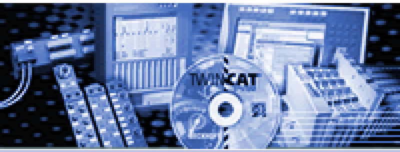


TwinCAT

The Windows Control and Automation Technology

NC PTP

Numerical Control Point To Point

NC-PTP

Part I General
- Overview
- Axis types
- Functional principle
- Referencing
- Motion Control Function blocks

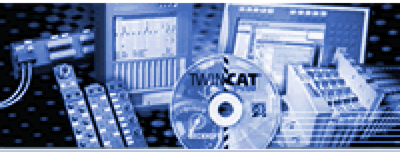
Teil II Practical Part:
- Setting up NC axes in the System Manager
- Starting NC axes from the PLC

Software NC PTP

TwinCAT NC Point-to-Point (PTP) is an axis positioning software with integrated PLC, NC interface, operating program for axes setup and I/O connection of the axes through the fieldbus.

Up to 255 axes can be moved at the same time.

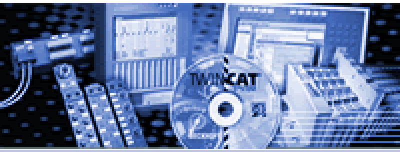
TwinCAT NC PTP supports axis drive by switched motors, stepper motors, frequency controlled and servo controlled motors.



Software NC PTP

TwinCAT NC PTP

Programming	Performed using function blocks for TwinCAT PLC according to IEC61131-3, convenient axis commissioning menus
Debugging	Online monitoring of all axis state variables such as actual/set value, enable, controller values, online axis tuning, forcing axis variables
Runtime system	NC Point-to-Point (NC PTP) including TwinCAT PLC
Number of axes	Up to 255 in up to 255 channels
Axis types	Electrical and hydraulic servo drives, frequency converter drives, stepper motor drives, switched drives (fast/crawl axes)
Cycle time	Min. 50 µs, typ. 1 ms (freely adjustable)
Axis functions	Standard axis functions: start/stop/reset/reference Velocity override, target override Special functions: master-slave cascading, electronic gearboxes, online distance compensation of segments



Camshafts, Flying saw, FIFO

Camshafts

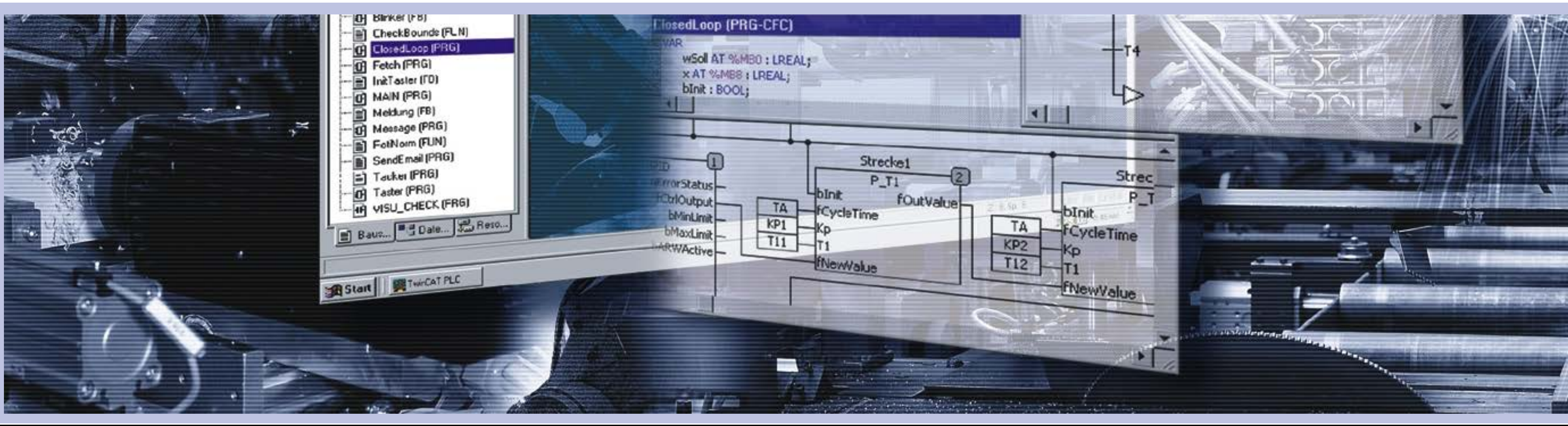
Software solution for electronic camshafts, obviating the need to use mechanical camshafts and special hardware assemblies. A table relates the position of the master axis (mainshaft) to the associated position to which the slave axis is driven.

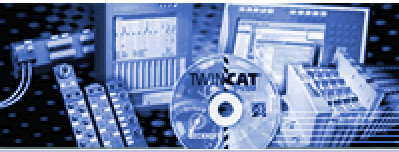
Flying saw

The "flying saw" (diagonal slave) is a special kind of slave coupling. The slave axis is brought from standstill to a speed synchronous with the master.

FIFO

Instead of using internal generation of standard set values, an axis can also obey an externally calculated sequence of set values that can be supplemented as the movement of the axis proceeds (FIFO buffer).





Software NC I

TwinCAT NC Interpolation (NC I) is the NC system for linear or circular interpolated path movements of axis groups each involving two or three drives. TwinCAT NC I offers 2D and 3D interpolation (interpreter, set point generation, position controller), an integrated PLC with an NC-I interface and an I/O connection for axes via the field bus.

TwinCAT NC I

Programming	DIN 66025 programs for NC interpolation, access via function blocks for TwinCAT PLC according to IEC61131-3
Debugging	Online monitoring in the TwinCAT System Manager with the following displays: present set/actual positions, following errors of all axes, NC program line presently being executed/interpreted, channel status
Runtime System	NC PTP + NC interpolation, including TwinCAT PLC
Number of axes	3 axes per group, 1 group per channel, max. 255 channels
Axis types	Electrical servo-axes
Interpreter-functions	Subroutines and jumps, programmed loops, zero shifts, tool compensations, M and H functions,
Geometries	Straight lines and circular paths in 3D space, circular paths in all main planes, helixes with base circles in all main planes
Axis functions	Online reconfiguration of axes in groups, path override, slave coupling to path axes

Axis types

Continuous axes

The axis responds to a continuously changeable set value
The set value is generated by TwinCAT NC,

e.g. servo with +/- 10 V, Sercos drive, frequency converter, linearised hydraulic axis, stepper motor drive with amplifier

Axis types

speed axes

two-stage set speed value
ction of rotation:

ORWARDS/REVERSE

The set value is generated by TwinCAT NC,

e.g. frequency converter with fast/slow inputs, combination interlock. Warning: Acquisition of actual value (Encoder is necessary)

Axis types

stepper motor

pper motor which is connected
acts to pulses (A/B from the
minals)

motor turns quicklylSlow

pulse sequence -> motor turns slowly

The set value (= pulse pattern) is generated by TwinCAT NC.

Axis types

per motor, Hardware

notor with 2A output terminals

er is NOT required
ual value, since the pulses that
are output are counted.
! The mechanical design and/or maximum rotary speed/torque should be examined to ensure that the motor will be able to "keep up", since an output terminal cannot provide an increased voltage at higher frequency

Axis types

coder axis,

nsists of an encoder.

xes can be coupled to this
w the set encoder value of
the virtual encoder axis.
(Gear ration possible)

HAND WHEEL FUNCTION

Axis types

a speed value
ition is monitored.

<u>utput:</u>
pre-control
oller output

(acceleration pre-control also is optional)

<u>Feedback:</u>
Actual position value
At specific axis types e.g. SERCOS is also a direct output of the **Setposition** in NC time possible.

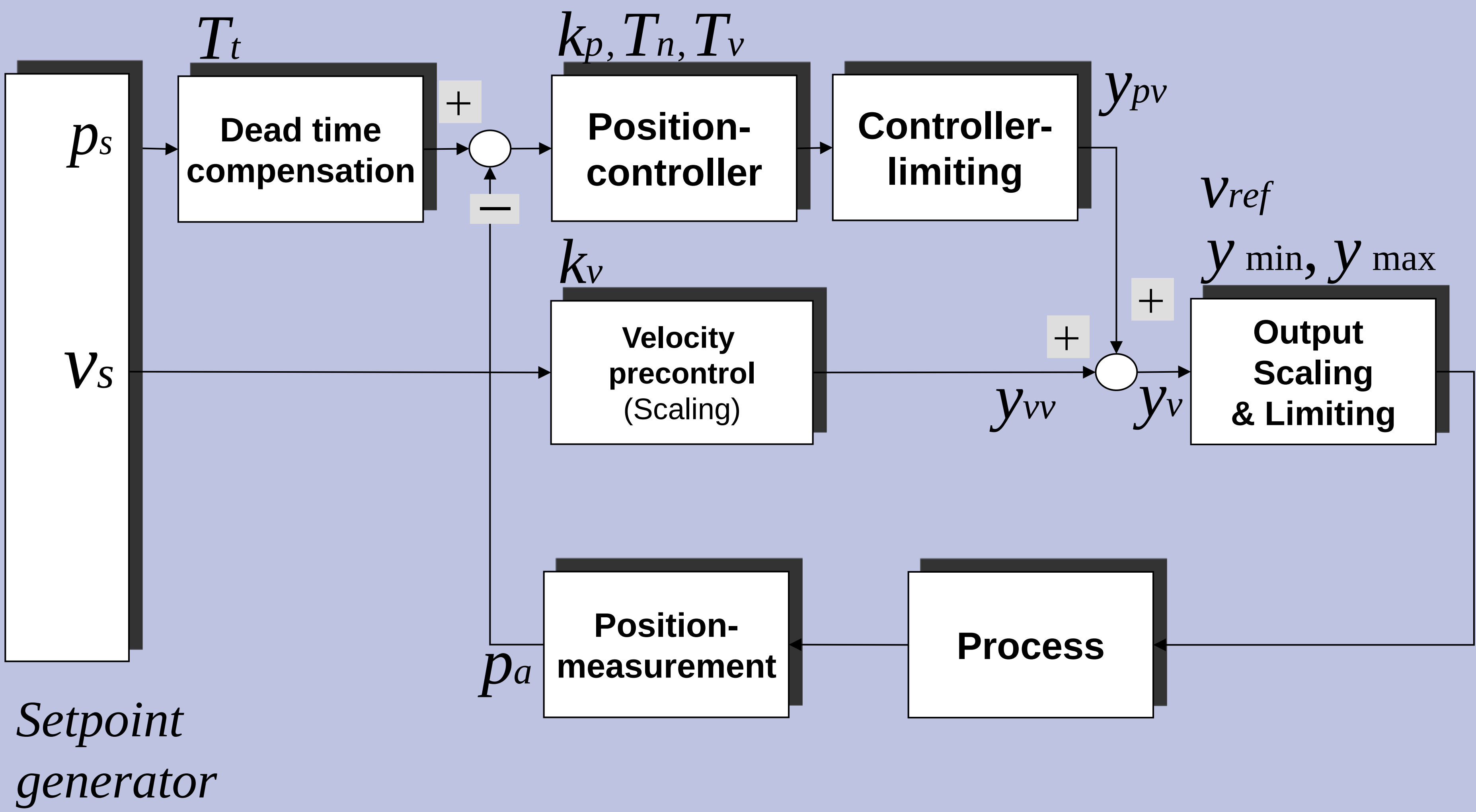
Functional principle of the TwinCAT NC

TwinCAT NC works with a
velocity pre control.
The **Position controller** controls the observance of the set position („Motion“ and position control).

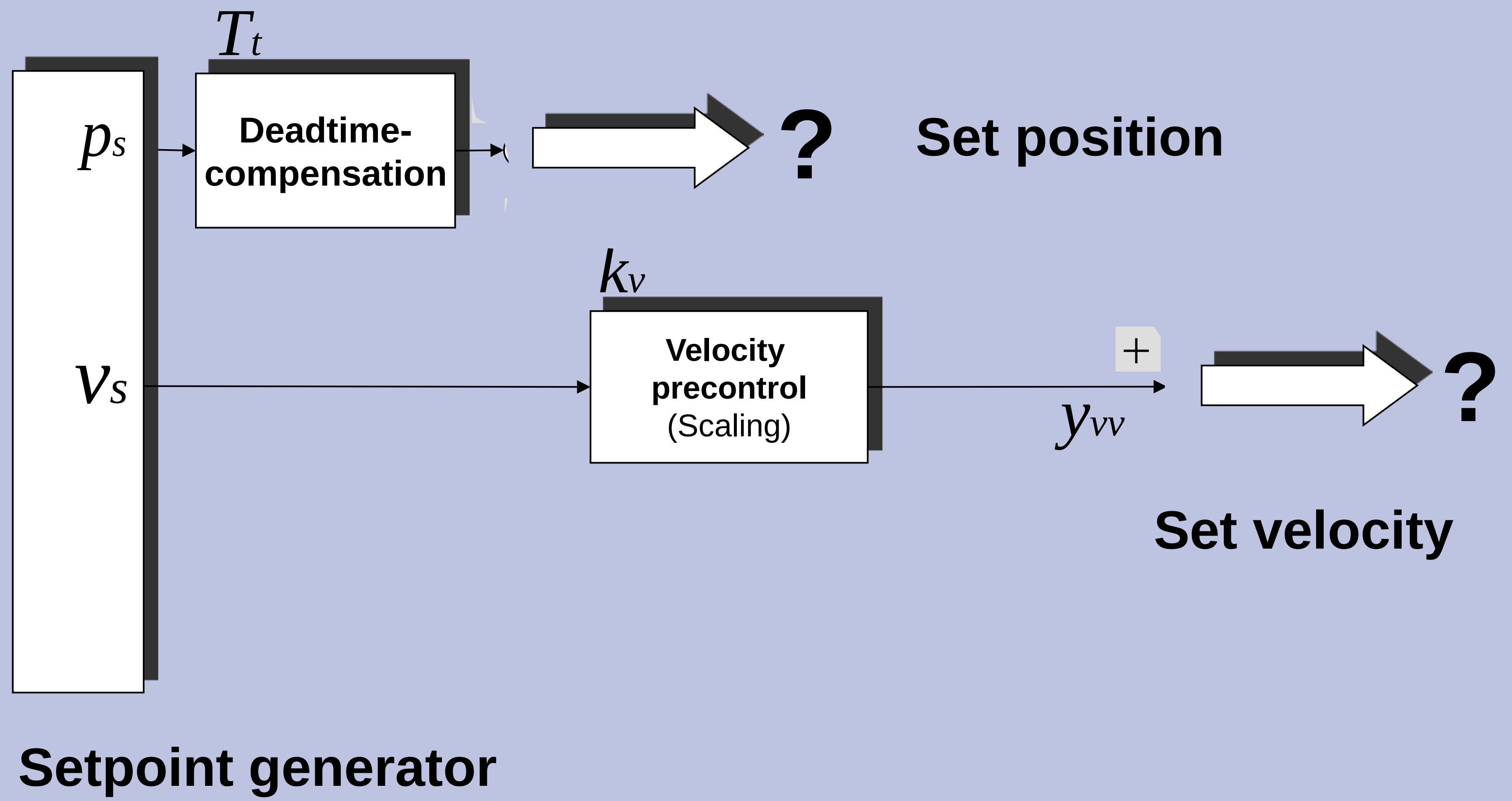
Further available options:
-Acceleration pre control
-Position control with two P constants
-direct output of the position. (Sercos Axes)

-High / low speed controller
-Stepper motor controller
-External Setpoint generation (ab TwinCAT 2.9)
-Linearisation of pre control for non linear axes (Hydraulic axes).

Functional principle of the TwinCAT NC



Set value generation

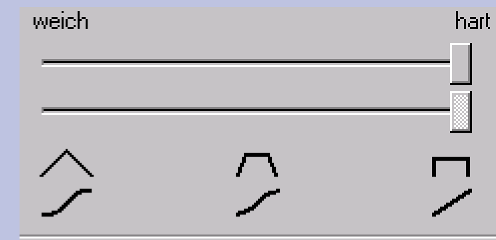


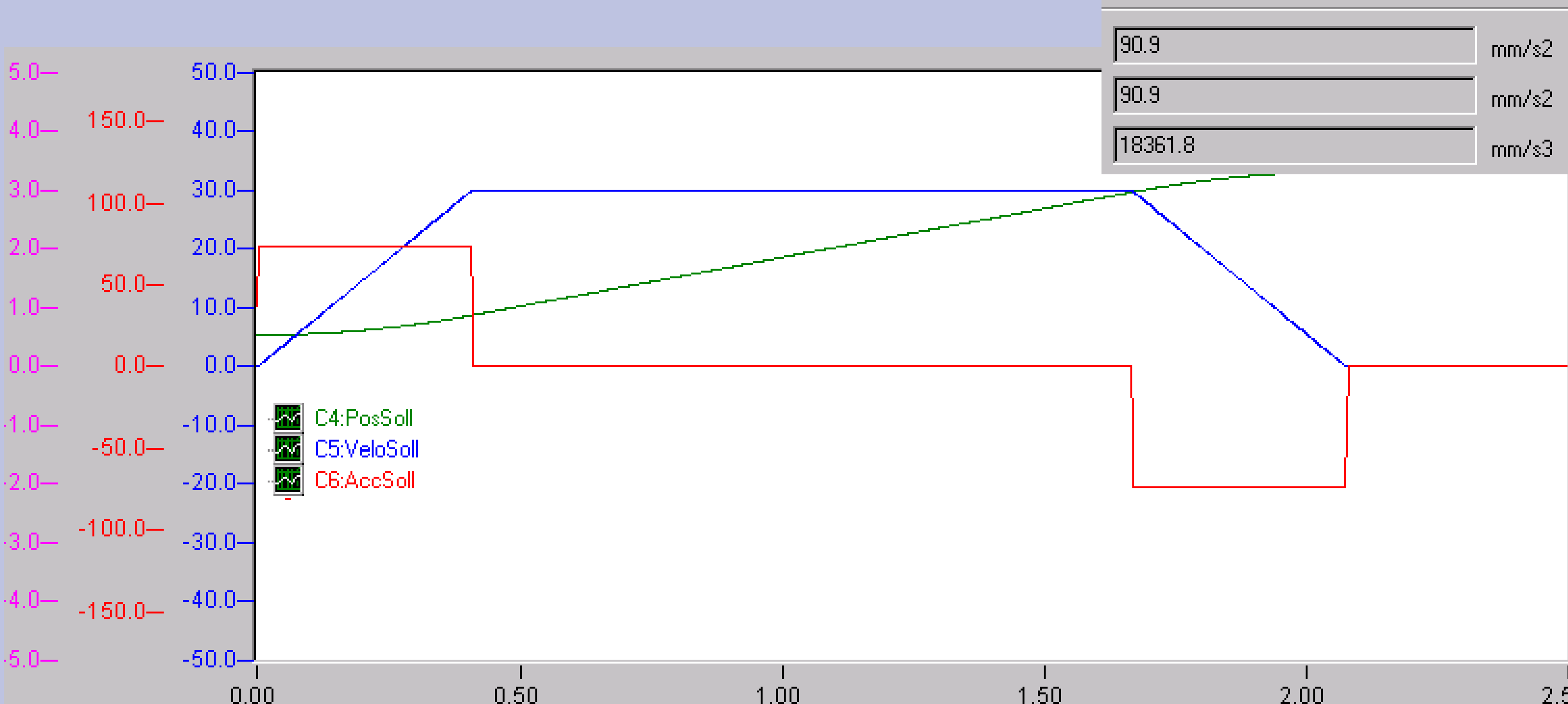
Set value profiles

The profile of the velocity output can be variied during an defined brake time
Thereby the acceleration change (jerk) can be reduced considerably.
This works out on in the short run mechanical burdens and commensurate with as well on the electric burden of the drive.

Set value profiles

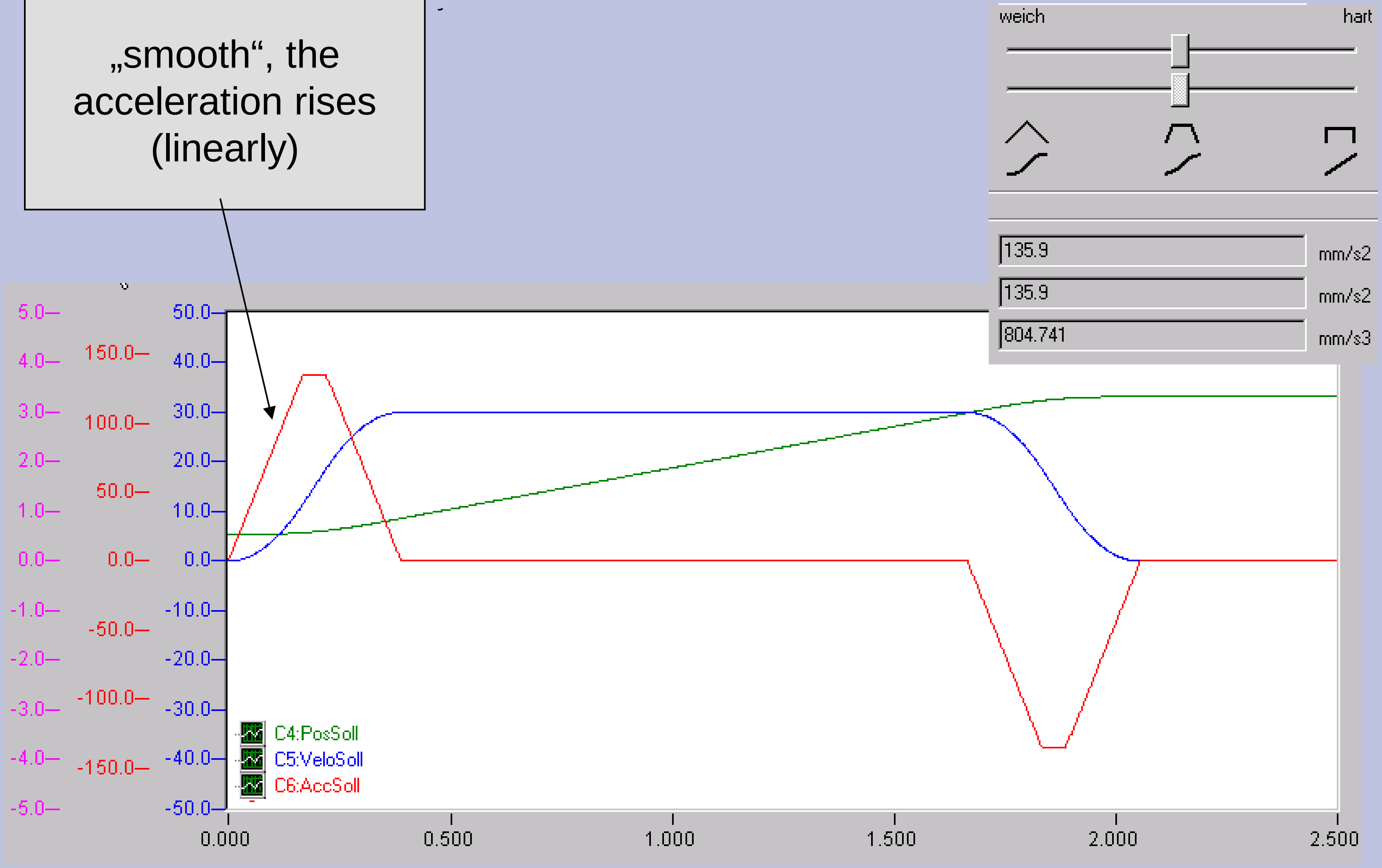
„hard“, big
Acceleration change





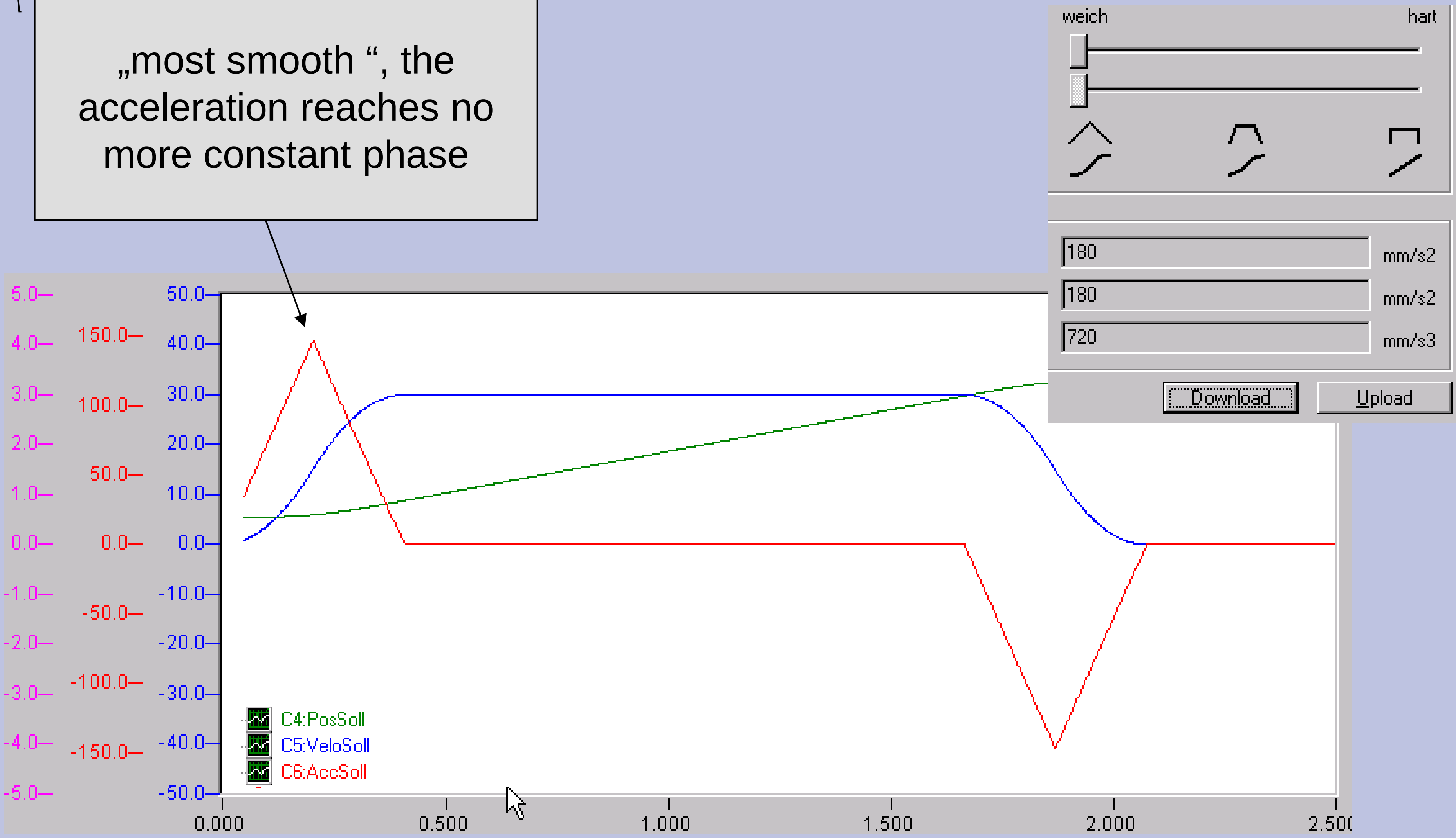
Set value profiles

„smooth“, the acceleration rises (linearly)



Set value profiles

„most smooth “, the acceleration reaches no more constant phase



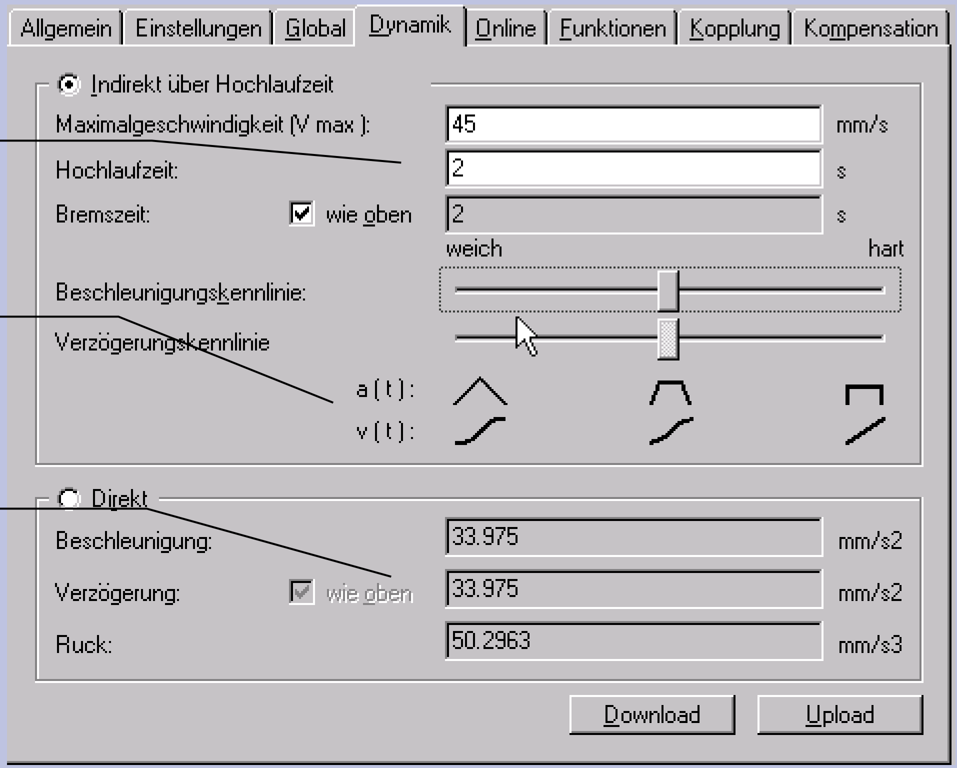
Set value profiles

Die Vorgabe kann sehr einfach über die Vorgabe der Hochlaufzeit und der Auswahl des Profils im System Manager erfolgen!

