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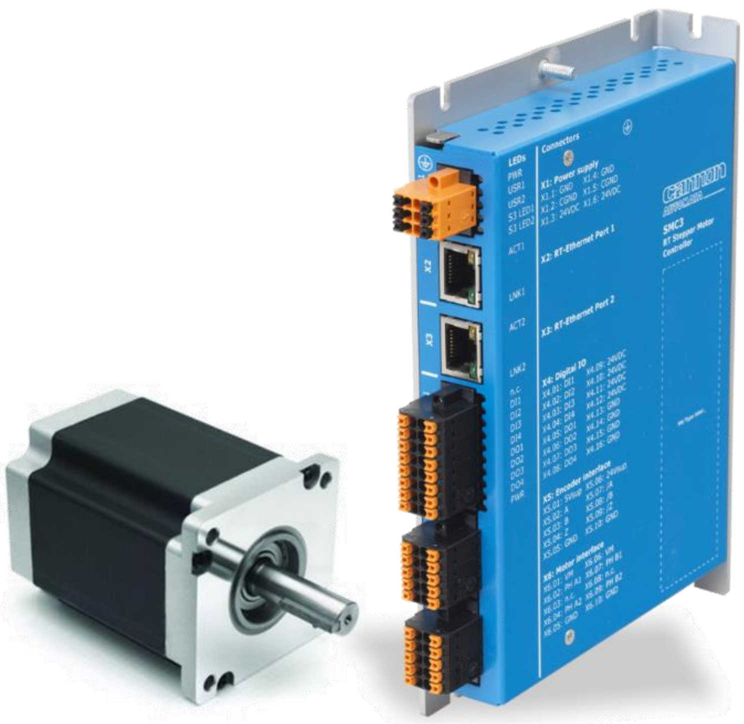

Technical Manual
[01.10.01/16.12.2019]

SMC3 Realtime-Ethernet Stepper Motor Controller
[70068300/70069900]

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Document information

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Revision status

Date	Author	Description
21.01.2016	MR	Renew from older manual
02.09.2016	MR	Added some new SMC3 IDNs with homing current, boost mode, config mode for velocity, correction of led names
28.10.2016	MR	Error in Object 0x1001 because of open load indicator
13.12.2017	MR	Object 0x2001 & configuration of digital input
13.12.2017	MR	Detailed explanation of Object 0x1001
14.12.2017	MR	Touch Probe
15.12.2017	MR	Adjustment of motor chip – 1. Part
16.12.2017	MR	Adjustment of motor chip – 2. Part with all register and stallGuard and coolStep…
29.12.2017	CM	Some formal corrections
30.08.2019	MR	Some correction and addet EC-Touch Probe; adjustment of motor chip
16.09.2019	CM	New document design
20.09.2019	MR	More details on IDN P-0-4000.0.7 and S-0-0116
16.12.2019	MT	Update document properties

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Markers for safety, danger and handling instructions

This is an important information that should be read by the user

This is a warning to which the user should pay attention!

This is a severe warning to which the user must pay attention!

This refers to ESD critical parts or handling

This refers to another document that should be read by the user

This refers to settings that must be made by the user

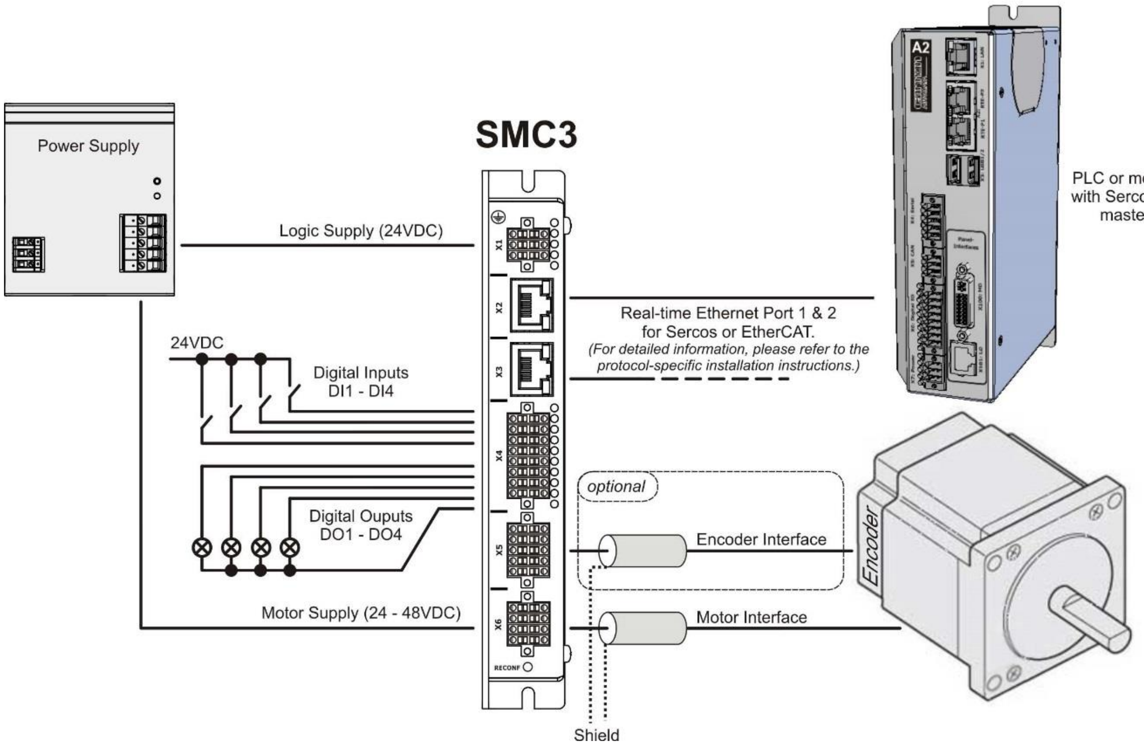
1 Scope

This document describes the SMC3 – RT Stepper Motor Controller (70068300/70069900). The SMC3 is a stepper motor controller with real-time Ethernet interface (Sercos® or EtherCAT®), integrated power stage for one 2-phase stepper motor, digital I/Os and incremental encoder input.

The device can be operated with or without incremental encoder. Depending on the selected real-time Ethernet protocol and the respective drive profile velocity, position, positioning and various homing modes are supported.

2 Functional description

The following diagram shows the basic wiring to operate a stepper motor with the SMC3 stepper motor controller.



Picture 1: Basic connection diagram

Features

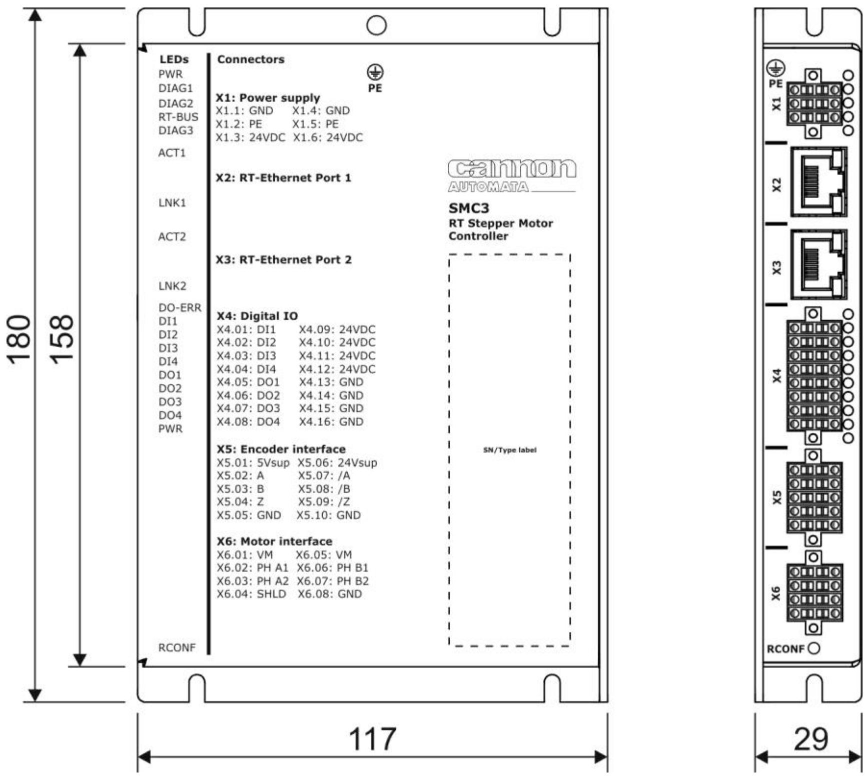
- Real-time Ethernet interface with 2 x RJ45 connectors
- Sercos III FSP-Drive profile or EtherCAT CoE with DS-402 profile
- 5 diagnosis LEDs
- Power stage for a 2-phase stepper motor with max. 8 A (peak) per phase at max. 48 VDC supply
- 4 digital inputs
- 4 digital outputs
- 1 encoder input for incremental encoder (A, /A, B, /B, N, /N)
- 5 VDC and 24 VDC output for encoder supply

3 Product data

Order information	
Order code	70068300 (SMC3 with Sercos-Interface) 70069900 (SMC3 with EtherCAT-Interface)
Name	SMC3 - Realtime-Ethernet Stepper Motor Controller
Technical data	
Housing dimension (WxHxD) and material	29 x 180 x 117 mm; metal
Mounting	Wall mount in two different positions
Weight	~ 0,5 kg
Power supply	Logic: 24 VDC Motor: 19 … 48 VDC
Stepper motor interface	2 phases, max. 8 A (peak) per phase, max. 256 micro steps
Real-time Ethernet	Sercos with FSP-Drive or EtherCAT with CoE DS-402
I/Os	1 encoder interface, 4 digital inputs, 4 digital outputs
Operation modes	Velocity mode, position mode, positioning mode, various homing modes

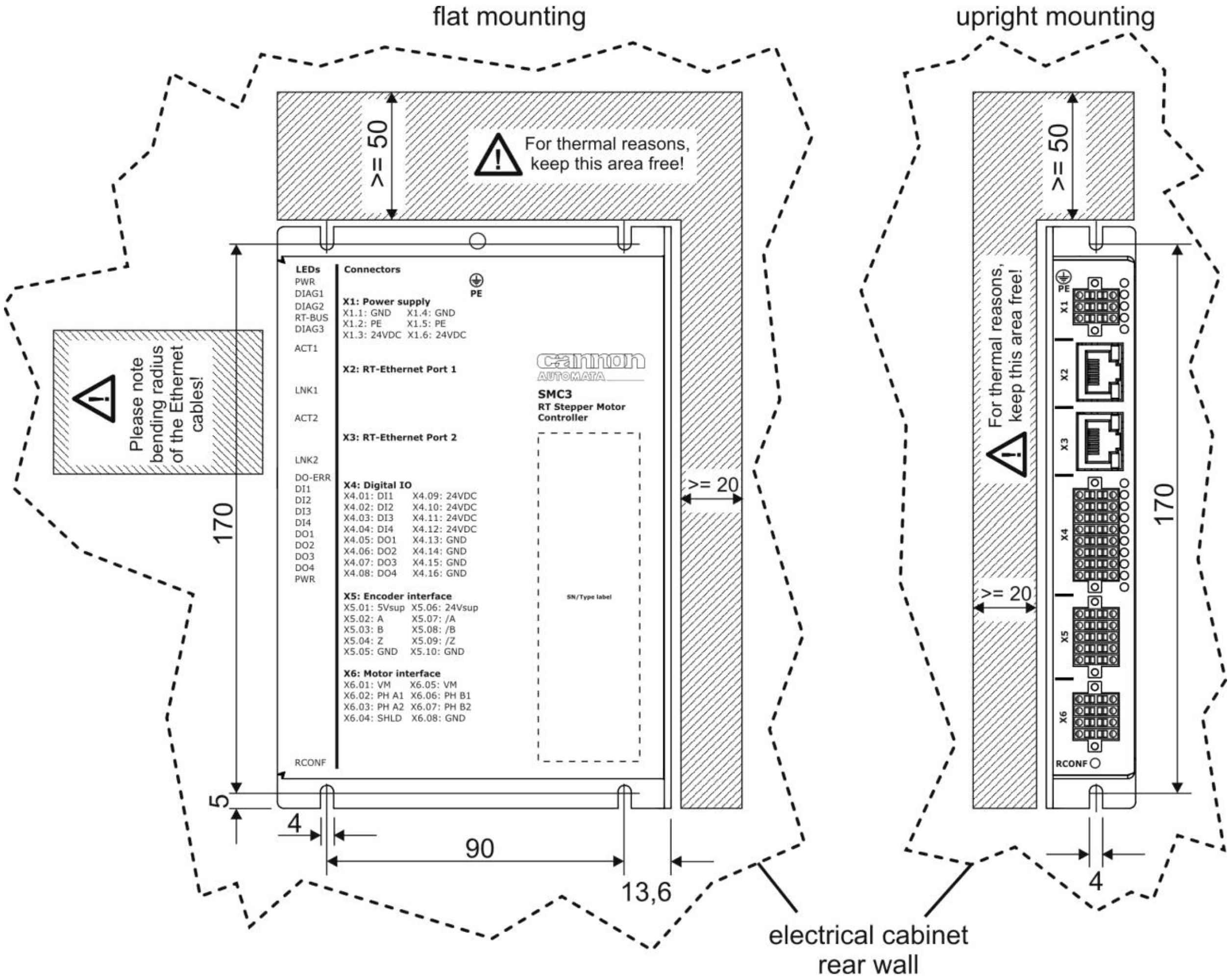
Table 1: Product data

3.1 Housing



Picture 2: Housing dimmensions (mm)

