TwinCAT 3 NC Axes and FAULHABER MC V3.0 EtherCAT

Summary

This application note describes the necessary steps to control a FAULHABER EtherCAT Motion-Controller using a TwinCat based PLC.

Applies To

All MotionController with ordering numbers ending in “ET”, like MC 50xx ET, MC3xxx ET, and MCS ET

Licensing

EtherCAT is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

Related FAULHABER Documents

Document	Description
Motion Manager 6	Instruction Manual for FAULHABER Motion Manager PC software
Quick start description	Description of the first steps for commissioning and operation of FAULHABER Motion Controllers
Drive functions	Description the operating modes and functions of the drive
Communications Manual EtherCAT	Description of the EtherCAT services implemented in a FAULHABER MotionController

Description

This example shows the necessary steps for the implementation of a Faulhaber EtherCAT controller using a Beckhoff TwinCat3 environment.

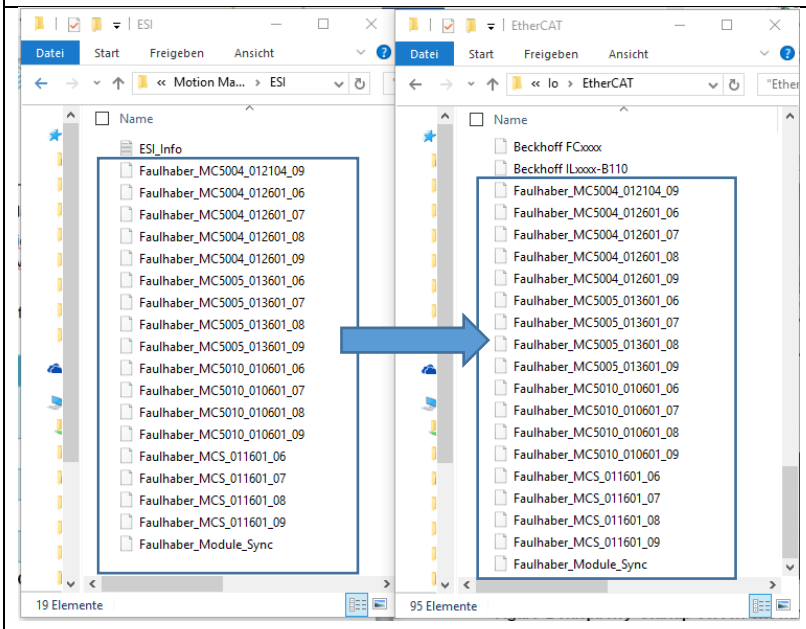
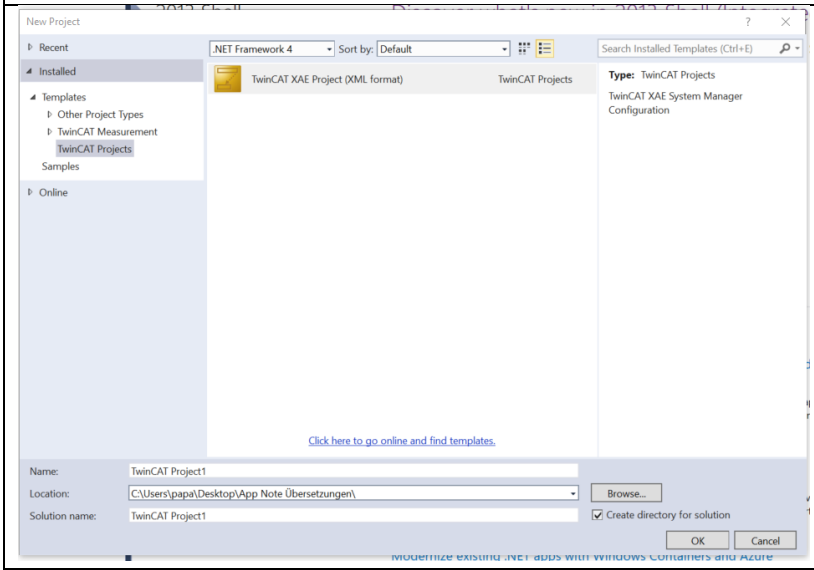
Therefore the application note is divided into two parts.

