



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 Ma- nual 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 MotionManag-
Datei Start Freigeben Ansicht V 🕜 Datei Start Freigeben Ansicht V 😨	
$\begin{array}{c c} \leftarrow \rightarrow & \checkmark & \uparrow & \blacksquare & \texttt{Motion Ma} \rightarrow \texttt{ESI} & \checkmark & \circlearrowright & \uparrow & \leftarrow \rightarrow & \checkmark & \uparrow & \blacksquare & \texttt{(lo > EtherCAT} & \checkmark & \circlearrowright & \texttt{"Ether} \\ \end{array}$	er version is installed.
^ □ Name ^ _ Name ^	
ESI_Info	Copy all .XML files from the Motion-
Faulhaber_MC5004_012104_09	Manager directory to the TwinCat file
Faulhaber_MC5004_012601_07 Faulhaber_MC5004_012601_06	
Faulhaber_MC5004_012601_08	system:
Faulhaber_MC5004_012601_09	Motion Manager 6:
Faulhaber_MC5005_013601_07	C:\Program Files
Faulhaber_MC5005_013601_08	
Faulhaber_MC5005_013001_09	(x86)\Fauinaber\Wotion Wanager
Faulhaber_MC5010_010601_07	<u>6\ESI</u>
Faulhaber_MCS010_010601_08 Faulhaber_MCS010_010601_08 Faulhaber_MCS010_010601_09 Faulhaber_MCS010_010601_08	Motion Manager 7:
Paulnaber_MCS_011601_06 Paulnaber_MCS_011601_06 Faulhaber_MCS_011601_07 Faulhaber_MCS_011601_06	C:\Users\Public\Documents\Faulhab
Faulhaber_MCS_011601_08 Faulhaber_MCS_011601_07 Faulhaber_MCS_011601_09 Faulhaber_MCS_011601_08	er\Motion Manager 7\Device descrip-
Faulhaber_MCS_011601_09 Faulhaber_MCS_01001_09 Faulhaber_MCS_01001_09 Faulhaber_MCS_01001_09 Faulhaber_MCS_01000_0000000000000000000000000000000	tion\ESI
	TwinCAT:
15 Lienience 35 Lienience U-	C:\TwinCAT\3.1\Config\lo\EtherCAT
	This stop is only possessory if there
	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 environ-
	ment
New Project ? X	Create a new TwinCat solution
Recent NET Framework 4 Sort by: Default Search Installed Templates (Crit+E) P - Installed	
TwinCAT XAE Project (XML format) TwinCAT Projects Type: winCAT Projects 4 Templates TwinCAT XAE System Manager TwinCAT XAE System Manager TwinCAT XAE System Manager	
Other Project Types Configuration Vin/CAT Measurement	
TwinCAT Projects	
P Online	
Click here to go online and find templates.	
Name: TwinCAT Project1 Location: C1USers)papa/Desktop/App Note (übersetzunnen)	
Solution name: TwinCAT Project1	
OK Cancel	