3.2 Mounting and shielding



Picture 3: Mounting in two different positions (all dimensions in [mm])

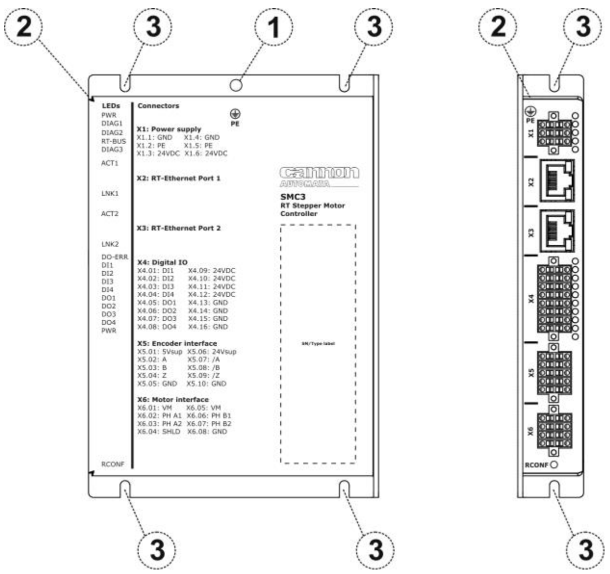
Cable shields can be connected in 4 different ways:

Method 1: Cable lug for M4 thread at position 1

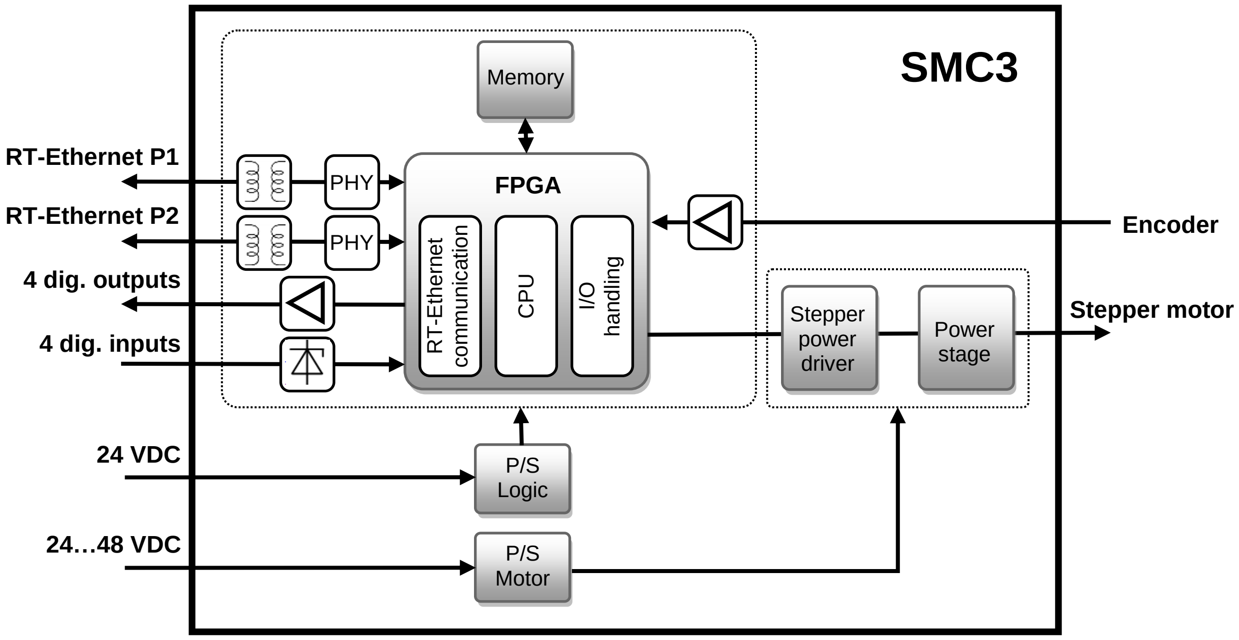
Method 2: Blade receptacle at position 2 (6,35 mm tab size)

Method 3: Cable lugs at position 3

Method 4: Clamp X1.2 and/or X1.5



Picture 4: Shielding points



Picture 5: Hardware block diagram

4 LEDs, controls, connectors and electrical characteristics

4.1 LEDs

Name	Function
PWR	24 VDC for logic supply; **X1.3** and **X1.6** (green = ON)
DIAG1	Software update indication (see also chapter **8**)
DIAG2	**OFF**: no internal error **green flashing**: error while saving configuration
RT-BUS	Depending on the communication protocol • **Sercos: S3-LED** • **EtherCAT: STATUS Indicator**
DIAG3	• **Sercos** ○ **red**: software is starting ○ **green flashing**: loading configuration ○ **green**: Software is successfully started • **EtherCAT** ○ **red**: not in op mode ○ **green flashing**: OP mode but motor not enabled ○ **green**: Motor enabled
ACT1	Activity on real-time Ethernet connector **X2** (**orange flashing**)
LNK1	Link on real-time Ethernet connector **X2** (**green**)
ACT2	Activity on real-time Ethernet connector **X3** (**orange flashing**)
LNK2	Link on real-time Ethernet connector **X3** (**green**)
DO-ERR	Digital output error (**red** = error)
DI1…DI4	Status LEDs of digital inputs; **X4.01…X4.04**
DO1…DO4	Status LEDs of digital outputs; **X4.05…X4.08**
PWR	24 VDC for digital outputs DO1 … DO4; **X4.0 … X4.12** (**green** = ON)

Picture:

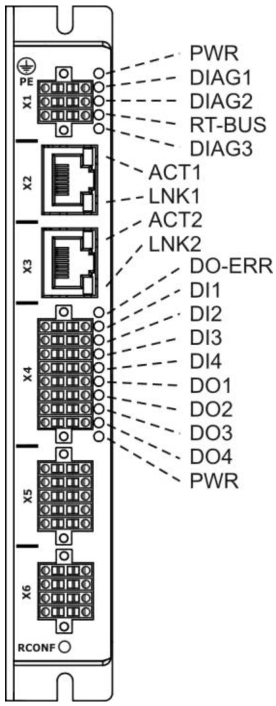


Table 2: Diagnosis LEDs

4.2 Controls

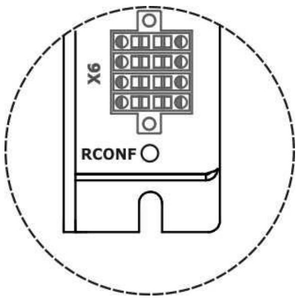
Name	Function	Picture
RCONF	The RCONF button is used to launch the logicware and firmware update of the SMC3 and to set factory default values. (see chapter **8 Firmware update in Fallback**)	

Table 3: Controls

4.3 Connectors

4.3.1 Logic power supply (X1)

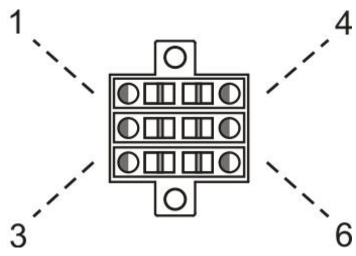
Pin	Signal	Picture
X1.1	GND	
X1.2	CGND (case ground)	
X1.3	+24 VDC	
X1.4	GND	
X1.5	CGND (case ground)	
X1.6	+24 VDC	

Table 4: Pin allocation logic power supply (X1)

4.3.2 Real-time Ethernet connectors (X2 and X3)

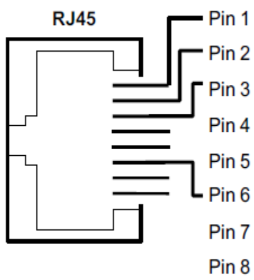
Pin	Signal	Picture
1	TxD+	
2	TxD-	
3	RxD+	
4	n.c.	
5	n.c.	
6	RxD-	
7	n.c.	
8	n.c.	

Table 5: Pin allocation real-time Ethernet ports (X2 and X3)

4.3.3 Digital I/O (X4)

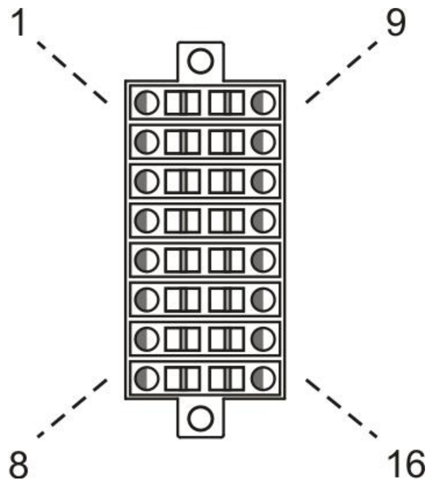
Pin	Signal	Picture
X4.1	DI1	
X4.2	DI2	
X4.3	DI3	
X4.4	DI4	
X4.5	DO1	
X4.6	DO2	
X4.7	DO3	
X4.8	DO4	
X4.9	+24 VDC supply	
X4.10		
X4.11		
X4.12		
X4.13	GND	
X4.14		
X4.15		
X4.16		

Table 6: Pin allocation digital I/Os (X4)

In order to use the digital inputs DI1 … DI4, the 24 VDC (X4.9 … X4.16) must be connected.

4.3.4 Encoder interface (X5)

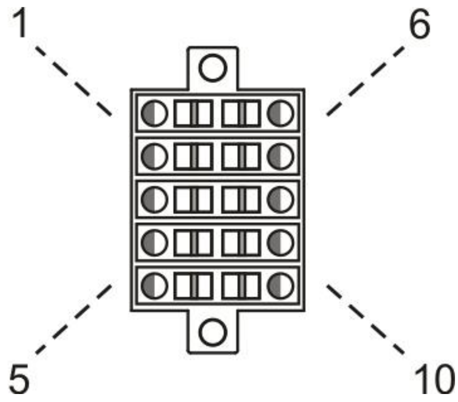
Pin	Signal	Picture
X5.1	5Vsup (+5 VDC output power supply for encoder) *(+24V DC input must be connected to X4, see* ***4.3.3 Digital I/O (X4)****)*	
X5.2	A	
X5.3	B	
X5.4	Z	
X5.5	SHLD	
X5.6	24Vsup (+24 VDC output power supply for encoder) *(+24V DC input must be connected to X4, see* ***4.3.3 Digital I/O (X4)****)*	
X5.7	/A	
X5.8	/B	
X5.9	/Z	
X5.10	GND	

Table 7: Pin allocation encoder interface (X5)

The encoder supply output (X5.1/5Vsup and X5.6/24Vsup) requires +24V DC power supply on connector X4 (see 4.3.3)

Please read and notice the datasheet of the encoder before connecting it with the SMC3!

4.3.5 Motor interface (X6)

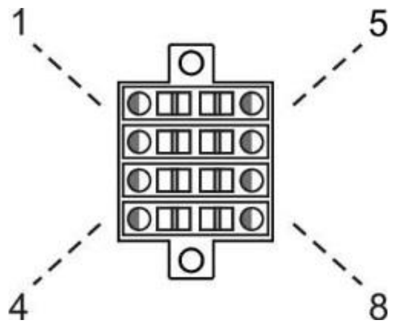
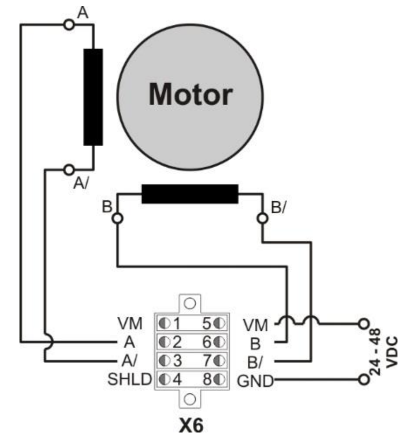
Pin	Signal	Picture
X6.1	VM (power stage supply, 19 – 48 VDC)	
X6.2	PH A1 (motor phase **A**)	
X6.3	PH A2 (motor phase **A/**)	
X6.4	SHLD	
X6.5	VM (power stage supply, 19 – 48 VDC)	
X6.6	PH B1 (motor phase **B**)	
X6.7	PH B2 (motor phase **B/**)	
X6.8	GND	

Table 8: Pin allocation motor interface (X6)

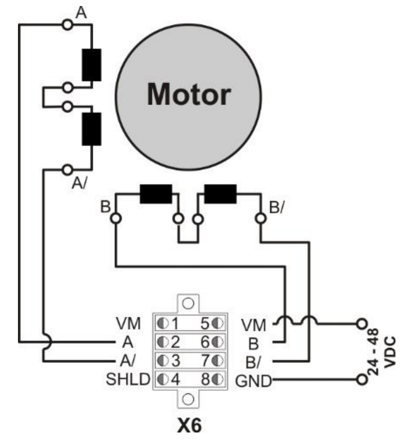
Please read and notice the datasheet of the stepper motor before connecting it with the SMC3!