Input via run-up time

Preselect profile

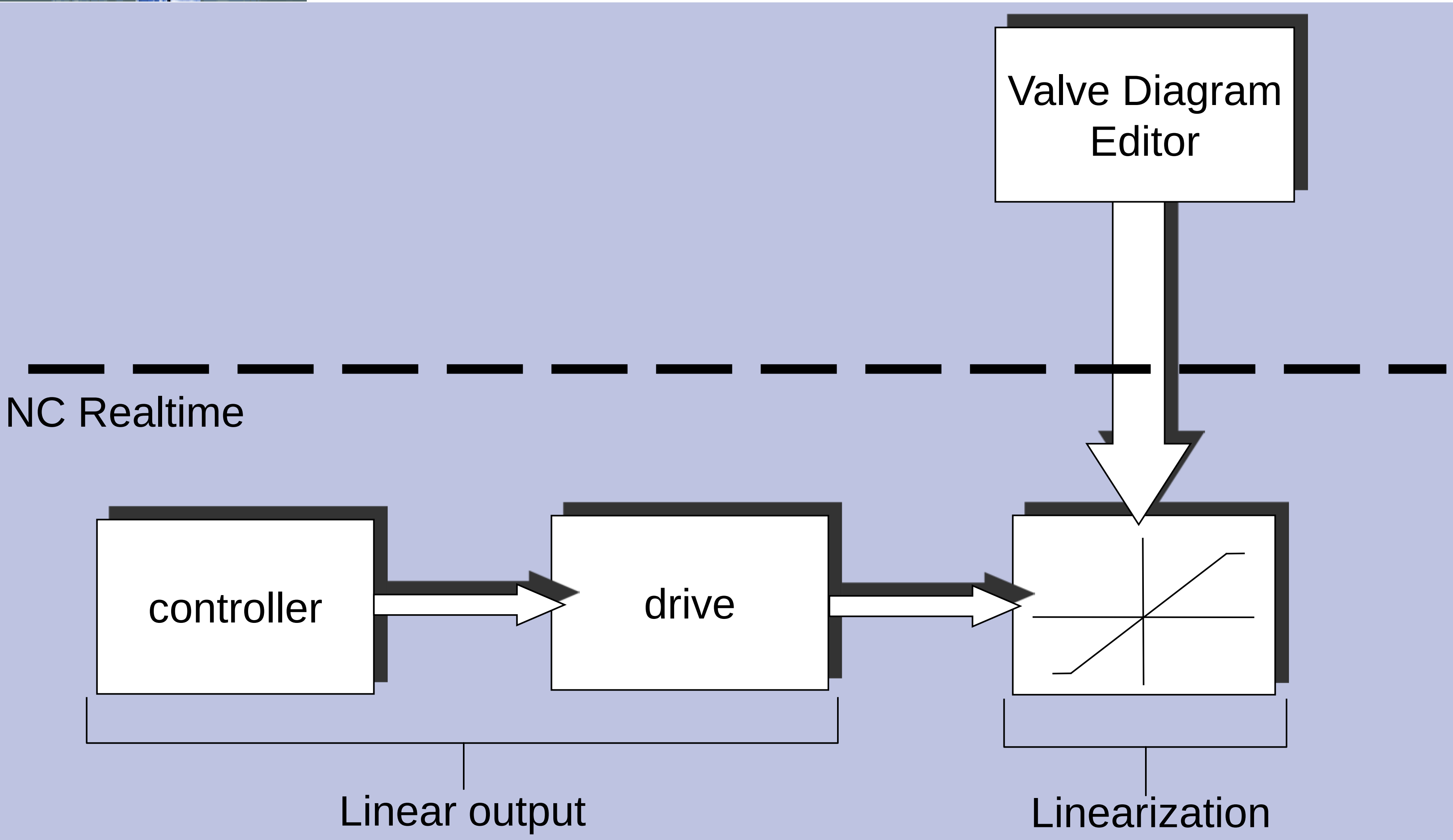
Calculation by the TwinCAT System Manager



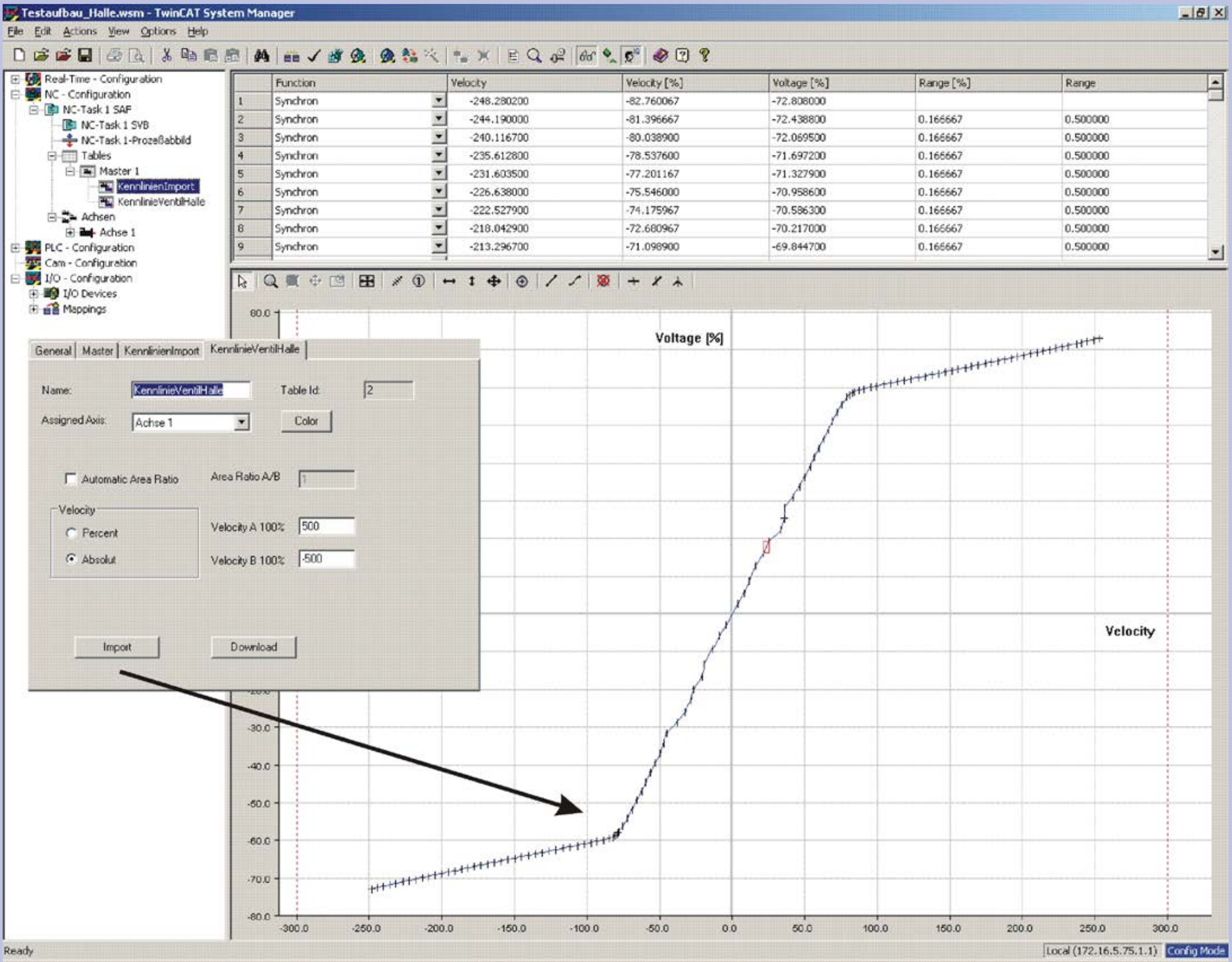
Output Linearisation: TwinCAT Valve Diagram Editor

- Problem: non linear charcateristic curves of valves
- Solution
  - Measurement of the curves with the PLC Program
  - import the values to the System Manager
  - graphical Linearisation
  - Interpolation (Polynomial of 5th degree)
  - Load to NC
  - Outputs are linearized

TwinCAT Valve Diagram Editor



TwinCAT Valve Diagram Editor

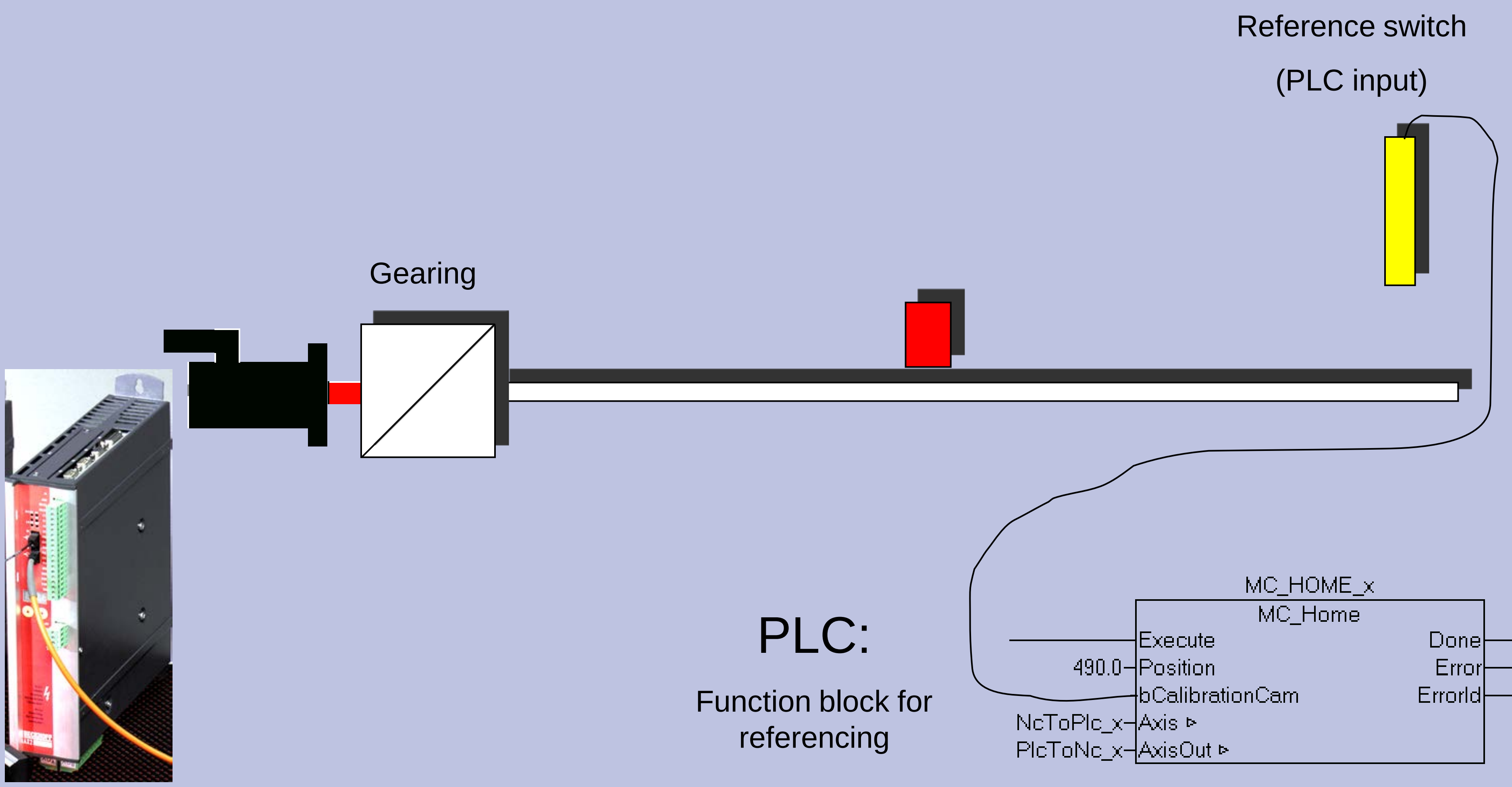


Referencing

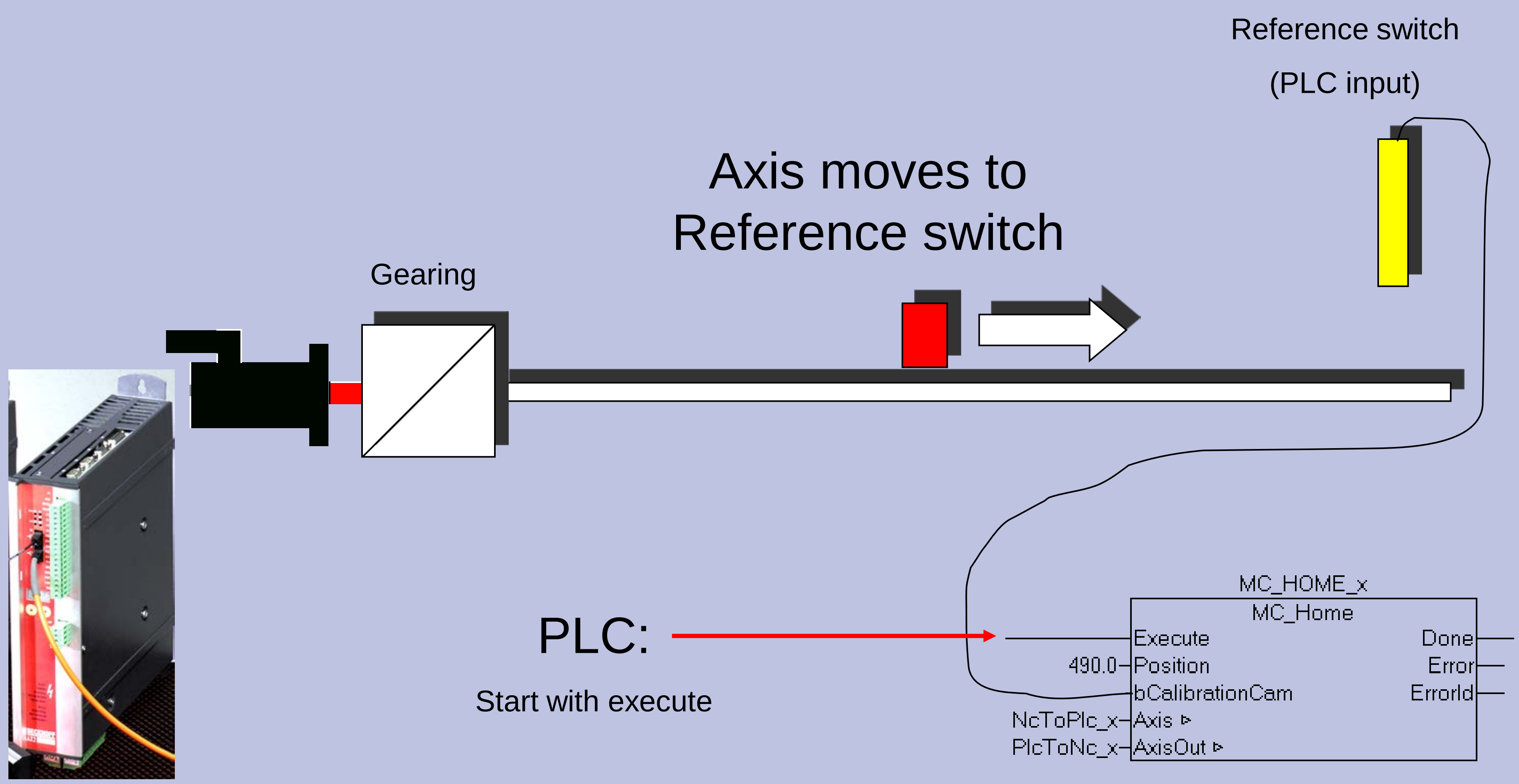
Referencing (calibrate) is necessary for axis with not absolute encoder systems.
Incremental Encoder, Single Turn Absolute Encoder, or not absolute encoder systems direct from the drive, (e.g. actual position value of AX2000).

At referencing the axis is lead to a fix reference position and the encoder is set to the current actual position.