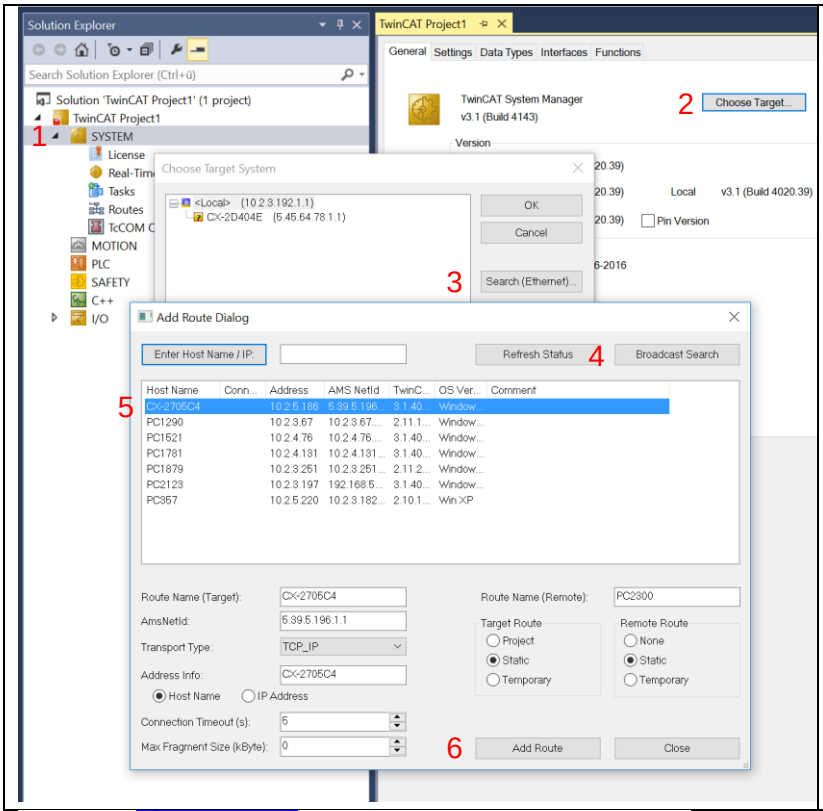
1. Installation of a FAULHABER drive into TwinCat 3
2. Configuring Motion Controller as NC axis

The general implementation of the MC is independent of configuration as an NC axis.

➔ It is possible to run the MC without an NC kernel on top

Installation of FAULHABER MotionController into TwinCat 3

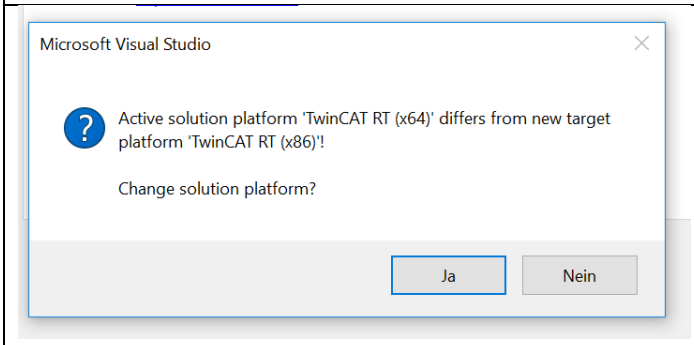
Screenshot	Description
	Ensure that the latest MotionManager version is installed. Copy all .XML files from the MotionManager directory to the TwinCat file system: Motion Manager 6: C:\Program Files (x86)\Faulhaber\Motion Manager 6\ESI Motion Manager 7: C:\Users\Public\Documents\Faulhaber\Motion Manager 7\Device description\ESI TwinCAT: C:\TwinCAT\3.1\Config\Io\EtherCAT This step is only necessary, if there was an update of the .xml files and for the first implementation of the Faulhaber components into TwinCat. Start TwinCat engineering environment
	Create a new TwinCat solution



Choose your target system:

1. Open the System configuration
2. „Choose Target System“
3. „Search“ for devices
4. „Broadcast search“ finds every PLC which is connected to your LAN
5. Select your target system
6. Add your target system route, preferably as IP address

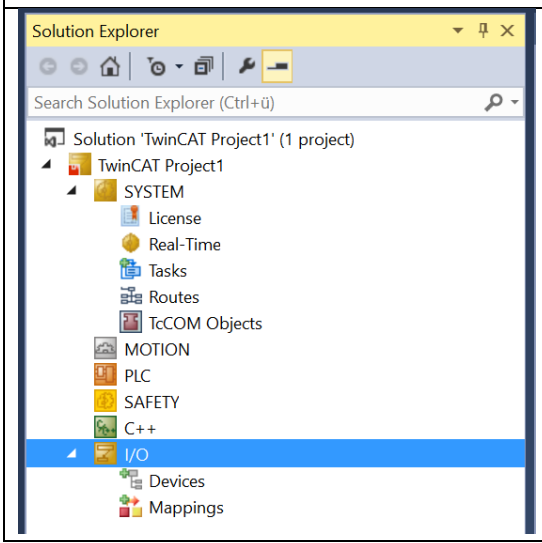
Hint: Beckhoff default account information:
User: administrator
Password: 1



