CC:8	6608	8213
CC:7	6608	8213
CC:6	6608	8213
CC:5	6608	8213
CC:4	5760	7408
CC:3	4912	6730
CC:2	4064	6051
CC:1	3216	4955
CC:0	2368	3737
CC:-1	1520	2032
CC:-2	0	0
CC:-3	-10000	0
CC:-4	-10000	0
CC:-5	-10000	0
CC:-6	-10000	0
CC:-7	-10000	0
CC:-8	-10000	0
CC:-9	-10000	0
CC:-10	-10000	0



An input value of "10000" corresponds to 100% stroke on the X-axis or the full load force FNORM.

Two curves are defined, one for extending the cylinder (CCFLE), the other (CCFLR) for retracting. It should be noted that the force during extension should always be greater than that during retraction. Otherwise, negative friction and thus physically impossible and unstable behaviour would be created. To rule out such a situation, the points of the CCFLR curve are automatically adjusted after changes to this curve or to the CCFLE curve if they lie above the forces during extension with the same stroke.

5 Use simulation

5.1 Connection of the simulation to the internal controller

Actual value (position): This value is replaced by the simulated value by the controller after the simulation is activated, regardless of what is assigned by the script in XN.

Output value of the controller / manipulated variable:

This value is assigned by the script. The "SIMU" line in the standard script already contains a direct assignment of the process variable "U", which can usually be retained without modification.

5.2 Use of an external signal interface

The script also offers the option of using other signals as inputs or outputs, allowing the device to be used as a universal axle simulator, for example.

To ensure that the outputs continue to be controlled, the SIM parameter must be set to EXT and the desired signal links made in the script:

Input signal Script from Sim	**Meaning**	**Value range**
X	Current position [mm]	0... Stroke
PPSIM	Pump pressure [bar]	
PASIM	Pressure cylinder connection A [bar]	
PBSIM	Pressure cylinder connection B [bar]	

The following script outputs are available in the direction of the simulation:

Output signal script for the sim	**Meaning**	**Value range**
SIMU	Control of the simulated directional control valve	+/- 100,0 %
SIMDB	Control of a simulated prop. DBV	0,0... 100,0%
SIMN	Control of a simulated frequency inverter	0,0... 100,0%

Please note:

The outputs of the script to the simulation are limited to the value ranges specified here.

Further restrictions with regard to the control range, such as a minimum speed, must be made in the script.

5.3 Activation of the simulation and observation of the values

By setting the SIM parameter to ON, the simulation is activated and the hardware outputs are switched off. It is recommended to use the remote control function of the WPC to activate the controller or manual mode and specify setpoints.

The simulated values are observed either in the monitor window of the WPC or better in the oscilloscope window, as the signal curves are displayed there.

6 Examples

The following examples are also suitable as a quick introduction to the topic.

Due to the large number of parameters, the module can only be used with WPC version 4.0 or higher.

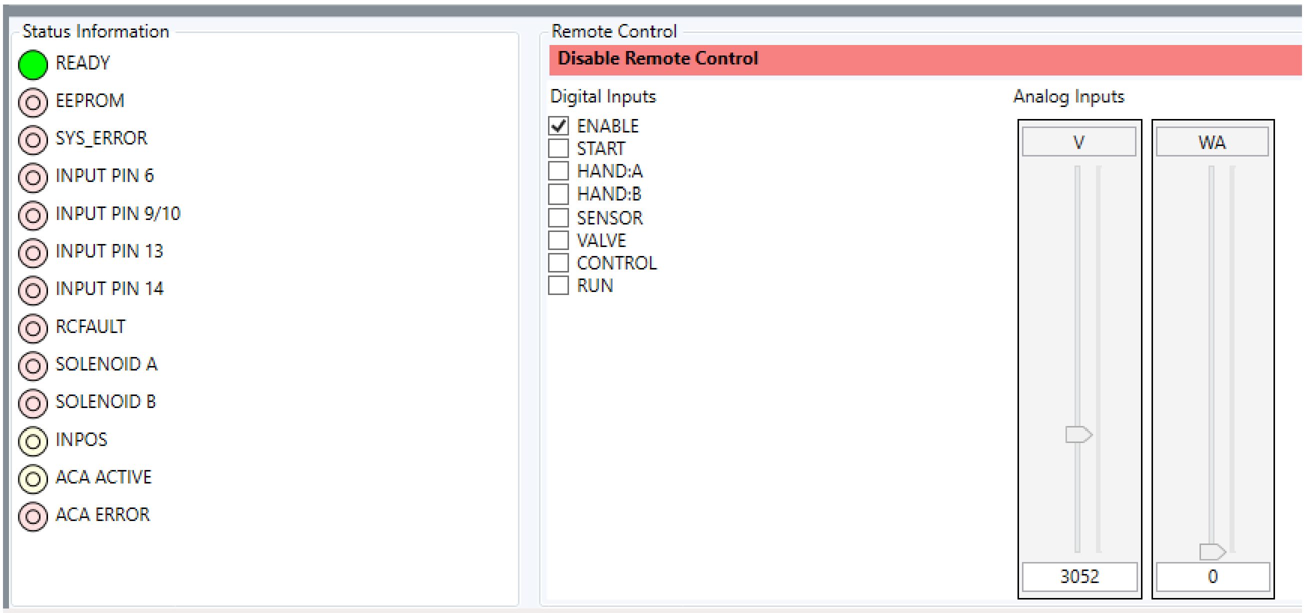
6.1 Simulation of the system according to factory settings

The starting point is a device with factory parameterisation; if necessary, reset it to this with "DEFAULT".