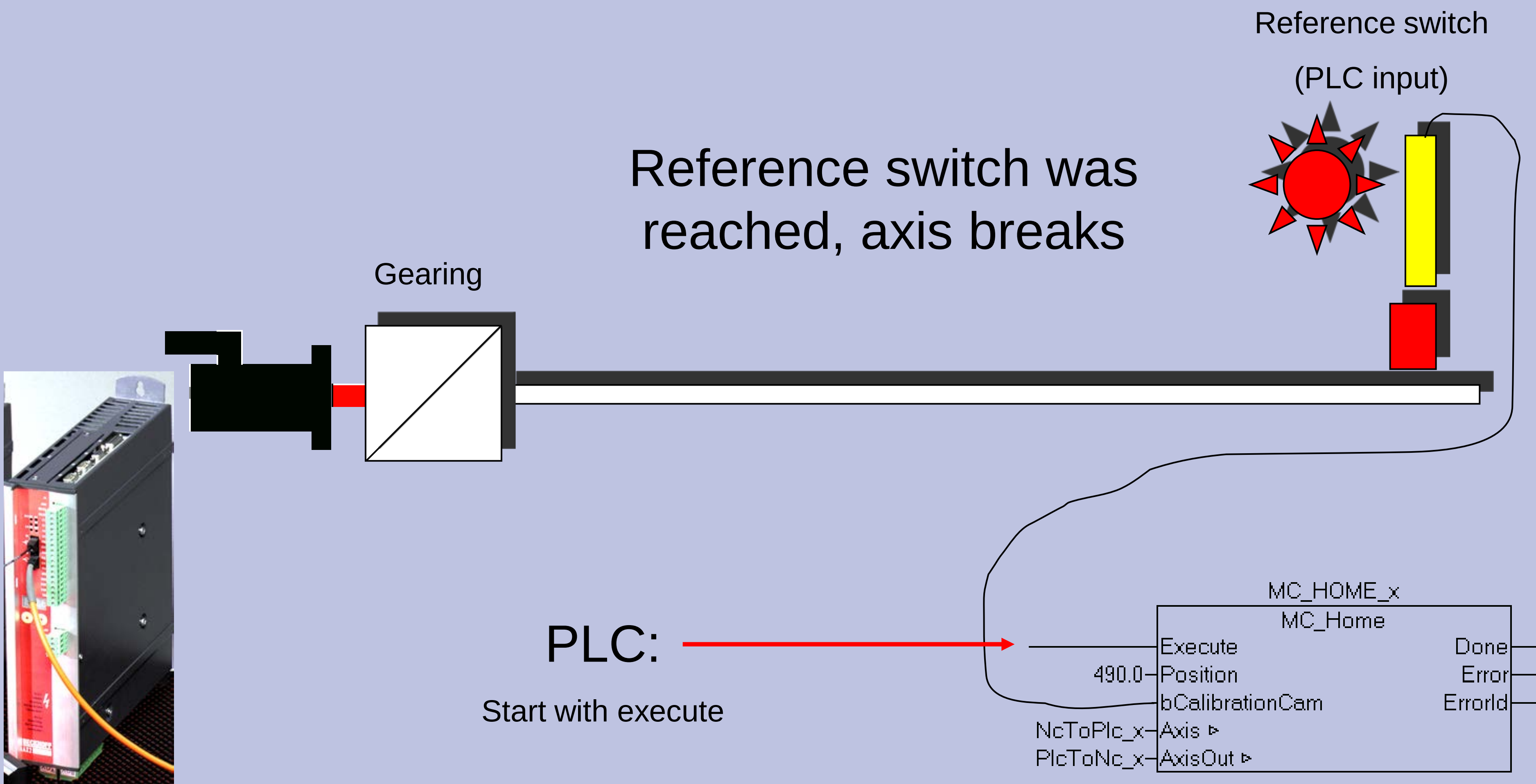
Referencing initial state



Referencing

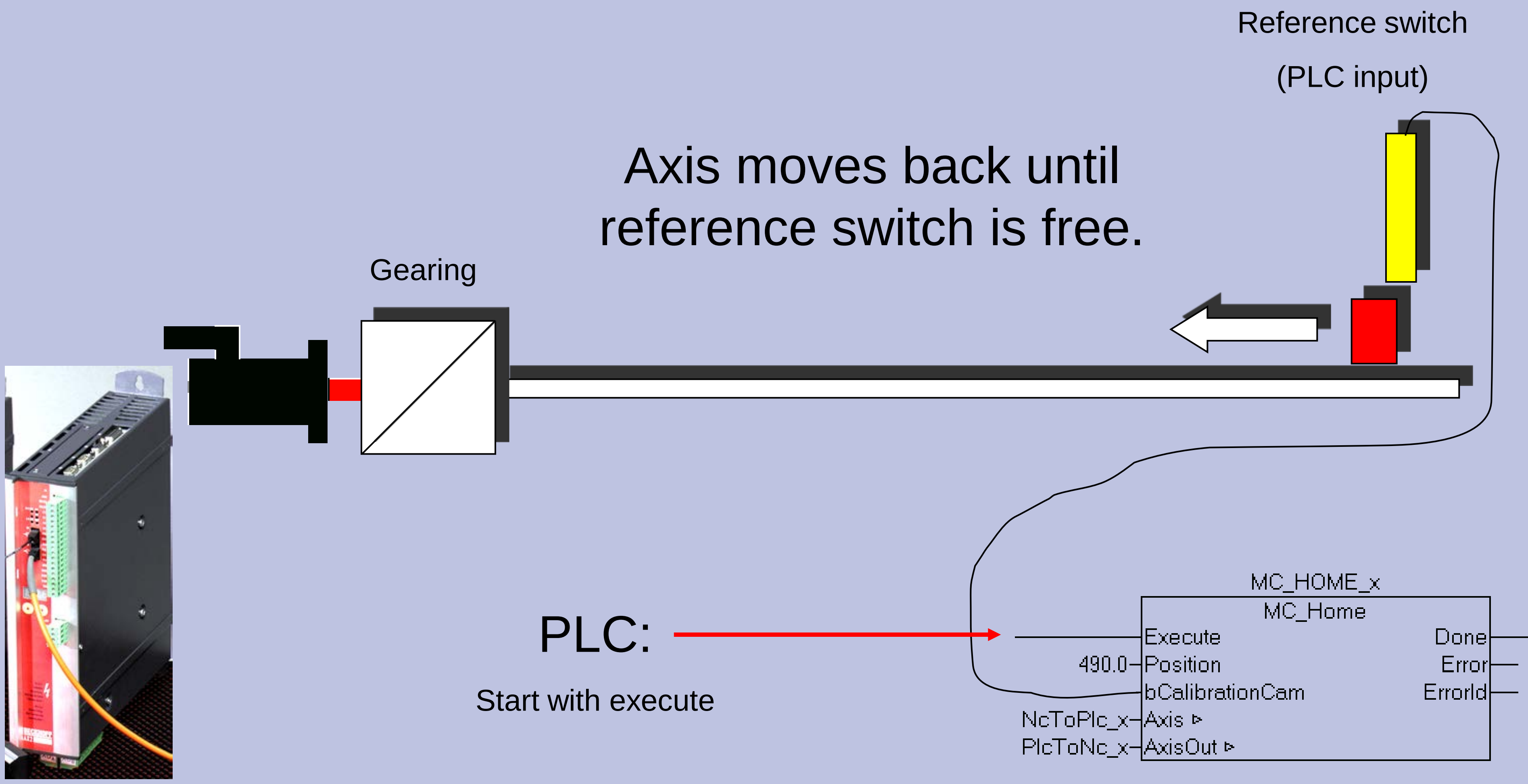


Referencing

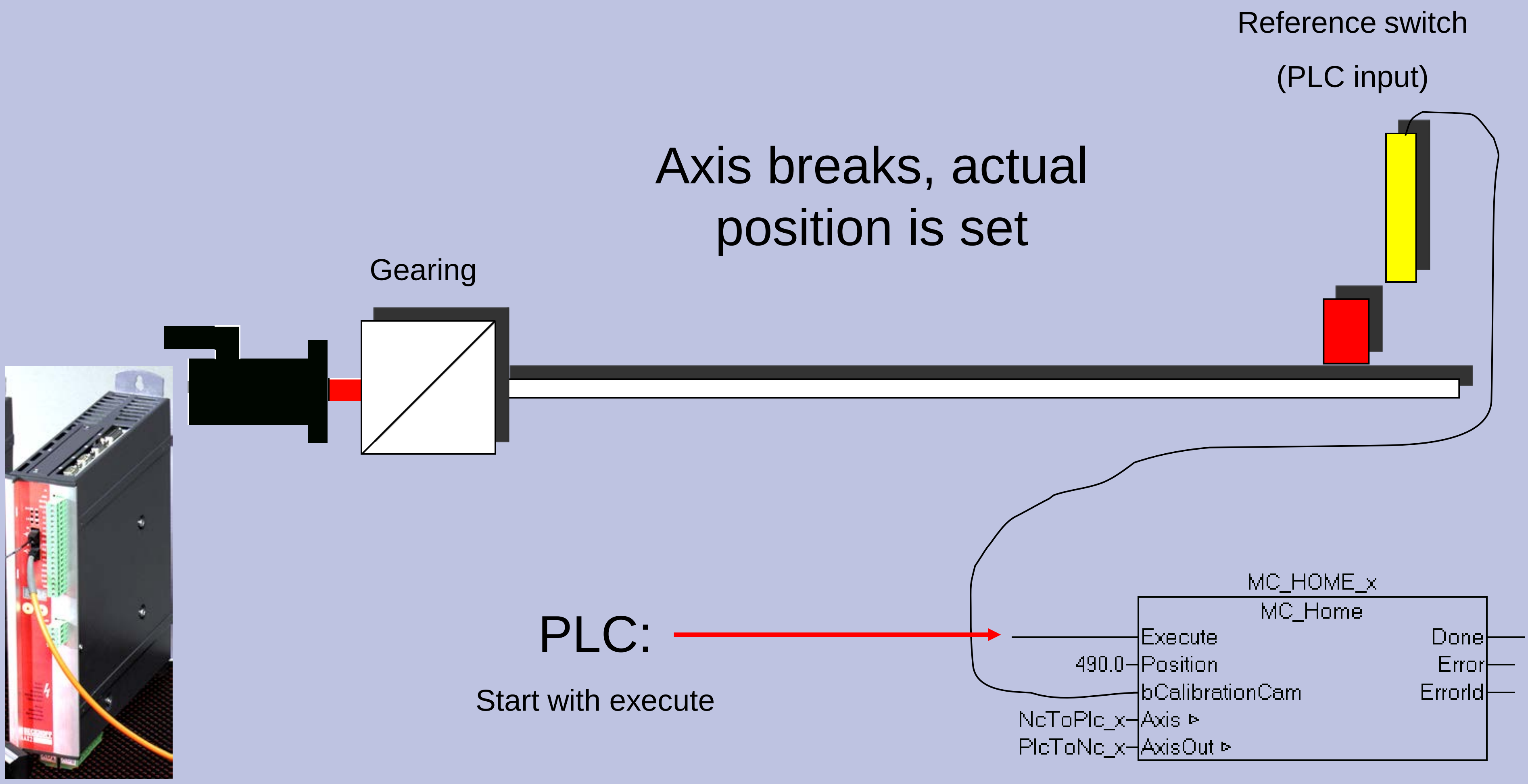


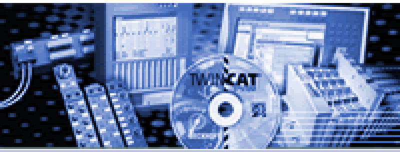
Referencing

Axis moves back until reference switch is free.



Referencing completed (a)





Referencing completed (b)

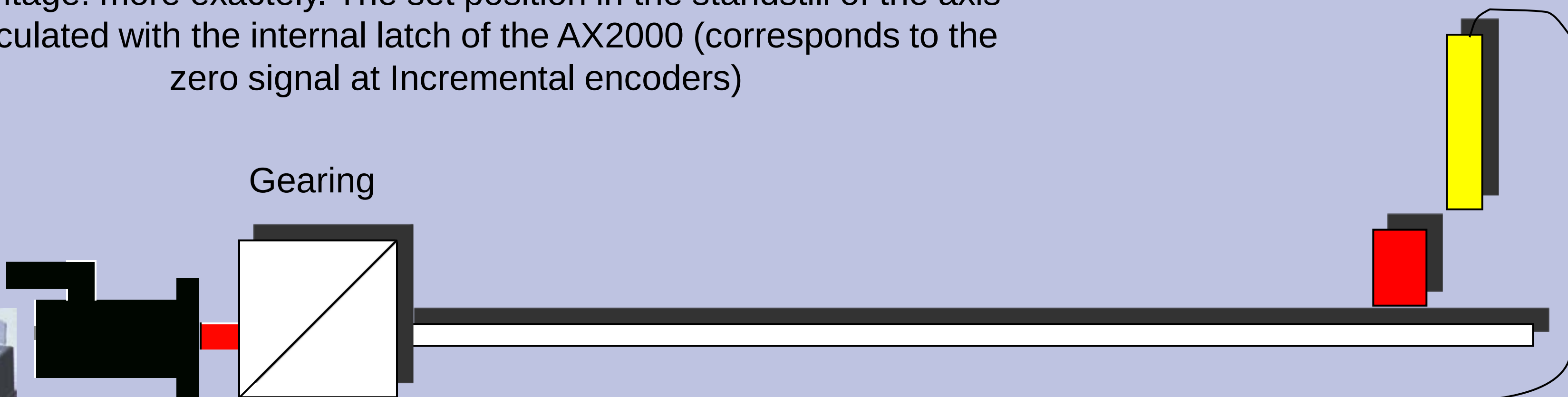
AX2000:
After leaving the reference switch, TwinCAT NC waits for the “Syncsignal” of AX2000 and then stops.

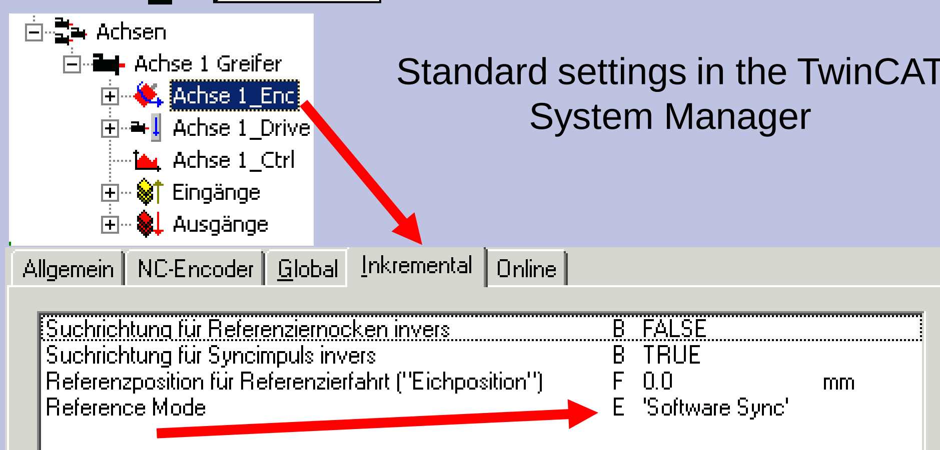
Advantage: more exactely. The set position in the standstill of the axis is calculated with the internal latch of the AX2000 (corresponds to the zero signal at Incremental encoders)

Reference switch

(PLC input)

Gearing

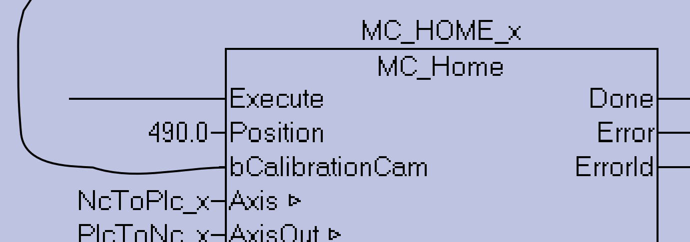



Achsen
Achse 1 Greifer
Achse 1_Enc
Achse 1_Drive
Achse 1_Ctrl
Eingänge
Ausgänge

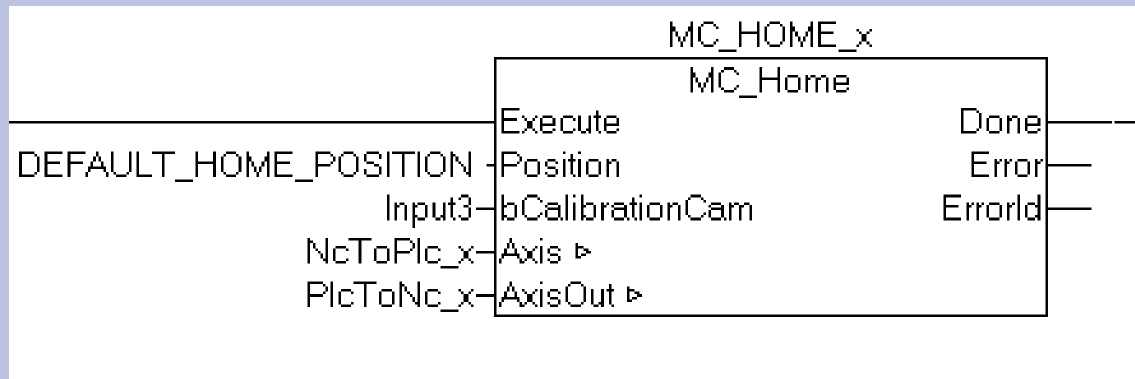
Allgemein | NC-Encoder | Global | Inkremental | Online

Suchrichtung für Referenziernocken invers	B	FALSE	
Suchrichtung für Syncimpuls invers	B	TRUE	
Referenzposition für Referenzierfahrt ("Eichposition")	F	0.0	mm
Reference Mode	E	'Software Sync'	

Standard settings in the TwinCAT System Manager

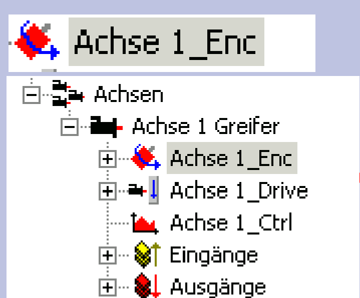


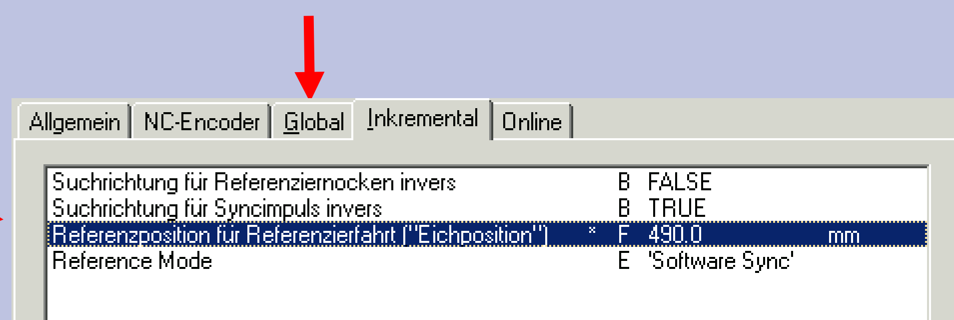
Referencing completed. Which position is set?

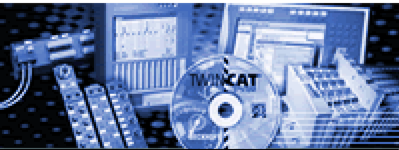


If „Position“**DEFAULT_HOME_POSITION** (global variable from TCMC.LIB) is submitted at the Fb input, the value is taken out of the System Manager.

Otherwise the value ist taken at the input „Position“







Motion Control Function blocks

Target: IEC61131-3 compatible programming interface for motion tasks

Motion Control Function blocks

Why a standard?

-Hardware independent Programming

-the same look and feel, identical Syntax

-IEC 61131-3 as Base

-Expansions for new application areas possible

-TwinCAT: Combination of MC blocks and TwinCAT specific Axis blocks possible.

⇒ Existing applications can be expanded with M Control blocks, without a new writing of the e flows.

Beckhoff:

Beispiel : es müssen nicht unbedingt alle FB‘s aus der spec vorhanden sein

Motion Control Function blocks

Defined in:

The PLCopen Task Force Motion Control
by Manufacturer and end user

- **Atlas Copco Control**
- **Baumueller**
- **Beckhoff**
- **Control Techniques**
- **Elau**
- **Giddings & Lewis**
- **Indramat**
- **Infoteam Software**
- **KW Software**
- **Lenze**
- **Siemens**
- **Softing**

TetraPak

Rovema Packaging Machines

Ford

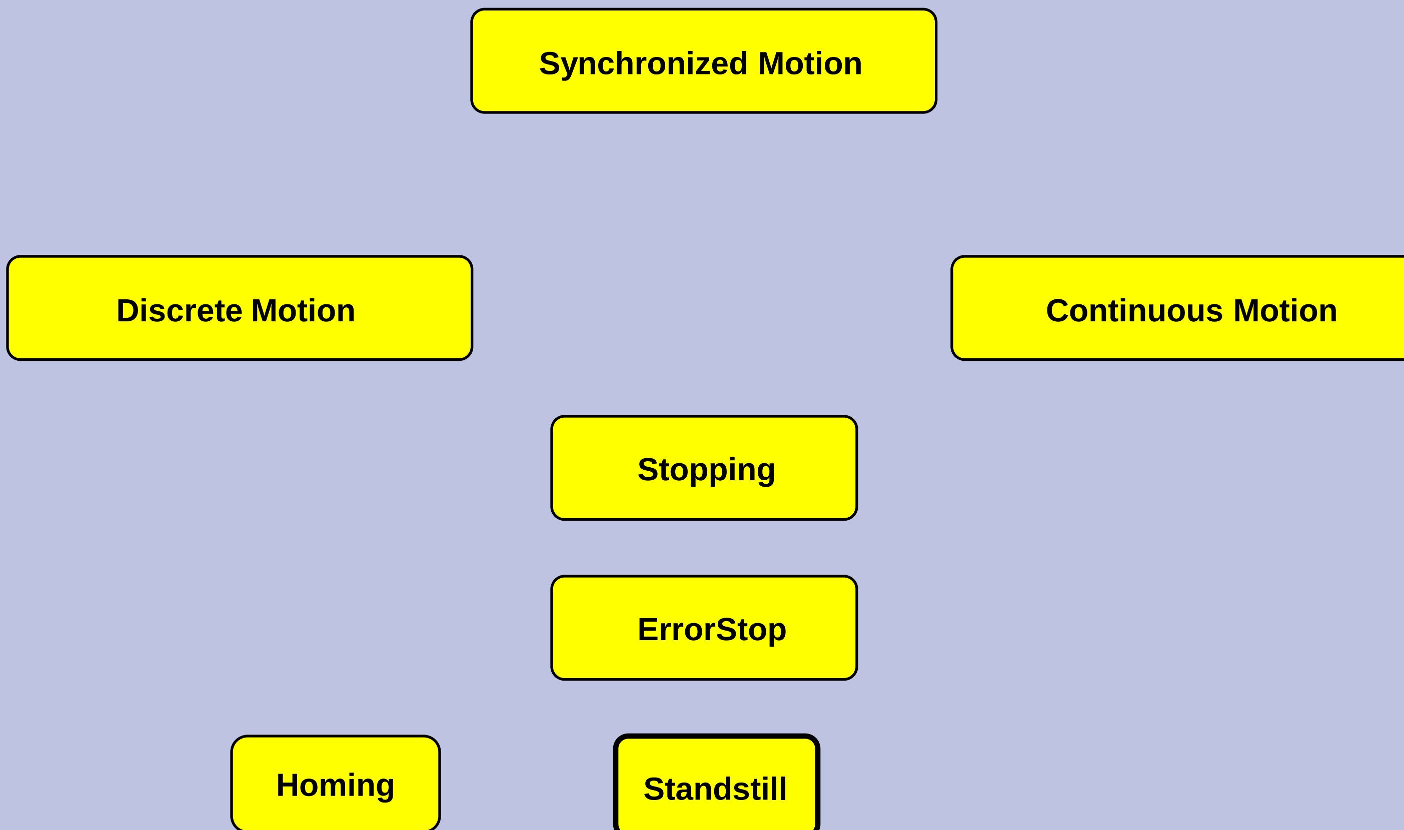
General Motors

Root: Task Force Motion Control presentation Version Febr2002. (www.plcopen.org)

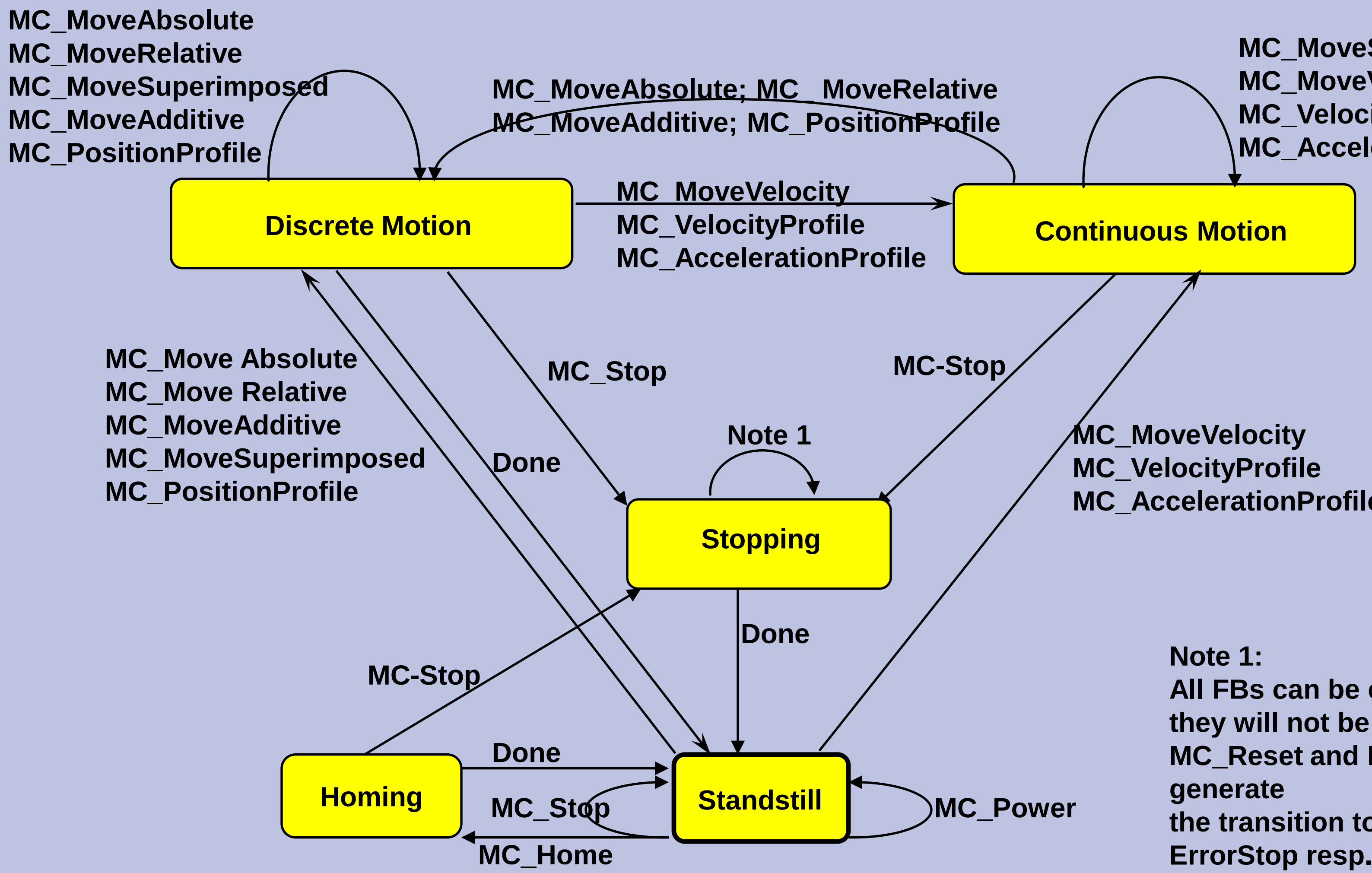
Beckhoff:

Beispiel : es müssen nicht unbedingt alle FB‘s aus der spec vorhanden sein

Statemachine:



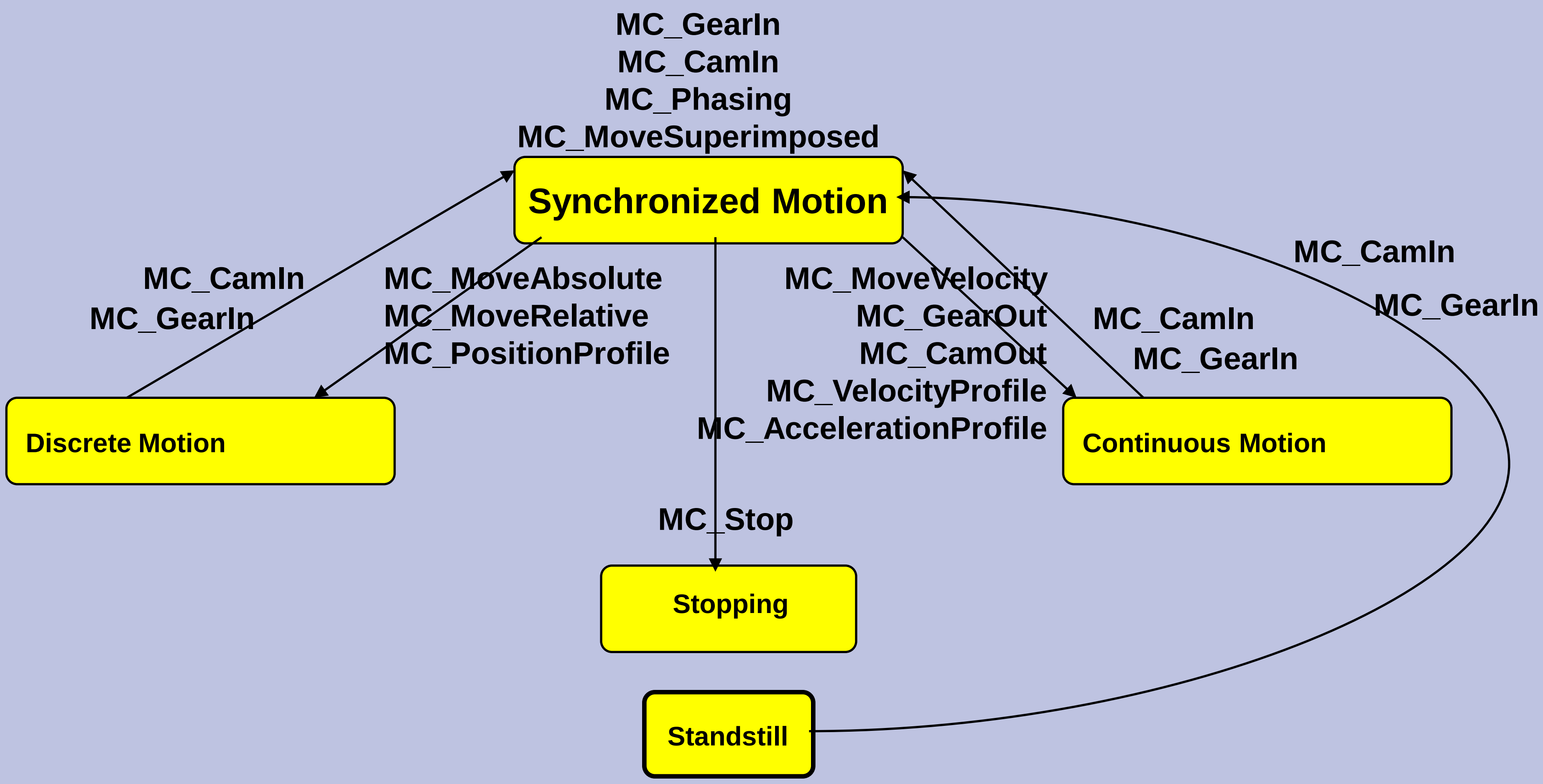
Statemachine:



Note 1:
All FBs can be called, although they will not be executed, except MC_Reset and Error– will generate the transition to StandStill or ErrorStop resp..