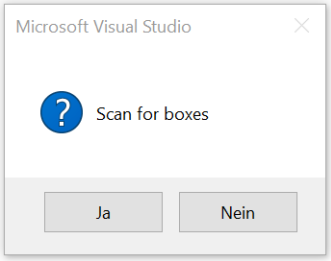
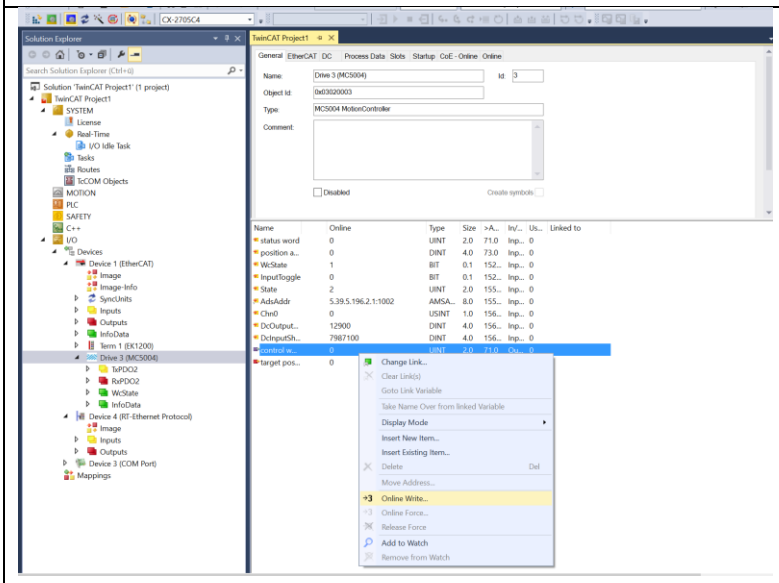
Switch to platform solution

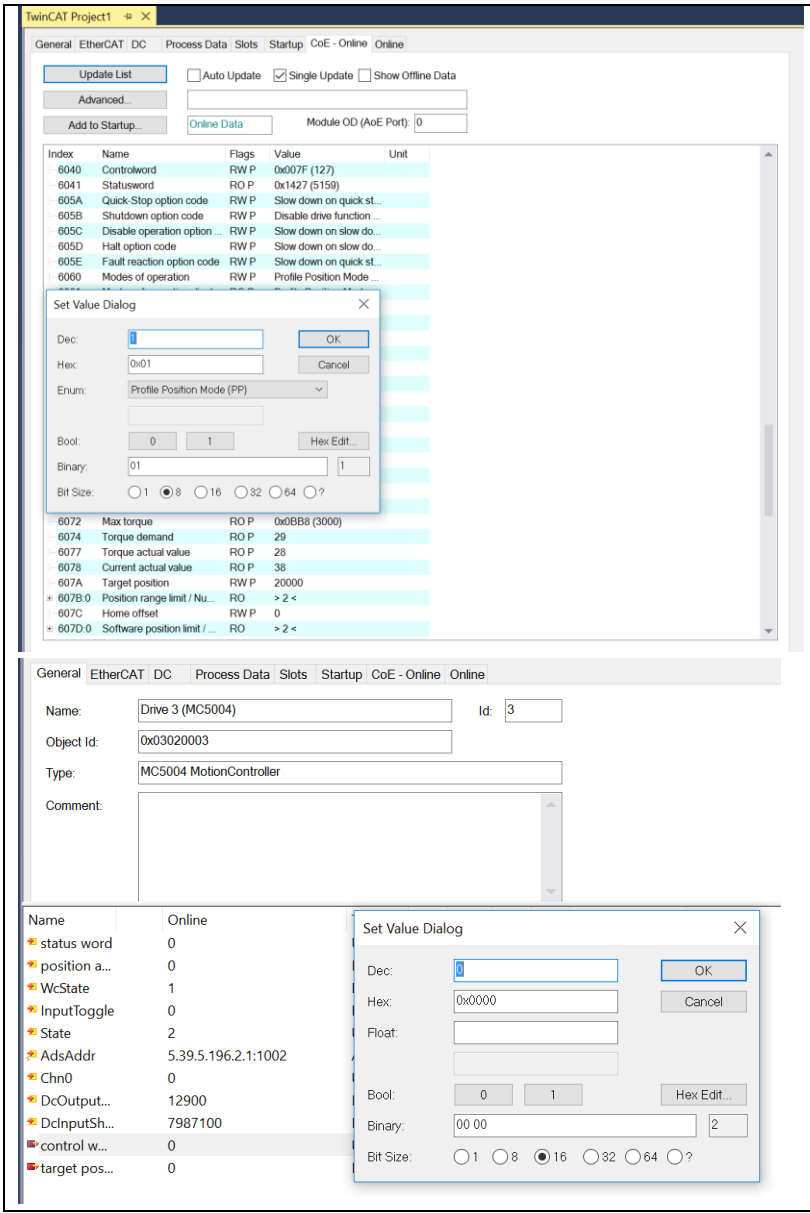
Now you are in remote control mode of your PLC.

For the further configuration, ensure that your plc is in “config Mode”



Open the I/O configuration and scan for devices by right clicking on „devices“

	Confirm the search for boxes Depended on the TwinCat version, the software recognizes the MC and is going to ask, if you would like to link the controller to a NC axis. Hit 'No' Chapter "2. Configure Motion Controller as NC axis" will show how to link the MC to the NC axis.
	Activate configuration After the configuration is activated, the PLC changes to run mode. You could also switch back to config mode (blue) and activate free run. Configuration changes are only possible in config mode of the plc. Every time the configuration has changed, it has to be reactivated.
	The Drive configuration offers access to the PDO mapping, object directory browser with online data (CoE), process data, … From that point, it is possible to control the MC manually, by writing online values.