Select the "Simulation" group:

Set the top parameter SIM to ON.

Activate the remote control in the monitor window of the WPC and set the ENABLE input:



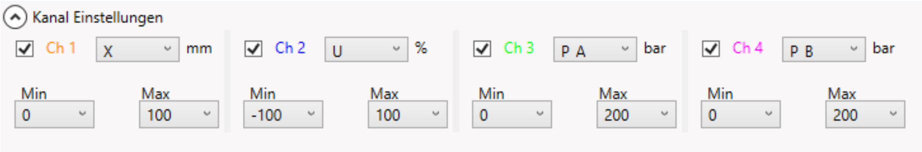
The green READY LED on the left-hand side indicates that the controller is ready for operation. Set the slider V slightly high as in this example and activate the HAND:A checkbox. Observe the process value displays of the actual value X and the pressures P_A and P_B. X increases until the cylinder has reached its end stop at 100 mm. During the movement, the pressure P_A is lower than P_B due to the area ratio of the differential cylinder and the absence of load force. As soon as the cylinder has reached the end stop, the pressure P_A rises to the pump pressure P_P and the pressure P_B drops to "0", as there is now no more flow through the valve.

To reverse the movement, remove the signal at HAND:A and set HAND:B instead. The cylinder retracts again.

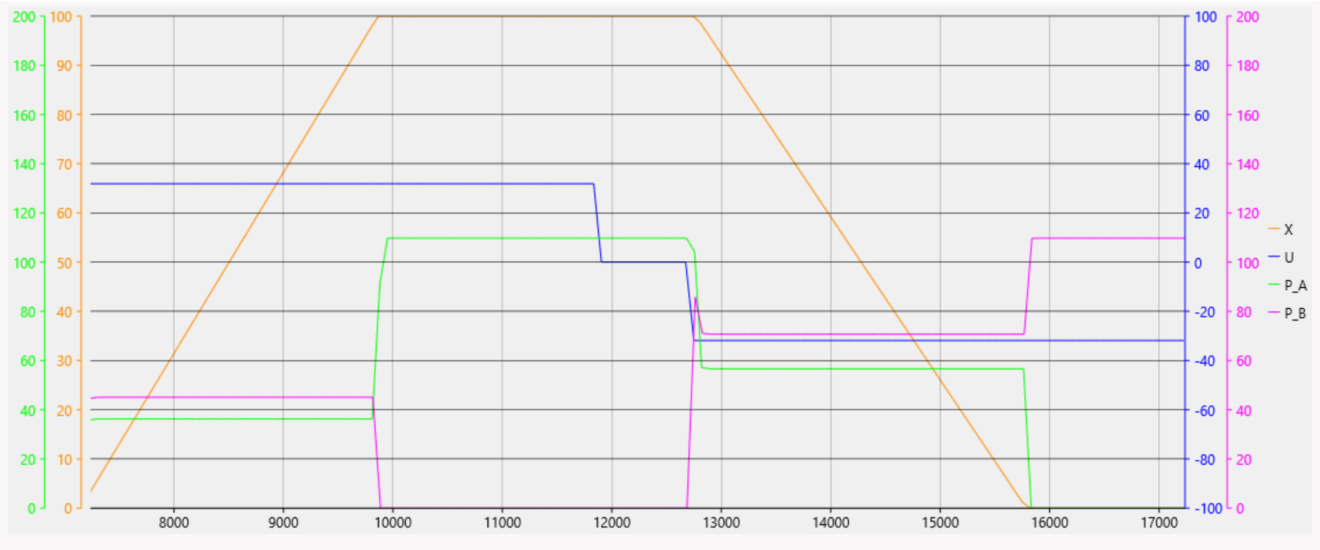
Now record the signal curves with the oscilloscope of the WPC.

To do this, first activate the corresponding window:

It is best to select these settings and value ranges:



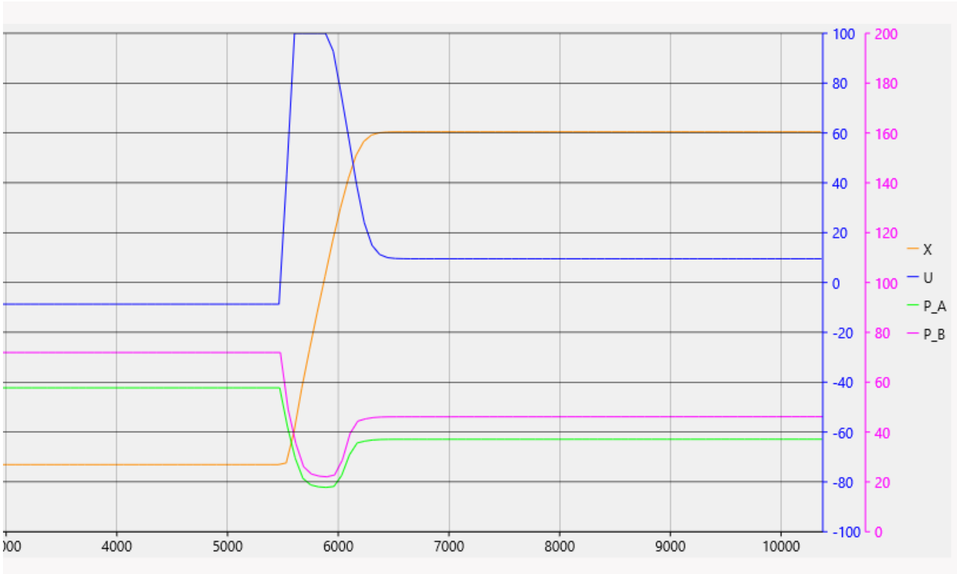
Recording can then be started and manual mode repeated:



The signal peak at P_B at the beginning of retraction is caused by the acceleration forces.

Release the maximum speed (= full control), move slider V all the way up.

Activate the position controller by pulling up the setpoint slider "WA" slightly and then setting the START signal. The controller moves the axis to the target position:

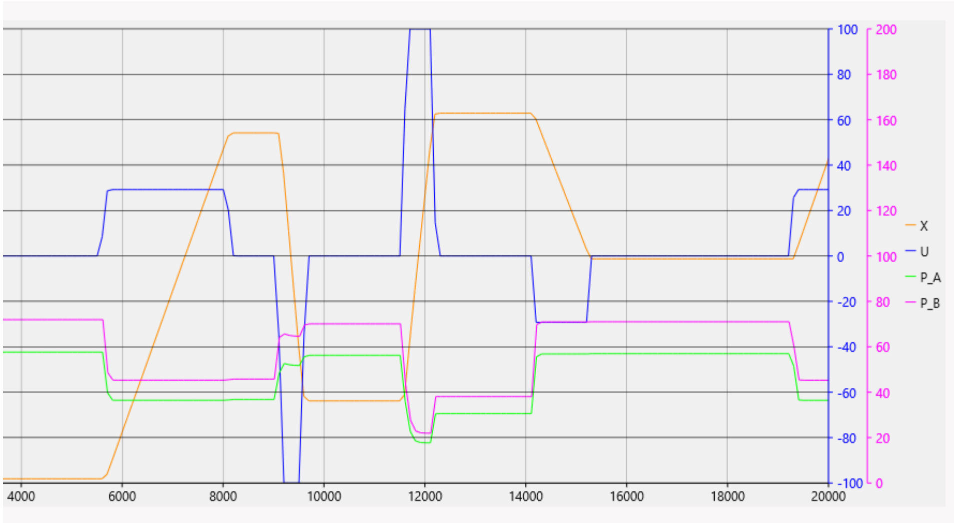


As you can see, the control of the valve (U) is approx. 10% after the movement and the axis no longer moves. This is due to the overlap, which is set to 10% via the VOVL parameter. In the monitor window you can read the control error E, which is approx. 0.9 mm. This is not yet a good result. Significant improvements are possible by adjusting the overlap compensation and braking distances accordingly.

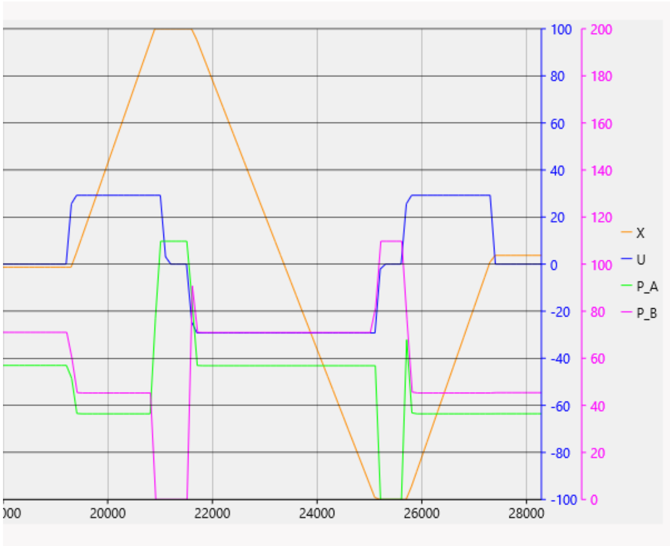
6.2 Commissioning the controller

To do this, use the wizard, see also chapter 3.3. of the device documentation.