Root: Task Force Motion Control presentation Version Febr2002. (www.plcopen.org)

Statemachine Synchronized Motion



Overview Function Block Class:

Administrative

Single Axes
- Power
- Reset
- ReadStatus
- ReadAxisError
- ReadParameter
- WriteParameter
- ReadActualPosition

Multiple Axes
- CamTableSelect

Motion

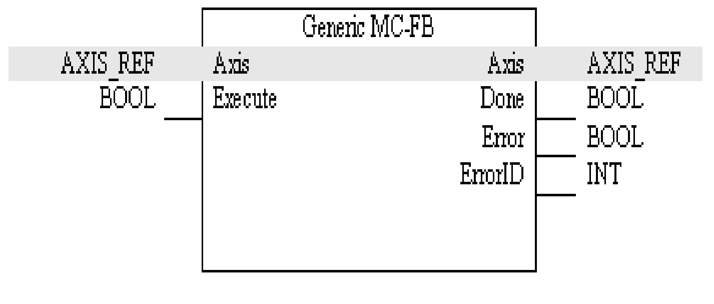
Single Axes
- MoveAbsolute
- MoveRelative
- MoveAdditive
- MoveSuperImposed
- MoveContinuous
- MoveVelocity
- Home
- Stop
- PositionProfile
- VelocityProfile
- AccelerationProfile

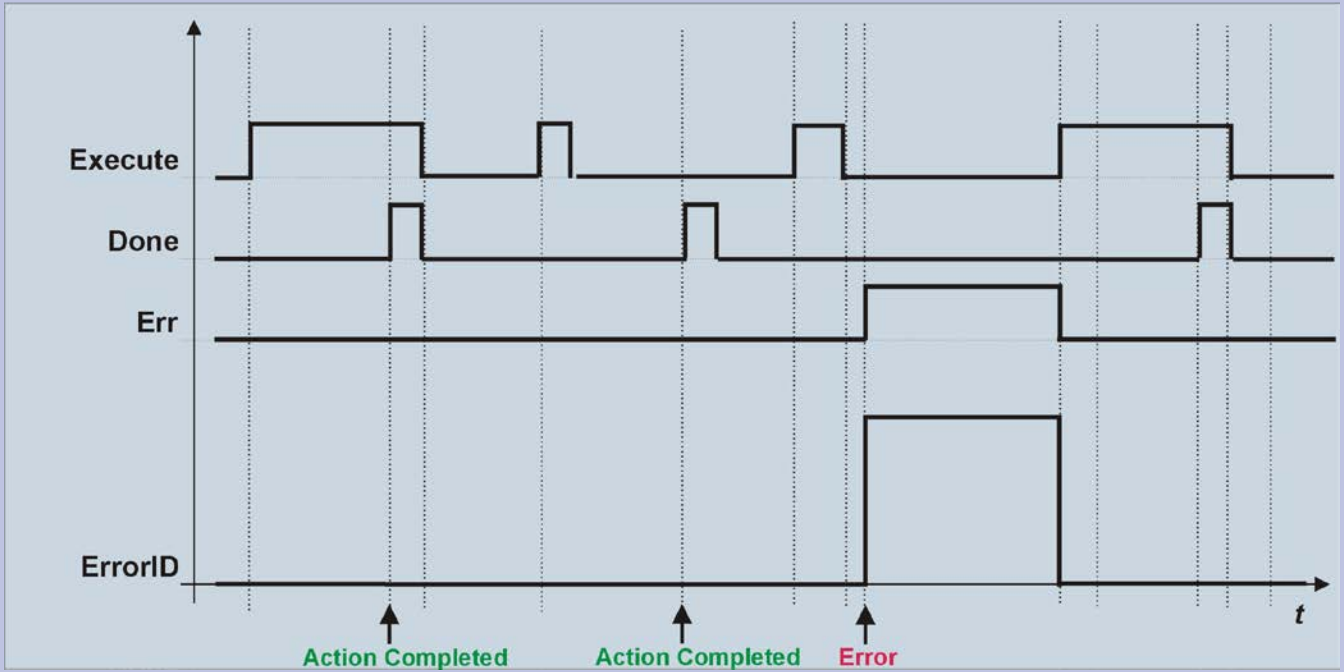
Multiple Axes

Non-Interpolated
- CamIn
- CamOut
- GearIn
- GearOut
- Phasing

Interpolated
- …

Standardized Handshake

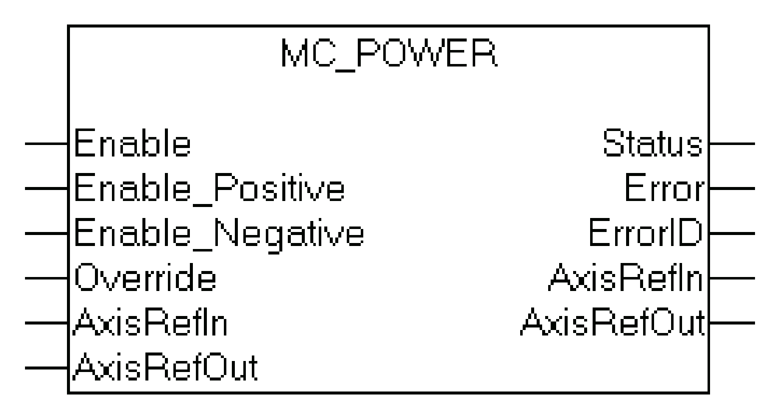




FB‘s

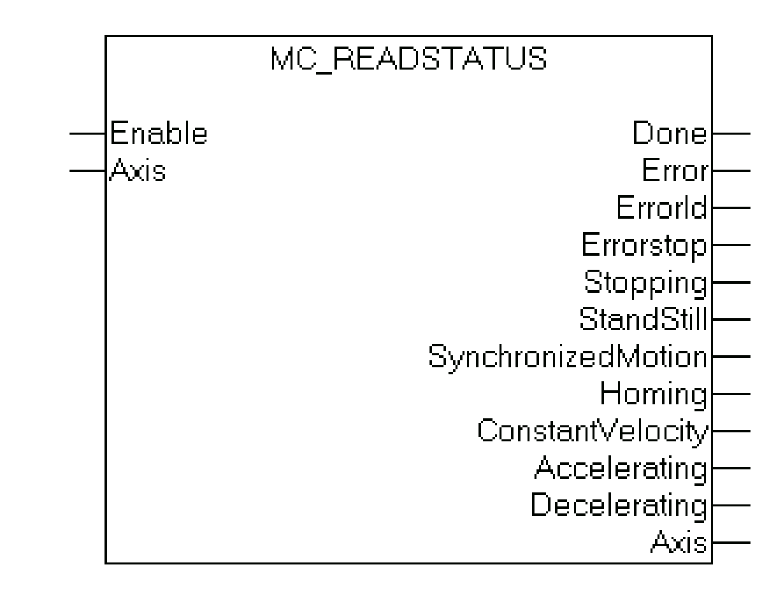
Administrative Function Blocks

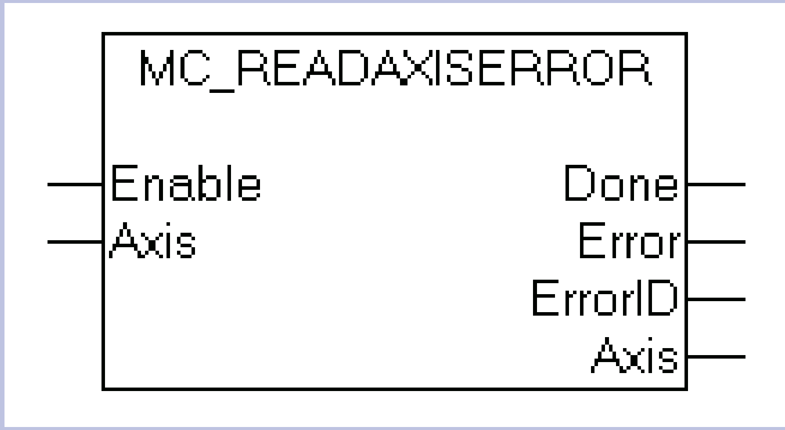
MC Power



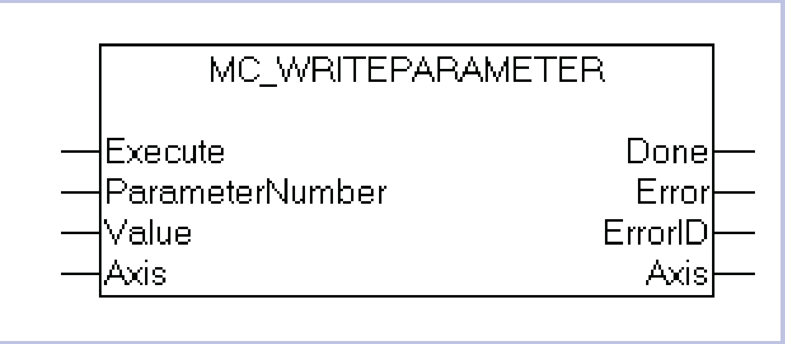
Enable	Enable_Positive	Enable_Negative	NC Controller allows:
1	**0**	**0**	Position control
1	**1**	**0**	Position control + Start in positive direction
1	**0**	**1**	Position control + Start in negative direction
1	**1**	**1**	Position control + Start in positive or negative direction

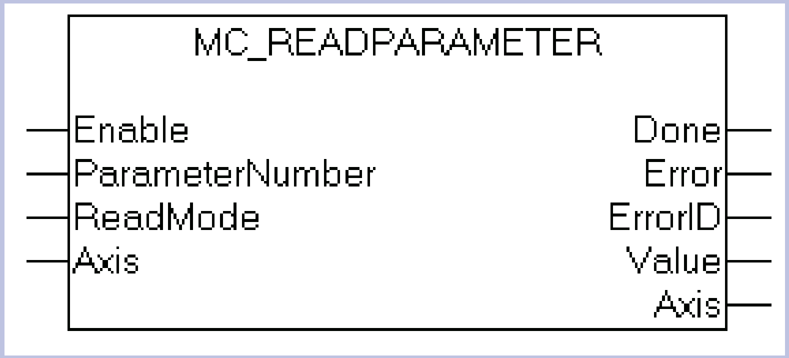
MC Read_...


MC_READSTATUS
Enable
Axis
Done
Error
Errorld
Errorstop
Stopping
StandStill
SynchronizedMotion
Homing
ConstantVelocity
Accelerating
Decelerating
Axis

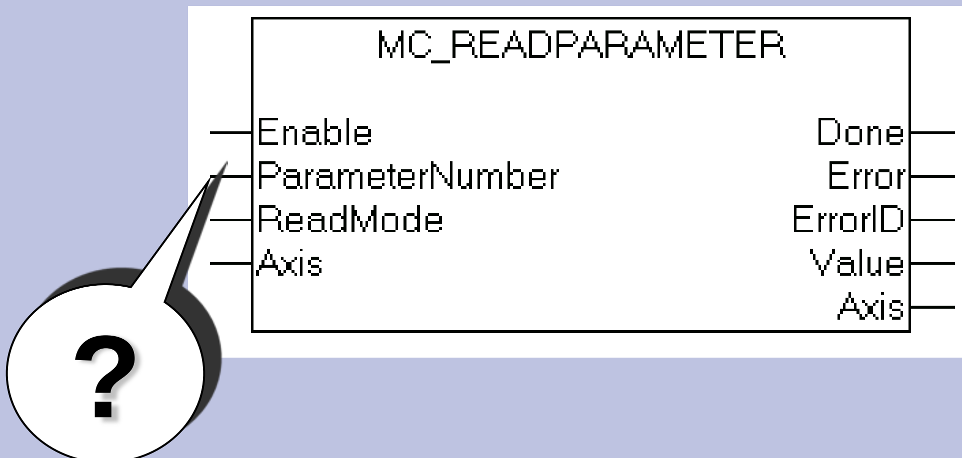

MC_READAXISERROR
Enable
Axis
Done
Error
ErrorID
Axis

MC Read_...


MC_WRITEPARAMETER
Execute
ParameterNumber
Value
Axis
Done
Error
ErrorID
Axis

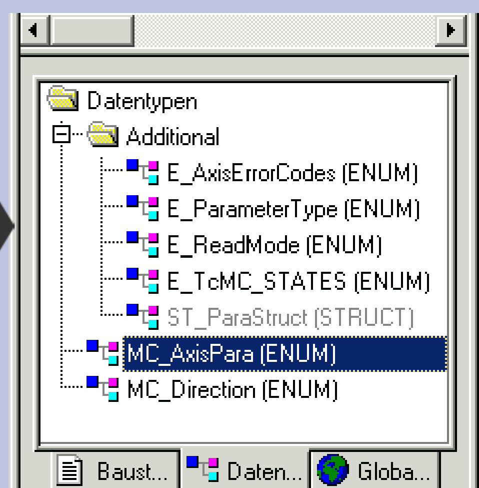

MC_READPARAMETER
Enable
ParameterNumber
ReadMode
Axis
Done
Error
ErrorID
Value
Axis

MC Read /Write Parameter Number in TCMC.LIB



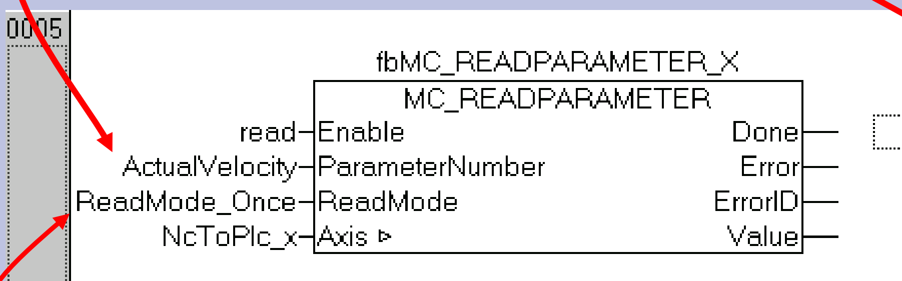
PLC Control Library Manager

TcNC.lib*16.10.02 09:05:00
TcMC.lib*16.10.02 09:05:00
STANDARD.LIB*5.6.98 09:05:02
TcBase.lib*16.9.02 09:05:02
TcSystem.lib*16.9.02 09:05:02




```
TYPE MC_AxisPara : (
(*                  PLCopen specific parameters *)
                    CommandedPosition := 1,    (* lreal *)
                    SWLimitPos,                (* lreal *)
                    SWLimitNeg,                (* lreal *)
                    EnableLimitPos,            (* bool *)
                    EnableLimitNeg,            (* bool *)
                    EnablePosLagMonitoring,    (* bool *)
                    MaxPositionLag,            (* lreal *)
                    MaxVelocitySystem,         (* lreal *)
                    MaxVelocityAppl,           (* lreal *)
                    ActualVelocity,            (* lreal *)
                    CommandedVelocity,         (* lreal *)
                    MaxAccelerationSystem,     (* lreal *)
                    MaxAccelerationAppl,       (* lreal *)
                    MaxDecelerationSystem,     (* lreal *)
                    MaxDecelerationAppl,       (* lreal *)
                    MaxJerk,                   (* lreal *)
(*                  Beckhoff specific parameters *)
                    AxisId     :=     1000,    (* lreal *)
                    AxisVeloManSlow,           (* lreal *)
                    AxisVeloManFast            (* lreal *)
```

Example Read ActualVelocity




```
TYPE MC_AxisPara : (
(*                  PLCopen specific parameters *)
                    CommandedPosition := 1,   (* lreal *)
                    SWLimitPos,               (* lreal *)
                    SWLimitNeg,               (* lreal *)
                    EnableLimitPos,           (* bool *)
                    EnableLimitNeg,           (* bool *)
                    EnablePosLagMonitoring,   (* bool *)
                    MaxPositionLag,           (* lreal *)
                    MaxVelocitySystem,        (* lreal *)
                    MaxVelocityAppl,          (* lreal *)
                    ActualVelocity,           (* lreal *)
                    CommandedVelocity,        (* lreal *)
                    MaxAccelerationSystem,    (* lreal *)
                    MaxAccelerationAppl,      (* lreal *)
                    MaxDecelerationSystem,    (* lreal *)
                    MaxDecelerationAppl,      (* lreal *)
                    MaxJerk,                  (* lreal *)
(*                  Beckhoff specific parameters *)
                    AxisId    :=    1000,     (* lreal *)
                    AxisVeloManSlow,          (* lreal *)
                    AxisVeloManFast           (* lreal *)
```

With ReadMode the single resp. permanent reading can be determined.

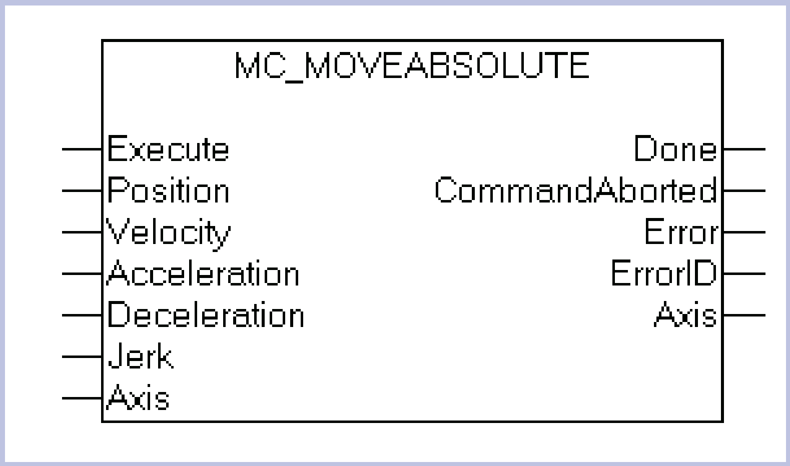
```
TYPE
    E_ReadMode :
        (   ReadMode_Once := 1,
            ReadMode_Cyclic
        );
END_TYPE
```

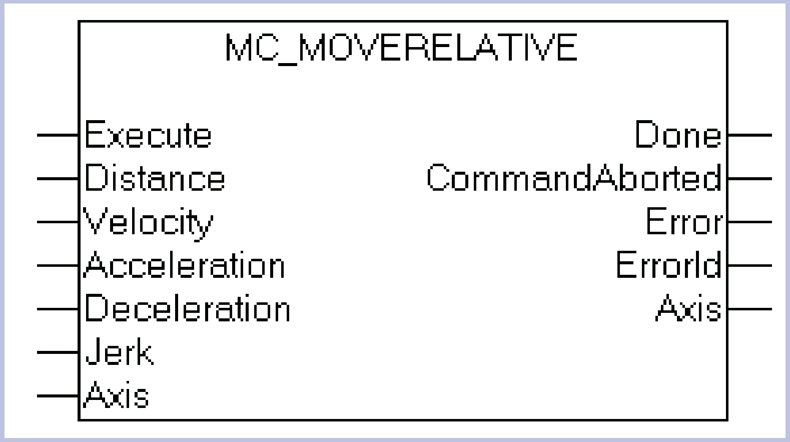
Motion Function Blocks

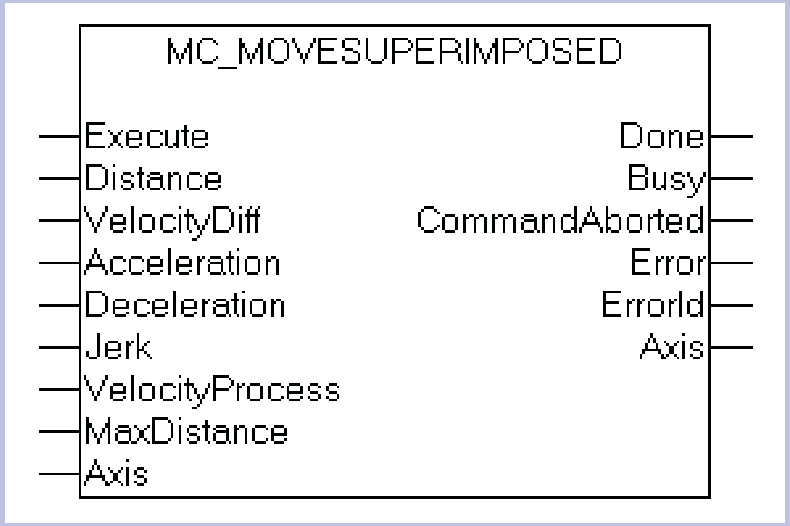
Single Axis

Motion Function Blocks

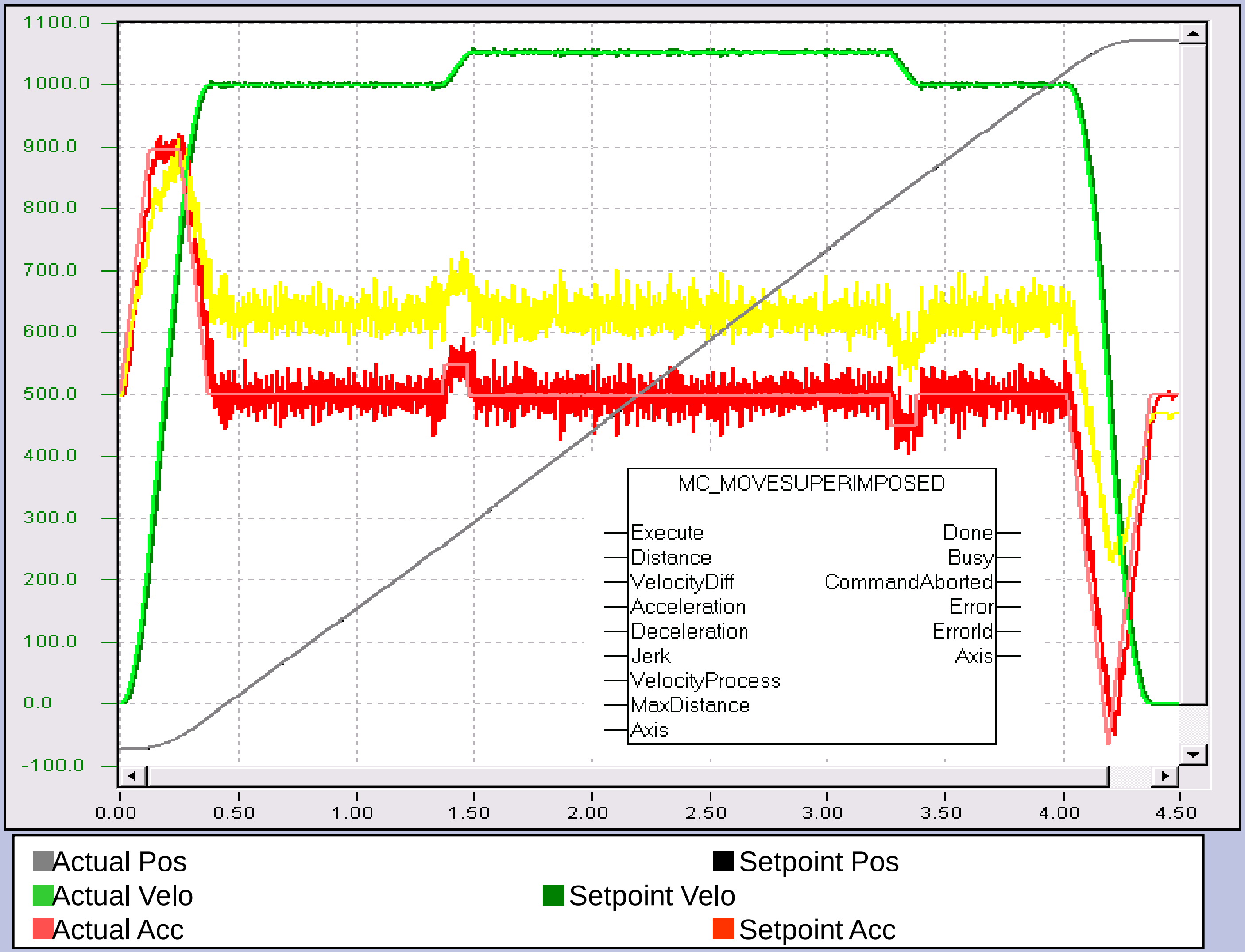
Motion Function Blocks



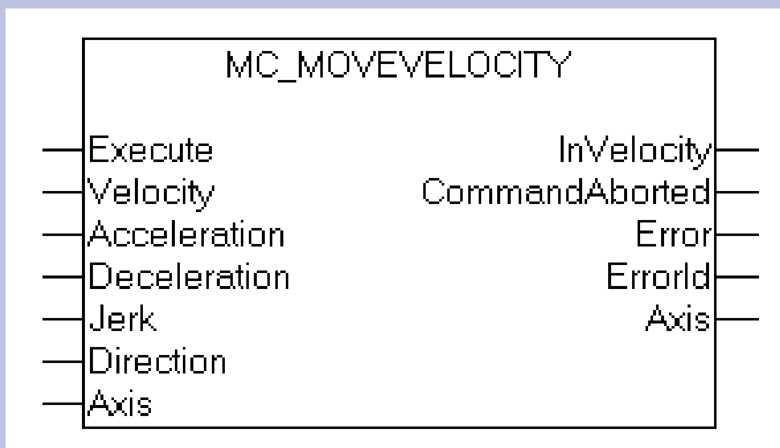


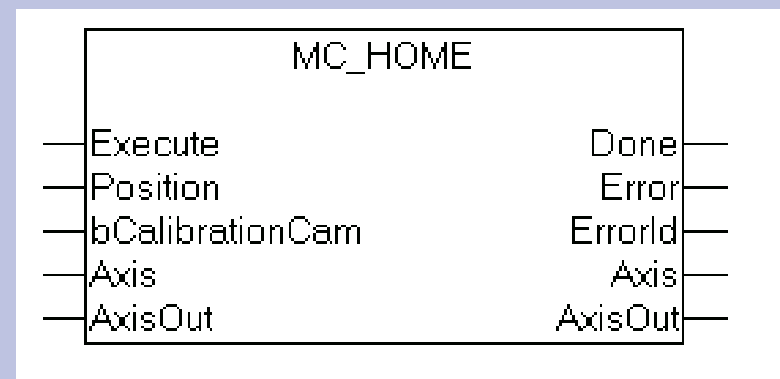


Mode of Operation Move Superimposed



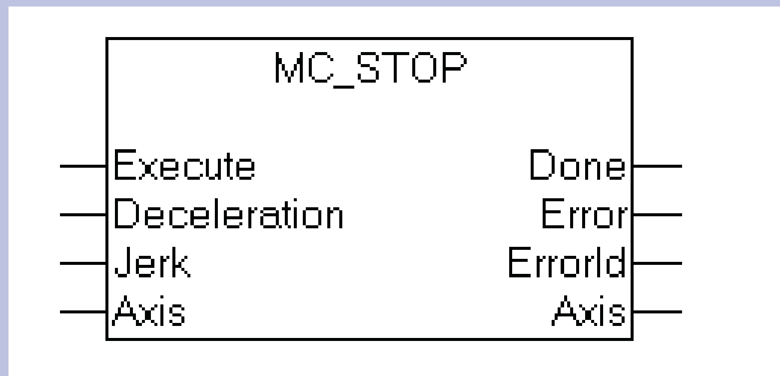
Motion Function Blocks

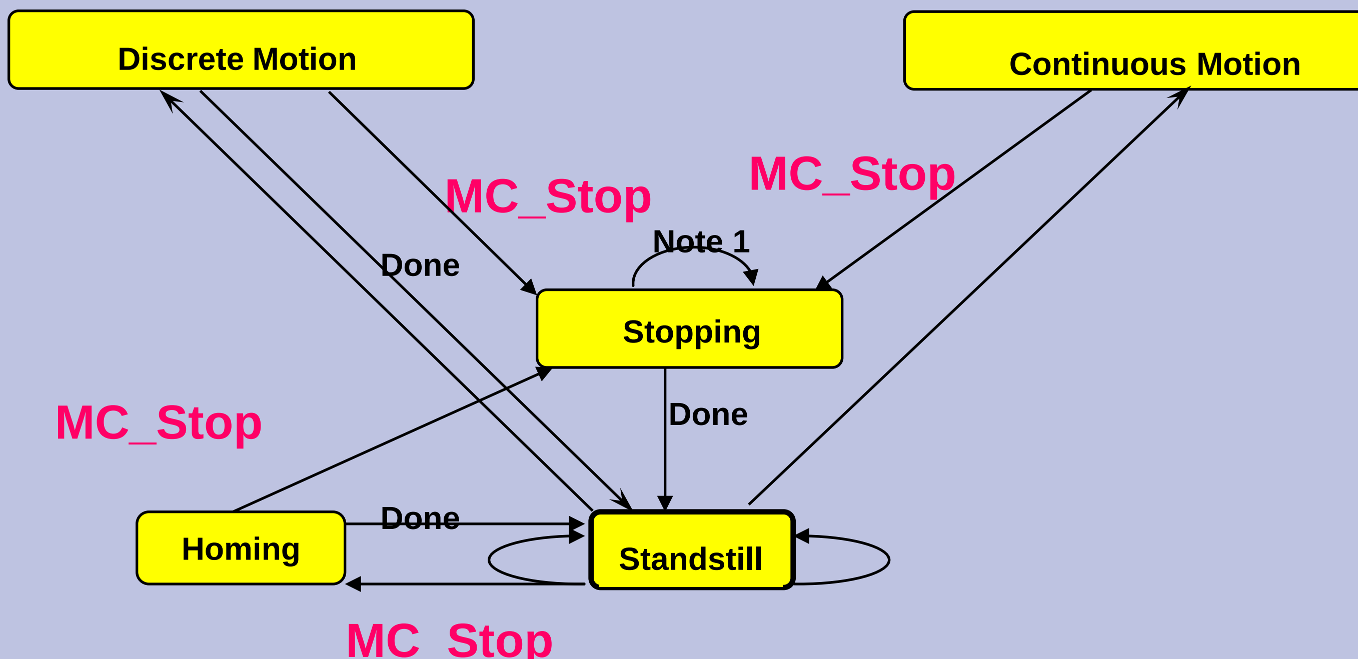




Mode of operation see „Referencing“

Motion Function Blocks





Motion Function Blocks Multiple Axis

Multiple Axis

Motion Function Blocks

(non-interpolated)