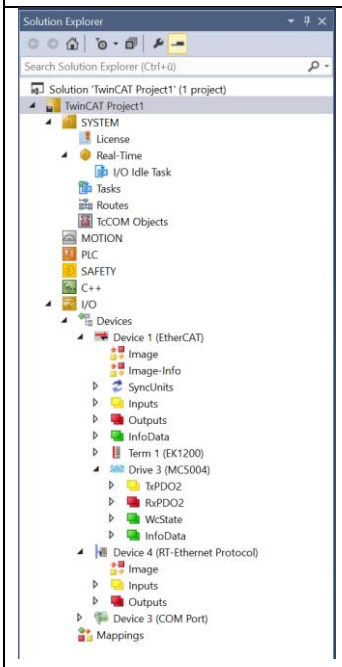
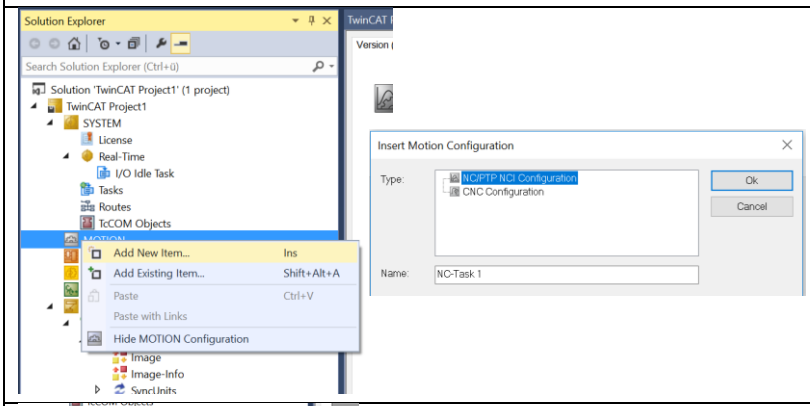
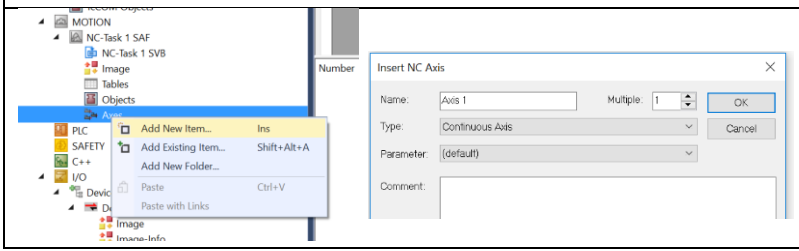
Test run:

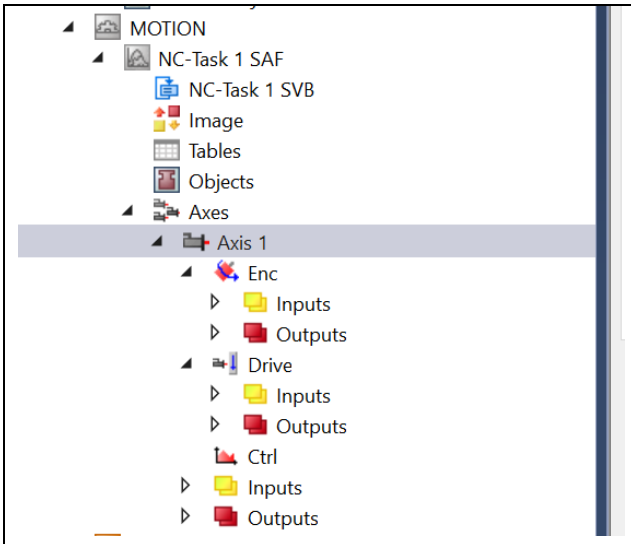
- Change Modes of Operation (Object 0x6060.00) := 1 (PP Mode)
- Enable the power stage by writing following commands to the controlword
    - 0x6040 := 0x0006
    - 0x6040 := 0x0007
    - 0x6040 := 0x000F
- Set Target Position to 4096
- Start positioning:
    - 0x6040 := 0x005F

The motor should execute a relative positioning of 4096 Inc.

From now on it is possible to link the controller mapping to the PLC program and run the drive without a NC axis.

Configuring Motion Controller as NC axis

Screenshot	Description
	Initial state: - Run through step 1-6 of “Implementation of Faulhaber MC3.ET into TwinCat3” - Set Modes of Operation 0x6060 := 8 (CSP)
	- Add New Motion Item - Add NC/PTP NCI Configuration
	- Add New NC Axes Item - Add New Continuous Axis



The NC axis has been added successfully.

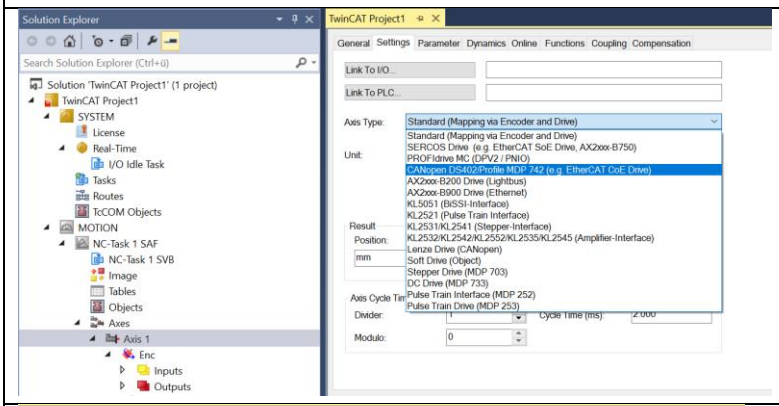
Settings of NC axis:
The NC axis is a virtual numerical controlled axis. Therefore there are 3 major configuration categories.