Solution Explorer	TwinCAT Project1 🔹 🗙	Choose your target system:
○ ○ ☆ ¹ 0 - II <i>P</i> _=	General Settings Data Types Interfaces Functions	choose your larger system.
Search Solution Explorer (CtrH 4) P - Solution TwinCAT Project1 (1 project) IminCAT Project1 (1 project) SinvinCAT Project1 SySTEM Real-Time Choose Target System Tasks Routes Total Tocose Target System Tasks Routes Tocose Target System Tasks Tocose Target System	TwinCAT System Manager v3 1 (Build 4143) 2 Choose Target. Version 20.39) 20.39) 20.39) OK 20.39) Local v3 1 (Build 4020.39) OK 20.39) Pin Version 6-2016 Search (Ethermet) 6-2016 X Interview Comment X Status 4 Broadcast Search 1 Window 31.40. Window 31.40. Window 31.40. Window 31.40. Window 31.40. Sindow 31.40. Window 31.40. Window 31.40. Window 31.40. Window 31.40. Window 31.40. Window 2112. Window 2112. Window 2110 Window 2112. Window	 Open the System configura- tion "Choose Target System" "Search" for devices "Broadcast search" finds eve- ry PLC which is connected to your LAN Select your target system Add your target system route, preferably as IP address
Route Name (Target): CX-2705C4 AmsNetId: 5.39.5.196.1.1 Transport Type: TCP_IP Address Info: CX-2705C4 • Host Name O IP Address Connection Timeout (s): 6 Max Fragment Size (kByte). 0	Route Name (Remote): PC2300 Target Route Remote Route Project None Static Static Temporary Temporary	Hint: Beckhoff default account infor- mation: User: administrator Password: 1
		Switch to platform solution
Active solution platform 'TwinCAT F platform 'TwinCAT RT (x86)'! Change solution platform?	RT (x64)' differs from new target	Now you are in remote control mode of your PLC. For the further configuration, ensure that your plc is in "config Mode"
Solution Explorer	→ ↓ ×	Open the I/O configuration and scan
Search Solution Explorer (Ctrl+ü) Solution 'TwinCAT Project1' (1 project) Solution 'TwinCAT Project1' (1 project) Real-Time Real-Time Tasks Real-Time Tasks Real-Time Tasks Real-Time Tasks Real-Time Tasks Real-Time Solution 'TwinCAT Project1' (1 project) Real-Time Solution 'TwinCAT Project1' (1 project) Solution 'TwinCAT Project1' (1 project) Solu		for devices by right clicking on "de- vices"



	Confirm the energy for hower
Microsoft Visual Studio $ imes$	Confirm the search for boxes
Scan 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 Con- troller 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 pos- sible in config mode of the plc. Every time the configuration has changed, it has to be reactivated.
Image: Control of the control of t	The Drive configuration offers ac- cess to the PDO mapping, object directory browser with online data (CoE), process data,
MCION □Delated Conter specific CVTY None Online Type CVTY Status and 0 DNT 20 Conter specific 0 DNT 20 7.00 Status and 0 DNT 0.1 Type Status and 0 DNT 0.1 1.2 Type Status and 0 DNT 0.1 1.2 Type Status and 0 DNT 0.1 1.2 Type Status 0 DNT 0.1 1.1 D.1 Status 0 DNT 0.1 1.1 D.1 Status 0 DNT 0.1 D.1 D.1 Status 0 DNT D.1 D.1 D.1	From that point, it is possible to con- trol the MC manually, by writing online values.



TwinCAT Project1	₩ X				Test run:
General EtherCAT	DC Process Data Slots Startup	D CoE - Online Online			
Update Lis	st 📃 Auto Update 🗹 Sir	ngle Update 🗌 Show Offline D	ta		 Change Modes of Operation
Advanced.	***				(Object 0x6060 00) = 1 (PP)
Add to Startu	up Online Data	Module OD (AoE Port): 0			(Colject exceeded) (C. 1
Index Name	e Flags Value	Unit		-	Wode)
6040 Conu	usword ROP 0x142	27 (5159)			 Enable the power stage by
605A Quick	k-Stop option code RW P Slow o down option code RW P Disab	down on quick st le drive function			writing following commande
605C Disab	ble operation option RW P Slow o	down on slow do			whiling following commands
-605E Fault	reaction option code RWP Slow of	down on quick st			to the controlword
-6060 Mode	es of operation RW P Profile	Position Mode			\circ 0x6040 ·- 0x0006
Set Value Dialo	og	×			
Dec:		ОК			\circ 0x6040 := 0x0007
Hex:	0x01	Cancel			○ 0x6040 := 0x000F
Enum:	Profile Position Mode (PP)	~			
					- Set larget Position to 4096
Bool:	0 1	Hex Edit			 Start positioning:
Binary:					
Bit Size.	01 08 016 032 064	07			0 0X0040 .= 0X003F
6072 Max t 6074 Torqu	torque ROP 0x0BE ue demand ROP 29	88 (3000)			
6077 Torqu	ue actual value RO P 28 ent actual value RO P 38				The motor should execute a relative
607A Targe	et position RW P 20000	0			positioning of 4006 Inc
607C Home	e offset RW P 0				positioning of 4090 mc.
e 607D:0 Softw	vare position limit / RO > 2 <			*	
General EtherC	CAT DC Process Data Slot	ts Startup CoE - Online	Online		
Name	Drive 3 (MC5004)		Id: 3		
Object Ide	0×03020003]		
-	MOE004 MatianOanhallar				
Type:					
Comment:			^		
			v		
Name	Online	Set Value Dia	og	×	
✓ status word	0				
 position a WcState 	1	Dec:		DK	
 InputToggle 	0	Hex:	0x0000 Ca	ncel	
✤ State	2	Float:			
🔊 AdsAddr	5.39.5.196.2.1:1002	4			
Chn0	0	Bool	0 1 Hey	Edit	
 DcOutput DcInputSh 	72900	Binony	00.00	2	
Control w	0	Binary:		۷.	
■target pos	0	Bit Size:	()1 ()8 (●)16 ()32 ()64 ()?		

