

# Software module for synchronization control of linear hydraulic actuators

## H4U.app SC (synchronization control)



- ▶ PLC function block for controlling a synchronized motion of hydraulic actuators
- ▶ Adjustable modes for the basic behavior of the synchronization controller
- ▶ Minimal synchronization error even with uneven load distribution on the cylinders
- ▶ For Siemens and Beckhoff control systems

### Features

- ▶ Synchronization control in the operating modes position, force and velocity
- ▶ Model-based following error monitoring
- ▶ Break mechanism to interrupt command value calculation
- ▶ Target integrator for minimizing the variations of target positions of individual axes

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**Ordering code:** Software license

| 01      |   | 02 |   | 03   |   | 04 |   | 05 |   | 06  |   | 07 |  |
|---------|---|----|---|------|---|----|---|----|---|-----|---|----|--|
| SWL-HYD | - | T  | - | SC** | - |    | - | 01 | - | P01 | - |    |  |

|    |                                             |         |
|----|---------------------------------------------|---------|
| 01 | Software license for hydraulic applications | SWL-HYD |
|----|---------------------------------------------|---------|

|    |                    |   |
|----|--------------------|---|
| 02 | Technology library | T |
|----|--------------------|---|

## Category

|    |                         |      |
|----|-------------------------|------|
| 03 | Synchronization control | SC** |
|----|-------------------------|------|

## Scope of functions

|    |                                                       |                      |
|----|-------------------------------------------------------|----------------------|
| 04 | Basic, number of axes in synchronous connection: 2    | <b>BASIC*M02*</b>    |
|    | Basic, number of axes in synchronous connection: 4    | <b>BASIC*M04*</b>    |
|    | Basic, number of axes in synchronous connection: 8    | <b>BASIC*M08*</b>    |
|    | Option 1, number of axes in synchronous connection: 2 | <b>OPT01*M02* 1)</b> |
|    | Option 1, number of axes in synchronous connection: 4 | <b>OPT01*M04* 1)</b> |
|    | Option 1, number of axes in synchronous connection: 8 | <b>OPT01*M08* 1)</b> |

## Version

|    |    |    |
|----|----|----|
| 05 | 01 | 01 |
|----|----|----|

|    |                                         |     |
|----|-----------------------------------------|-----|
| 06 | Permanent license, 1 license activation | P01 |
|----|-----------------------------------------|-----|

## Target system

|    |                    |             |
|----|--------------------|-------------|
| 07 | Siemens TIA Portal | <b>TIA*</b> |
|    | Beckhoff TwinCAT 3 | <b>TC3*</b> |

| Target system | PLC runtime system                   | Recommended control hardware <sup>2)</sup> |
|---------------|--------------------------------------|--------------------------------------------|
| Siemens       | TIA Portal<br>(version 18 or higher) | SIMATIC S7-1500                            |
| Beckhoff      | TwinCAT 3                            | Embedded PC series<br>CX5100, CX8100       |

1) Requires valid licensing of the Basic functional scope.

- 2) The PLC runtime system is a prerequisite for the use of the software. Selection of suitable control hardware depends on the specific application and is determined by the user.

## Function

The software module "H4U.app SC" allows the synchronized operation of a defined group of axes (synchronized group of slave axes). The relative positions of the axes are regulated in this case. The basic behavior of the synchronization controller is parameterized via adjustable modes. This enables the realization of applications from a variety of areas, such as press technology, metallurgical and rolling mill technology or general mechanical engineering. The command values of the synchronized group are commanded via the synchronization axis. From an outside perspective, the synchronized group is thus a controller axis. The synchronization controller calculates the command values of each individual slave axis, taking into account the selected synchronization mode and the current actual values.

In the "Basic" functional scope, the synchronism is regulated via the variables force and velocity. With the "Option 1" functional scope, the force of the slave axes can also be limited to enable alternating position/force control. There is also the option of specifying a constant sum force for all slave axes.