Axis1 contains the general configuration of the NC axis e.g. link to the I/O device, definition of the axis type (DSP402,…), monitoring functions of the NC axis etc.

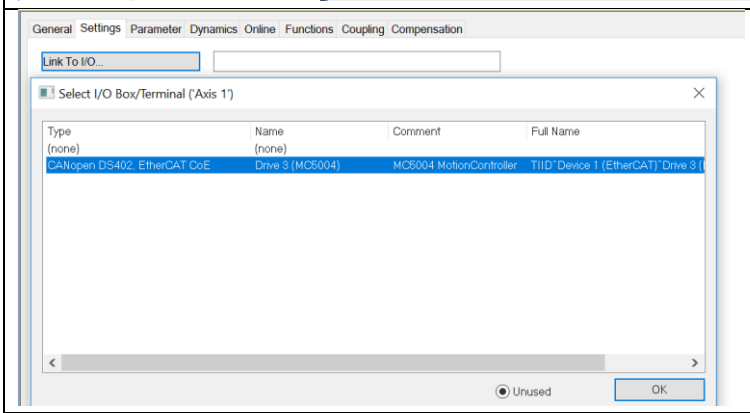
Enc contains the NC-Encoder configuration e.g. scaling factor mm/inc, soft position limits etc.

Drive contains the NC-Drive configuration e.g. Invert motor polarity, reference velocity etc.

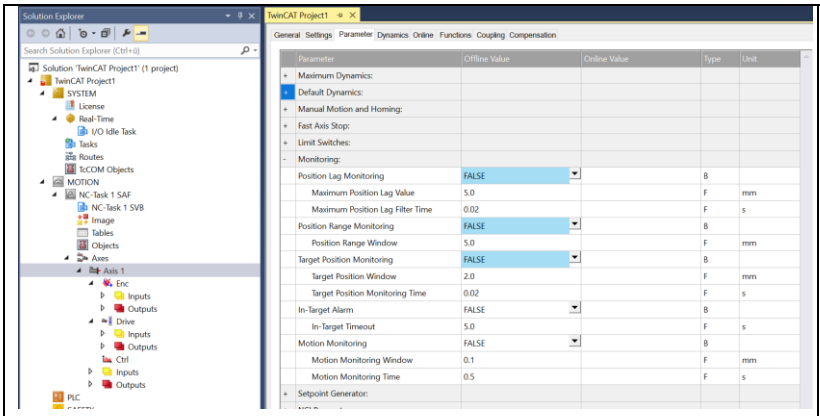
For more detailed information, take a look at https://infosys.beckhoff.com/



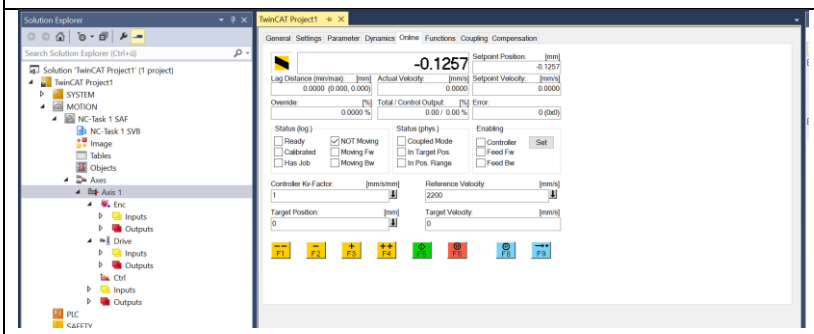
- Configure the NC axis type as CANopen (DSP 402 CoE)



- Link the NC axis to Faulhaber I/O device

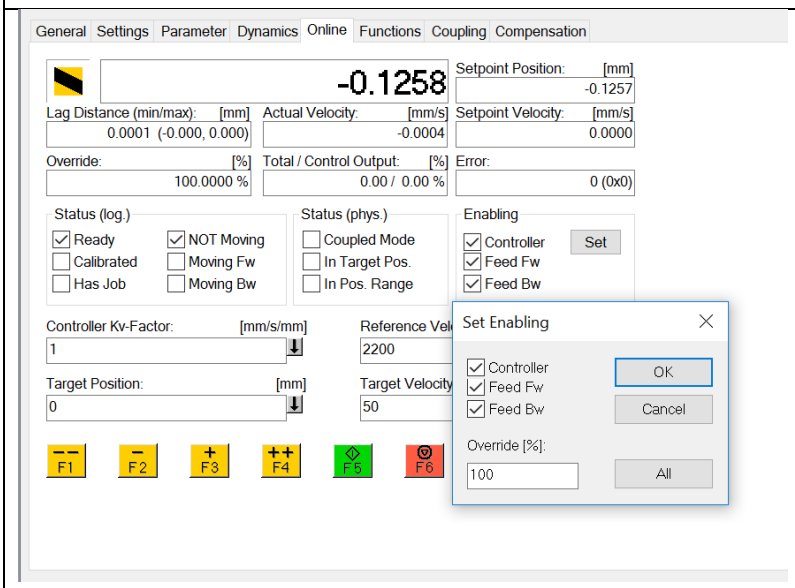


- For the first test run, set all Monitoring functions of Axis 1 to FALSE
- Activate the configuration