Motion Function Blocks Multiple Axis

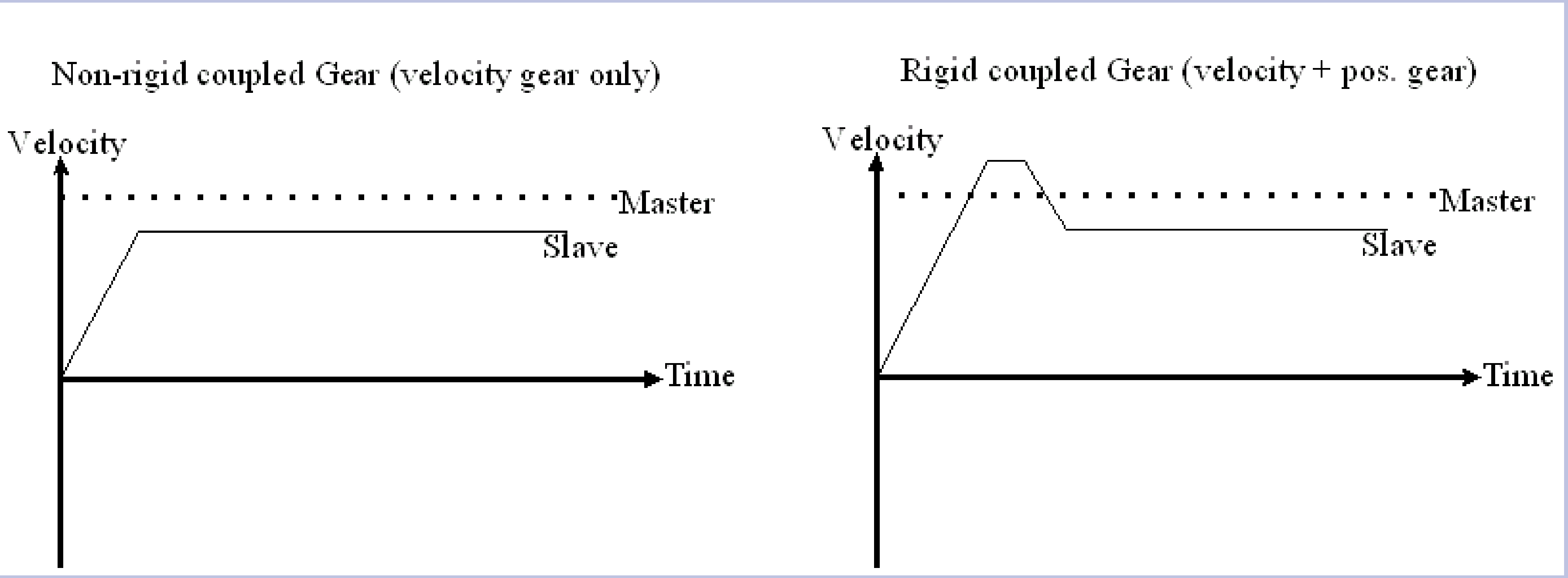
GEARING is the activation of a numeric ratio between master and slave axis.

(comparable with a mechanical gearbox).

Motion Function Blocks Multiple Axis

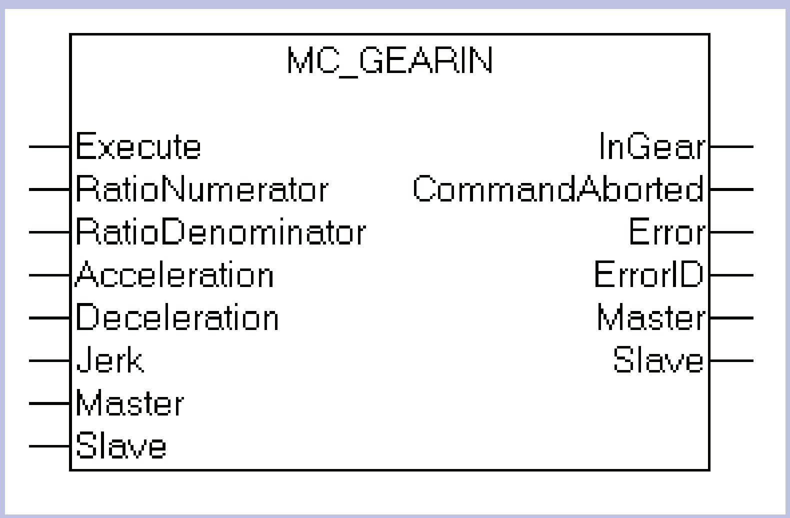
Linear “gearbox”
fixed ratio of transmission : Vm/Vs

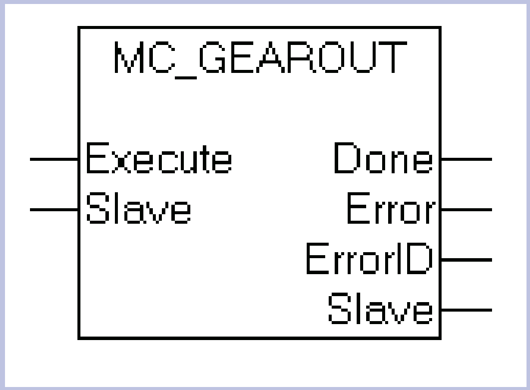
“Flying Saw”



Motion Function Blocks Multiple Axis

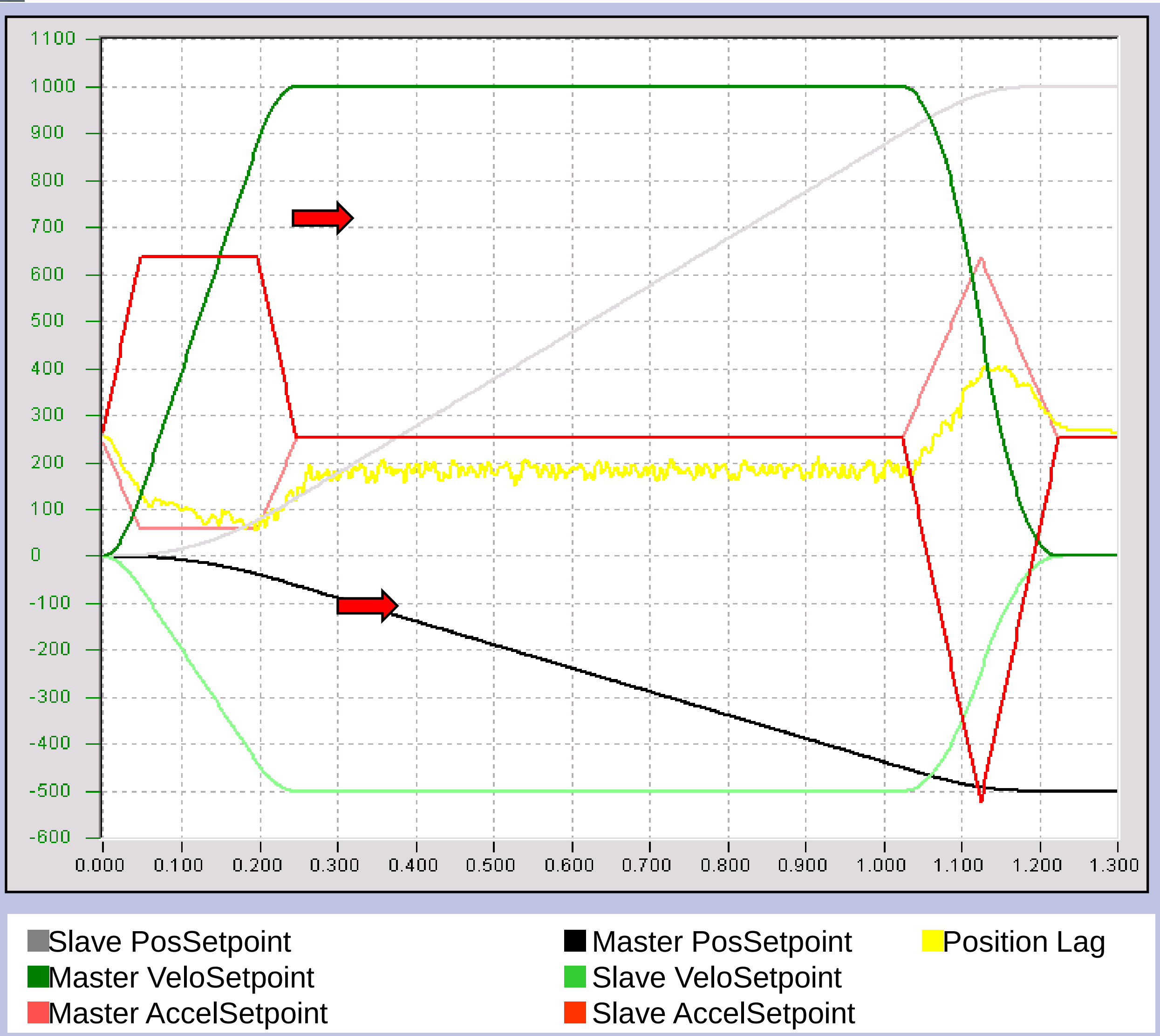
MOTION DIAGRAM FOR GEARING





Motion Function Blocks Multiple Axis

Movement diagram



Practical Part
Setting up NC Axes in System Manager

Note: These bitmaps show all basic steps in the System Manager in for AX2000. Not all possible combinations are shown.

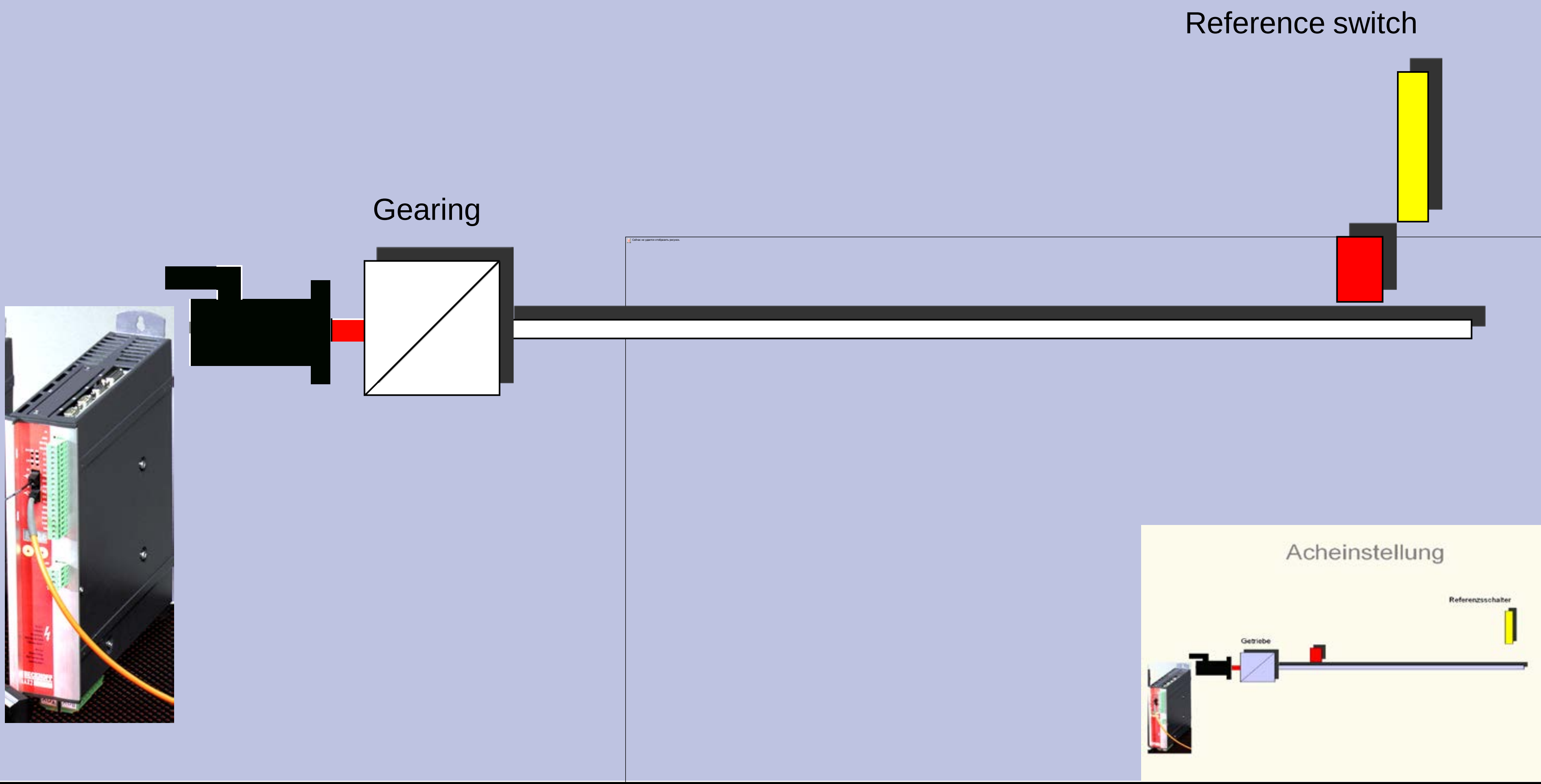
Furthermore the Safety instructions are to be considered absolutely.

TwinCAT Information System NC -> Safety functionalities.

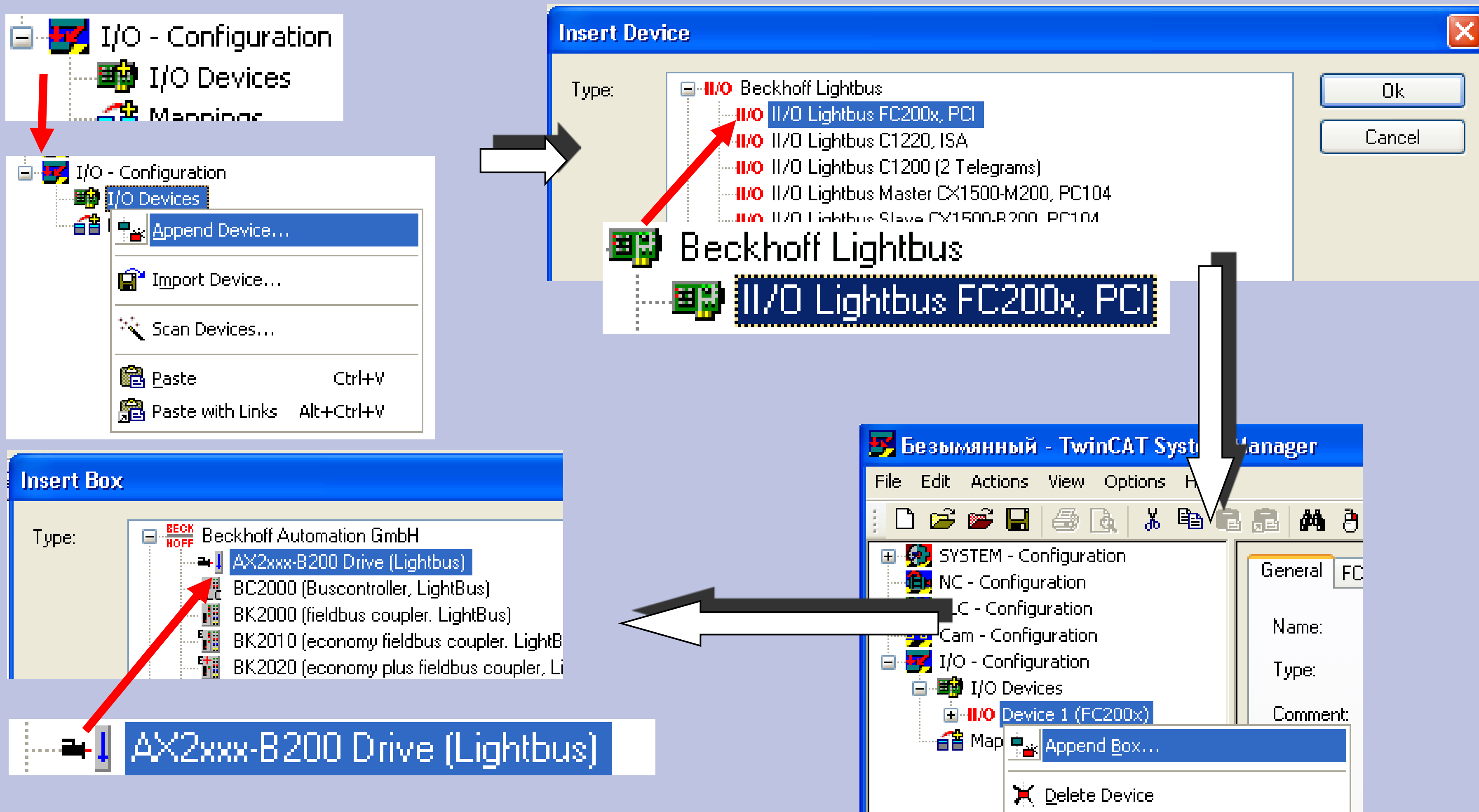
Axes Settings

Example configuration	
Data AX2000: Settings at the training devices	
Max. r.p.m.	3000
Increments per Motor revolution (Encoderemulation of AX2000)	65535
Adopted mechanical ration	1 motor revolution is equivalent to 1mm mechanical way

Axes Settings (adopted Application modell)

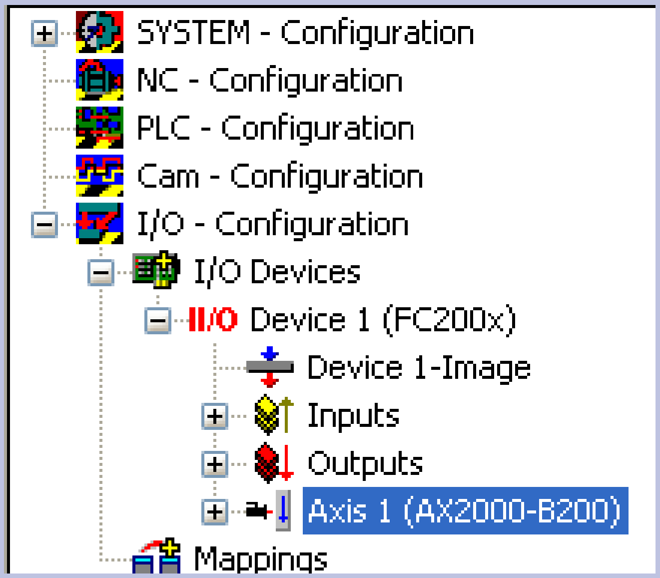


Enter Hardware

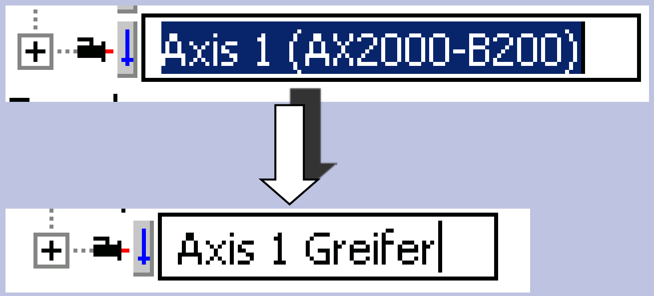


Enter Hardware

Result

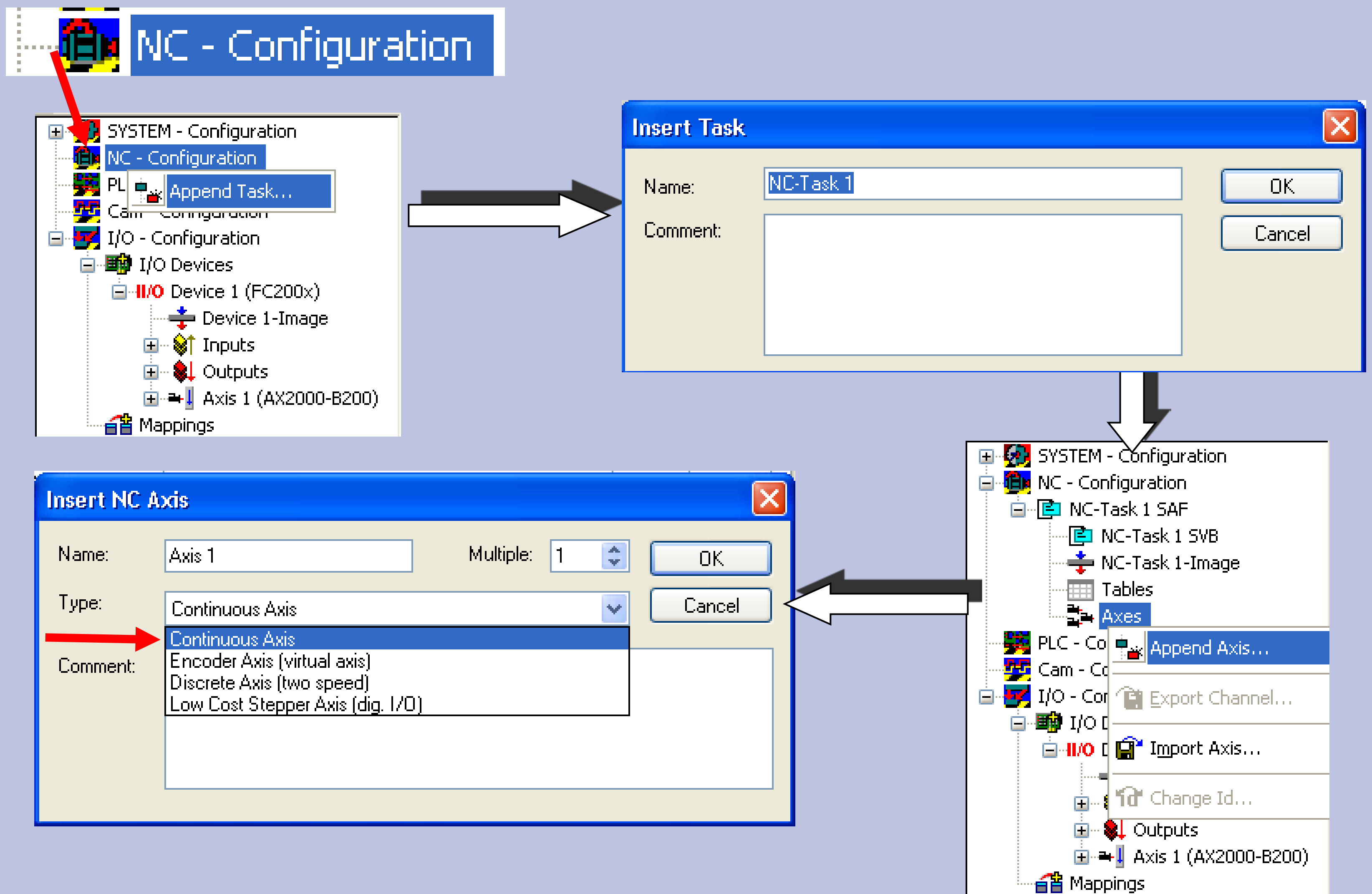


Rename?