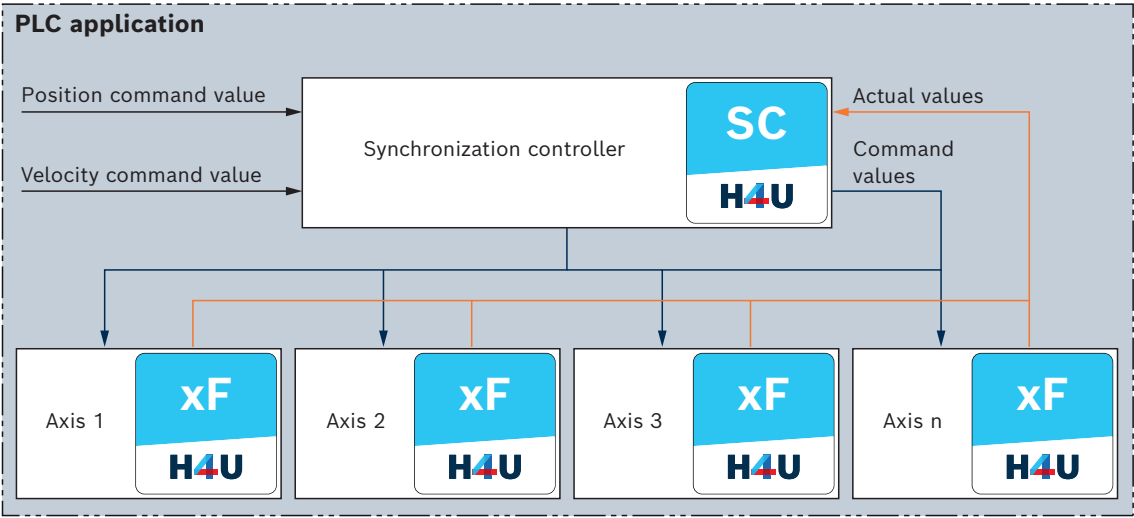
The software module "H4U.app SC" continuously determines and monitors the lag error based on the modeled and the measured actual position value. If the synchronized group can no longer follow the position command value, the "H4U.app SC" requests that the higher-level command value generator be stopped. The same applies if an axis in the synchronous connection alternates between position and force control. The now effective break mechanism provides the upstream command value generator with a brake acceleration in order to reach the velocity command value "0".

The setpoint tracking calculates an initial position command value at which the command value generator should start when the request to stop the command value generator has been withdrawn.

The target integrator minimizes the variations of the target positions of individual axes when reaching the target position of the synchronized group in all modes of the synchronization controller.

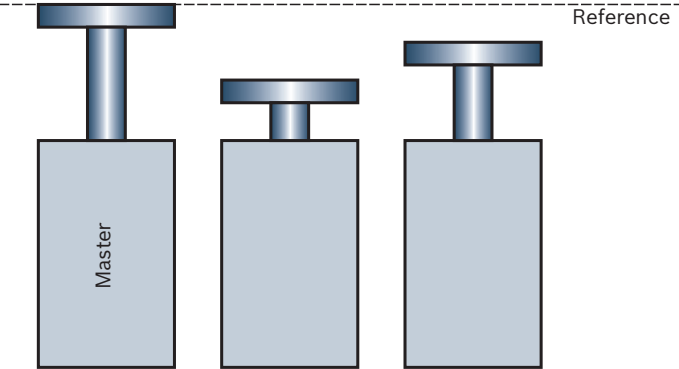
Basic possible applications

The software module "H4U.app SC" is used in conjunction with an upstream command value generator for continuous motion command values and the software module "H4U.app xF" for the control of valves and pump systems for valve and displacement-controlled drive concepts.



Synchronization mode 0: master command value principle

For applications with a master axis.  
 The reference value for the synchronism is the actual position value of the first axis of the synchronized group.

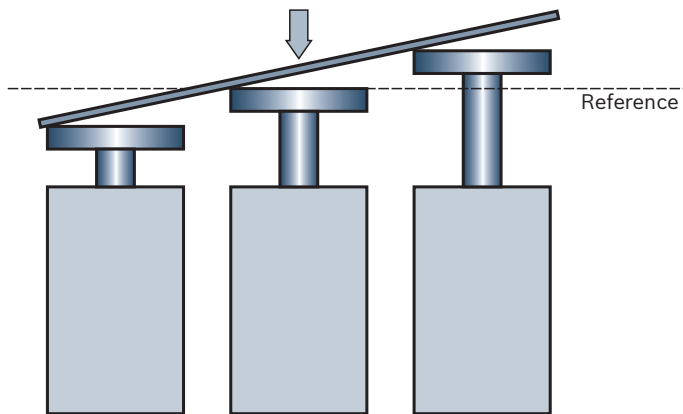


## Basic possible applications

### Synchronization mode 1: mean value principle

For applications with parallel positioning. No force limitation of the slave axes is required.