The online View allows you to control the NC axis manually

- Enter a target velocity >0



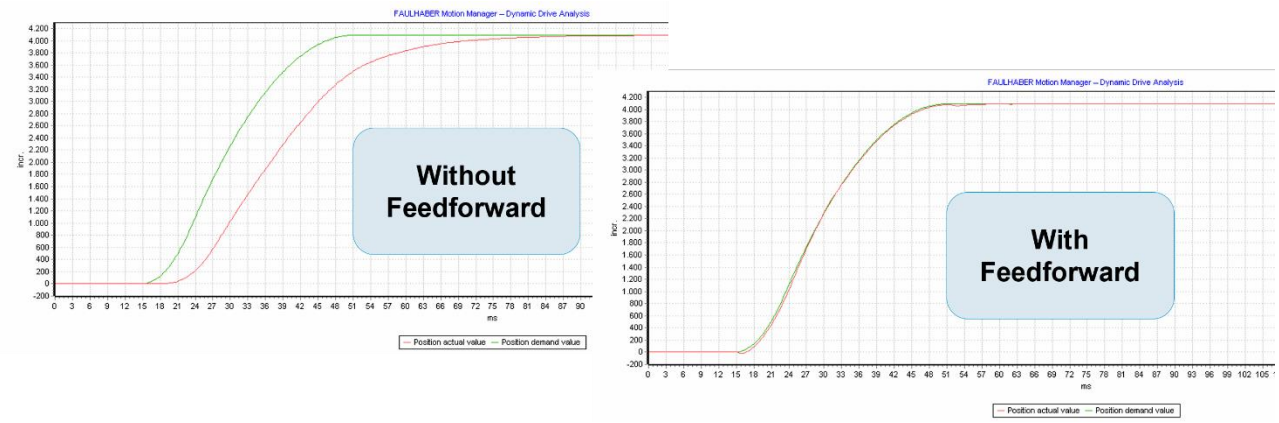
- Enable the NC state machine

Now it is possible to run the motor with F1 – F4

Implementation of FAULHABER EtherCAT MotionController in TwinCat environment as NC axis is finished successfully

Activation of feedforward control

Feedforward control makes it possible to reduce the following error of a drive system and thus have a faster response time to new setpoints.



In the modes of operation Profile Position (PP) and Profile Velocity (PV), the feedback control loop of a FAULHABER MC V3.0 calculates velocity and current feedforward profiles by itself.
In the modes of operation Cyclic Synchronous Position (CSP) and Cyclic Synchronous Velocity (CSV) however, the velocity and current feedforward profile must be calculated by the PLC.

Calculation of the feedforward profiles is part of the NC axis functionality. The following steps describe how this function can be used in combination with a FAULHABER Motion Controller.

1. Adjust the dynamic settings

Axis x -> Parameter:

General | Settings | Parameter | Dynamics | Online | Functions | Coupling | Compensation

	Parameter	Offline Value	Online Value	T...	Unit
-	Maximum Dynamics:				
	Reference Velocity	25000.0		F	°/s
	Maximum Velocity	25000.0		F	°/s
	Maximum Acceleration	1800000.0		F	°/s2
	Maximum Deceleration	600000.0		F	°/s2
-	Default Dynamics:				
	Default Acceleration	1800000.0		F	°/s2
	Default Deceleration	600000.0		F	°/s2
	Default Jerk	5000000.0		F	°/s3

How to choose reasonable values:
The dynamic settings should be chosen based on the profile parameters that are calculated by the FAULHABER Motion Manager during commissioning of the drive system. When Motion Manager 6 is used, the profile parameters can be checked in the “Control parameters” window. Motion Manager 7 shows reasonable profile parameters for the PLC in the “Select mode of operation” overview.

Always make sure to transform the profile parameters into the unit that is used by the PLC!

Example:
2232S024BX4 with a load inertia of 5 gcm² (Factor of inertia: 2)

Profile velocity (0x6081.00)	5500 1/min	33000 °/s
Profile acceleration (0x6083.00)	6619 1/s²	2382840 °/s²
Profile deceleration (0x6084.00)	1989 1/s²	716040 °/s²

2. Adjust the encoder settings

Axis x -> Enc -> Parameter:

General | NC-Encoder | Parameter | Time Compensation | Online

	Parameter	Offline Value	Online Value	T...	Unit
-	Encoder Evaluation:				
	Invert Encoder Counting Direction	FALSE		B	
	Scaling Factor Numerator	360.0		F	°/INC
	Scaling Factor Denominator (default: 1.0)	4096.0		F	
	Position Bias	0.0		F	°
	Modulo Factor (e.g. 360.0°)	360.0		F	°
	Tolerance Window for Modulo Start	0.0		F	°
	Encoder Mask (maximum encoder value)	0xFFFFFFFF		D	
	Encoder Sub Mask (absolute range maximum value)	0x00000FFF		D	
	Reference System	'INCREMENTAL'		E	

Scaling Factor Numerator and Denominator must be configured according to the position unit and the resolution of the feedback system. In this case the position unit is configured to °, and the resolution of the feedback system is 4096 increments/revolution.