Before connecting a stepper motor to the SMC turn OFF the power stage supply (X6.1/X6.5)

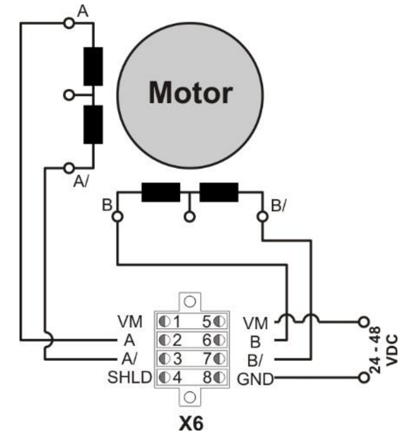
4.3.6 Stepper motors connection



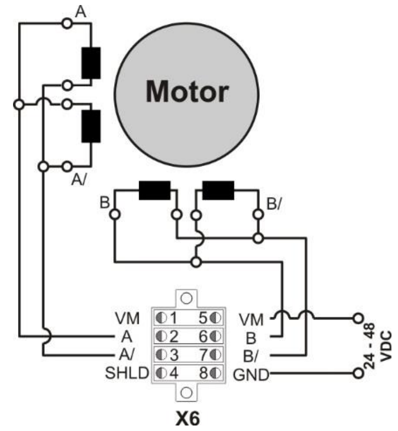
A: Motor with 4 wires



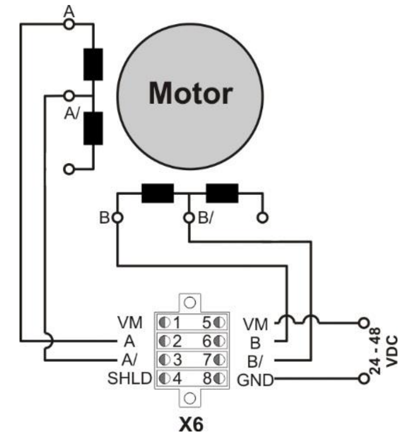
B: Motor with 8 wires serial



C: Motor with 6 wires serial



D: Motor with 8 wires parallel



E: Motor with 6 wires, 1 coil

Picture 6: Different ways to connect a stepper motor to the SMC3

If the motor is connected with the SMC3 in a different way than shown in Picture 6, the motor parameters must be set correct! (e.g. current serial != current parallel)

4.4 Electrical characteristics

General data	
Conductor cross section (connectors X1, X4, X5 and X6)	0,14 mm^2 … 1,5 mm^2 (solid or stranded) 26 … 16 AWG
Logic power supply (X1)	
Nominal value	24 VDC (constant voltage rise from 0 VDC to 24 VDC within less than 50 ms)
Tolerance	+/-20% incl. +/-5% ripple
Current consumption	Typical: 270 mA, max. 300 mA (without 5 VDC encoder supply, clamp **X5.01**)
Digital inputs (clamps X4.01 … X4.04)	
Number of digital inputs	4 (DI1 … DI4)
Nominal input voltage U_{IN}	24 VDC
Nominal input current	5 mA at U_{IN} (typical)
Switching thresholds	U_{Lmax} < 5 VDC; U_{Hmin} > 15 VDC
Common potentials	GND (**X4.13 … X4.16**)
Permissible input voltage U_{IN}	-30 VDC < U_{IN} < +30 VDC
Permissible cable length to sensor	100 m
Digital outputs (clamps X4.05 … X4.08)	
Number of digital outputs	4 (DO1 … DO4)
Nominal input voltage U_{OUT}	24 VDC
Nominal current I_{NOM} per channel	0.5 A
Total current	2 A
Nominal load	Ohmic: 48 Ω/12 W; Lamp: 12 W; Inductive: 12 VA (1.2 H, 50 Ω)
Protective measures	protected against short circuit and overload
Common supply	24V DC (**X4.09 … X4.12**)
Common potentials	GND (**X4.13 … X4.16**)
Encoder interface (X5)	
Signals	5 VDC … 24 VDC
Connection method of encoders	A and /A, B and /B, Z and /Z (symmetrical incremental encoders)
Count frequency	max. 2 MHz (after quadrupling)
5 VDC encoder supply	+5 VDC (clamp **X5.01**), max. load 200 mA
24 VDC encoder supply	+25 VDC (clamp **X5.06**), max. load limited by 24 VDC power supply connected to **X1**
Permissible cable length to encoder	30 m
Motor interface (X6)	
Phases	2 phases, 8 A peak (6 A eff) per phase
Supply	19 VDC … 48 VDC (**X6.01**, **X6.05**)

Table 9: Electrical characteristic

5 Communication over Real-time Ethernet

5.1 Sercos interface

5.1.1 Basic features

Profile	Classes & Function groups
SCP	SCP_VarCFG, SCP_Sync, SCP_Diag, SCP_TFTP, SCP_NRTPC, SCP_RTB 4 connections (1 x MS, 1 x SM, 2 x CC)
GDP	GDP_Basic, GDP_Id, GDP_Rev, GDP_StM, GDP_CKs, GDP_BKP, GDP_DiagT, GDP_DiagTAdv, GDP_PWD, GDP_PrBBasic
FSP	FSP-Drive • Drive class "Velocity axis" • Drive class "Velocity axis with position feedback" • Drive class "Position axis" • Drive class "Positioning axis" • Support of secondary operation modes • FG_Motor_Feedback • FG_Drive_Homing (drive controlled homing with homing switch) • FG_Position_Switch • FG Probe
min. cycle time	1ms
Firmware and logicware update	Compliant to Sercos specification for update over TFTP in NRT mode

Table 10: Sercos slave interface features

5.1.2 UCC settings and capabilities

IDN	Name	Description
S-0-1019	MAC Address	*(unique for the device, not changeable)*
S-0-1020	IP Address	Default = 192.168.100.100, changes over SVC are stored immediat and become effective when entering the NRT mode.
S-0-1021	Subnet Mask	Default = 255.255.255.0, changes over SVC are stored immediat and become effective when entering the NRT mode.
S-0-1022	Gateway address	Default = 0.0.0.0, changes over SVC are stored immediat and become effective when entering the NRT mode.
S-0-1027.0.1	Requested MTU	Default = 1500, changes over SVC are stored immediat and become effective when entering the NRT mode.

Table 11: UCC settings

The IDNs S-0-1020, S-0-1021, S-0-1022 and S-0-1027.0.1 are stored after a write access over SVC but don't become effective. New settings become effective at PowerOn or by exexuting the procedure command S-0-1048.

The UCC (Unified Communication Channel) is only active while the communication phases NRT, CP0 and CP1. The following S/IP services and features are supported:

- Service "Reset (97)" (UDP/IP mode)
- Update over TFTP (see 8)

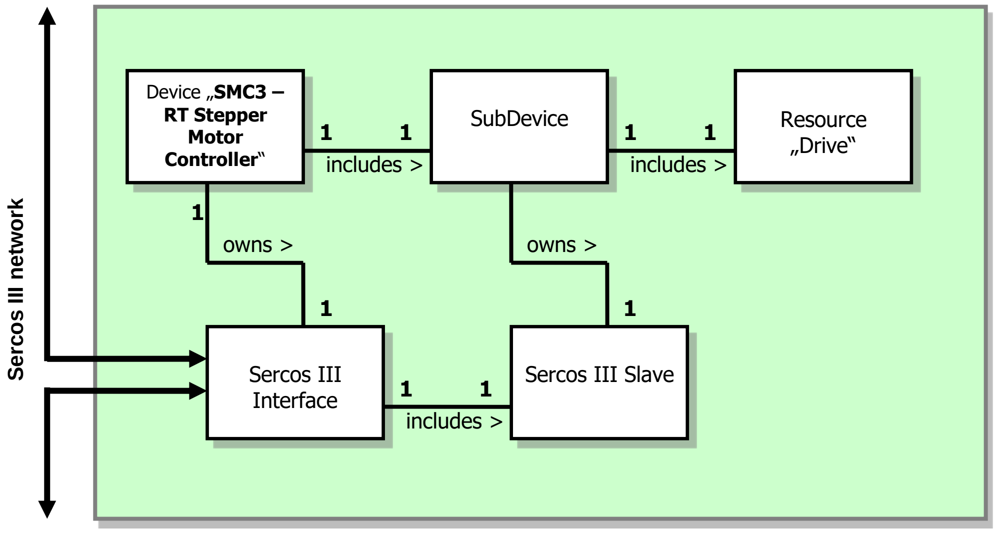
5.1.3 Sercos boot process indication

Boot process state	LED DIAG3 (see 4.1 LEDs)
Power ON	**red**
Boot process running	**green flashing**
Boot process finished	**green**

Table 12: Sercos boot process indication

5.1.4 FSP-Drive

The SMC3 Realtime-Ethernet Stepper Motor Controller includes the FSP-Drive with one instance (= 1).



Picture 7: Sercos III device model

5.1.4.1 Stepper motor configuration data sets

The SMC3 has **8** configuration data sets: IDN/P-**0**-4000.0.y to IDN/P-**7**-4000.0.y. These data sets are stored in Flash-Memory. Data set 0 is active and must contain settings valid for the connected stepper motor. Data sets 1 to 7 are not active and can contain settings for any other stepper motor type. The active data set 0 is used to initialize the SMC3 hardware in the following states:

- Immediately after power on
- With procedure command IDN/S-0-0216 (Switch parameter set procedure command)

To select and activate a stepper motor configuration data set, please proceed as follows:

- **Step 1**: Change to **CP2** or parameterization level (**PL**)
- **Step 2**: Write the number of the desired data set [0…7] to **IDN/S-0-0217** (Parameter set preselection)
- **Step 3**: Execute the procedure command **IDN/S-0-0216** (Switch parameter set procedure command)

Note that the change and activation of a new data set can have influence on the behavior of the stepper motor! Therefore, check carefully the new settings before activating them!

The stepper motor configuration data sets are stored in Flash-Memory with the procedure command **IDN/S-0-0264** (Backup working memory procedure command)

IDN	Name	Description
P-x-4000.0.6	Motor steps per rev	Steps per motor revolution (e.g. 1.8° motor step angle = 200)
P-x-4000.0.7	Encoder increment per rev	Increments per encoder revolution (0 = no encoder connected) If 0 then: S-0-0116 is P-x-4000.0.6 * P-x-4000.0.9 Increments per rev. If e.g. 2000 then: S-0-0116 is 2000 Increments per rev.
P-x-4000.0.8	Motortype and number	Type or name of the corresponding stepper motor
P-x-4000.0.9	Micro steps	Number of micro steps. Possible values are 1 (full step), 2, 4, 8, 16, 32, 64, 128 or 256.
P-x-4000.0.10	Desired current	Current per phase in [0.01A] (e.g. 200 = 2A current per phase)
P-x-4000.0.11	Current in standstill	Percentage of P-x-4000.0.10

Table 13: Stepper motor configuration

5.1.5 Product specific IDNs

IDN	Name	Description
S-0-1300.0.128	FPGA register BOARD-ID	Board ID
S-0-1300.0.129	FPGA register SYSID-ID	SYSID-ID of the FPGA content
S-0-1300.0.130	FPGA register SYSID-Timestamp	SYSID- Timestamp of the FPGA content
S-0-1300.0.131	Configuration data-set identification	Identification string of the configuration data set
S-0-1300.0.132	Firmware checksum	Checksum of the firmware
S-0-1300.0.133	Firmware File Name	Filename of the firmware
S-0-1300.0.135	Slave communication stack	Identification string of the Sercos slave communication stack
S-0-1300.0.136	Application Build Info	Identification string of the firmware
P-0-4002.1.1	SMC3 digital input	Bit 0: DI1 Bit 1: DI2 Bit 2: DI3 Bit 3: DI4 Bit 4 ... 31: *n.c.*
P-0-4002.1.2	SMC3 DI1 configuration	Configuration of the digital input DI1 (see also 5.1.6)
P-0-4002.1.3	SMC3 DI2 configuration	Configuration of the digital input DI2 (see also 5.1.6)
P-0-4002.1.4	SMC3 DI3 configuration	Configuration of the digital input DI3 (see also 5.1.6)
P-0-4002.1.5	SMC3 DI4 configuration	Configuration of the digital input DI4 (see also 5.1.6)
P-0-4002.2.1	SMC3 digital output	Bit 0: DO1 Bit 1: DO2 Bit 2: DO3 Bit 3: DO4 Bit 4 ... 31: *n.c.*
P-0-4002.2.2	SMC3 DO1 configuration	Configuration of the digital output DO1 (see also 5.1.6)
P-0-4002.2.3	SMC3 DO2 configuration	Configuration of the digital output DO2 (see also 5.1.6)
P-0-4002.2.4	SMC3 DO3 configuration	Configuration of the digital output DO3 (see also 5.1.6)
P-0-4002.2.5	SMC3 DO4 configuration	Configuration of the digital output DO4 (see also 5.1.6)
P-0-4002.3.1	SMC3 raw position	Raw position counter before scaling
P-0-4002.4.0	StallGuard value of TMC	Internal torque value
P-0-4002.5.0	StallGuard offset	Torque offset value for homing on block
P-0-4002.6.0	StallGuard measurement turns	Time for homing on block