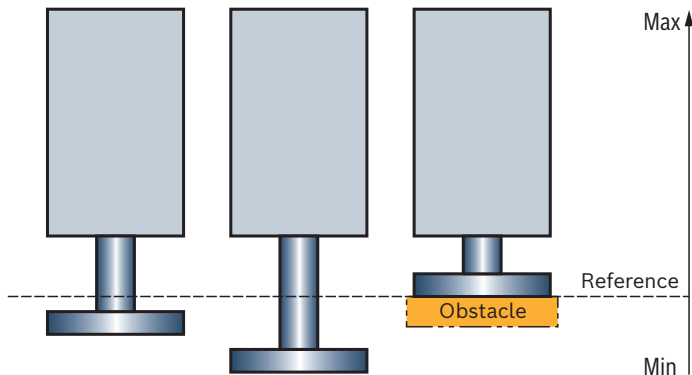
The actual reference value for synchronism is the mean value of all position actual values of the slave axes.



### Synchronization mode 2: maximum value principle

For applications with vertical axes with inverted encoder analysis (e.g. downstroke presses).

The reference value is always the slave axis with the greatest actual position value. This can switch smoothly during motion.

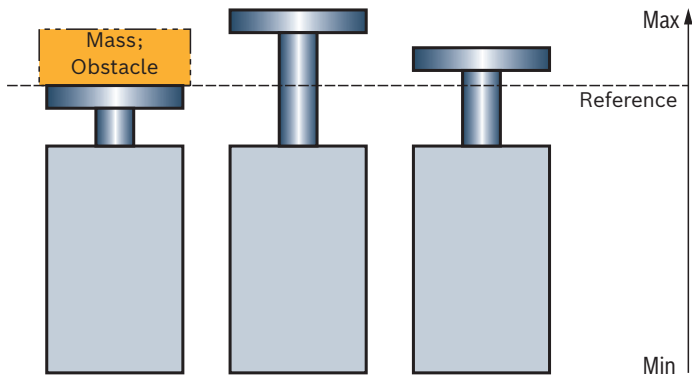


## Basic possible applications

### Synchronization mode 3: minimum value principle

For applications with vertical axes (e.g. lifts or lifting platforms). No force limitation of the slave axes is required.

The reference value is always the slave axis with the smallest actual position value. During the movement, smooth switching of the master axis may take place.



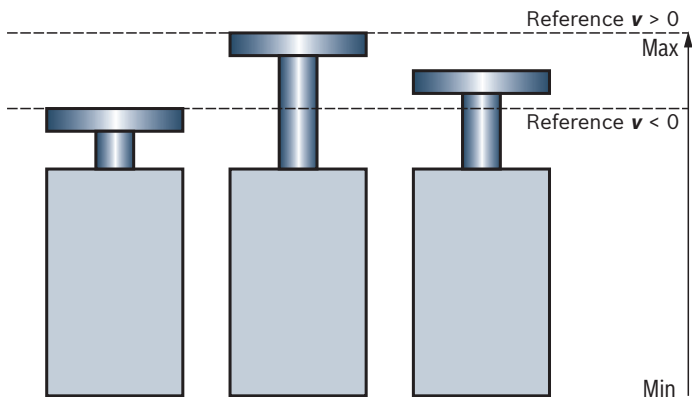
### Synchronization mode 4: coast-down principle

Combination of "minimum value principle" and "maximum value principle" for applications with constant load ratios in both operating directions.

No applicative switching between the two synchronization modes takes place.

The reference axis is always the slave axis that lags behind based on the travel direction (sign of velocity command value).