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









Solution Embour	TwinCAT Project 1 - R X				
	General Settings Parameter Departice Onione For	Time Counting Companyation			 For the first test run, set all
Search Solution Explorer (Ctrl+0)	General Setungs Fordinated Dynamics Online For	auts cooping compensator		_	
Solution 'TwinCAT Project1' (1 project)	Parameter	Ottline Value	Online Value Type	Unit	Monitoring functions of Axis 1
TwinCAT Project1 SYSTEM	Default Dynamics:				
License	+ Manual Motion and Homing:				to FALSE
 Heal-Time I/O Idle Task 	+ Fast Axis Stop:				A attiviate the configuration
🔡 Tasks	+ Limit Switches:				 Activate the configuration
TcCOM Objects	- Monitoring:	TALCE .			
MOTION	Maximum Position Lan Value	FALSE _	B		
Image NC-Task 1 SAF Image NC-Task 1 SVB	Maximum Position Lag Value	0.02	F	s	
🚔 Image	Position Range Monitoring	FALSE	• в		- I I I I I I I I I I I I I I I I I I I
I I I I I I I I I I I I I I I I I I I	Position Range Window	5.0	F	mm	
A De Axes	Target Position Monitoring	FALSE	B		
A 👯 Enc	Target Position Window	2.0	F	mm	
Inputs	Target Position Monitoring Time	0.02	F	5	
A Prive	In-Target Alarm	5.0	F F	5	
Inputs	Motion Monitoring	FALSE	• в		
La Colpita	Motion Monitoring Window	0.1	F	mm	
 Inputs Outputs 	Motion Monitoring Time	0.5	F	s	
PLC Capters	+ Setpoint Generator:				
- careno					
Solution Explorer + P ×	TwinCAT Project1 + ×				
Search Solution Employer (Ctrl+0)	General Settings Parameter Dynamics Online Function	Coupling Compensation			
Solution TwinCAT Project1' (1 project)	-0.12	57 Setpoint Position: [mm] -0.1257		Ē	The online View allows you to con-
TwinCAT Project1	Lag Distance (min/mat): [mm] Actual Velocity: [0.0000 (0.000, 0.000) 0.	1000 Setpoint Velocity: [mm/s] 0.000			
SYSTEM	Ovenide: [%] Total / Control Output:	[%] Error:			trol the NC axis manually
IM NC-Task 1 SAF	Status (log.) Status (phys.)	Enabling		E	tion the two axis manually
the last i svb	Ready NOT Moving Coupled Mode	Controller Set			
Tables Objects	Calibrated Moving Pw In Target Pos. Has Job Moving Bw In Pos. Range	Feed Bw			
Axes	Controller Ky-Factor: [mmisimm] Referen	e Velocity: [mm/s]			Enter a target velocity > 0
A table Axis 1	1 2200	1			
Inputs	Target Position: [mm] Target V 0 U 0	kodły. (mm/s)			
Outputs Outputs					
Inputs	F1 F2 F3 F4 F5	F8 F9			
Line Ctri					
 Inputs Outputs 					
PLC .					
Sale IV					
General Settings Parameter Dyr	namics Online Functions Co	pling Compensatio	on		- Enable the NC state machine
ge a anno a sea anno a		-p			
	~	Setpoint Position:	[mm]		
	-0.1258		-0.1257		
a Distance (min/max): [mm]	Actual Volocity: [mm/s]	Sotpoint Volocity	[mm/c]		
		Serpoint velocity.	0.0000		Now it is possible to rup the motor
0.0001 (-0.000, 0.000)	-0.0004		0.0000		Now it is possible to full the motor
Override: [%]	Total / Control Output: [%]	Error:			with E1 E4
100.0000 %	0.00 / 0.00 %		0 (0x0)		wiui F I - F4
Status (log.)	Status (phys.)	Enabling			
Ready NOT Movin	g Coupled Mode	Controller	Set		
Calibrated Moving Fw	In Target Pos.	Feed Fw			
Has Job Moving Bw	In Pos Range	Feed Bw			
Controller Ky Eactor:	m/s/mm] Deference Vol	Set Enabling	×		
					Implementation of FAULHABER
1	• 2200	Controlle			
Target Position	[mm] Target Velocity		ОК		EtherCAT MotionController in Twin-
		V Feed FW			
U	• 50	Feed Bw	Cancel		Cat environment as NC axis is fin-
		Outputid - 1971			
	++ 📀 💿	Override [%]:			ished successfully
F1 F2 F3	F5 F6	100	All		
-					1