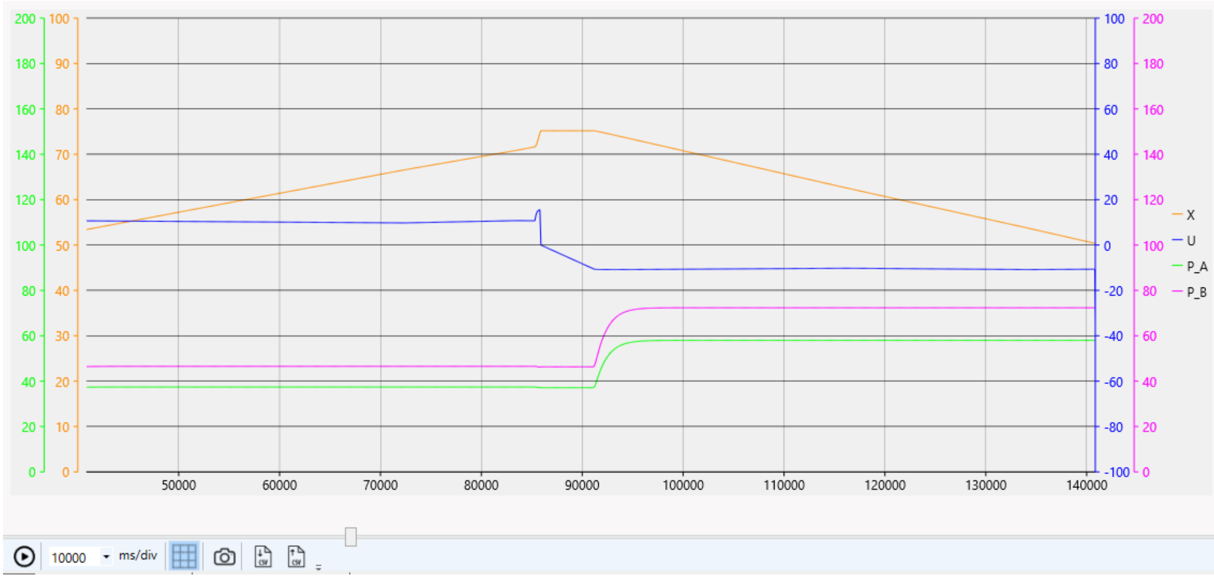
While the wizard is running, you can observe the relevant signals. These are, in particular, X and U. The cylinder pressures are also shown in the following diagrams:



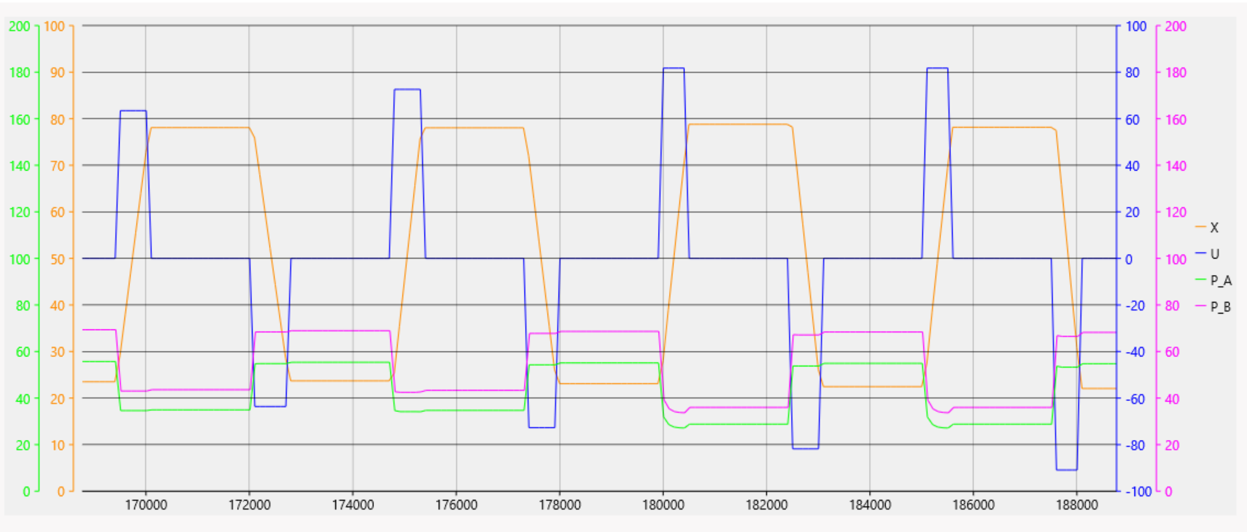
The polarity and maximum speeds are tested at the beginning.



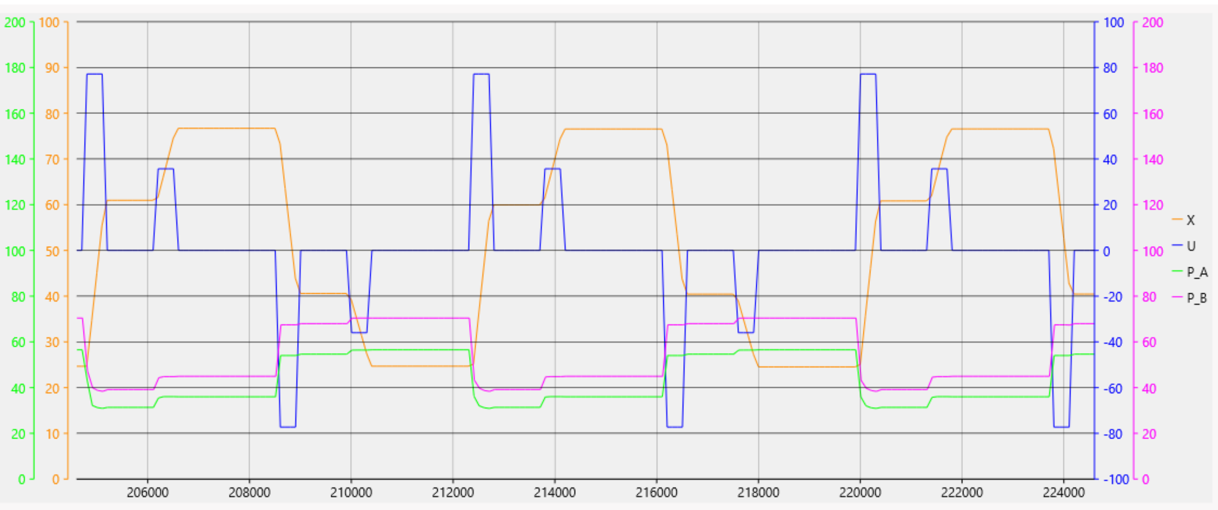
The sensor scaling is then performed by moving to the end positions. This is done with reduced control.