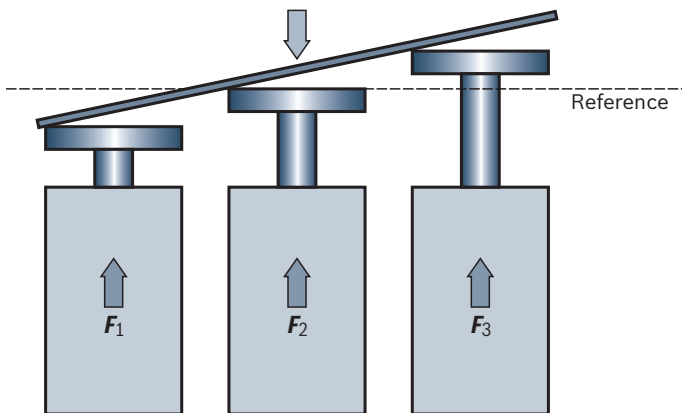
For a positive travel direction, this is the slave axis with the smallest actual position value, while for a negative travel direction, it is the slave axis with the highest actual position value.



## Basic possible applications

### Synchronization mode 5: mean value principle with alternating position/force control and minimum force limitation

For applications with parallel positioning, if the force of the slave axes may not drop below a minimum force. The actual reference value for synchronism is the mean value of all position actual values of the slave axes.



The synchronized group can be moved in position control or velocity control as well as passively displaced by an imposed movement in force limitation. The transition from position to force synchronization control takes place as soon as one of the slave axes is switched to force control.

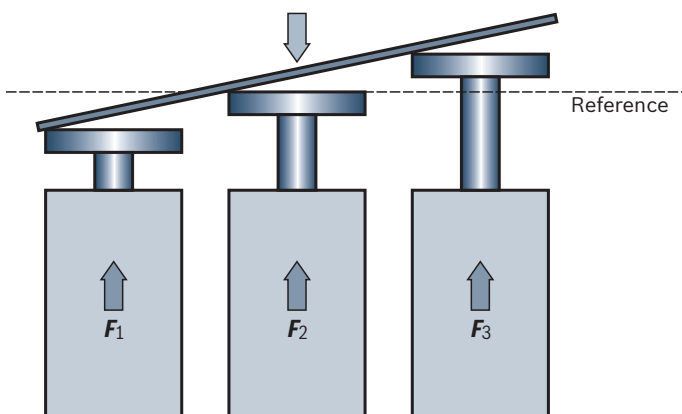


**Notice:**

$F_1 + F_2 + F_3$  can exceed the sum of the basic forces (force base values) of the cylinders.

### Synchronization mode 6: mean value principle with alternating position/force control and constant sum force

For applications with parallel positioning, such as roller and strip tension control, when the sum of all forces of the slave axes is kept constant. The actual reference value for synchronism is the mean value of all position actual values of the slave axes.



The synchronized group can be moved in position control or velocity control as well as passively displaced by an imposed movement in force control.



**Notice:**

$F_1 + F_2 + F_3 = \text{constant}$

## Technical data

| Synchronization controller |                                                                                             |         |
|----------------------------|---------------------------------------------------------------------------------------------|---------|
| Position control           |                                                                                             | ✓       |
| Velocity control           |                                                                                             | ✓       |
| Force control              |                                                                                             | ✓       |
| Target integrator          |                                                                                             | ✓       |
| Synchronization mode       |                                                                                             |         |
| Basic                      | ► Position                                                                                  |         |
|                            | – Master command value principle                                                            | ✓       |
|                            | – Mean value principle                                                                      | ✓       |
|                            | – Maximum/minimum value principle                                                           | ✓       |
|                            | ► Velocity                                                                                  |         |
|                            | – Coast-down principle                                                                      | ✓       |
| Option 1                   | ► Force                                                                                     |         |
|                            | – Mean value principle with alternating position/force control and minimum force limitation | ✓       |
|                            | – Mean value principle with alternating position/force control and constant sum force       | ✓       |
| Slave axes                 |                                                                                             |         |
| Quantity                   |                                                                                             | 2 ... 8 |
| Special functions          |                                                                                             |         |
| Model error calculation    |                                                                                             | ✓       |
| Break mechanism            |                                                                                             | ✓       |
| Setpoint tracking          |                                                                                             | ✓       |
| Possible applications      |                                                                                             |         |
| Inverted synchronism       |                                                                                             | ✓       |
| Relative synchronism       |                                                                                             | ✓       |
| Offset synchronism         |                                                                                             | ✓       |