IDN	Name	Description
P-0-4002.7.0	Homing current reduced	Reduced current while homing on block, similar to P-0-4000.x.10
P-0-4002.9.0	Boost current	Current for the boost functionality in [0.01A] (e.g. 200 = 2A)
P-0-4002.11.0	Boost time	Time in [ms] for how long the boost is activated after start
P-0-4002.12.0	Config mode SMC3	Bit 0 = TRUE : Velocity mode has its own ramp calculation Bit 0 = FALSE : Velocity mode is controled by the master

Table 14: Product specific IDNs

5.1.6 Product specific IDNs details

IDN		S-0-1300.0.128
Name		FPGA register BOARD ID
Attribute	Length (octet)	2
	Data type and display format	hexadecimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 15: S-0-1300.0.128

IDN		S-0-1300.0.129
Name		FPGA register BOARD ID
Attribute	Length (octet)	1, variable
	Data type and display format	text
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 16: S-0-1300.0.129

IDN		S-0-1300.0.130
Name		FPGA register SYSID-Timestamp
Attribute	Length (octet)	1, variable
	Data type and display format	text
	Function	Parameter

IDN		S-0-1300.0.130
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 17: S-0-1300.0.130

IDN		S-0-1300.0.131
Name		Configuration data-set identification
Attribute	Length (octet)	1, variable
	Data type and display format	text
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 18: S-0-1300.0.131

IDN		S-0-1300.0.132
Name		Firmware checksum
Attribute	Length (octet)	2
	Data type and display format	hexadecimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 19: S-0-1300.0.132

IDN		S-0-1300.0.133
Name		Firmware File Name
Attribute	Length (octet)	1, variable
	Data type and display format	text
	Function	Parameter

IDN		S-0-1300.0.133
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 20: S-0-1300.0.133

IDN		S-0-1300.0.135
Name		Slave communication stack
Attribute	Length (octet)	1, variable
	Data type and display format	text
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 21: S-0-1300.0.135

IDN		S-0-1300.0.136
Name		Application Build Info
Attribute	Length (octet)	1, variable
	Data type and display format	text
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 22: S-0-1300.0.136

IDN		P-0-4000.x.6 (x = 0..7)
Name		Active motortype with register: motor steps per rev (x = 0) Motortype x with register: motor steps per rev (x = 1..7)
Attribute	Length (octet)	4
	Data type and display format	Unsigned decimal
	Function	Parameter

IDN		P-0-4000.x.6 (x = 0..7)
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		1000

Table 23: P-0-4000.x.6

IDN		P-0-4000.x.7 (x = 0..7)
Name		Active motortype with register: encoder increment per rev (x = 0) Motortype x with register: encoder increment per rev (x = 1..7)
Attribute	Length (octet)	4
	Data type and display format	Unsigned decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 24: P-0-4000.x.7

IDN		P-0-4000.x.8 (x = 0..7)
Name		Active motortype: motortype or number (x = 0) Motortype x: motortype or number (x = 1..7)
Attribute	Length (octet)	1, variable
	Data type and display format	text
	Function	Parameter
	Positions after decimal point	0
	Write protection	allways
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 25: P-0-4000.x.8

IDN		P-0-4000.x.9 (x = 0..7)
Name		Active steps (x = 0) Motortype x: steps (x = 1..7)
Attri but	Length (octet)	4

IDN		P-0-4000.x.9 (x = 0..7)
	Data type and display format	Unsigned decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		n/a

Table 26: P-0-4000.x.9

IDN		P-0-4000.x.10 (x = 0..7)
Name		Active desired current (x = 0) Motortype x: desired current (x = 1..7)
Attribute	Length (octet)	4
	Data type and display format	Unsigned decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		44
Maximum value		800

Table 27: : P-0-4000.x.10

IDN		P-0-4000.x.11 (x = 0..7)
Name		Active value current in standstill (x = 0) Motortype x: value current in standstill (x = 1..7)
Attribute	Length (octet)	4
	Data type and display format	Unsigned decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		10
Maximum value		100

Table 28: : P-0-4000.x.11

IDN		P-0-4002.1.1
Name		SMC3 digital input
Attribute	Length (octet)	4
	Data type and display format	binary
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 29: : P-0-4002.1.1

IDN		P-0-4002.1.2 - P-0-4002.1.5
Name		SMC3 DIx configuration (x = 1..4)
Attribute	Length (octet)	4
	Data type and display format	binary
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 30: P-0-4002.1.2 - P-0-4002.1.5

IDN		P-0-4002.2.1
Name		SMC3 digital output
Attribute	Length (octet)	4
	Data type and display format	binary
	Function	Parameter
	Positions after decimal point	0
	Write protection	never
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 31: P-0-4002.2.1

IDN		P-0-4002.2.2 - P-0-4002.2.5
Name		SMC3 DOx configuration (x = 1..4)
Attribute	Length (octet)	4
	Data type and display format	binary
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 32: P-0-4002.2.2 - P-0-4002.2.5

IDN		P-0-4002.3.1
Name		SMC3 raw position
Attribute	Length (octet)	4
	Data type and display format	Signed decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	always
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 33: P-0-4002.3.1

IDN		P-0-4002.5.0 (Torque offset value for homing on block)
Name		StallGuard Offset
Attribute	Length (octet)	4
	Data type and display format	Signed decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	never
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 34: P-0-4002.5.0

IDN		P-0-4002.6.0 (StallGuard Measurement turns)
Name		StallGuard Measurement turns
Attribute	Length (octet)	4
	Data type and display format	Signed decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	never
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 35: P-0-4002.6.0

IDN		P-0-4002.7.0 (Reduced current while homing on block similar to P-0-4000.x.10)
Name		Homing current reduced
Attribute	Length (octet)	4
	Data type and display format	Signed decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*10*
Maximum value		*100*

Table 36: P-0-4002.7.0

IDN		P-0-4002.9.0 (Current for the boost functionality (100 = 1 A))
Name		Boost current
Attribute	Length (octet)	4
	Data type and display format	Signed decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*44*
Maximum value		*800*

Table 37: P-0-4002.9.0

IDN		P-0-4002.11.0 (Time for how long the boost is activated after start)
Name		Boost time
Attribute	Length (octet)	4
	Data type and display format	Signed decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	no
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*ms*
Minimum value		*n/a*
Maximum value		*n/a*

Table 38: P-0-4002.11.0

IDN		P-0-4002.12.0 (Bit 0 = TRUE : Velocity mode has its own ramp calculation Bit 0 = FALSE : Velocity mode is controled by master)
Name		Config mode SMC3
Attribute	Length (octet)	4
	Data type and display format	Signed decimal
	Function	Parameter
	Positions after decimal point	0
	Write protection	OL
	Conversion factor	1
	Scaling / resolution of LSB	1
Unit		*n/a*
Minimum value		*n/a*
Maximum value		*n/a*

Table 39: P-0-4002.12.0

5.1.7 Product specific error and warning codes (IDN/S-0-0390)

Code	Text (IDN/S-0-0095)	Description
		Only FSP-Drive standard error/warnings codes are used

Table 40: Error and warning codes

See https://wiki.sercos-service.org/current/Main_Page

5.1.8 Configuration and usage of digital I/Os (DI1…DI4 & DO1…DO4)

IDN	Name	Description
P-0-4002.1.2 … P-0-4002.1.5	SMC3 Dix configuration	Bit 0: 0 = signal is HIGH active 1 = signal is LOW active Bit 1..7: *(reserved)* Bit 8: direct use Bit 9: enable power stage Bit 10: positive limit switch Bit 11: negative limit switch Bit 12: homing switch Bit 13: motor over temperature Bit 14: common error input (manufacturer specific) Bit 15: use as probe signal (only DI1 and DI2, see also 5.1.10 Probe function) Bit 16..31: *(reserved)*
P-0-4002.2.2 … P-0-4002.2.5	SMC3 Dox configuration	Bit 0: 0 = signal is HIGH active 1 = signal is LOW active Bit 1..7: *(reserved)* Bit 8: direct use Bit 9: power stage state (ON/OFF) Bit 10: position switch Bit 11: drive shut down error (bit 13 of IDN/S-0-0135) Bit 12: emergency stop (bit 7 of IDN/S-0-0135) Bit 13: drive halt (bit 4 of IDN/S-0-0135) Bit 14: command value processing (bit 3 of IDN/S-0-0135) Bit 15: *(reserved)* Bit 16..19: position switch- or cam-mode (IDN/S-0-0060 .. IDN/S-0-0075) or (IDN/S-0-0460..IDN/S-0475), only used if bit 10 = 2 Bit 20..31: *(reserved)*

Table 41: Configuration and usage of digital I/Os

5.1.9 Sercos LED (RT-BUS)

The following table shows the codes indicating the device status according to the Sercos specification V1.3.

#	Color	Description	Priority	Comments
#1	Dark	NRT-Mode	0	no sercos communication
#2	orange	CP0	0	communication phase 0 is active
#3		CP1	0	communication phase 1 is active
#4		CP2	0	communication phase 2 is active
#5		CP3	0	communication phase 3 is active
#6	green	CP4	0	communication phase 4 is active
#7		HP0	1	device is in hot-plug phase 0
#8		HP1	1	device is in hot-plug phase 1
#9		HP2	1	device is in hot-plug phase 2
#10		Fast forward => Loopback	2	RT-state has changed from fast-forward to loopback
#11		Application error	3	see GDP & FSP Status codes class error
#12		MST losses ≥ (S-0-1003/2)	4	as long as the communication warning (S-DEV.Bit15) in the Device status is present, at least 2 sec.
#13	red	Communication error	5	see SCP Status codes class error
#14		Identification	6	Invoked by (C-DEV.Bit 15 in the Device Control) or SIP Identification request
#15		Watchdog error	7	application is not running
	|-------------------- 3 sec ----------------------|			

Table 42: Sercos III LED coding

5.1.10 Probe function

The SMC3 probe function is compliant with the Sercos specification

- IDNs, that are available for capturing (see also S-0-0428.0.0 and S-0-0428.1.0): S-0-0051
- Available probe signals
  - DI1 (**X4.1**) (the input behaviour is configurable over IDN/P-0-4002.1.2)
  - DI2 (**X4.2**) (the input behaviour is configurable over IDN/P-0-4002.1.3)

5.1.11 Firmware update

To update the SMC3 firmware and logicware the TFTP protocol is used.

5.1.11.1 Preconditions for error free functioning of the TFTP server present on the SMC3

- The device must be in Sercos NRT mode
- The device must have a valid MAC address (IDN/S-0-1019)
- The device must have a valid IP address (IDN/S-0-1020)
- The device must have a valid Subnet Mask (IDN/S-0-1021)
- The device must have a link on real-time Ethernet port 1 (X2) or 2 (X3). For this purpose the PC can be connected direct with the device or the device is connected to a network, from which the PC can reach it.
- There must be a TFTP client on the PC.
- On the PC, an update file (smc3.ocf) must be present. This file contains Sercos logicware, Sercos firmware, (EtherCAT logicware and EtherCAT firmware) .

5.1.11.2 Restrictions of the TFTP server

- A TFTP client cannot download files from the SMC3
- The update file must be transmitted in binary mode (octet)
- The transmitted file must have the same name as defined in the IDN/S-0-1300.0.133, typically “smc3.ocf”.

5.1.11.3 TFTP server error messages

Error	Description
Access violation: Ongoing transmission in progress	While an ongoing file transmission an attempt was made to transmit another file. The TFTP server doesn’t support simultaneous transmission of files.
Illegal TFTP operation: Read request not supported	An attempt was made to download a file from the SSI-Gateway.
Illegal TFTP operation: 0xYYYY	An illegal (undefined) TFTP op-code was received.
Illegal TFTP operation: Awaiting <Filename X> but received <Filename Y>	A write request for file X was received. Now actually file data should follow, but instead a write request for file Y was received.
Unknown transfer ID: Wrong filename or extension: ‘<Received Filename>’, ‘<Received Extension>’ expected: ‘<Expected Filename …>’	A file with name <Received Filename> and extension <Received Extension> was received. However, the file <Expected Filename …> was expected.
Unknown transfer ID: Wrong Block#: <Block#X>, expected: <Block#Y>	While the TFTP transmission each block is enumerated. The number sequential and incremented by 1 with each block. This message indicates that a sequence error has occurred.
Unknown transfer mode: Allowed transfer mode: octet, used transfer mode: <Transfer Mode>	An attempt was made to transfer a file in a not supported mode. The TFTP server supports only binary mode (octet).
Disk full or allocation exceeded	It was not possible to allocate enough memory to save the received data.

Table 43: TFTP server error messages

5.1.11.4 Update process

To execute the update a command shell window has to be opened on the PC.

Sample for updating the firmware under Windows®:

```
c:\update_dir>tftp –i 192.168.100.100 PUT smc3.ocf
```

5.1.11.5 Visualization of the update process

State	Visualization over LEDs (see also 8.2)	
	DIAG1	DIAG3
File transfer is started	**green**	**orange**
File transfer is successfully completed, programming is started	**green**	**off**
Programming successfully completed	**off**	**green**
Programming aborted with error	**green**	**red**

Table 44: Visualization of the update process

5.1.11.6 Reset service

For a remote reset of the SMC3 the S/IP service “Reset” (UDP/IP version) can be used (for details see S/IP specification).