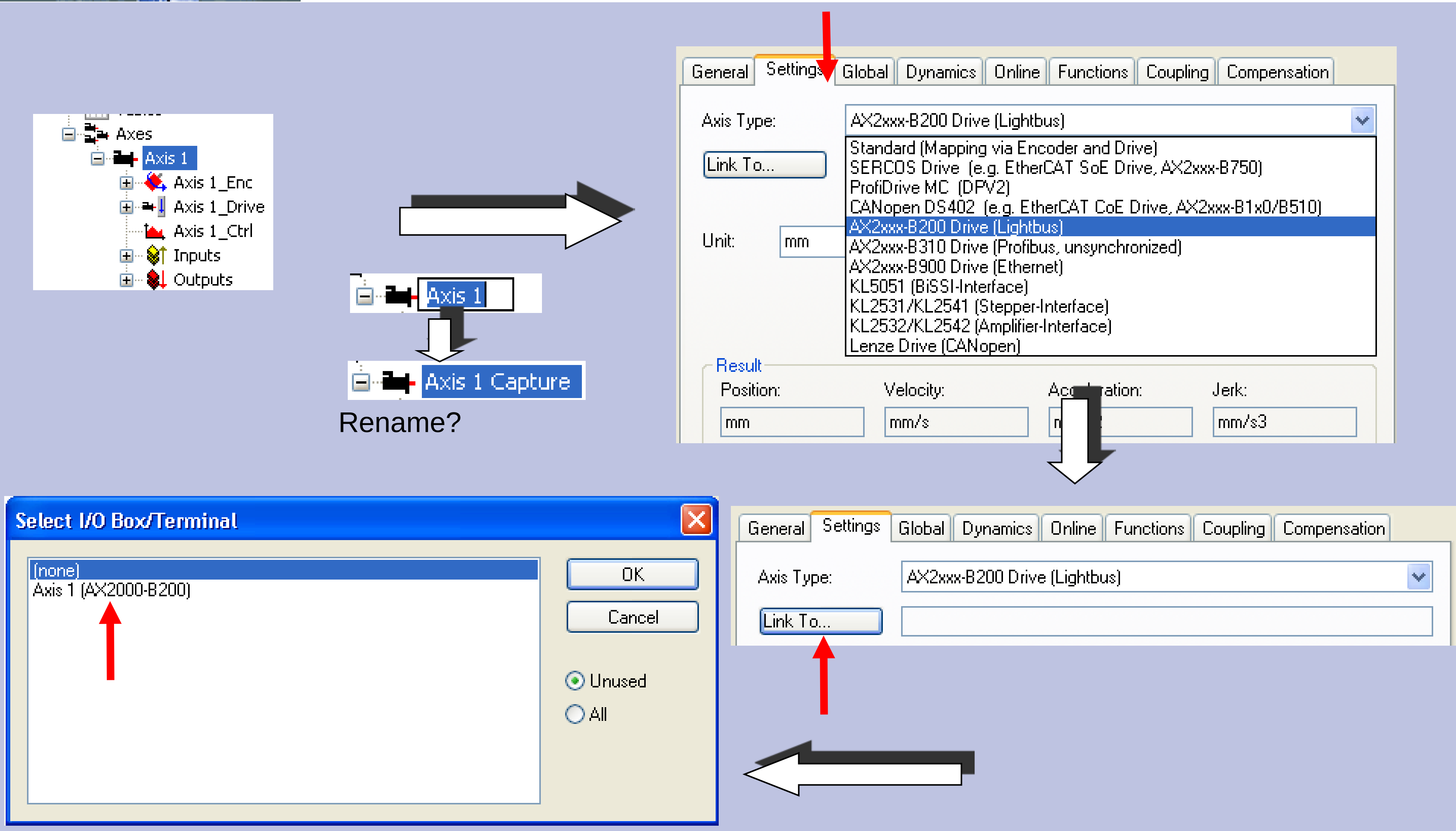


Repeat steps for all further drives

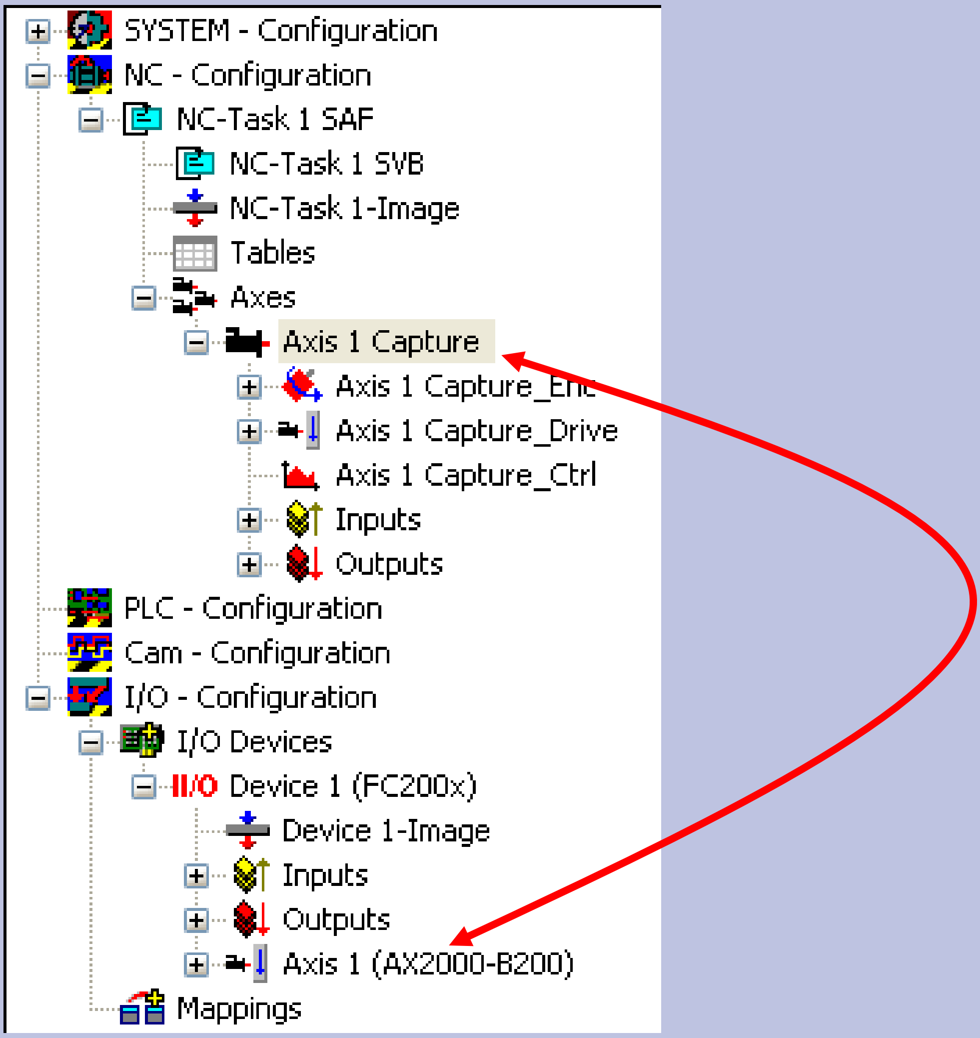
Setting up NC Axes in the System Manager



Select and link drive type

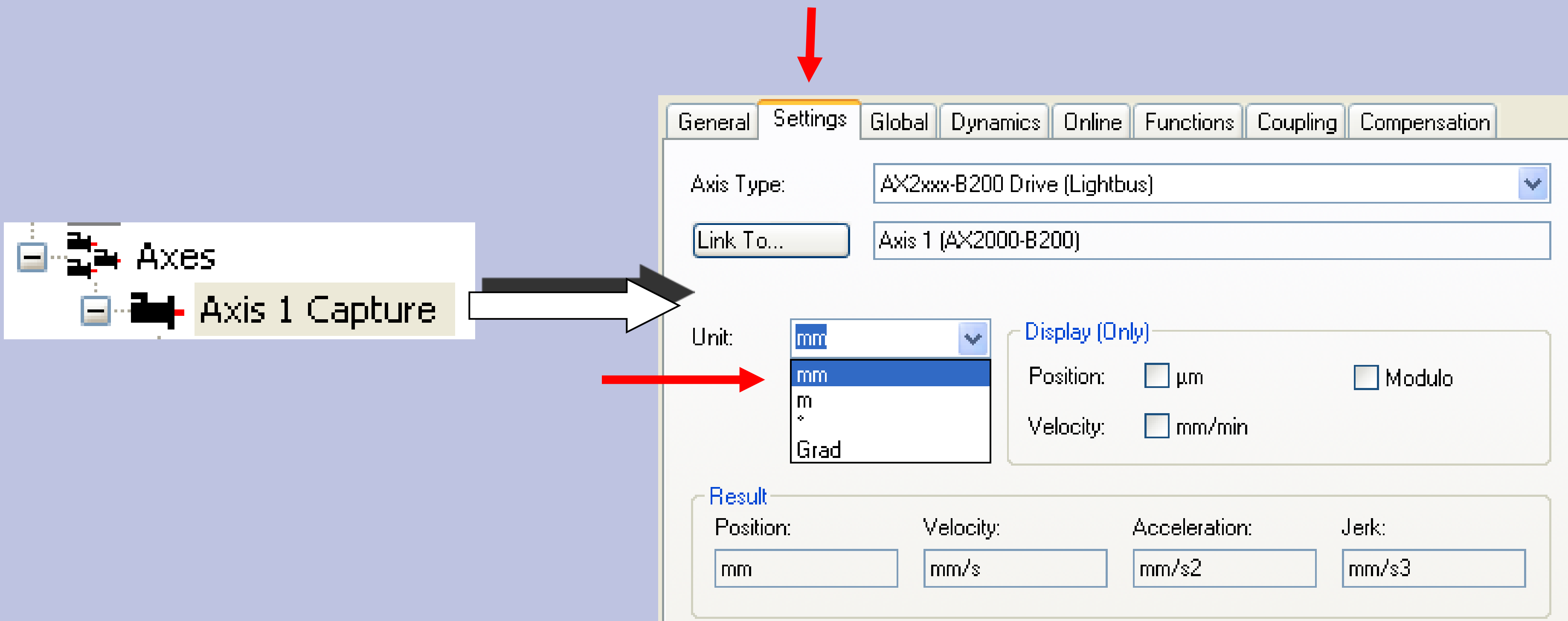


Select and link drive type



Связываем входы и выходы TwinCAT NC Controller и сервоусилителя AX 2000

Определение единиц измерения для оси



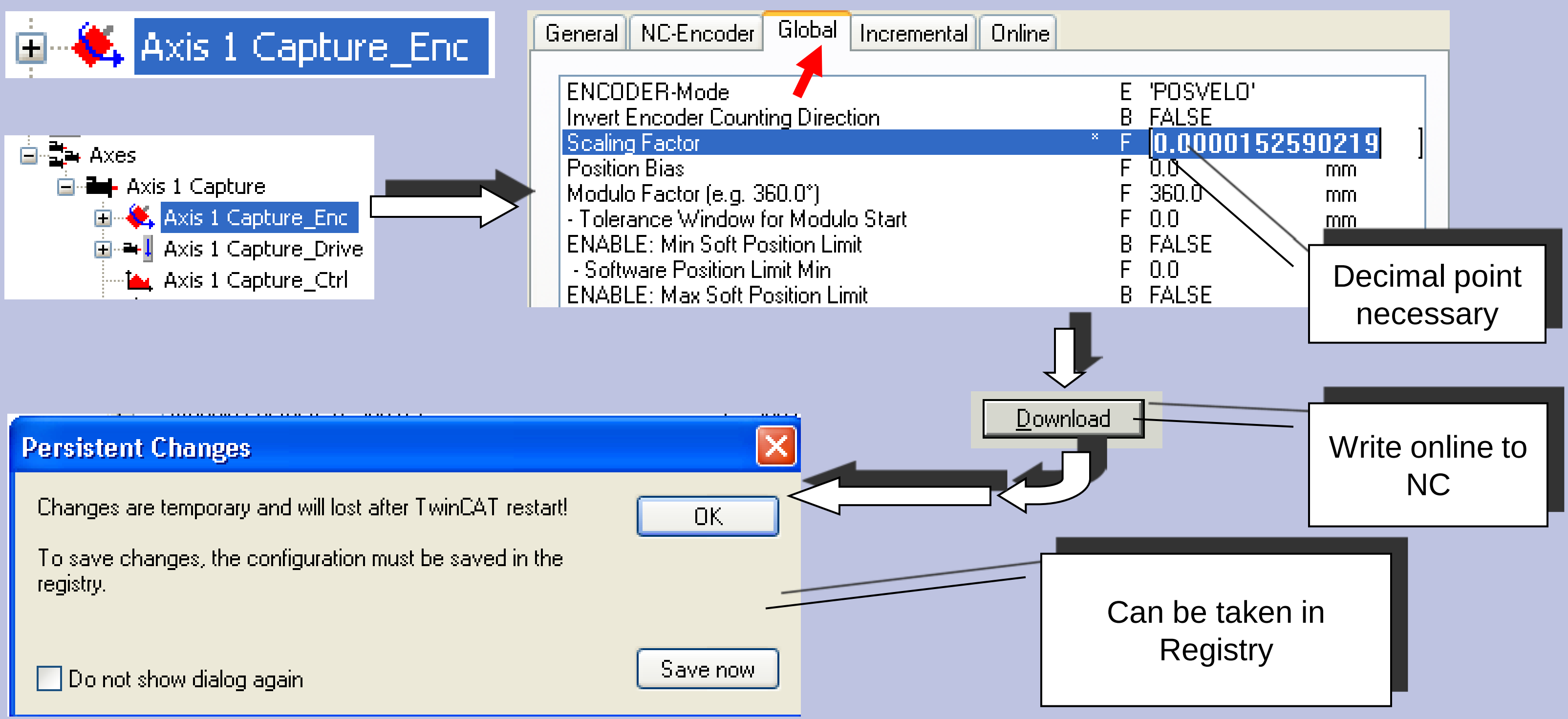
Параметры энкодера. Коэффициент масштабирования (Scaling factor)

Translation of the collected actual position value in the way unit

$$ScalingFactor = \frac{milageWay}{NumberIncrements}$$

$$Example:$$

$$ScalingFactor = \frac{1mm}{65535inc} = 1{,}52590e\text{-}5\,\frac{\text{mm}}{\text{inc}}$$



Further Encoder parameter (Notice)

General | NC-Encoder | Global | Incremental | Online

ENCODER-Mode		E	'POSVELO'	
Invert Encoder Counting Direction		B	FALSE	
Scaling Factor	*	F	0.0000152590219	mm/INC
Position Bias		F	0.0	mm
Modulo Factor (e.g. 360.0°)		F	360.0	mm
- Tolerance Window for Modulo Start		F	0.0	mm
ENABLE: Min Soft Position Limit		B	FALSE	
- Software Position Limit Min		F	0.0	mm
ENABLE: Max Soft Position Limit		B	FALSE	
- Software Position Limit Max		F	0.0	mm
Filter Time for Actual Position (P-T1)		F	0.0	s
Filter Time for Actual Velocity (P-T1)		F	0.01	s
Filter Time for Actual Acceleration (P-T1)		F	0.1	s
Encoder Mask (Maximal Value)	r	D	0x0000FFFF	
ENABLE: Actual Position Correction		B	FALSE	
Filter Time Actual Position Correction (P-T1)		F	0.0	s

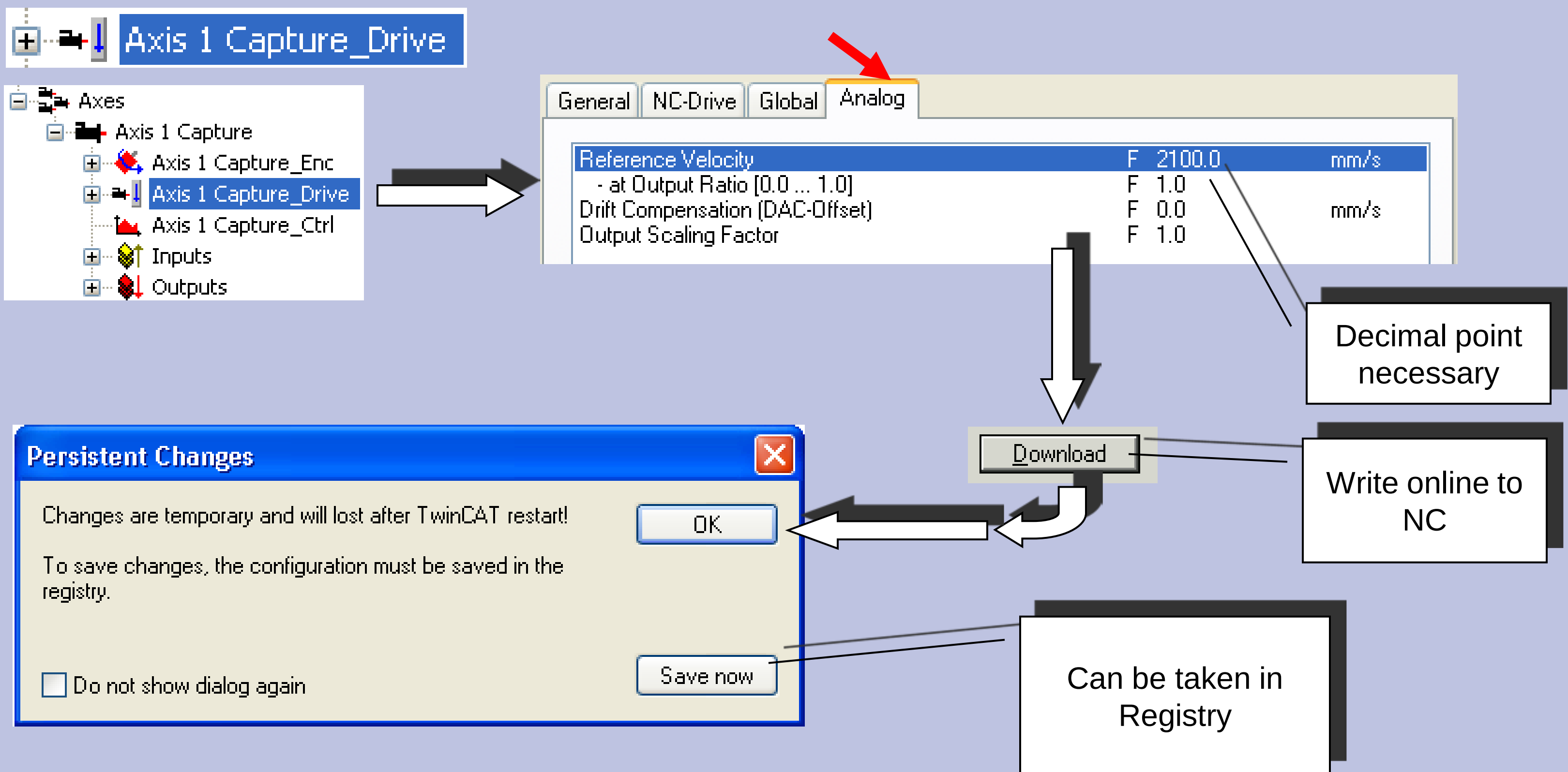
Drive parameter reference velocity

Translation of the max. rotation speed of the drive to a velocity

$$Referencevelocity = \max Rotationspeed * \frac{Way}{Rotation}$$

Example:

$$ReferenceVelocity = \frac{3000U}{60s} * \frac{1mm}{U} = 50\frac{mm}{s}$$

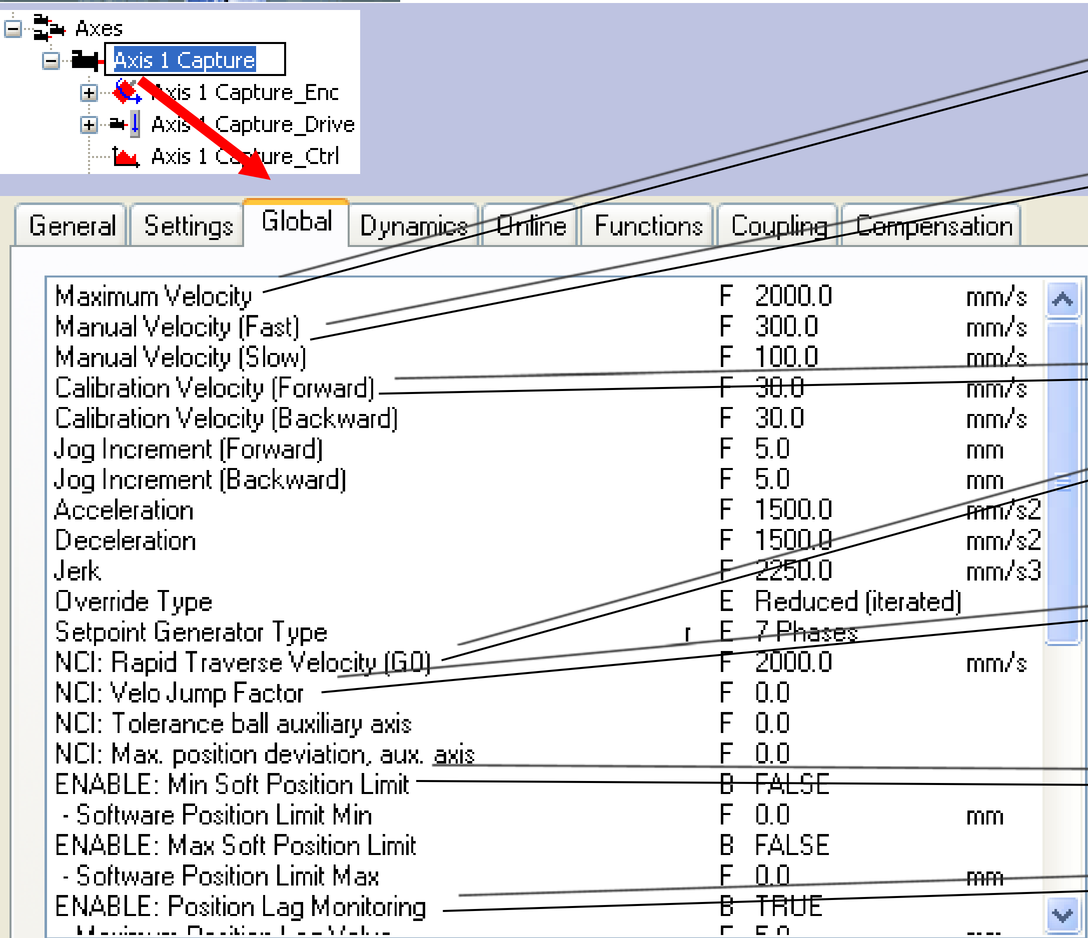


Further Drive parameter (Notice)

General | NC-Drive | Global | Analog

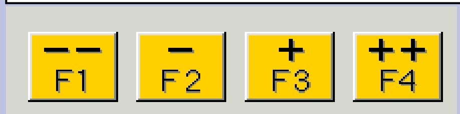
DRIVE-Mode	E	'STANDARD'
Invert Motor Polarity	B	FALSE
Minmum Drive Output Limitation [-1.0 ... 1.0]	F	-1.0
Maximum Drive Output Limitation [-1.0 ... 1.0]	F	1.0

Global Axis parameter



Допустимая максимальная скорость

Скорость в ручном режиме



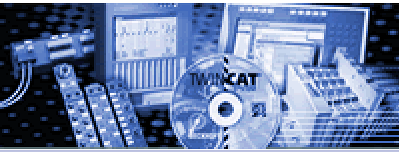
Скорость при калибровке

Быстрое перемещение инструмента к позиции обработки (NCI only)

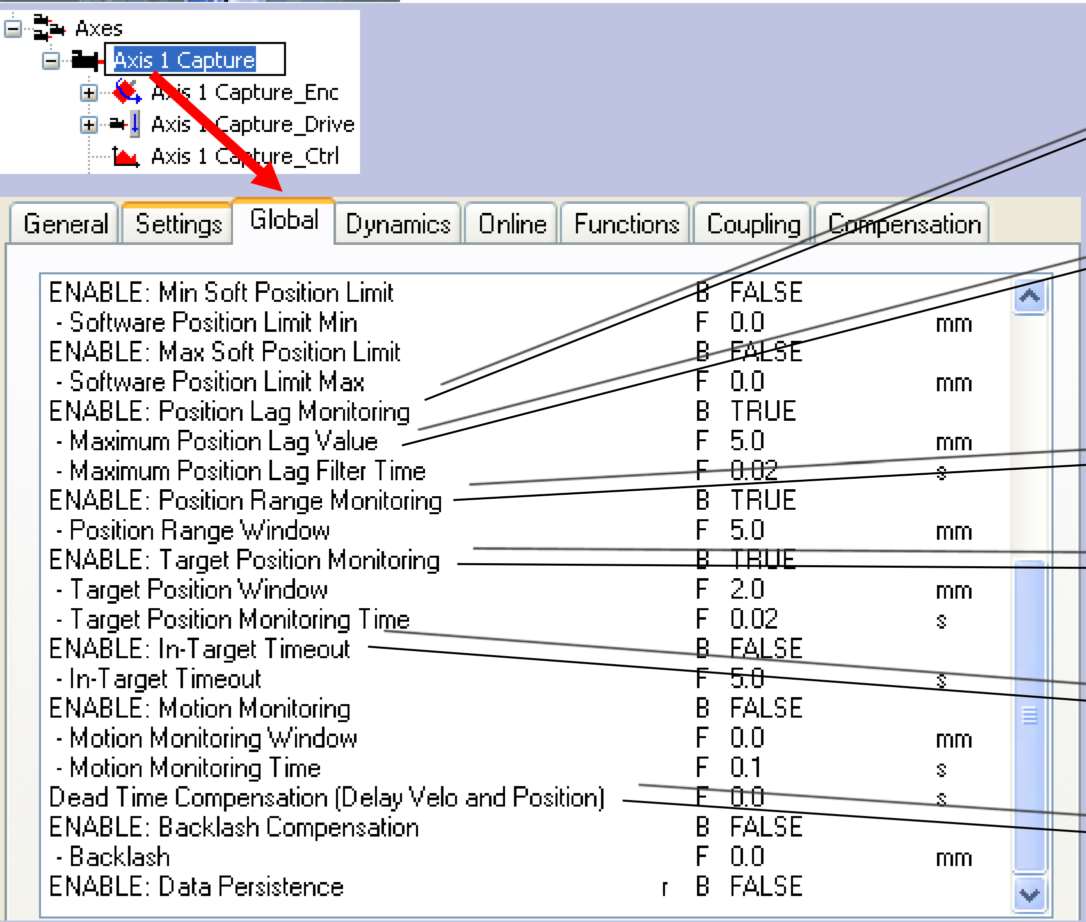
Коэффициент понижения скорости в области сопряжения траекторий (NCI only)

Программное ограничение перемещения (Min, Max)

Мониторинг следующих ошибок:



Global Axis parameter



Мониторинг следующих ошибок:

Расхождение актуальной и заданной позиции, временной фильтр ошибки Для сообщения в ПЛК „Axis in target position“ (Ось в заданном диапазоне)