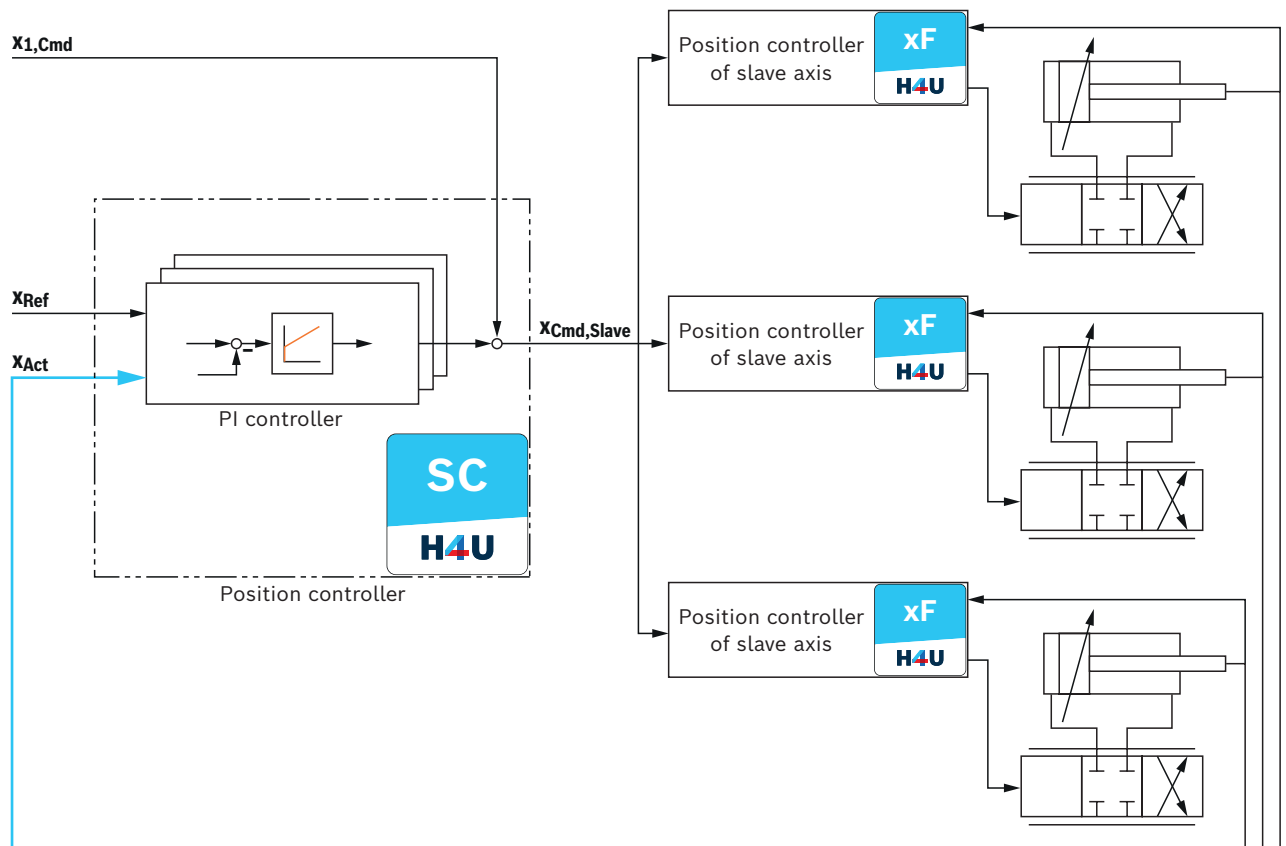
## Block diagram (simplified)

### Controller function

The controller module of the software module "H4U.app SC" is composed of a position controller, velocity controller and force controller. One instance of the controllers exists for each slave axis. All 3 controllers of the controller module regulate the synchronization error – that is, the relative position deviation among the slave axes. They differ in which controller on the slave axes is operated with a command value.