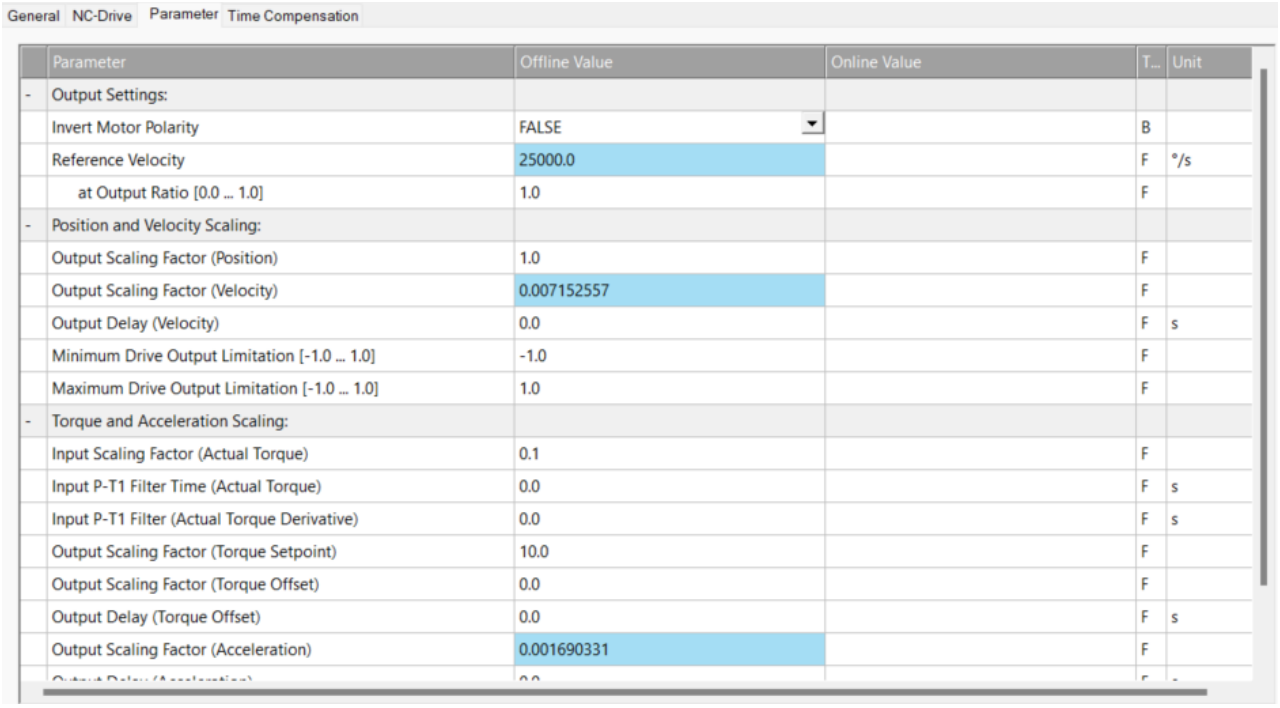
In addition, the Encoder Sub Mask must be configured according to the resolution of the feedback system.

$$Encoder\ Sub\ Mask\ =\ Resolution\ [Increments/revolution] - 1$$

In this example, the Encoder Sub Mask is set to 0xFFF = 4095.

3. Adjust the drive settings

Axis x -> Drive -> Parameter:



	Parameter	Offline Value	Online Value	T...	Unit
-	Output Settings:				
	Invert Motor Polarity	FALSE		B	
	Reference Velocity	25000.0		F	°/s
	at Output Ratio [0.0 ... 1.0]	1.0		F	
-	Position and Velocity Scaling:				
	Output Scaling Factor (Position)	1.0		F	
	Output Scaling Factor (Velocity)	0.007152557		F	
	Output Delay (Velocity)	0.0		F	s
	Minimum Drive Output Limitation [-1.0 ... 1.0]	-1.0		F	
	Maximum Drive Output Limitation [-1.0 ... 1.0]	1.0		F	
-	Torque and Acceleration Scaling:				
	Input Scaling Factor (Actual Torque)	0.1		F	
	Input P-T1 Filter Time (Actual Torque)	0.0		F	s
	Input P-T1 Filter (Actual Torque Derivative)	0.0		F	s
	Output Scaling Factor (Torque Setpoint)	10.0		F	
	Output Scaling Factor (Torque Offset)	0.0		F	
	Output Delay (Torque Offset)	0.0		F	s
	Output Scaling Factor (Acceleration)	0.001690331		F	

In the drive settings of the axis, the reference velocity must be configured according to the dynamic settings.

Furthermore, the output scaling factors for velocity and acceleration must be adapted.