This diagram shows the measurement of the overlaps. Note the longer time scale. Very slow (controlled) movements in both directions determine the valve control required for this.



To determine the maximum speeds, movements are made at gradually increasing speeds.



Dynamic measurements: Braking behaviour at different speeds.

Controller Settings		
A:A	63	Acceleration time A [ms]
A:B	63	Acceleration time B [ms]
D:A	13	Deceleration stroke [mm]
D:B	14	Deceleration stroke [mm]
D:S	10	Emergency stop stroke (PIN 7 = OFF) [mm]
PT1	1	PT1-filter time constant [ms]
Valve Adaption		
CTRL	SQRT1	Control characteristic
MIN:A	9,13	MIN adjustment / deadband compensation A [%]
MIN:B	9,54	MIN adjustment / deadband compensation B [%]
MAX:A	100,0	Output scaling A [%]
MAX:B	100,0	Output scaling B [%]
TRIGGER	0,5	Trigger point of the MIN adjustment [%]
OFFSET	0,0	Output offset [%]
POL:U	+	Polarity of the output signal

The controller parameters after running through the wizard:

- The braking distances D:A and D:B have been reduced, which increases the gain of the controller
- The acceleration times have also been shortened
- The overlap of the valve was compensated: The set values of 9.13% and 9.54% are below the simulated value of 10%. The algorithm takes into account a certain, but small, safety margin so as not to overcompensate for the true overlap under any circumstances. The fact that this distance is not the same is due to the asymmetrical surface ratios in the cylinder.

If you now allow the controller to work again by switching on the test signal and observe the control deviation, you will notice that it is only 0.03 mm after the positioning process has been completed.

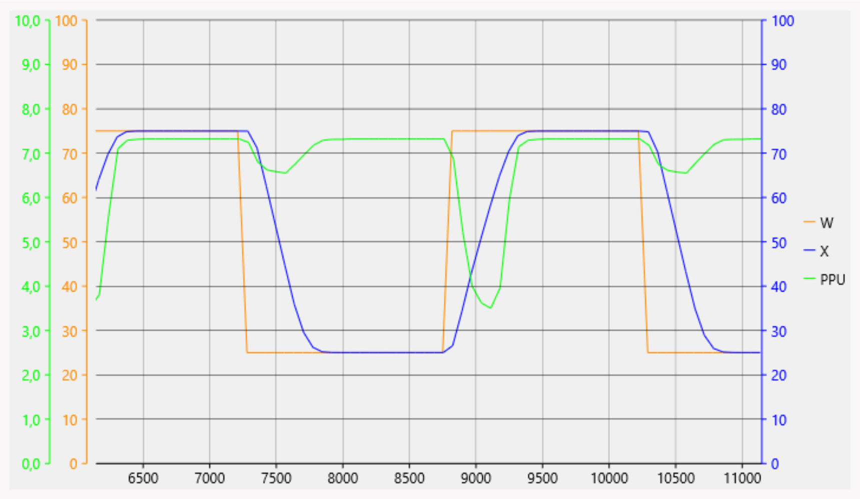
This meant that it could be reduced to 1/30 of the original value with the correct setting.

6.3 *Examples of parameter changes and their effects*

Based on this well-adjusted system, the effects of some variations will now be analysed. These are typical changes in behaviour that are considered here in purely qualitative terms. More precise statements on a specific system require its data to be used for parameterisation.

6.3.1 Energy consumption of different pressure supplies

The process variable PPU shows the current pump output in the unit [kW], disregarding hydraulic-mechanical losses. If this signal is also recorded, the CDBV system produces this image:



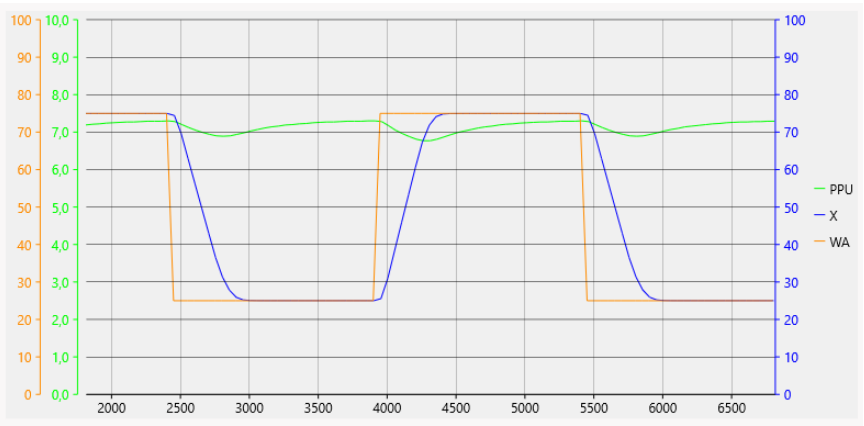
Since a fixed displacement pump is used, the power consumption depends only on the line pressure.