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

_	7		r		
-	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	500000.0		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

			Online Value		
-	Encoder Evaluation:				
	Invert Encoder Counting Direction	FALSE		В	
	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)	OxFFFFFFF		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:

General NC-Drive Parameter Time Compensation

Parameter		Online Value	T Unit
- Output Settings:			
Invert Motor Polarity	FALSE	•	В
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
0.4+ D-1(A1A())	0.0		e .

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 $^{\circ}/s^2$, 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.

General	EtherCA	AT DC	Process Data	Plc Sta	rtup						
Sync M	lanager:			PDO List							
SM	Size	Туре	Flags	Index	Size	Name		Flags	SM	SU	
0	128	MbxOut		0x1A01	6.0	TxPDO	2		3	0	
1	128	MbxIn		0x1A02	4.0	TxPDO	3		3	0	
2	12	Outputs		0x1A03	4.0	TxPD04	4			0	
3	10	Inputs		0x1600	2.0	RxPDO	1			0	
				0x1601	12.0	RxPD0	2		2	0	
				0x1602	0.0	RxPD0	3			0	
				0x1603	4.0	RxPD0	4			0	
PDO A	ssignmer	nt		PDO Conten	t (0x1601)	:					
				Index	Size	Offs	Name	Т	уре	Default (hex)	
				0x6040:00	2.0	0.0	control word	U	INT		· · · · ·
				0x607A:00	4.0	2.0	target position	D	INT		
				0x60B1:00	4.0	6.0	Velocity offset	D	INT		1 1
				0x60B2:00	2.0	10.0	Torque offset	II	ΝT		
Down	load			Predefined	PDO Ass	ignment: (n	ione)				~
PDO Assignment Load PDO info from device											
∠ P	DO Cont	iguration		Sync Unit A	ssignmen	t					

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":

Variable Flags Online								
Name:	Velocity offset							
Туре:	DINT							
Group:	RxPD02	Size:	4.0					
Address:	87 (0x57)	User ID:	0					
Linked to	nDataOut2 . Out . Outputs . Drive	. Axis 2 . Axis 2 . Ax	es . NC-Task 1 SAF					

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

Variable Flags	Online		
Name:	Torque offset		
Туре:	INT		
Group:	RxPD02	Size:	2.0
Address:	91 (0x5B)	User ID:	0
Linked to	nDataOut3[0] . nDataOut3 . Out . Outputs . Drive . Axis 2 . Axis 2 . Axes . NC-Task 1 \$		

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



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