### Position controller

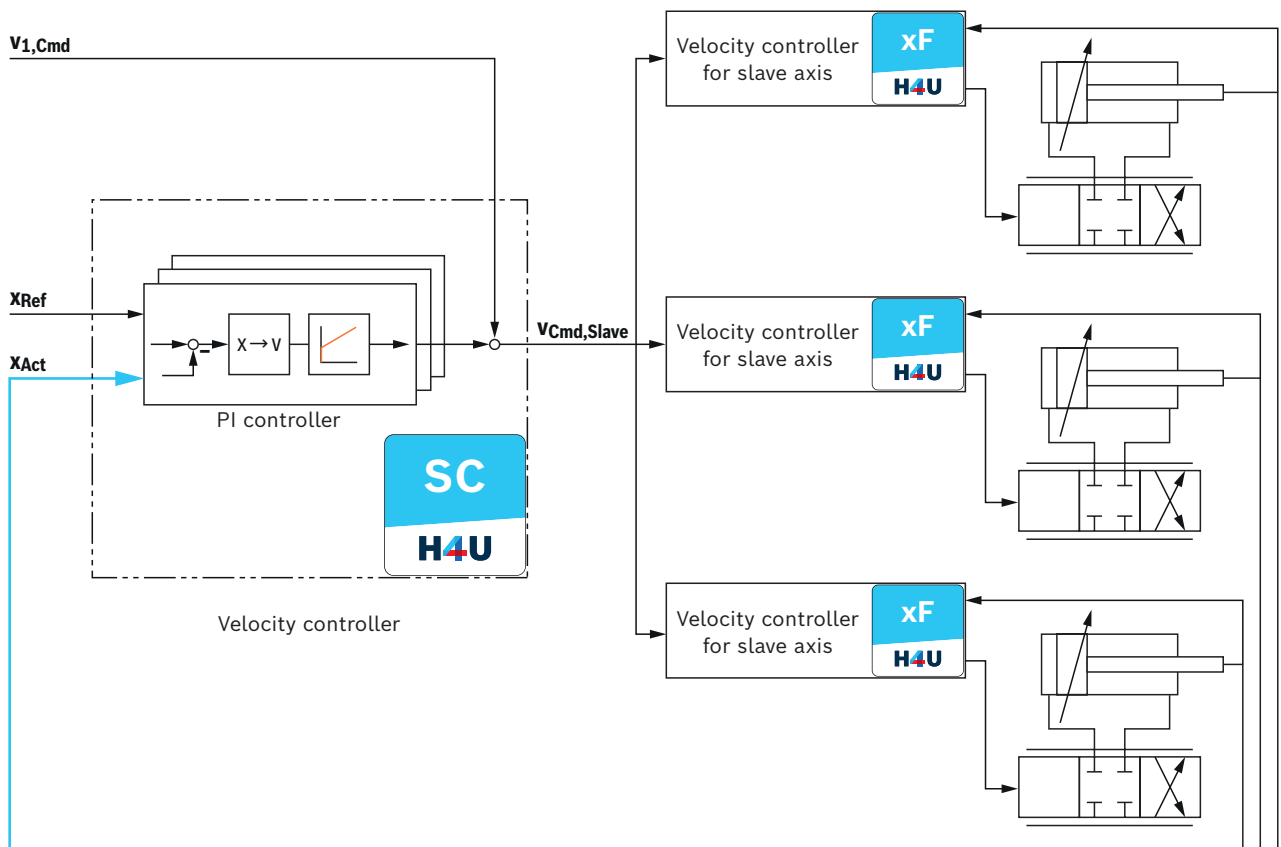
The position controller of the synchronization control regulates the positions of the slave axes to the reference value " $x_{Ref}$ " of the synchronized group, which is calculated on the basis of the synchronization mode. For this purpose, the position controller uses a PI controller to correct the position command values of the individual slave axes relative to the position command value of the synchronized group " $x_{1,Cmd}$ " specified in the application.



## Block diagram (simplified)

### Velocity controller

The velocity controller of the synchronization control regulates the positions of the slave axes to the reference value " $x_{Ref}$ " of the synchronized group, which is calculated on the basis of the synchronization mode. For this purpose, the position control deviation is first converted into an equivalent velocity deviation. Axis-specific PI controllers in the velocity controller minimize this velocity deviation by adapting the velocity command value of the individual slave axes relative to the velocity command value of the synchronized group specified in the application.