As can be seen, the power consumption decreases during the movement phases, which is also due to a collapse of the supply pressure. In a conventionally designed system, this in turn indicates that the valve is oversized or the pump is undersized.

If you enter the "ST_ACA" command in the terminal after running the commissioning wizard, the recommendation is given to set the MAX parameters to less than 100%, which reduces the maximum valve opening and allows you to work with a higher supply pressure during the movements. In this example, however, this would also lead to an increase in energy consumption.

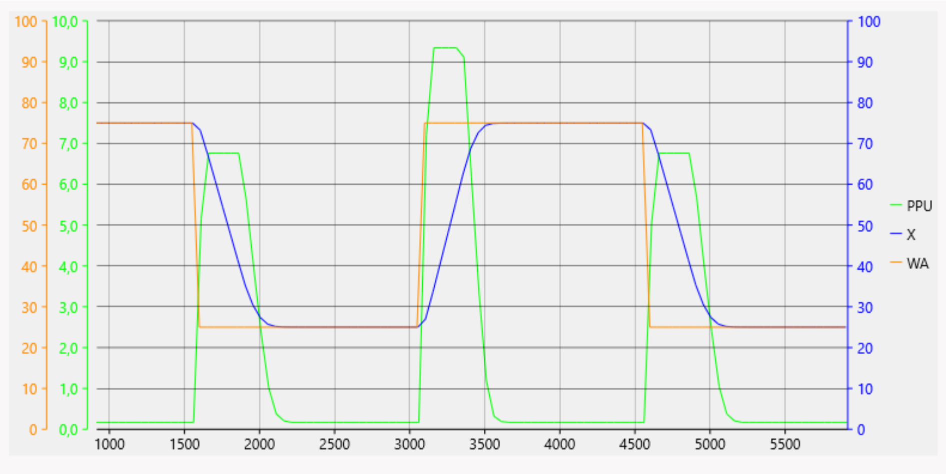
In order to be able to compare different systems, it is possible to output the drive power integrated over a movement cycle. This is done using the terminal command "ECYCLE". The output is in [J]. In this example, this command provides the value approx. 20300 J. As it was averaged over 3s, this corresponds to an average power of approx. 6.76 kW.

If you now change the supply system and add an accumulator (CADBV), the time curve of the variables shown above changes:



It can be seen that the supply pressure no longer collapses so sharply in the phases with movement, as the missing volume is covered by the accumulator. You can also see that the extension movement is somewhat faster. Unfortunately, however, this measure has increased the cycle energy to 21.38 kJ.

The situation is different if you consider the limiting case of an ideal, pressure-controlled pump (VTYPE = IDPMP):

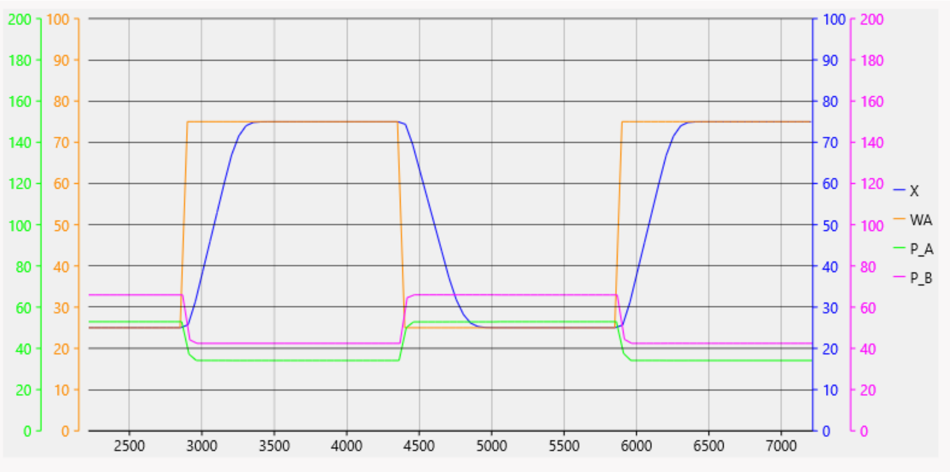


As the pressure now remains constant, the movement is just as fast as in the version with an accumulator. The power consumption now pulsates and reaches its maximum during the movements.