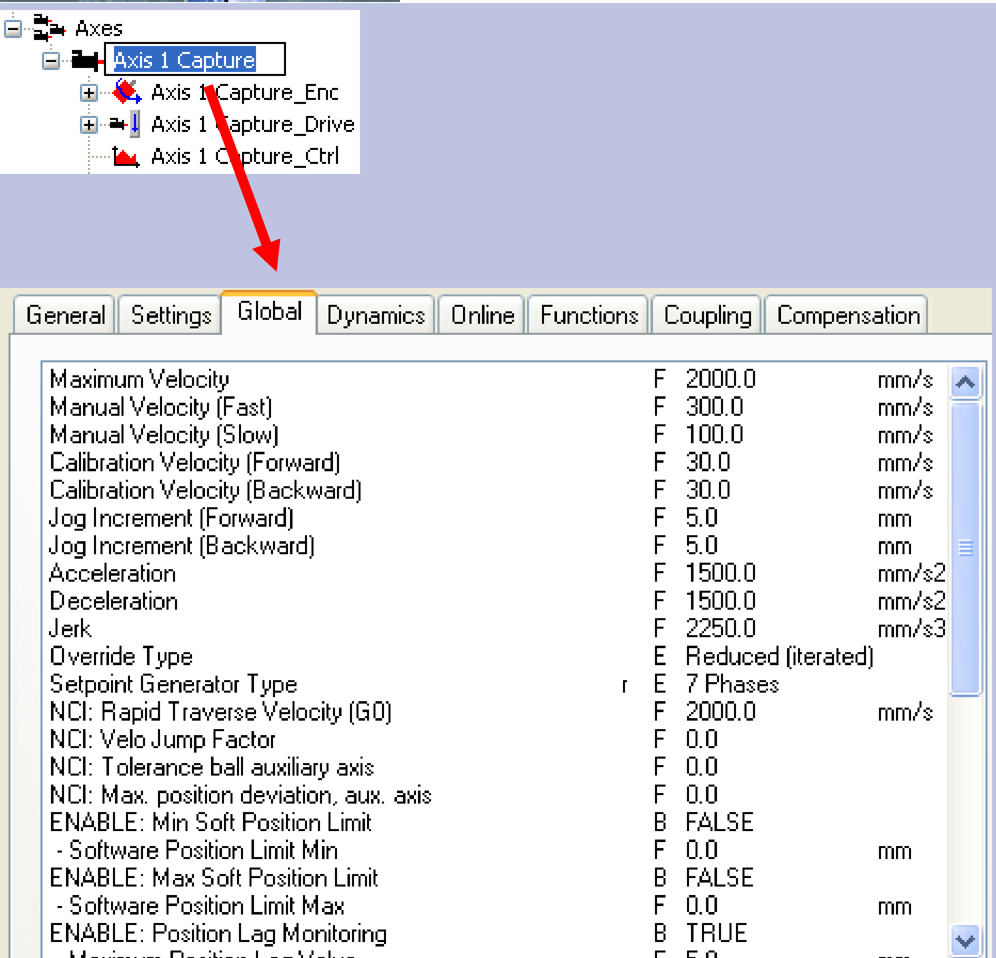
Контроль текущей позиции при перемещении (NCI only)

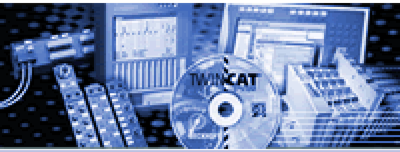
Контроль заданной позиции из G-кодов (NCI only)

Оси не пришли в заданную позицию за данное время – Error channel

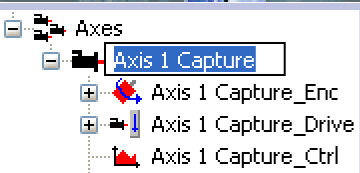
Время задержки компенсации скорости и позиции

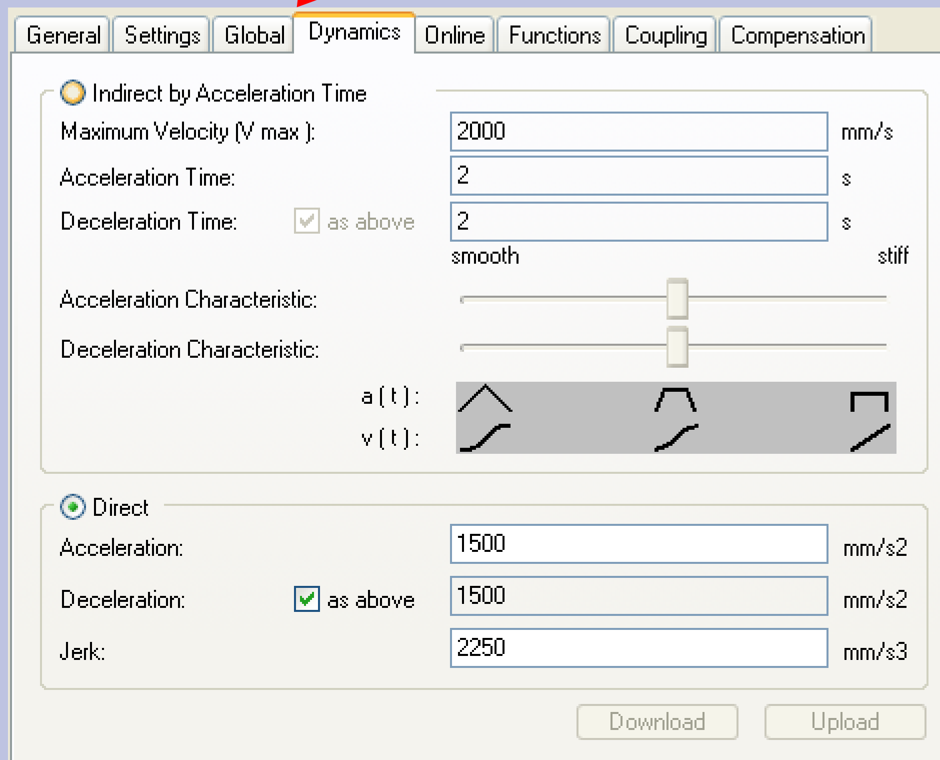
Global Axis parameter (Notice)





Dynamic





Взаимосвязь при изменении пераметров

Effects see Set value profiles

Starting NC Axes from the PLC

Example: A small project for starting an single axis should be created with the help of the MC Library

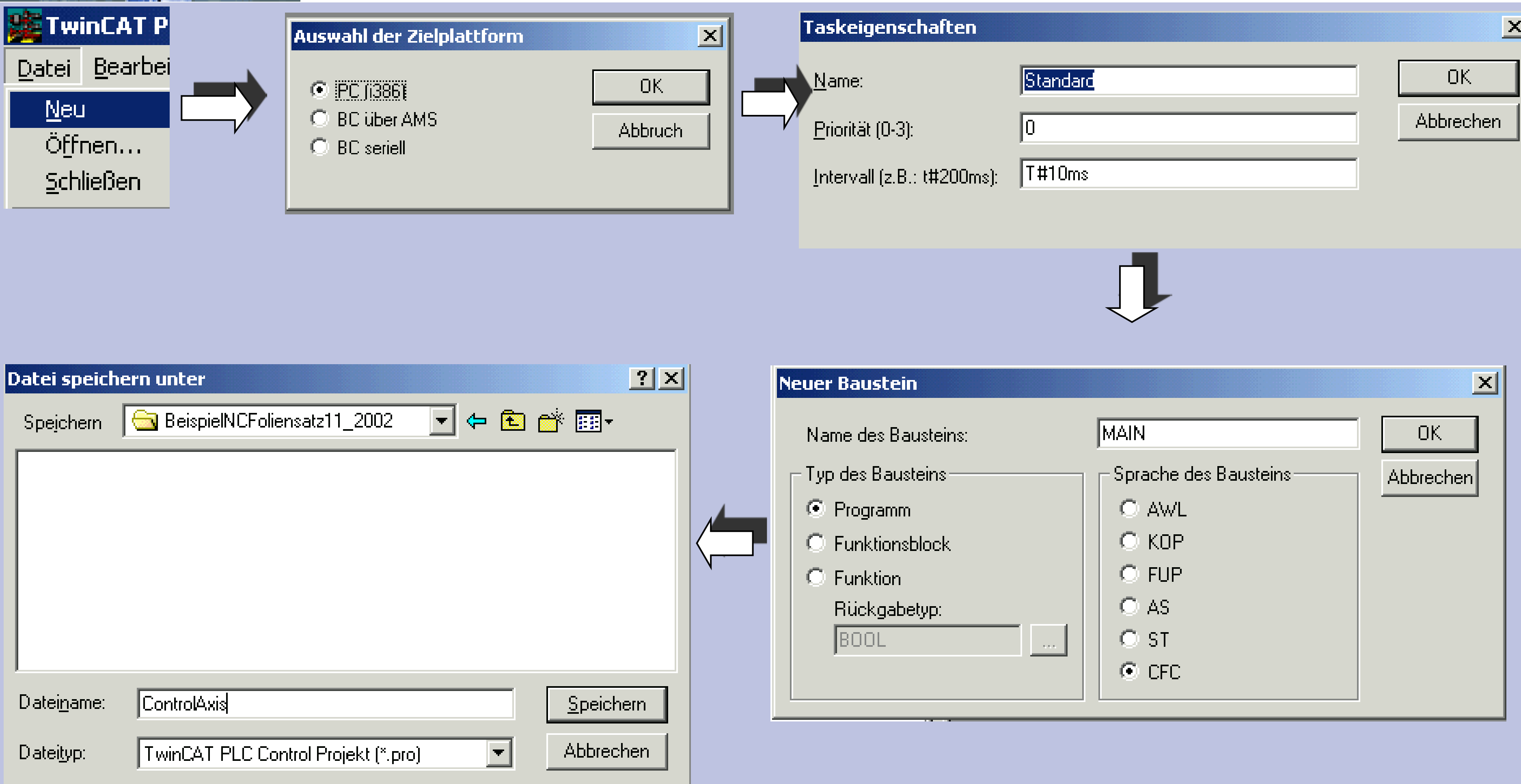
Notes:

- The control of the enable signals (hardware) is not treated in this example.

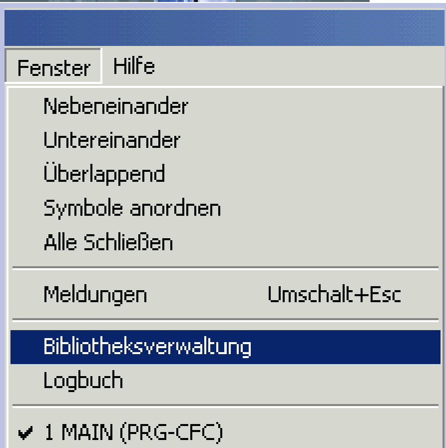
- The programming mode corresponds in this example to the classical PLC programming, that means global variables for the inputs and outputs and referencing in the POUs.

- An alternative is the creation of FBs, which work internally with not total located variables for the axis interface.(VAR_CONFIG)

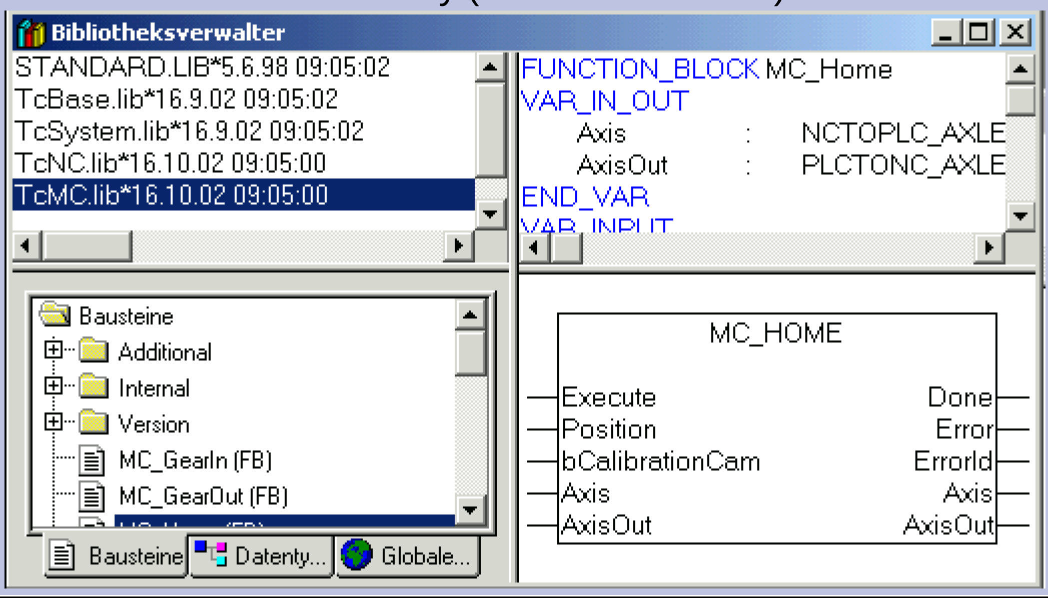
Creating a PLC Project

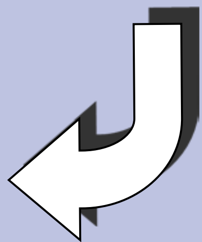


Inserting TcMC Library



Further required libraries will be inserted automatically (from TwinCAT 2.8)





Creating Input / Output variable between NC and PLC

Globale_Variablen

```
VAR_GLOBAL
	(*Axisinterface*)
	Axis1GreiferPlcToNc	AT%QB1000 :	PLCTONC_AXLESTRUCT;
	Axis1GreiferNcToPlc	AT%IB1000 :	NCTOPLC_AXLESTRUCT;

```

To consider:

1 Variable occupies 128 Byte. Thus the next free address to start is IB/QB 1128.

In addition the possibility of auto addressing can be used.

Axis1GreiferPlcToNc **AT%QB*** : PLCTONC_AXLESTRUCT;

Globale_Variablen

```
VAR_GLOBAL
	(*Axisinterface*)
	Axis1GreiferPlcToNc	AT%QB1000 :	PLCTONC
	Axis1GreiferNcToPlc	AT%IB1000 :	NCTOPLC


	(*I/O for control *)
	genRelease		AT%IX0.0:	BOOL;
	RequestHoming		AT%IX0.1:	BOOL;
	RequestSequence		AT%IX0.2:	BOOL;
	SwitchReferenceCamAxis1 AT%IX0.3:	BOOL;
```

Control inputs.

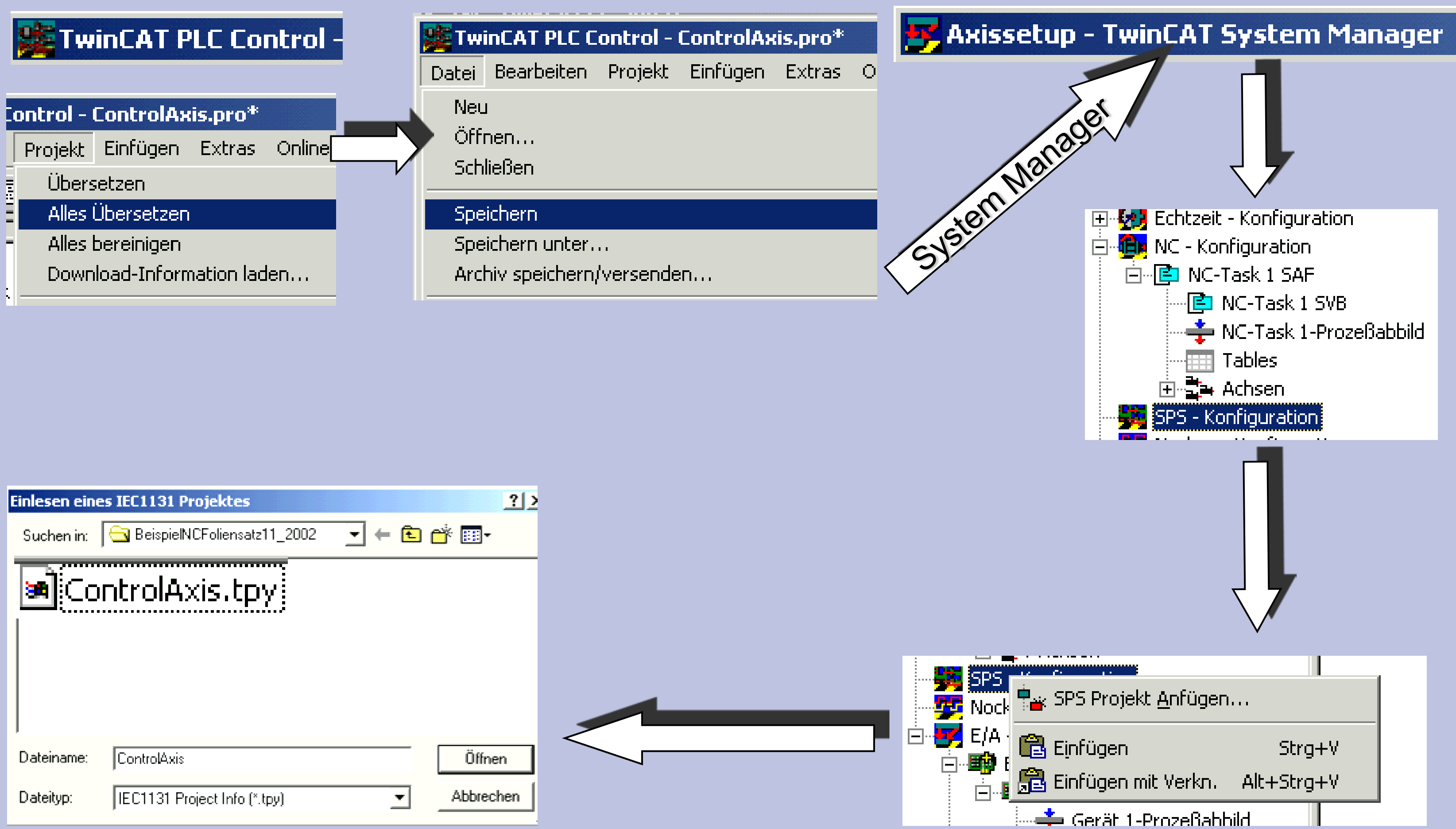
Linking with hardware,

„ Writing values“ in PLC Control, or

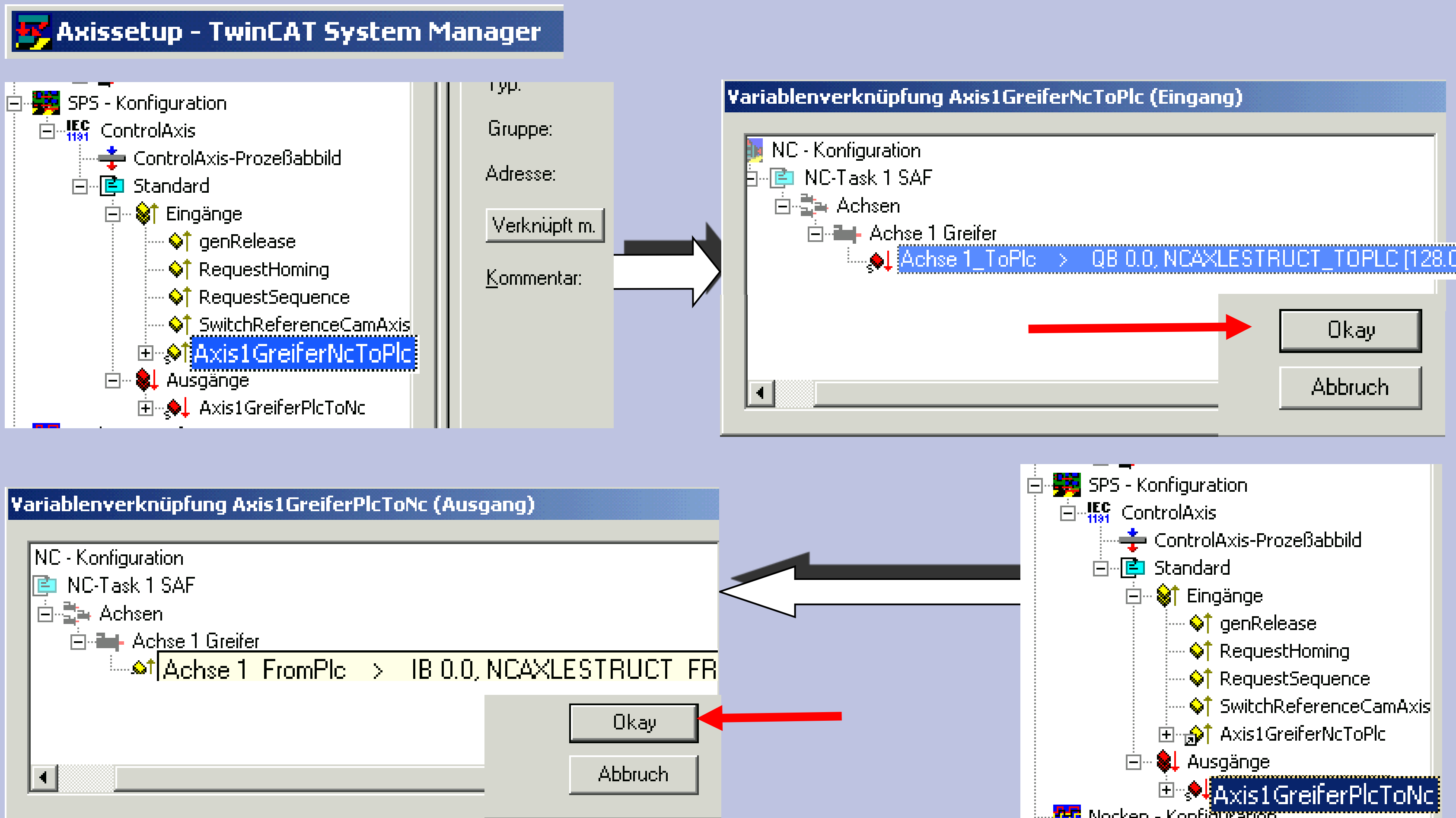
Control with a small VB / VC++

It´s understood, that at direct commissioning at a movement, the safety precautions are to be considered

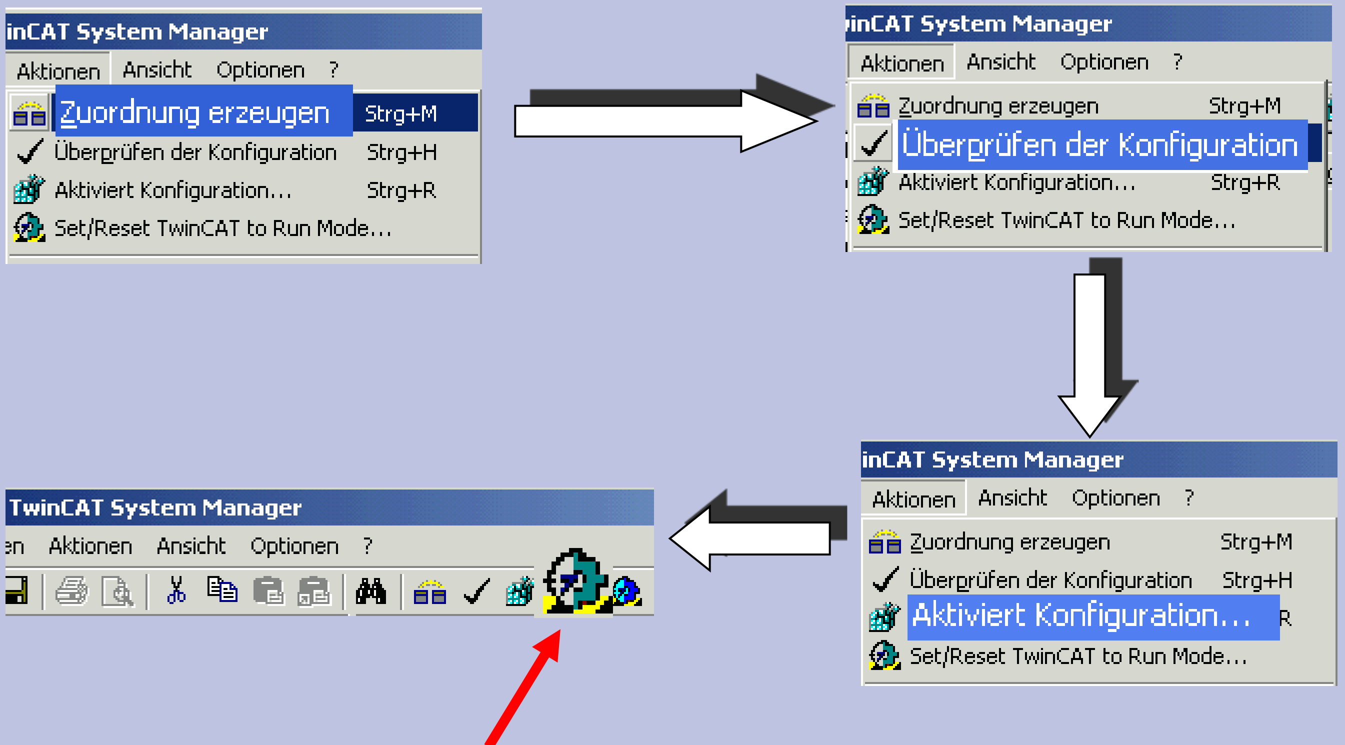
Linking Input / Output variable between NC and PLC



Linking Input / Output variable between NC and PLC

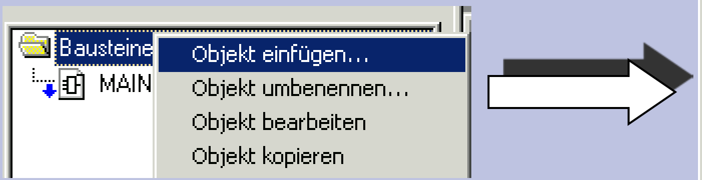


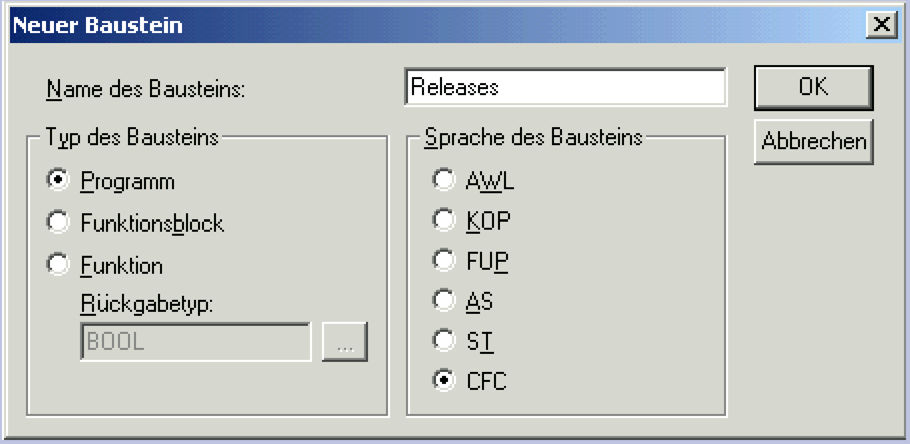
Linking further control inputs and writing configuration in registry



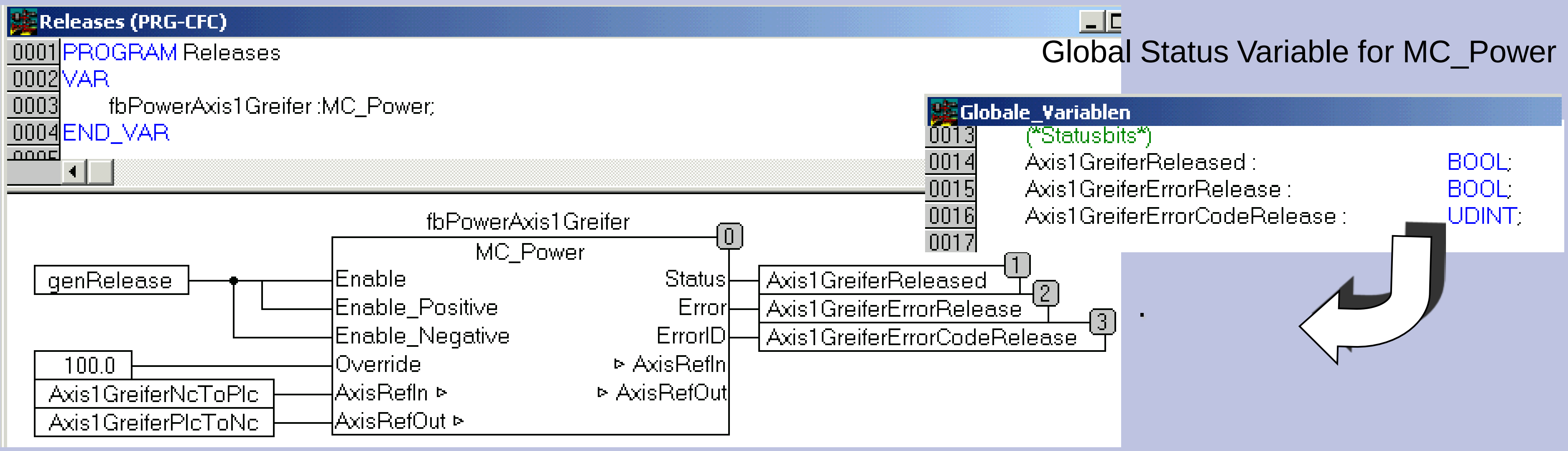
System can be started here.