5.2 EtherCAT

5.2.1 EtherCAT boot process indication

Boot process state	LED DIAG3 (see 4.1 LEDs)
Operational mode, power stage is disabled	**green flashing**
Operational mode, power stage is enabled	**green**
Boot process finished without error	**red**
Boot process aborted with error	**red flashing**

Table 45: EtherCAT boot process indication

5.2.2 Product specific objects

Object	Name	Description
0x2000	Kv factor	Gain of the position closed loop
0x2001	Manufacturer Error	Bit-coded additional errors (see 5.2.5)
0x2022	Stall Guard Offset	Offset for homing on block
0x2023	Stall Guard Turns	Measurement for homing on block
0x2024	Stall Guard Value	Fictitious torque value
0x2050	SMC3 digital output	Bit 0: DO1 Bit 1: DO2 Bit 2: DO3 Bit 3: DO4 Bit 4 … 31: *n.c.*
0x2051	SMC3 DO1 configuration	Configuration of the digital output DO1 (see also 5.2.4)
0x2052	SMC3 DO2 configuration	Configuration of the digital output DO2 (see also 5.2.4)
0x2053	SMC3 DO3 configuration	Configuration of the digital output DO3 (see also 5.2.4
0x2054	SMC3 DO4 configuration	Configuration of the digital output DO4 (see also 5.2.4)
0x2055	SMC3 digital input	Bit 0: DI1 Bit 1: DI2 Bit 2: DI3 Bit 3: DI4 Bit 4 … 31: *n.c.*
0x2056	SMC3 DI1 configuration	Configuration of the digital input DI1 (see also 5.2.4)
0x2057	SMC3 DI2 configuration	Configuration of the digital input DI2 (see also 5.2.4)
0x2058	SMC3 DI3 configuration	Configuration of the digital input DI3 (see also 5.2.4)
0x2059	SMC3 DI4 configuration	Configuration of the digital input DI4 (see also 5.2.4)
0x2060	Homing current reduced	Reduces the desired current while homing on block
0x8010	Active motor configuration	All motor parameters for the active motor

Object	Name	Description
0x8011 – 0x8017	Motor configuration X (X = 1..7)	All motor parameters for non active motor (see also 5.2.3)
0x8018	motor configuration select	Selection of desired motor configuration
0x8019	activate motor configuration	Activation of motor configuration with True value while writing
0x2600	Save configured data	Saving of motor data

Table 46: Product specific objects

5.2.3 Product specific object (details)

Object		0x2000
Name		Kv factor
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Gain of the position loop regulator
	Subindex amount	0
	Write protection	(ACCESS_READWRITE)

Table 47: 0x2000

Object		0x2001
Name		Manufacturer Error
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	See bit description in (see 5.2.5)
	Subindex amount	0
	Write protection	(ACCESS_READ)

Table 48: 0x2001

Object		0x2022
Name		Stall Guard Offset
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Offset for homing on block
	Subindex amount	0
	Write protection	(ACCESS_READWRITE)
	Subindex amount	0

Table 49: 0x2022

Object		0x2023
Name		Stall Guard Turns
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Internal time of the motor while measurement the lowes SG-value
	Subindex amount	0
	Write protection	(ACCESS_READWRITE)

Table 50: 0x2023

Object		0x2024
Name		Stall Guard Value
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Internal torque value of TMC262
	Subindex amount	0
	Write protection	(ACCESS_READ|ACCESS_WRITE_PREOP)

Table 51: 0x2024

Object		0x2050
Name		SMC3 digital output
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Switching the digital output
	Subindex amount	0
	Write protection	(ACCESS_READWRITE)

Table 52: 0x2050

Object		0x2051 – 0x2054
Name		SMC3 DOx configuration (x = 1 ..4)
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Configuration of digital output behaviour (see 5.2.4)
	Subindex amount	0
	Write protection	(ACCESS_READ|ACCESS_WRITE_PREOP)

Table 53: 0x2051 – 0x2054

Object		0x2055
Name		SMC3 digital input
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Reading the digital input
	Subindex amount	0
	Write protection	(ACCESS_READ)

Table 54: 0x2055

Object		0x2056 – 0x2059
Name		SMC3 DIx configuration (x = 1 ..4)
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Configuration of digital input behaviour (see 5.2.4)
	Subindex amount	0
	Write protection	(ACCESS_READ|ACCESS_WRITE_PREOP)

Table 55: 0x2056 – 0x2059

Object		0x2060
Name		Homing current reduced
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	For reducing the motor current for the homing on block (This is working like the subindex 12 in object 0x8010 – 0x8017)
	Subindex amount	0
	Write protection	(ACCESS_READWRITE)

Table 56: 0x2060

Object		0x8010
Name		Active motor configuration
Attribue	Length (octet)	X
	Data type and display format	DEFTYPE_RECORD
	Function	Setting of active motor parameter
	Subindex amount	13
	Write protection	(ACCESS_READ|ACCESS_WRITE_PREOP)
	Subindex 1	*Internal use*
	Subindex 2	*Internal use*
	Subindex 3	*Internal use*
	Subindex 4	*Internal use*
	Subindex 5	*Internal use*
	Subindex 6	*Internal use*
	Subindex 7	Motor steps per revolution of the stepper motor (see 5.1.6 P-0-4000.X.6)
	Subindex 8	Encoder increments per revolution (see 5.1.6 P-0-4000.X.7)
	Subindex 9	Motor type number (see 5.1.6 P-0-4000.X.8)
	Subindex 10	Steps (see 5.1.6 P-0-4000.X.9)
	Subindex 11	Desired current (see 5.1.6 P-0-4000.X.10)
	Subindex 12	Value of current in standstill (see 5.1.6 P-0-4000.X.11)
	Subindex 13	*Internal use*

Table 57: 0x8010

Object		0x8011 – 0x8017
Name		Motortype configuration x (x = 1..7)
Attribue	Length (octet)	X
	Data type and display format	DEFTYPE_RECORD
	Function	Setting of active motor parameter
	Subindex amount	13
	Write protection	(ACCESS_READ|ACCESS_WRITE_PREOP)
	Subindex 1	*Internal use*
	Subindex 2	*Internal use*
	Subindex 3	*Internal use*
	Subindex 4	*Internal use*
	Subindex 5	*Internal use*
	Subindex 6	*Internal use*
	Subindex 7	Motor steps per revolution of the stepper motor (see 5.1.6 P-0-4000.X.6)
	Subindex 8	Encoder increments per revolution (see 5.1.6 P-0-4000.X.7)
	Subindex 9	Motor type number (see 5.1.6 P-0-4000.X.8)
	Subindex 10	Steps (see 5.1.6 P-0-4000.X.9)
	Subindex 11	Desired current (see 5.1.6 P-0-4000.X.10)
	Subindex 12	Value of current in standstill (see 5.1.6 P-0-4000.X.11)
	Subindex 13	*Internal use*

Table 58: 0x8011 – 0x8017

Object		0x8018
Name		Motor configuration select
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Selecting of your desired motor configuration to the active motor configruation
	Subindex amount	0
	Write protection	(ACCESS_READ|ACCESS_WRITE_PREOP)

Table 59: 0x8018

Object		0x8019
Name		Activate motor configuration
Attribute	Length (octet)	4
	Data type and display format	DEFTYPE_UNSIGNED32
	Function	Activation of the in object 0x8018 selected configuration to the active motor configuration.
	Subindex amount	0
	Write protection	(ACCESS_READ|ACCESS_WRITE_PREOP)

Table 60: 0x8019

5.2.4 Configuration and usage of digital I/Os (DI1...DI4 & DO1...DO4)

Object	Name	Description
0x2056 … 0x2059	SMC3 DI**x** configuration	Bit 0: 0 = signal is HIGH active, 1 = signal is LOW active Bit 1..7: *(reserved)* Bit 8: direct use Bit 9: enable power stage Bit 10: positive limit switch Bit 11: negative limit switch Bit 12: homing switch Bit 13: motor over temperature Bit 14: fault reset (if activated, no longer controlled by master) Bit 15: quick stop (if activated, no longer controlled by master) Bit 16: stop (if activated, no longer controlled by master) Bit 17..31: *(reserved)*
0x2051 … 0x2054	SMC3 DO**x** configuration	Bit 0: 0 = signal is HIGH active, 1 = signal is LOW active Bit 1..7: *(reserved)* Bit 8: direct use Bit 9: power stage state (ON/OFF) Bit 10: *(reserved)* Bit 11: fault (bit 3 of 0x6041) Bit 12: quick stop (bit 4 of 0x6041) Bit 13: warning (bit 7 of 0x6041) Bit 14: internal limit active (bit 11 of 0x6041) Bit 15..31: *(reserved)*

Table 61: Configuration and usage of digital IOs

5.2.5 Detailed description of manufacturer error (0x2001)

Bit	Name	Description	Solution
0	Motor chip error	Motor chip has an internal error	Please contact CANNON-Automata for further information
1	Limit switch pos	The positive limit switch is active. This error can only occure if the positive limit switch is activated in the digital input configuration 5.2.4. This is not acitve while homing mode.	At first the error should be reseted over the control word (object 0x6040) by setting bit 7 = 0 and then bit 7 = 1. As long as the limit switch pos is active, the motor can only move in negative direction. If the limit switch pos is no longer active, the motor can move in both directions.
2	Limit switch neg	The negative limit switch is active. This error can only occure if the neagtive limit switch is activated in the digital input configuration 5.2.4. This is not acitve while homing mode.	At first the error should be reseted over the control word (object 0x6040) by setting bit 7 = 0 and then bit 7 = 1. As long as the limit switch neg is active, the motor can only move in positive direction. If the limit switch neg is no longer active, the motor can move in both directions.
3	Limit switches are inverted	The positive limit switch is recognized as limit switch neg or vice versa or the motor moves in reverse direction as commanded.	Check limit switches or cabeling of limit switches and motor

Table 62: Detailed description of manufacturer error (0x2001)

5.2.6 EtherCAT parameter and operation mode description

5.2.6.1 Error register 0x1001

Bit	Name	Description	Solution
0	Generic error	Open load indicator This is not an error/indication that necessarily prevents moving the motor. It is possible to move it although the bit is set. This error is always active if no motor is connected and the master wants to move it. Attention: This error doesn’t set bit 3 (FAULT) of the status word (object 0x6041)	Connect a motor if no motor is connected and then reboot the SMC3. or Check and correct motor cabeling and then reboot the SMC3. You get no error in the StatusWord and you can´t reset the error with controlword 0x6040 bit 0x80. You can reset the error only by connected motor cable and switched on and off the X6 voltage. Or you connect the motor cable and start a movement in a safe direction till the error delete by itself.
1	Over current	Motor controller chip signals over current.	Please contact CANNON-Automata for further information
2	Under voltage	No voltage or under voltage on the connector X6.	Connect min. 19 VDC on X6 and then reset the error over the control word

Bit	Name	Description	Solution
			(object 0x6040) by setting bit 7 = 0 and then bit 7 = 1. If the error is present, reboot the SMC3.
3	Max. temperature exceeded	Over current in the motor controller chip or in the power stage	The SMC3 must cool down. The error should be reseted by the control word = 128. If it not works, reboot the SMC3.
7	Specific error	See details in Manufacturer Error 0x2001 **Fehler! Verweisquelle konnte nicht gefunden werden.**	

Table 63: Error register 0x1001

5.2.6.2 Mode of operation 0x6060

The drive device provides the modes of operation display object to indicate the actual activated operation mode. Controlword, statusword, and set-points are used mode-specific. This implies the responsibility of the control device to avoid inconsistencies and erroneous behaviour. The next figure shows the supported drive modes.

Value	Definition
0	No mode change/no mode assigned
1	Profile position mode
2	Velocity mode
3	Profile velocity mode
6	Homing mode
8	Cyclic sync position mode
9	Cyclic sync velocity mode

Picture 8: Supported drive modes

5.2.6.3 Motor resolutions in EtherCAT

The motor resolutions in EtherCAT depends on the working with or without encoder. For working with encoder the resolution is identical with the amount of the encoder hardware, that you have to set in pre operational to object 0x8010:0x7. If you work without encoder, then it depends on the set steps in object 0x8010:0xA.

Resolution without encoder = Value of 0x8010:0xA * 200

This is valid in all operation modes except velocity mode (vl).

5.2.6.4 Controlword 0x6040

This object shall indicate the received command controlling the power drive systems. It shall be structured as defined in next figure. The bits 7, 3, 2, 1, and 0 are explained. The other bits depending on the operation mode.

15 … 11	10	9	8	7	6 … 4	3	2	1	0
ms	*r*	*oms*	*h*	*fr*	*oms*	*eo*	*qs*	*ev*	*so*
MSB									LSB

LEGEND: ms = manufacturer-specific; r = reserved; oms = operation mode specific; h = halt; fr = fault reset; eo = enable operation; qs = quick stop; ev = enable voltage; so = switch on

Picture 9: General controlword

Command	Bits of the *controlword*					Transitions
	Bit 7	Bit 3	Bit 2	Bit 1	Bit 0	
Shutdown	0	X	1	1	0	2,6,8
Switch on	0	0	1	1	1	3
Switch on + enable operation	0	1	1	1	1	3 + 4 (NOTE)
Disable voltage	0	X	X	0	X	7,9,10,12
Quick stop	0	X	0	1	X	7,10,11
Disable operation	0	0	1	1	1	5
Enable operation	0	1	1	1	1	4,16
Fault reset	↑	X	X	X	X	15
NOTE Automatic transition to Enable operation state after executing SWITCHED ON state functionality.						