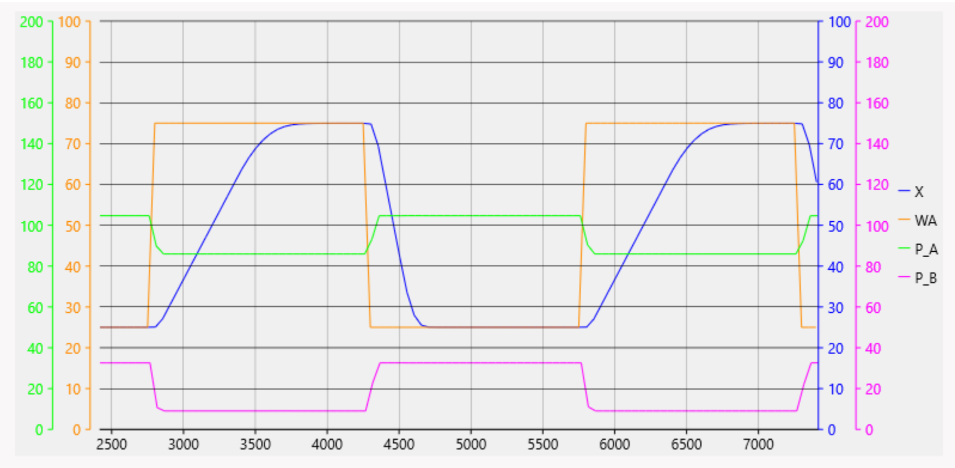
However, at 6.23 kJ, the cycle energy is less than 30% of the previous value!

6.3.2 Load forces

A modified signal selection is interesting here, in which the pressures in the cylinder chambers are added:



With a constant load force of 50 kN against A:

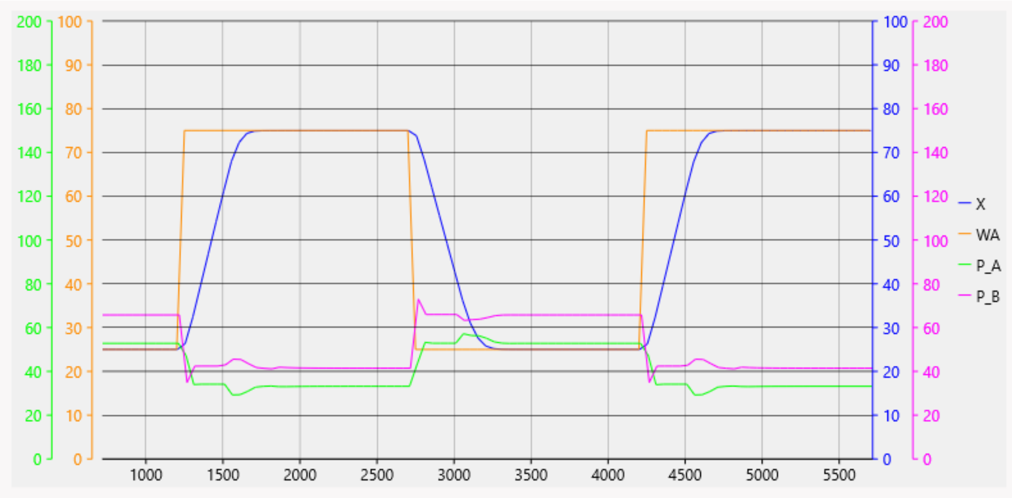


The pressure ratios in the cylinder change significantly due to the load, so that the pressure on side A is now always higher. As the force always acts in the same direction, retraction is a driving load. Nevertheless, with the conditions selected here, the pressure on side B is always >= 9 bar, so that there is no risk of cavitation there. Load holding valves are therefore not required. However, the asymmetrical movement profile is now clearly recognisable, the extension is significantly slower than the retraction.

You could now experiment further and try limiting the signal in direction B using the MAX:B parameter, or switch the controller to NC mode so that the movement follows the target profile.

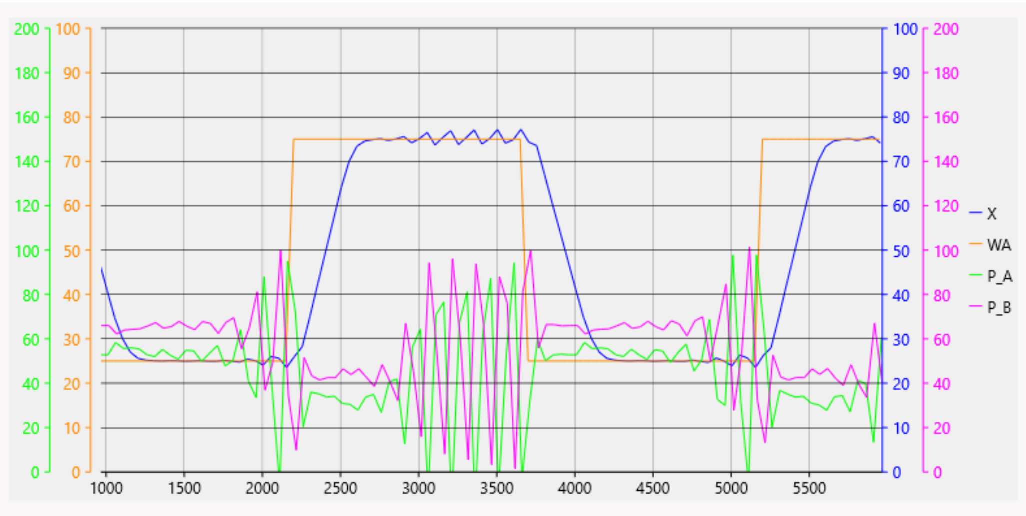
6.3.3 Line volumes

The load force is reset and the MOVMA moving mass is increased to 5000 kg:



Now you can recognise the acceleration forces from the pressure curves.