The output scaling factor for the velocity is a fix value, which is defined by Beckhoff:

$$Output\ Scaling\ Factor\ (Velocity) = \frac{1}{\frac{2^{20}}{60 * 125}} = 7.152557373 * 10^{-3}$$

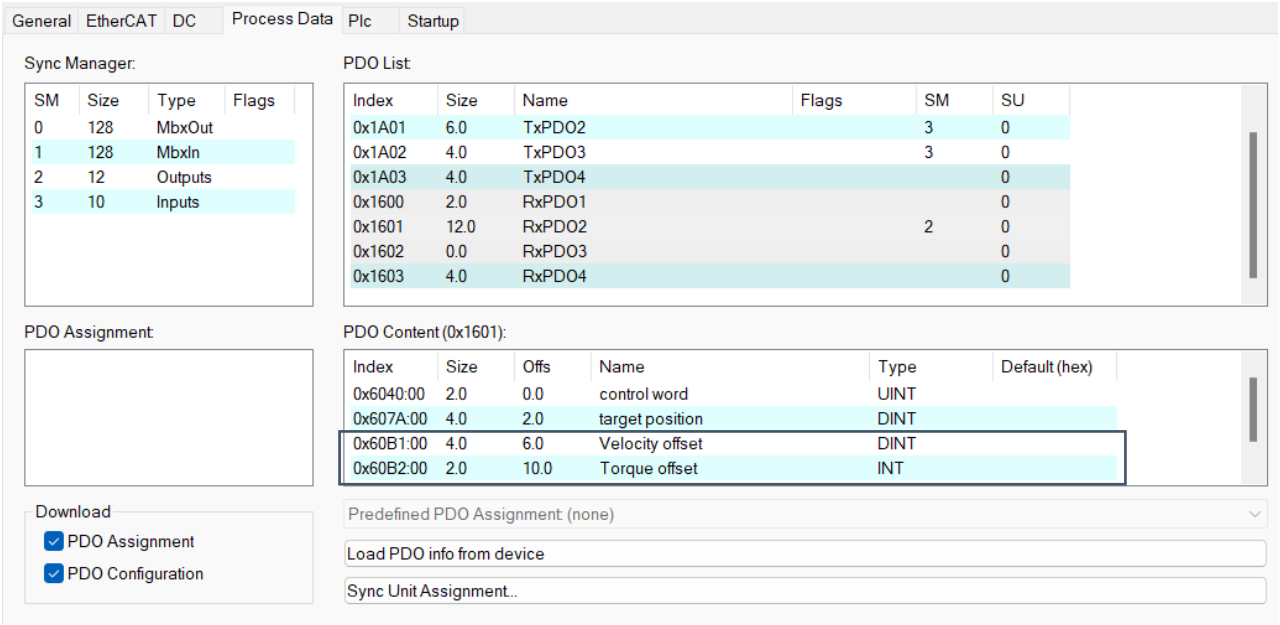
The output scaling factor for the acceleration can be calculated as follows:

$$Output\ Scaling\ Factor\ (Acceleration) = \frac{3000}{Maximum\ Acceleration}$$

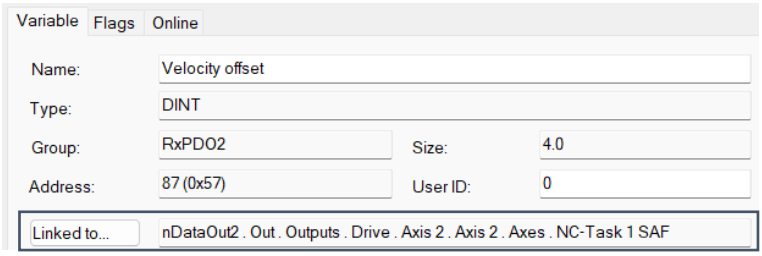
With a maximum acceleration of e.g. 1800000 °/s², the output scaling factor for the acceleration is 0.0016.

4. Add torque and velocity offset to the process data and link variables to the NC axis

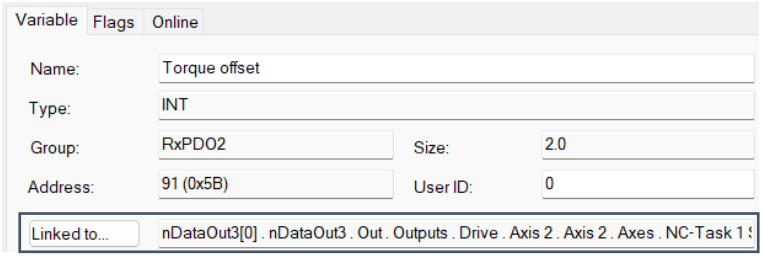
The feedforward values for torque and velocity must be transferred to the Motion Controller cyclically via Process Data. Therefore the objects 0x60B1.00 (Velocity offset) and 0x60B2.00 (Torque offset) must be added to one of the RxPDO's.



Last but not least, those variables must be linked to the corresponding output from the NC axis.
The Velocity offset must be linked to "nDataOut2":



The torque offset must be linked to "nDataOut3[0]":



Finally, the configuration is complete and feedforward control can successfully be used in combination with a FAULHABER Motion Controller.

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