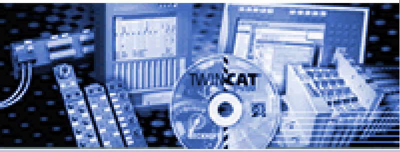
Programming axis enables MC_POWER





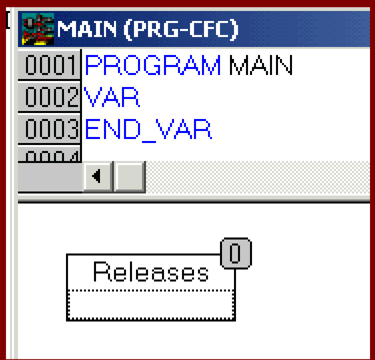
Global Status Variable for MC_Power





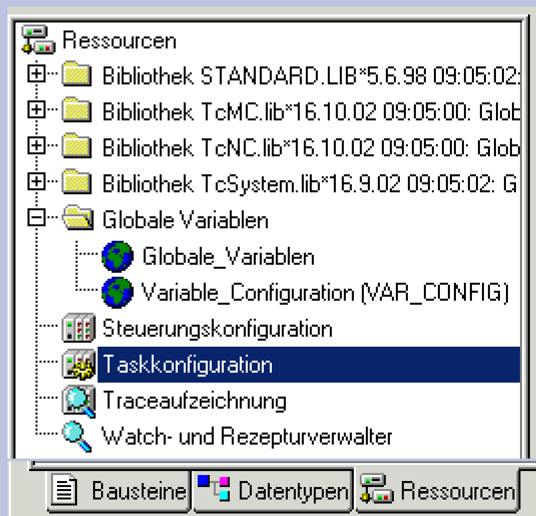
Calling axis enables

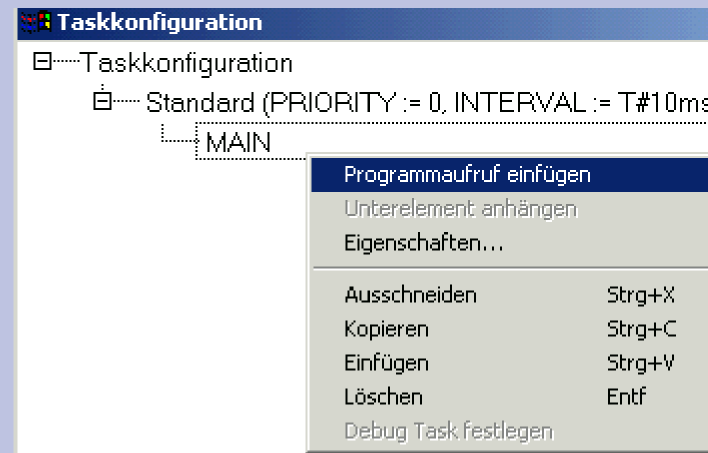
Direct in Main

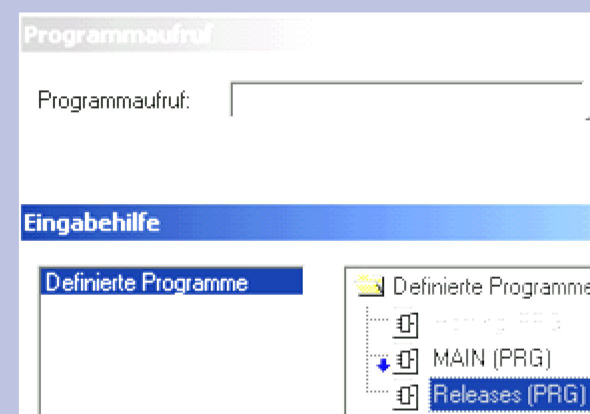


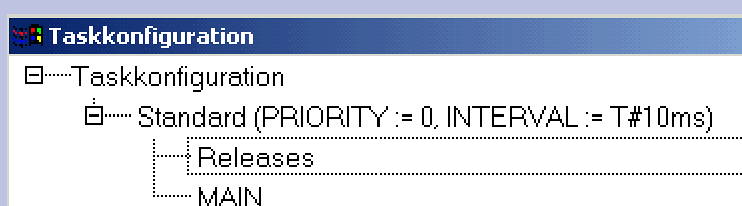
USE ONLY ONE POSSIBILITY!

Or via Taskconfiguration

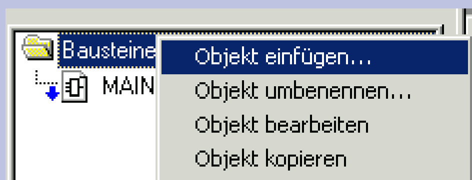


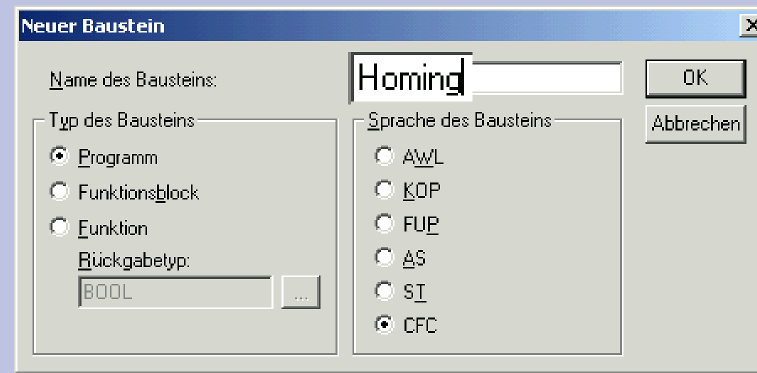




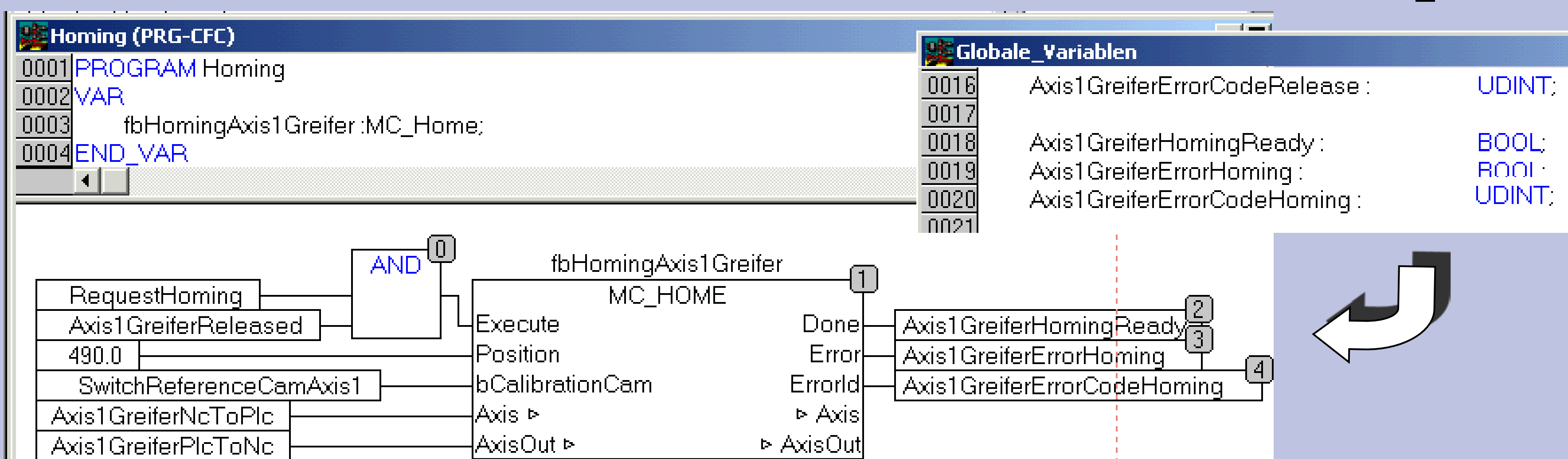


Instantiate and call MC Home block



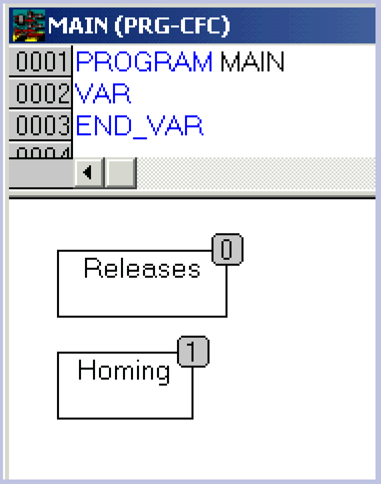


Global Status Variable for MC_Home



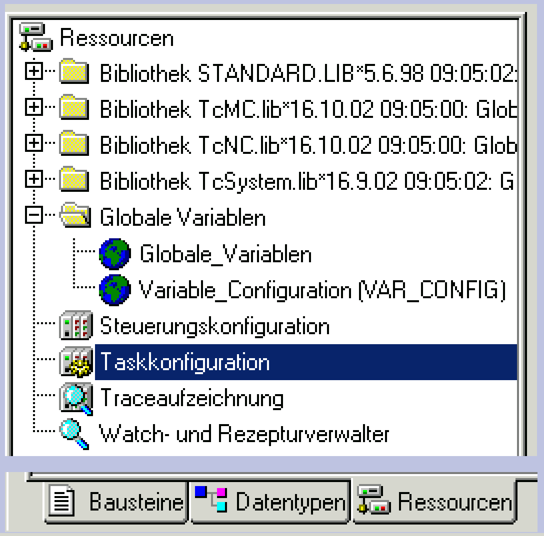
Calling Homing

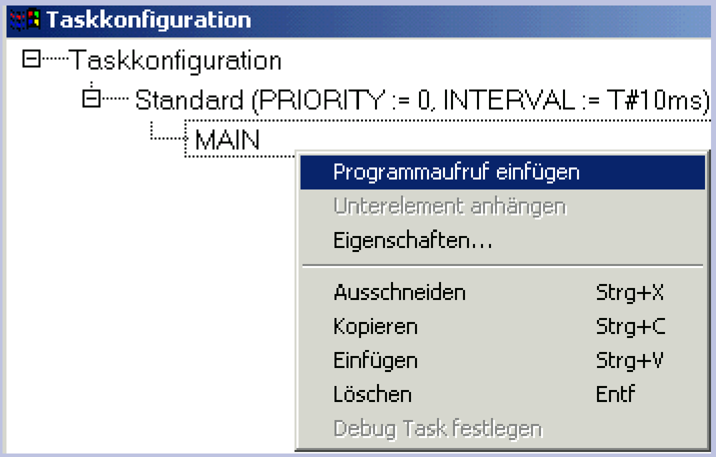
Direct in Main

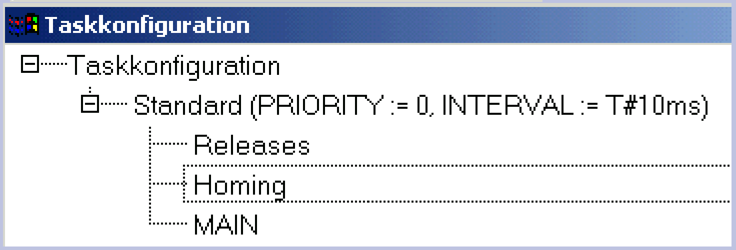


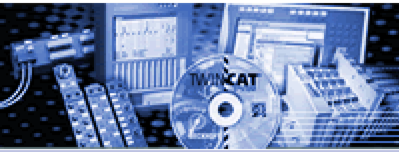
USE ONLY ONE POSSIBILITY!

Or via Taskconfiguration

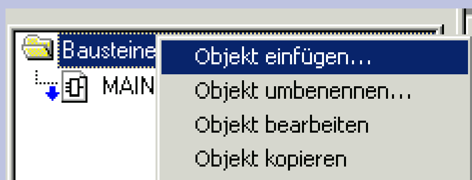


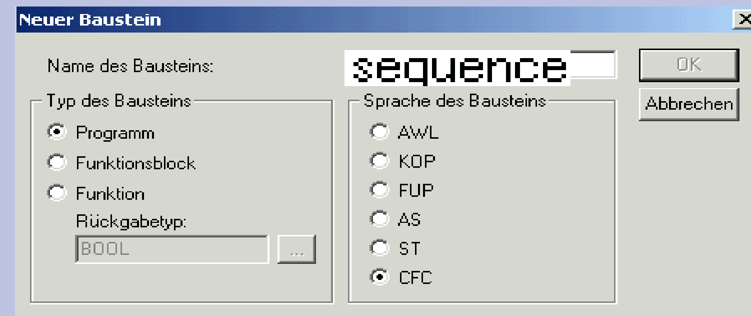




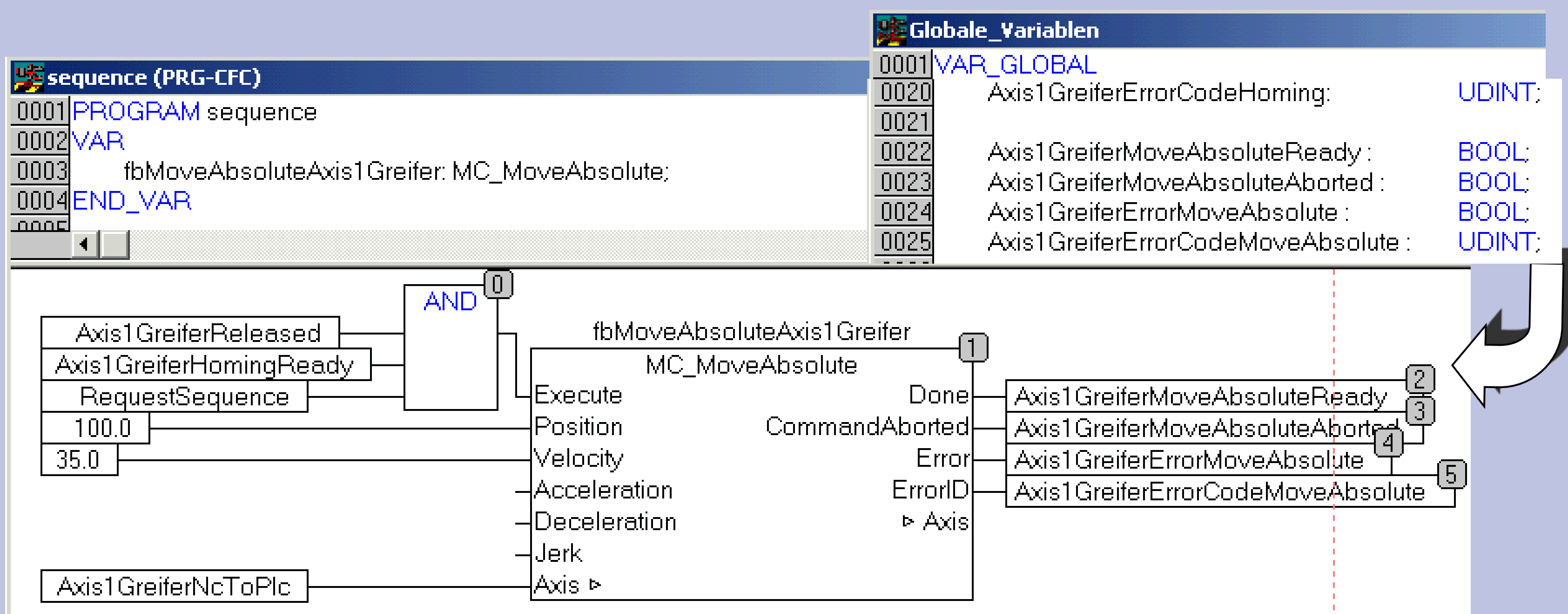


Instantiate and call MC MoveAbsolute block



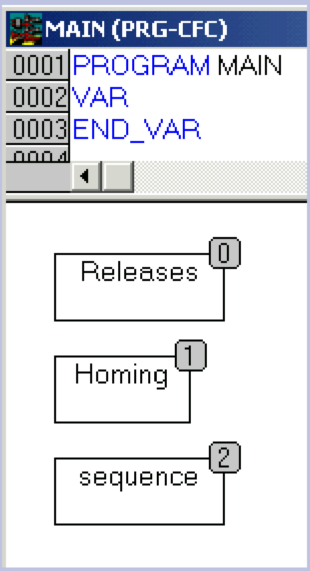


Global Status Variable for MC_MoveAbsolute



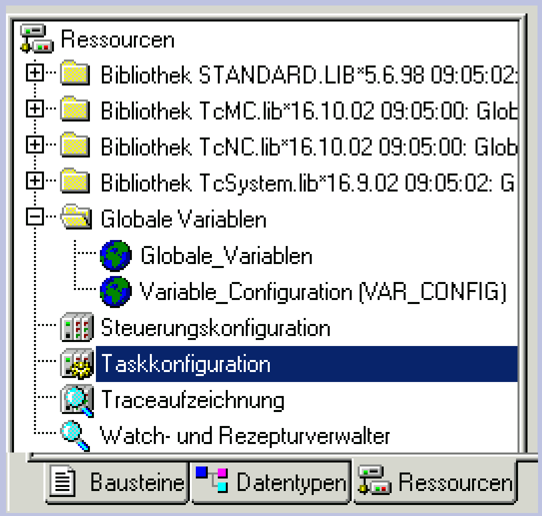
Calling Sequence

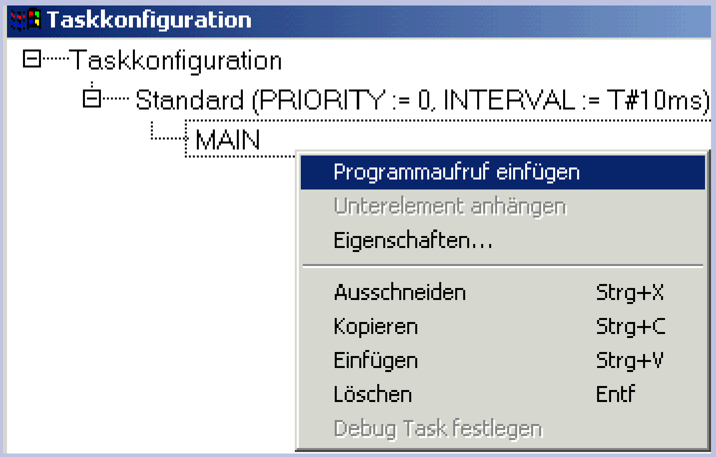
Direct in Main

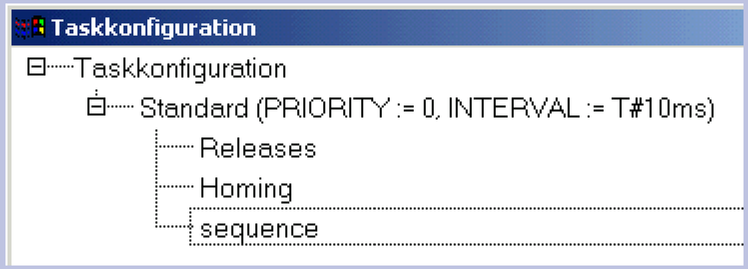


USE ONLY ONE POSSIBILITY!

Or via Taskconfiguration





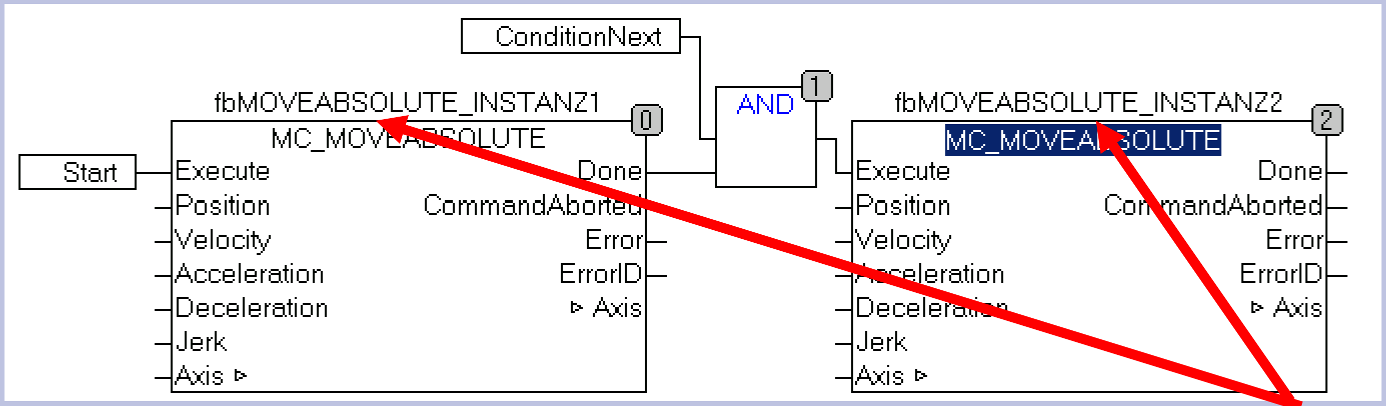


How can a flow be realised??

If the application requires flows, the MC blocks are normally used in sequence cascades.

The MC_XXXXX blocks are suited well for the use in Sequential Function Chart or in a case instruction in ST.

At graphic languages like CFC is in the first attempt a so-called cascading possible:



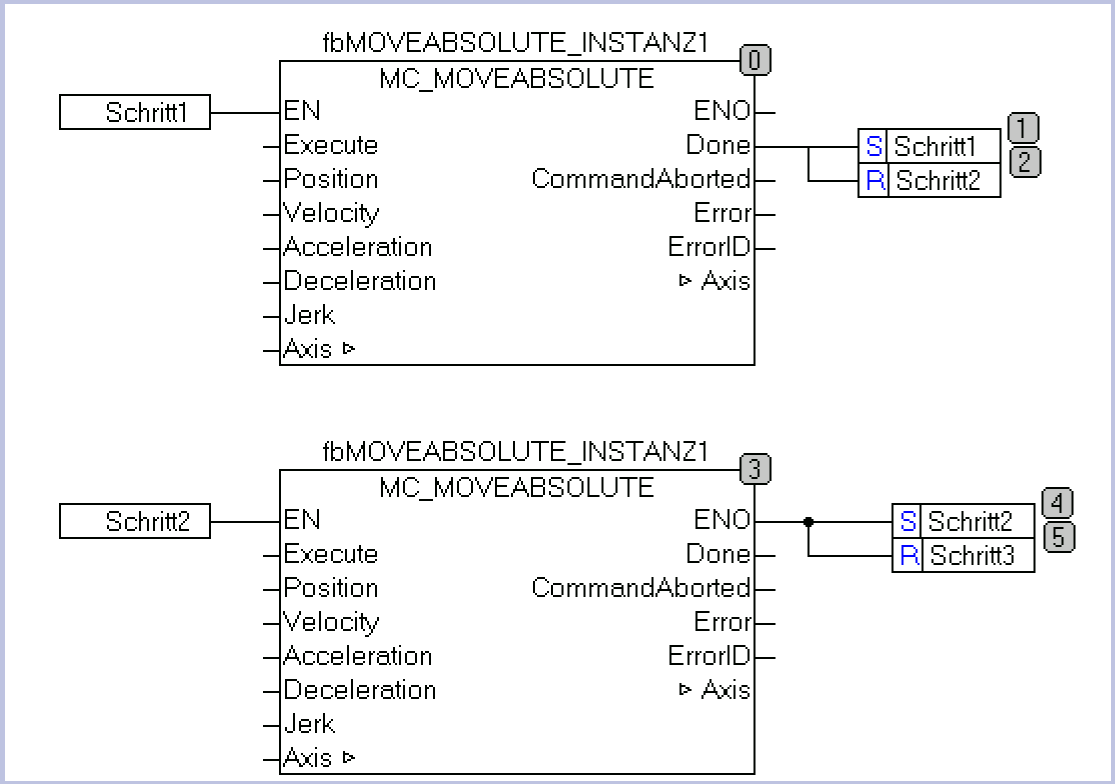
This acts reasonable, if for each command a new instance of the MC block is created

How can a flow be realised?

A further possibility is the using of the same instance with „EN” inputs which are controlled by step reminder.

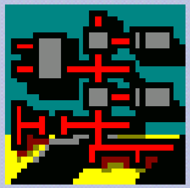
To consider:
The Fb accepts the next „execute” only, if there´s a flank at the input.

In addition „Disturbances in the flow“ like Command aborted and Error have to be considered.

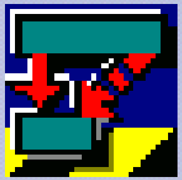


How can a flow be realised?

PLC Project with „flow in CFC by using the EN inputs



ControlAxis.pro



Axissetup.tsm