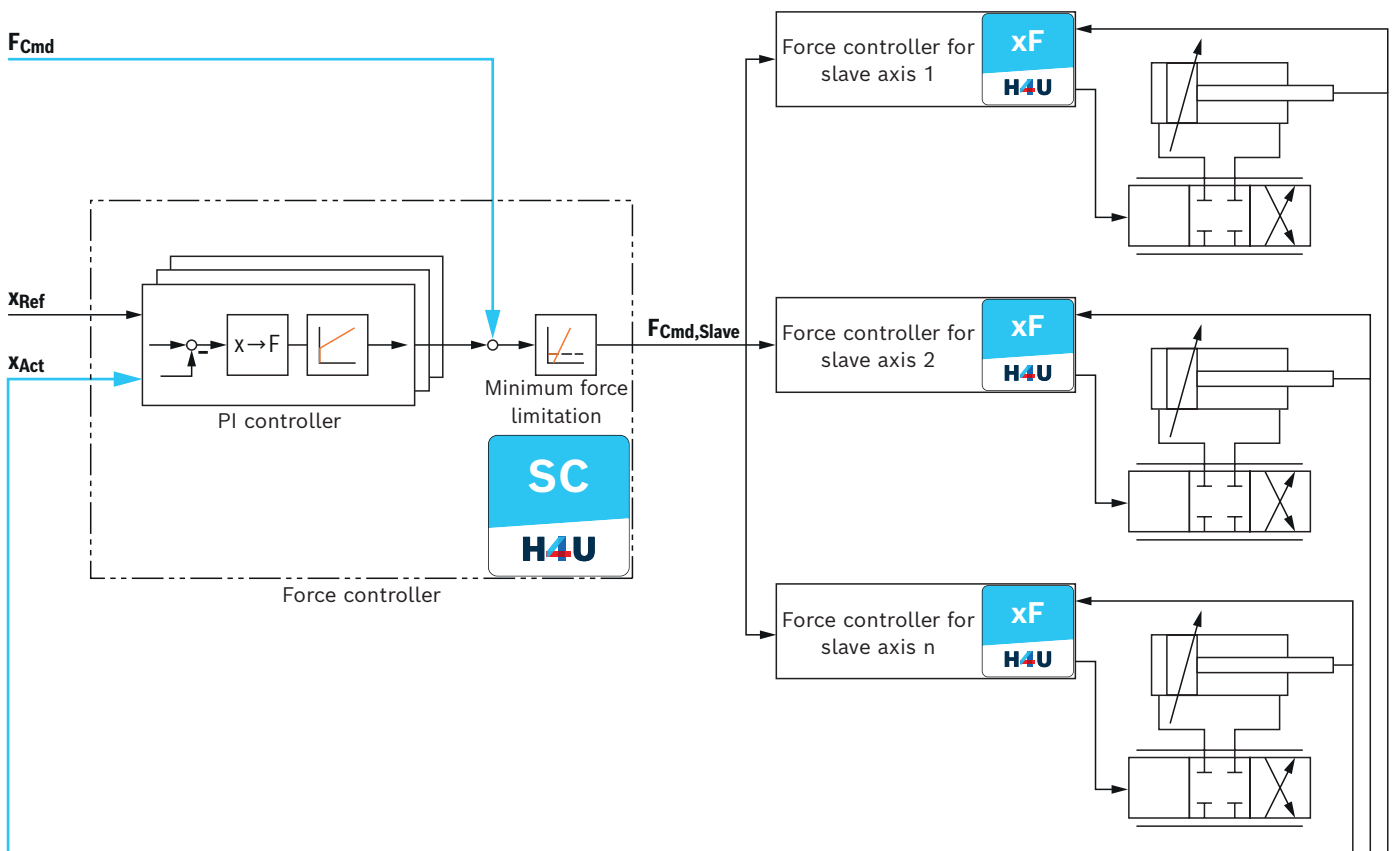


## Block diagram (simplified)

### Force controller

The force controller of the synchronization control regulates the positions of the slave axes to the reference value " $x_{Ref}$ " of the synchronized group, which is calculated on the basis of the synchronization mode. For this purpose, the position control deviation is first converted into an equivalent force deviation. Axis-specific PI regulators in the force controller minimize this force deviation by adapting the force command values of the individual slave axes specified in the application relative to the input force command values.

The force controller operates either in parallel with the motion controller mode "position controller" or "velocity controller." On the slave axis, either the force controller or one of the motion controllers has access to the axis.



## Further information

- ▶ Software module for position/force control of a hydraulic drive; type H4U.app xF
- ▶ Function block H4U.app synchronization
- ▶ Function block H4U.app synchronization for Beckhoff TwinCAT 3
- ▶ Function block H4U.app synchronization for Siemens TIA Portal

Data sheet 01939

Functional description 01945-FK

Quick start guide 01945-01-Z

Quick start guide 01945-02-Z

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