Picture 10: Command coding

5.2.6.5 Statusword 0x6041

The bits 10, 9, and 6 to 0 are explained. The other bits depending on the operation mode.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ms		*oms*		*ila*	*tr*	*rm*	*ms*	*w*	*sod*	*qs*	*ve*	*f*	*oe*	*so*	*rtso*
MSB															LSB

LEGEND: ms = manufacturer-specific; oms = operation mode specific; ila = internal limit active; tr = target reached; rm = remote; w = warning; sod = switch on disabled; qs = quick stop; ve = voltage enabled; f = fault; oe = operation enabled; so = switched on; rtso = ready to switch on

Picture 11: Gerneral statusword

Statusword	
xxxx xxxx x0xx 0000_b	Not ready to switch on
xxxx xxxx x1xx 0000_b	Switch on disabled
xxxx xxxx x01x 0001_b	Ready to switch on
xxxx xxxx x01x 0011_b	Switched on
xxxx xxxx x01x 0111_b	Operation enabled
xxxx xxxx x00x 0111_b	Quick stop active
xxxx xxxx x0xx 1111_b	Fault reaction active
xxxx xxxx x0xx 1000_b	Fault

Picture 12: Status coding

5.2.6.6 Description of pp mode (profile positioning)

The SMC3 must be in state Operational. With the object 0x6060 Modes of operation you are able to change with the value 1 to the profile positioning mode. The following controlword 0x6040 is than valid:

15 … 9	8	7	6	5	4	3 … 0
(see 10.3.1)	Halt	(see 10.3.1)	abs / rel	Change set immediately	New set-point	(see 10.3.1)
MSB						LSB

Picture 13: Controlword in pp-mode

Name	Value	Description
New set-point	0	Does not assume *target position*
	1	Assume *target position*
Change set immediately	0	Finish the actual positioning and then start the next positioning
	1	Interrupt the actual positioning and start the next positioning
abs / rel	0	*Target position* is an absolute value
	1	*Target position* is a relative value
Halt	0	Execute positioning
	1	Stop axle with *profile deceleration* (if not supported with *profile acceleration*)

Picture 14: Details of controlword in pp-mode

The following statusword 0x6041 is than valid:

15 … 14	13	12	11	10	9 … 0
(see 10.3.2)	Following error	Set-point acknowledge	(see 10.3.2)	Target reached	(see 10.3.2)
MSB					LSB

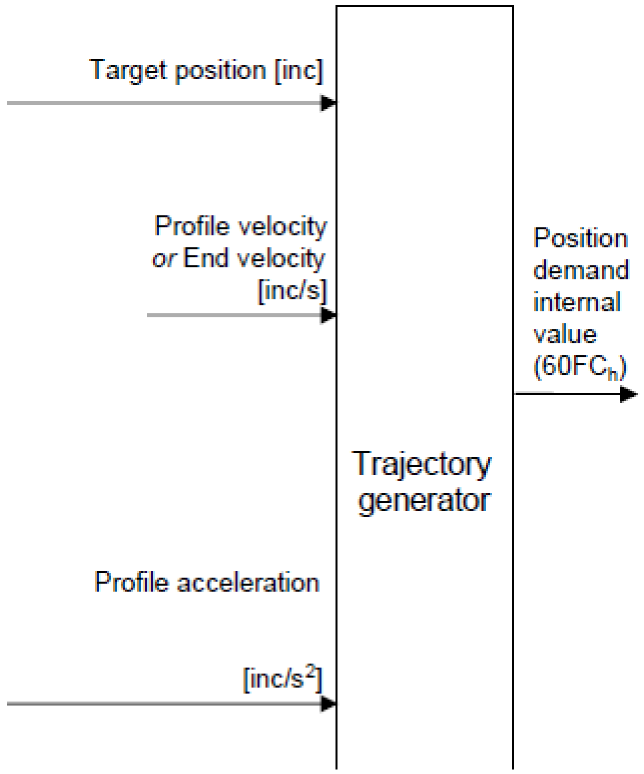
Picture 15: Statusword in pp-mode

Name	Value	Description
Target reached	0	Halt = 0: *Target position* not reached Halt = 1: Axle decelerates
	1	Halt = 0: *Target position* reached Halt = 1: Velocity of axle is 0
Set-point acknowledge	0	Trajectory generator has not assumed the positioning values (yet)
	1	Trajectory generator has assumed the positioning values
Following error	0	No following error
	1	Following error

Picture 16: Details of statusword in pp-mode

For pp-mode you need only a few objects (see next figure):

- 0x6081 Profile velocity
- 0x6083 Profile acceleration
- 0x6064 Position actual value
- 0x607A Target Position



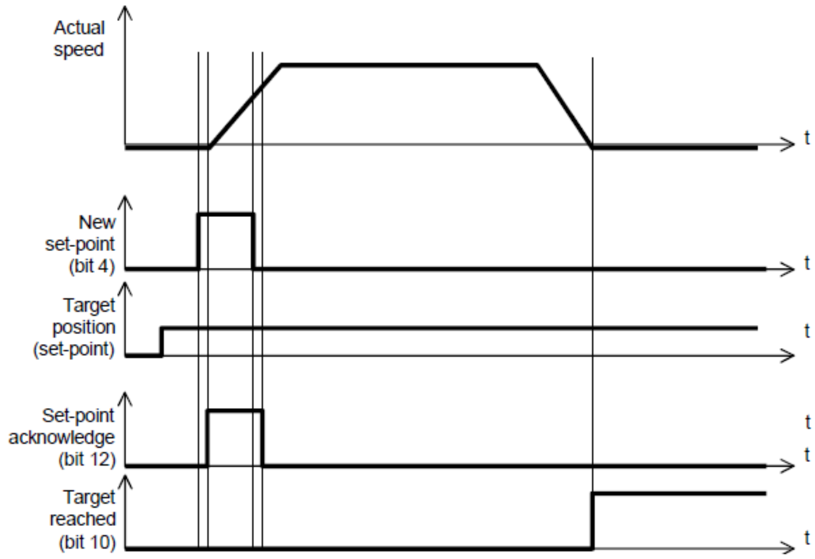
Picture 17: Trajectory generator for pp-mode

5.2.6.7 Detailed explanation of pp-mode

The setting of set-points is controlled by the timing of the new set-point bit and the change set immediately bit in the controlword as well as the set-point acknowledge bit in the staturword.

If the change set immediately bit of the controlword is set to 1, a single set-point is expected by the drive device. If the change set immediately bit of the controlword is set to 0, a set of set-points is expected by the drive device.

After a set-point is applied to the drive device, the control device signals that the set-point is valid by a rising edge of the new wet-point bit in the controlword. The drive device sets the set-point acknowledge bit in the statusword to 1, and afterwards, the drive device signals with the set-point acknowledge bit set to 0 its ability to accept new set-points. An example is shown in next figure.

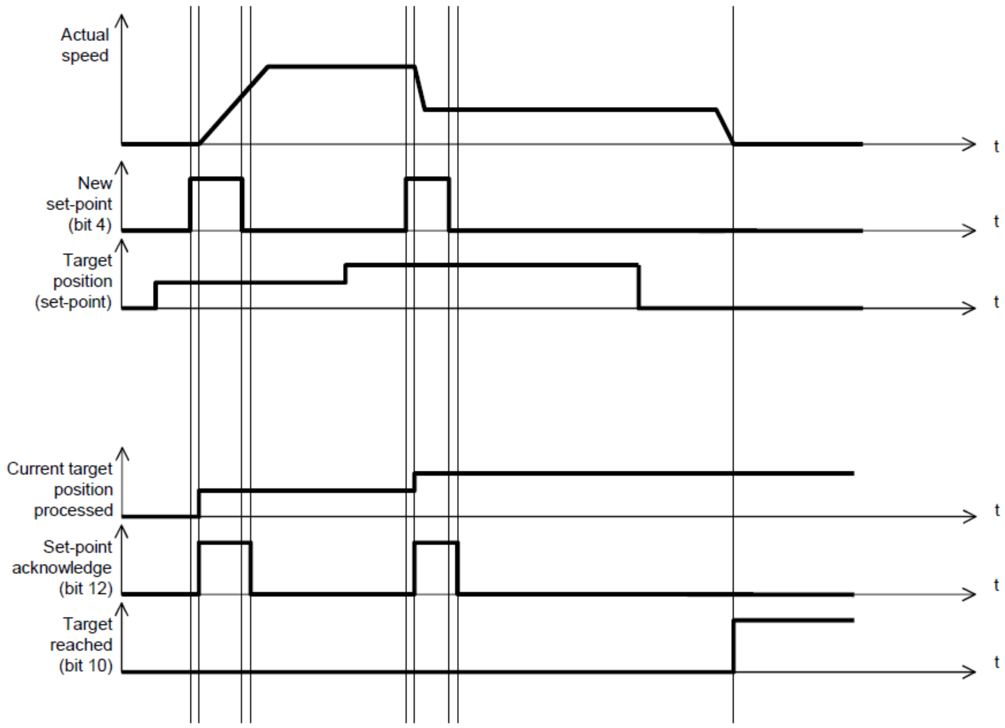


Picture 18: Set-points control

If one set-point is still in progress and a new one is validated, two methods of handling are supported: single set-point (change set immediately bit of controlword is 1) and set of set-points (change set immediately bit of controlword is 0)

5.2.6.8 Single set-point

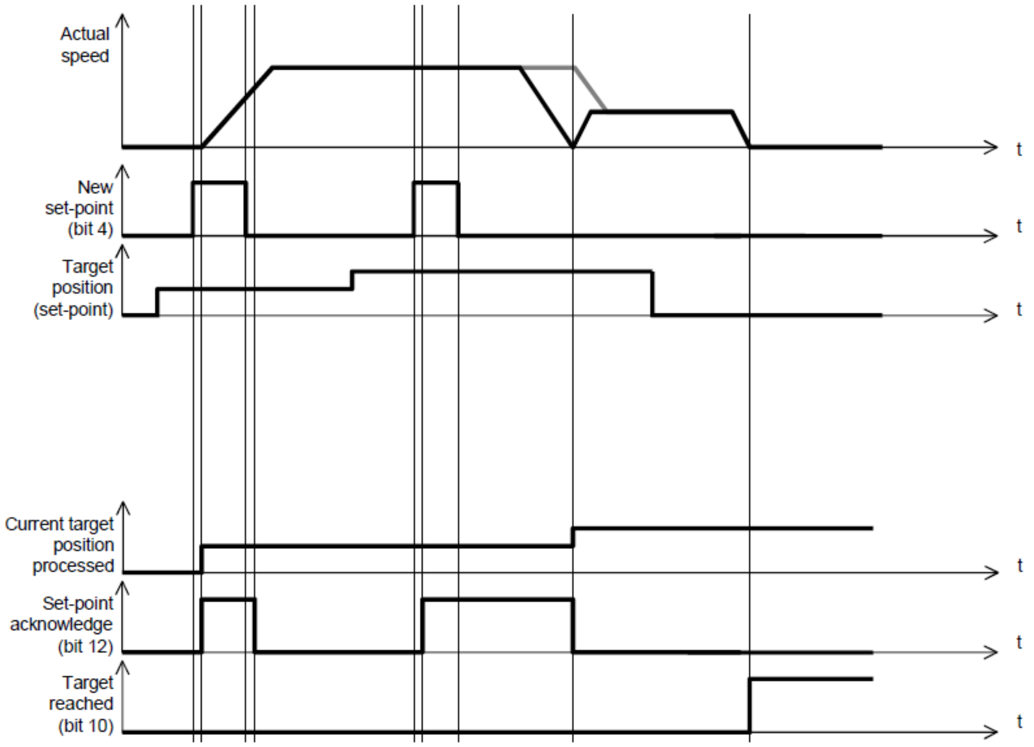
When a set-point is in progress and a new set-point is validated by the new set-point (bit 4) in the controlword, the new set-point shall be processed immediately. The handshaking procedure shown in next figure is used for the single set-point method.