In the next step, the dead volumes VTOTA / VTOTB are increased from 0.2 to 2 litres each. The result is an unstable behaviour of the position controller in the phases in which it is engaged, particularly in direction A:



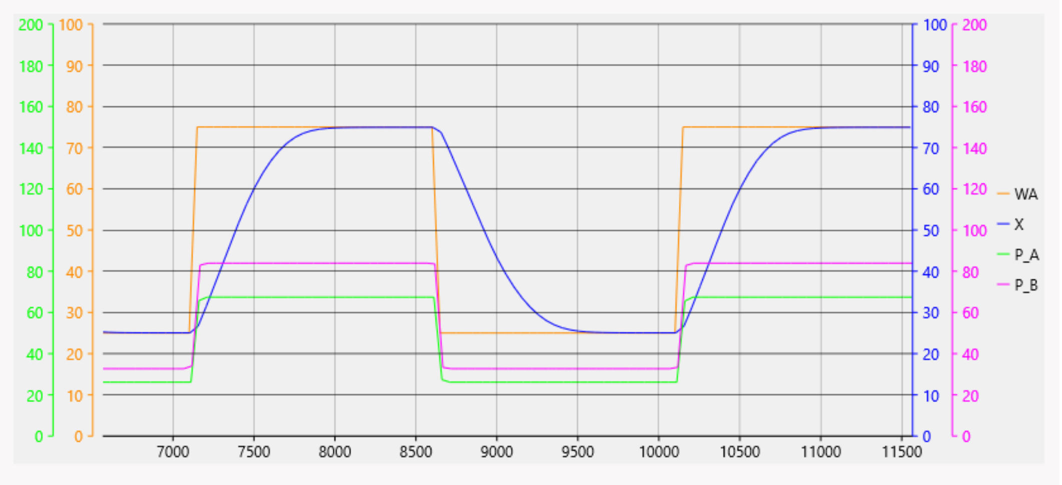
This corresponds to the theoretical prediction, as the hydraulic natural frequency of the drive has now decreased. By extending the braking distances D:A / D:B, the oscillation can be eliminated again. However, this is also associated with a deterioration in control accuracy.

6.3.4 Asymmetric valve

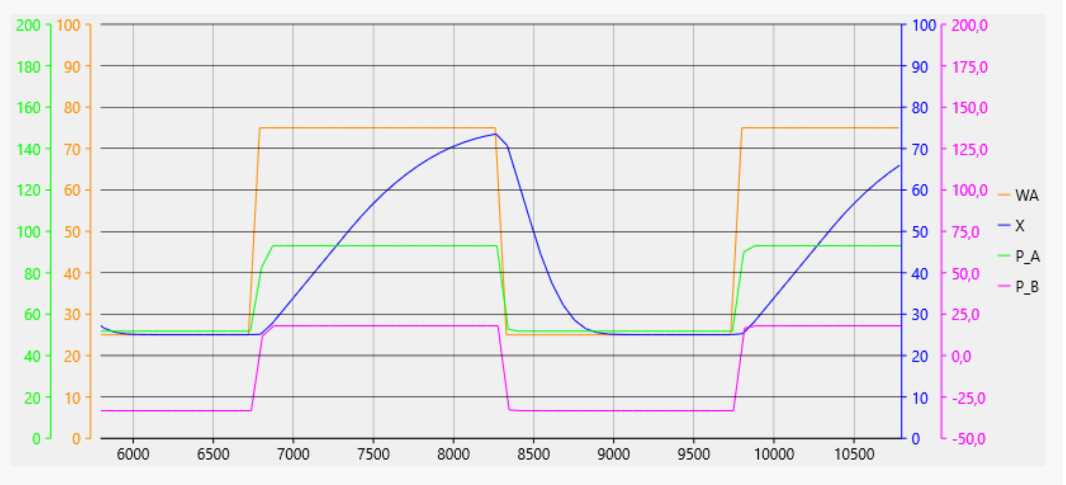
The simulated cylinder is a differential cylinder with an area ratio of approx. 1.24 (A to B). The behaviour of the actuator is now to be investigated if a valve with different flow rates is used for A and B, e.g. in a ratio of 2:1.

For this purpose, the simulations from section 6.3.2 (load forces) are repeated with this valve spool.

Firstly, we consider the case without load force:



It can be seen that the pressure level in both cylinder chambers is increased when extending and reduced when retracting. A valve with flow rates ideally matched to the cylinder, on the other hand, would deliver approximately the same pressures in both directions. The speed is reduced for both directions.



If the load force is now added, the pressure in chamber B drops to below "0" due to the driving load during retraction. In the real system, the pressure could of course not assume negative values, but the simulation processes this anyway in order to maintain numerically stable behaviour in any case. In reality, air dissolved in the oil would now separate and form bubbles, which should be avoided at all costs.

In this constellation, only an increase in the supply pressure to values of around 250 bar ensures that sufficient oil can flow into chamber B.

With the given system, the use of a 2:1 slide valve is therefore not a good solution.

7 Notes