Picture 19: Single set-point

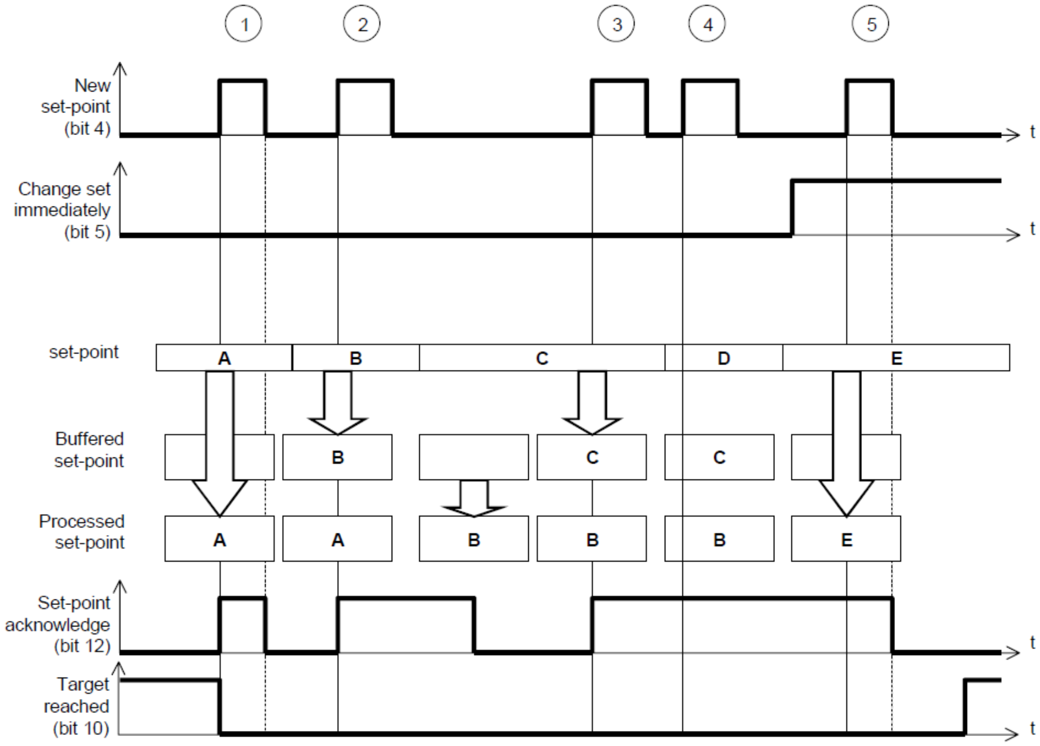
5.2.6.9 Set of set-points

When a set-point is in progress and a new set-point is validated by the new set-point (bit 4) in the controlword, the new set-point shall be processed only after the previous has been reached. The handshaking procedure shown in next figure is used for the set of set-points method. The additional grey line segment in the graph 'actual speed' shows the actual speed if the change of set point bit (bit 9) is set to 1.



Picture 20: Set of set-points

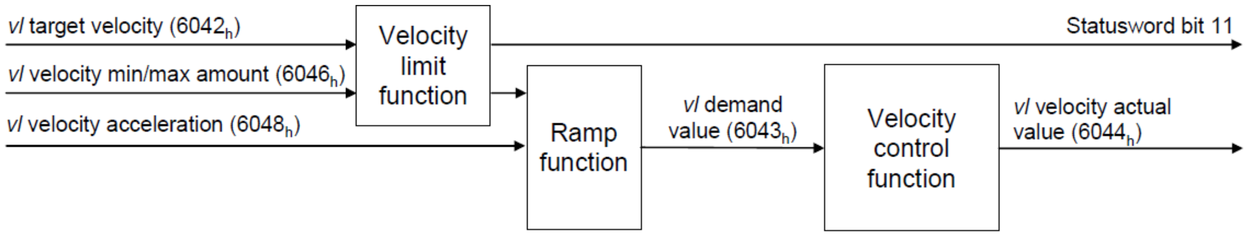
If a drive device supports set of set-points, a minimum of two set-points are available, a setpoint that is currently been processed and a buffered set-point. The set-points are handled as shown in next figure.



Picture 21: Set-point handling for two set-points

5.2.6.10 Description of vl mode (Velocity mode)

The SMC3 must be in state Operational. With the object 0x6060 Modes of operation you are able to change with the value 2 to the velocity mode.



Picture 22: Velocity mode with mandatory objects only

All velocity parameters should be given in rotations per minute (rpm). The limit-value message is generated if the input value of the speed limit results in a value outside the speed limit's operating range. The limit-value message is mapped as one bit in the statusword.

The velocity mode uses some bits of the controlword and the statusword for mode-specific purposes. Next figure shows the structure of the controlword.

15 … 9	8	7	6	5	4	3 … 0
(see 8.4.1)	*Halt*	(see 8.4.1)	*reference ramp*	*unlock ramp*	*enable ramp*	(see 8.4.1)
MSB						LSB

Picture 23: Controlword in vl mode

The next table and the next figure define the values for bit 4, bit 5, bit 6, and bit 8 of the controlword. These bits are optional.

Bit	Value	Definition
4	0	Velocity demand value shall be controlled in any other (manufacturer-specific) way, for example by a test function generator or manufacturer-specific halt function
	1	Velocity demand value shall accord with ramp output value
5	0	Ramp output value shall be locked to current output value
	1	Ramp output value shall follow ramp input value
6	0	Ramp input value shall be set to zero
	1	Ramp input value shall accord with ramp reference
8	0	No command
	1	Motor shall be stopped

Picture 24: Definition of bit 4,5,6,8

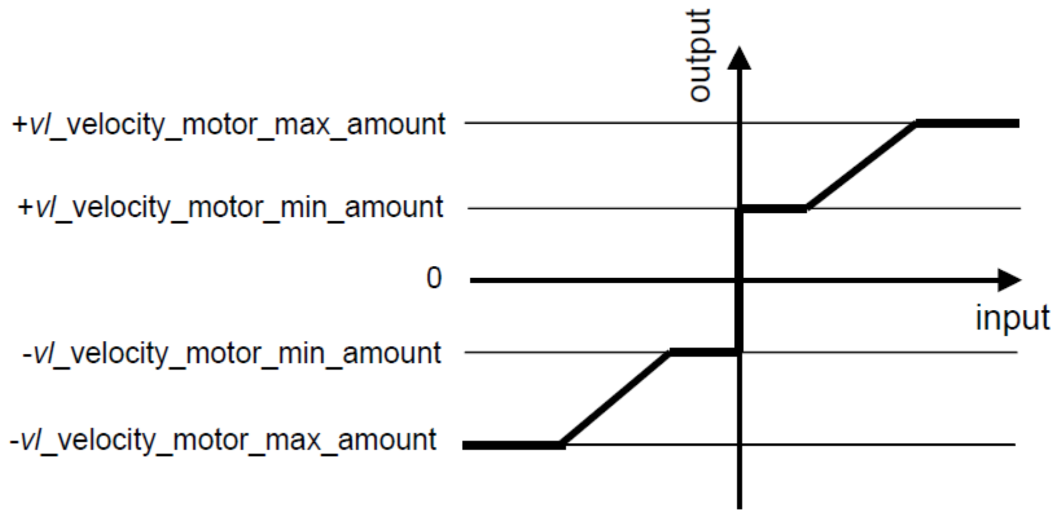
The next figure shows the structure of the statusword.

15 … 14	13 … 12	11	10	9 … 0
(see 8.4.2)	reserved (0)	(see 8.4.2)	reserved (0)	(see 8.4.2)
MSB				LSB

Picture 25: Statusword in vl-mode

5.2.6.10.1 vl velocity min max amount 0x6046

This object shall indicate the configured minimum and maximum amount of velocity. The values shall be given in rotations per minute (rpm)

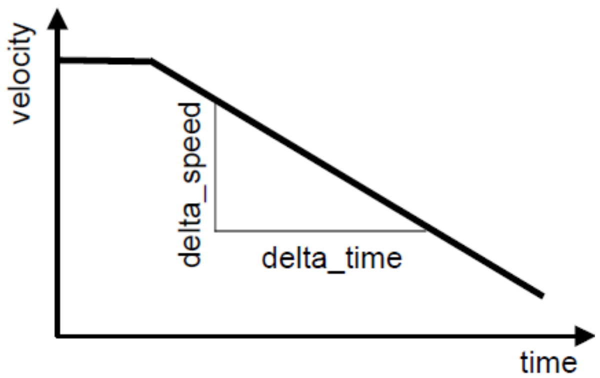


Picture 26: Transfer characteristic of vl velocity min max amount

5.2.6.10.2 vl velocity acceleration 0x6048

The value for acceleration is the same as for deceleration. This object shall indicate the configured delta speed and delta time of the slope of the deceleration ramp as shown in next figure.

$$vl\ velocity\ deceleration = \frac{delta\ speed}{delta\ time}$$



Picture 27: Transfer characteristic of the velocity deceleration

5.2.6.11 Profile velocity mode

The SMC3 must be in state Operational. With the object 0x6060 Modes of operation you are able to change with the value 3 to the profile velocity mode. The following controlword 0x6040 is than valid:

15 … 9	8	7	6 … 4	3 … 0
(see 8.4.1)	*Halt*	(see 8.4.1)	*reserved*	(see 8.4.1)
MSB				LSB

Picture 28: Controlword in profile velocity mode

The following statusword 0x6041 is than valid:

15 … 14	13	12	11	10	9 … 0
(see 8.4.2)	Max slippage error	Speed	(see 8.4.2)	Target reached	(see 8.4.2)
MSB					LSB

Picture 29: Statusword in profile velocity mode

Bit	Value	Definition
10	0	Halt (Bit 8 in controlword) = 0: Target not reached Halt (Bit 8 in controlword) = 1: Axis decelerates
	1	Halt (Bit 8 in controlword) = 0: Target reached Halt (Bit 8 in controlword) = 1: Velocity of axis is 0
12	0	Speed is not equal 0
	1	Speed is equal 0
13	0	Maximum slippage not reached
	1	Maximum slippage reached

Picture 30: Definitions of bit 10, 12, 13

5.2.6.12 Touchprobe

The Function Group "Touch Probe" uses only the digital input 1 (Probe 1) and digital input 2 (Probe 2). The following objects are used:

Object	Name
0x60B8	Touch probe function
0x60B9	Touch probe status
0x60BA	Touch probe position 1 positive value
0x60BB	Touch probe position 1 negative value
0x60BC	Touch probe position 2 positive value
0x60BD	Touch probe position 2 negative value

Table 64: Touchprobe Objects

The object of "Touch probe function" 0x60B8 used this bit combinations:

BIT	Value	Definitions
0	0 1	Switch off touch probe 1 Enable touch probe 1
1	0 1	Trigger first event continuous
3,2	00 01	Trigger with touch probe 1 input Trigger with zero impulse signal
4	0 1	Switch off sampling at positive edge of touch probe 1 Enable sampling at positive edge of touch probe 1
5	0 1	Switch off sampling at negative edge of touch probe 1 Enable sampling at negative edge of touch probe 1
8	0 1	Switch off touch probe 2 Enable touch probe 2
9	0 1	Trigger first event continuous
11,10	00	Trigger with touch probe 2 input

BIT	Value	Definitions
	01	Trigger with zero impulse signal
12	0 1	Switch off sampling at positive edge of touch probe 2 Enable sampling at positive edge of touch probe 2
13	0 1	Switch off sampling at negative edge of touch probe 2 Enable sampling at negative edge of touch probe 2

Table 65: Value definition object 0x60B8

It is not allowed to use both probe on the zero impule signal of the encoder!

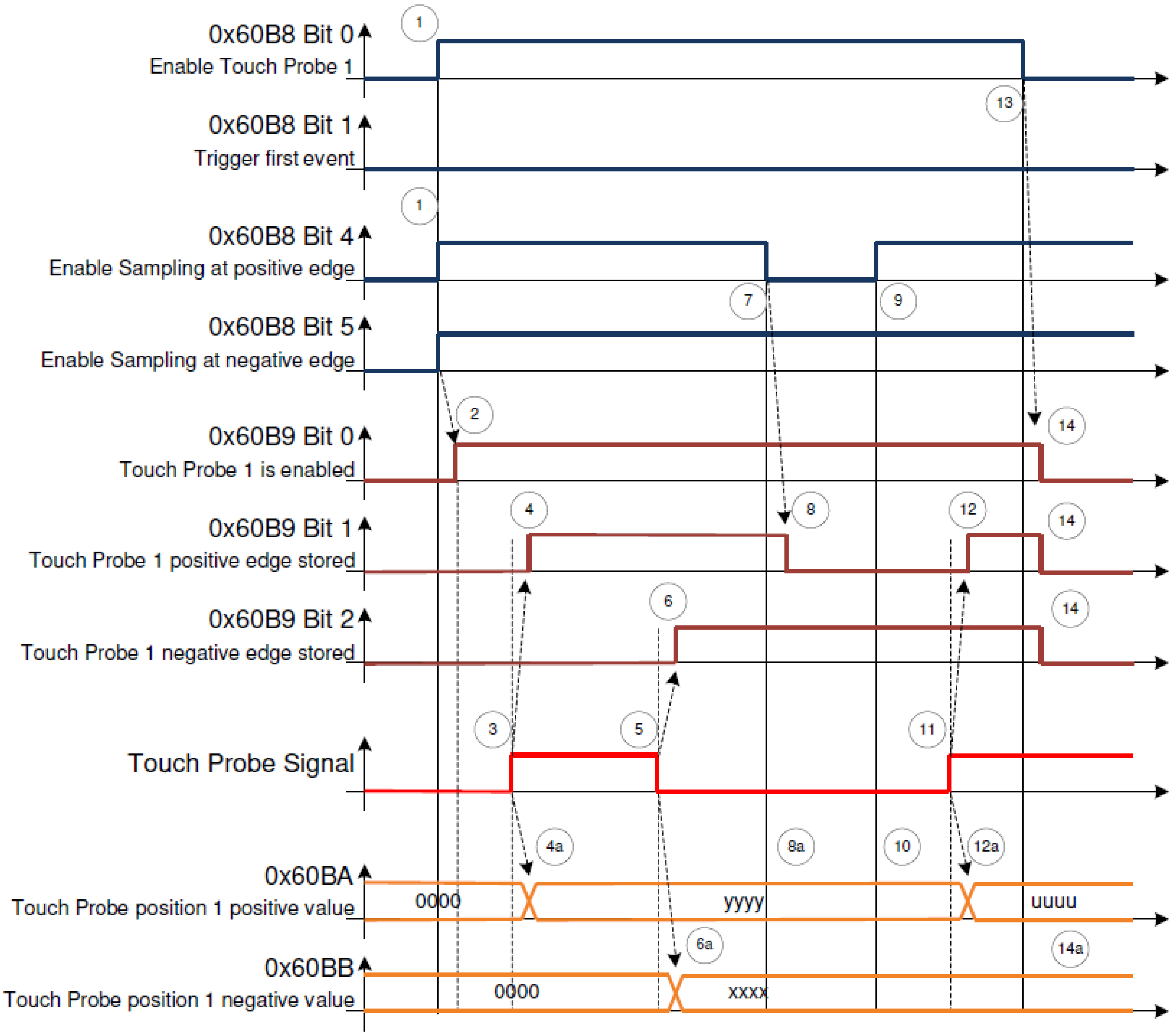
The object of "Touch probe status" 0x60B9 used this bit combinations:

BIT	Value	Definitions
0	0 1	Touch probe 1 is switched off Touch probe 1 is enabled
1	0 1	Touch probe 1 no positive edge value stored Touch probe 1 positive edge position stored
2	0 1	Touch probe 1 no negative edge value stored Touch probe 1 negative edge position stored
8	0 1	Touch probe 2 is switched off Touch probe 2 is enabled
9	0 1	Touch probe 2 no positive edge value stored Touch probe 2 positive edge position stored
10	0 1	Touch probe 2 no negative edge value stored Touch probe 2 negative edge position stored

Table 66: Value definition object 0x60B9

Bit 1 and bit 2 are set to 0b when touch probe 1 is switched off (object 60B8h bit 0 is 0b). Bit 9 and 10 are set to 0b when touch probe 2 is switched off (object 60B8h bit 8 is 0b).

The next figure shows a timing diagram for a touch probe configuration and the corresponding behaviour.



Picture 31: Timing diagram for Touch probe example

Number	Touch probe behaviour
1	0x60B8, Bit 0 = 1 Enable Touch Probe 1, 0x60B8 Bit 1, 4, 5 Configure and Enable Touch Probe 1 positive and negative edge
2	→ 0x60B9 Bit 0 = 1 Status ―Touch Probe 1 enabled‖ is set
3	External touch probe signal has positive edge
4	→ 0x60B9 Bit 1 = 1 Status ―Touch Probe 1 positve edge stored‖ is set
4a	→ 0x60BA Touch probe position 1 positive value is stored
5	External touch probe signal has negative edge
6	→ 0x60B9 Bit 2 = 1 Status ―Touch Probe 1 negative edge stored‖ is set
6a	→ 0x60BB Touch probe position 1 negative value is stored
7	0x60B8:4 Sample positive edge is disabled
8	→ 0x60B9 Bit 0 = 0 Status ―Touch Probe 1 positve edge stored‖ is reset
8a	→ 0x60BA Touch probe position 1 positive value is not changed
9	0x60B8 Bit 4 = 1 Sample positive edge is enabled
10	→ 0x60BA Touch probe position 1 positive value is not changed
11	External touch probe signal has positive edge
12	→ 0x60B9 Bit 1 = 1 Status ―Touch Probe 1 positve edge stored‖ is set

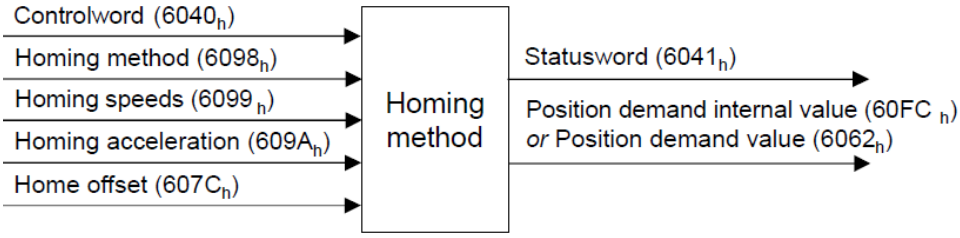
Number	Touch probe behaviour
12a	→ 0x60BA Touch probe position 1 positive value is stored
13	0x60B8 Bit 0 = 0 Touch Probe 1 is disabled
14	→ 0x60B9 Bit 0, 1, 2 = 0 Status Bits are reset
14a	→ 0x60BA, 0x60BB Touch probe position 1 positive/negative value are not changed

Table 67: Touch Probe Timing example

5.2.6.13 EtherCAT homing modes 0x6098

This clause describes the methods by which a drive seeks its home position. There are various methods of achieving this by using block, limit switches or homing switches. Most of the methods also use the index (zero) pulse train from an incremental encoder. The SMC3 must be in state Operational. With the object 0x6060 Modes of operation you are able to change with the value 6 to the homing mode.

The next figure shows the defined input objects as well as the output objects. The user may specify the speeds, acceleration and the method of homing. There is a further object home offset, which allows the user to displace zero in the user's coordinate system from the home position.



Picture 32: Homing function

There are two homing speeds; in a typical cycle, the faster speed is used to find the home switch and the slower speed is used to find the index pulse.

15 … 9	8	7	6 … 5	4	3 … 0
(see 10.3.1)	Halt	(see 10.3.1)	reserved	Homing operation start	(see 10.3.1)
MSB					LSB

Picture 33: Controlword in homing mode

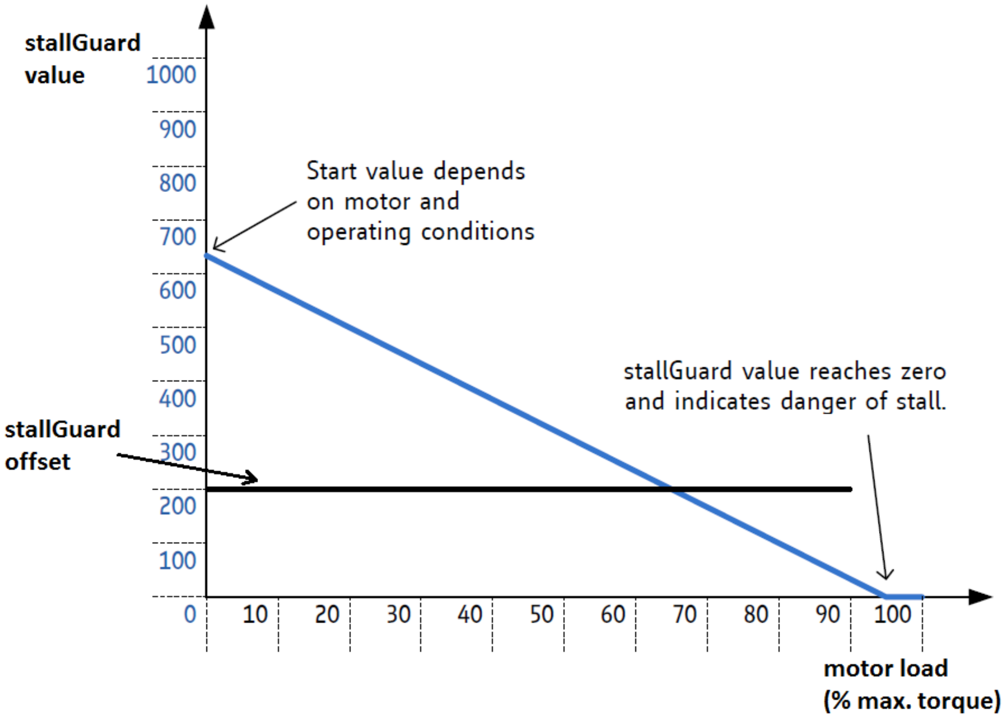
15 … 14	13	12	11	10	9 … 0
(see 10.3.2)	Homing error	Homing attained	(see 10.3.2)	Target reached	(see 10.3.2)
MSB					LSB

Picture 34: Statursword in homing mode

5.2.6.13.1 Homing method: 0 – Homing on block

Using this method, the initial direction of movement shall be selected in the object 0x2021 Smc3 Homing Parameter. The homing speed is here only the speed for switch searching. The default parameter are very good for a lot of stepper motors, you could adjust this, but you have to know, that the internal torque measuring works with back EMF and works good at velocity greater 100rpm.

The stallGuard (internal torque mode) measurement value changes linearly over a wide range of load, velocity, and current settings, as shown in next figure. At maximum motor load, the value goes to zero or near to zero. This corresponds to a load angle of 90° between the magnetic field of the coils and magnets in the rotor.



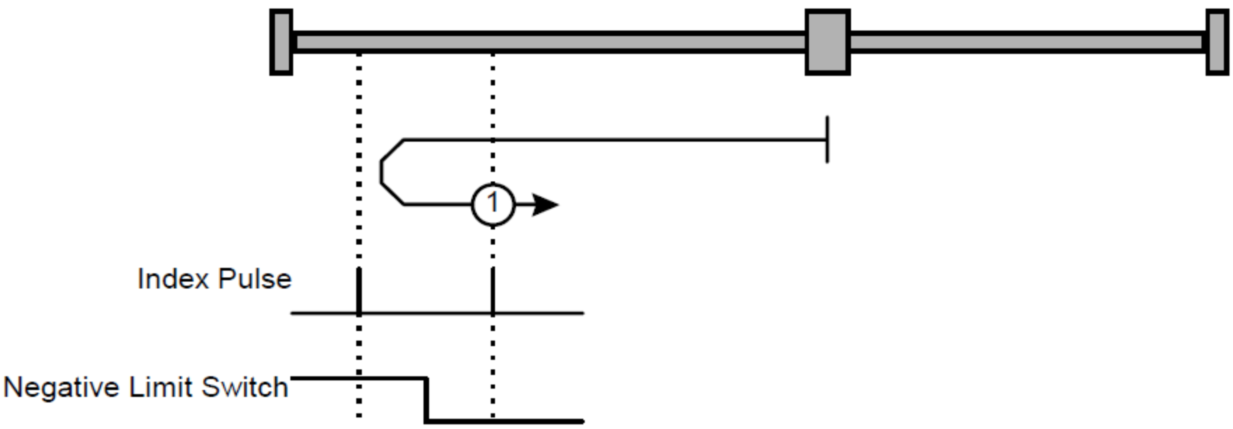
Picture 35: Figure 33: Homing on block

When you start homing on block, then the motor accelerates fast to the velocity and has a stallGuard value (internal torque value) greater 0 (e.g. 300). If the load increased, then the stallGuard value fells under the stallGuard offset and when on block to stallGuard 0.

If you don´t want to drive hard on a block, so you can set a stallGuard offset value (object 0x2022) and the motor will stall by underrange this value. You could adjust this value and also the stallGuard turns value (object 0x 2023) to select how often the underrange should be allowed before the motor stalls. Because some time you are setting good values and the motor stalls before the block is found. This could happen due to dirt particles or friction or something else.

5.2.6.13.2 Homing method: 1 – Homing on negative limit switch and index pulse

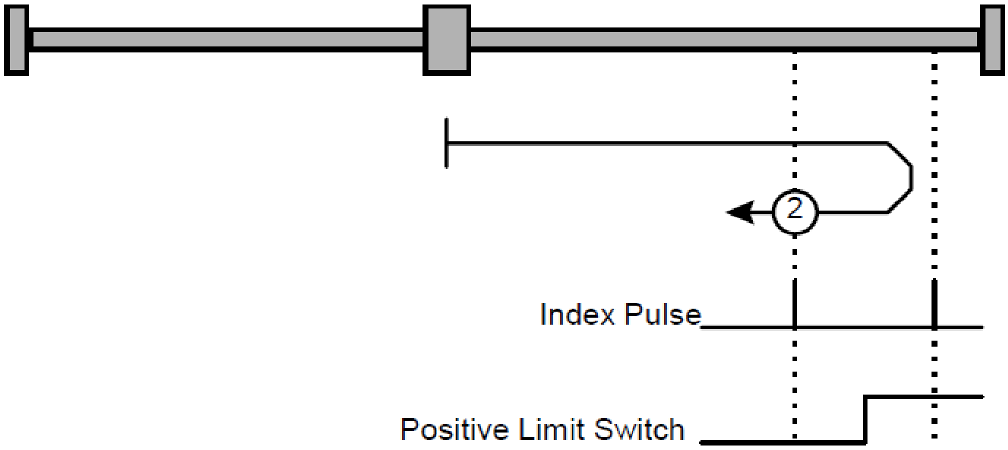
Using this method as shown in next figure, the initial direction of movement shall be leftward if the negative limit switch is inactive (here: low). The home position shall be at the first index pulse to the right of the position where the negative limit switch becomes inactive.



Picture 36: Homing on negative limit switch and index pulse

5.2.6.13.3 Homing method: 2 – Homing on positive limit switch and index pulse

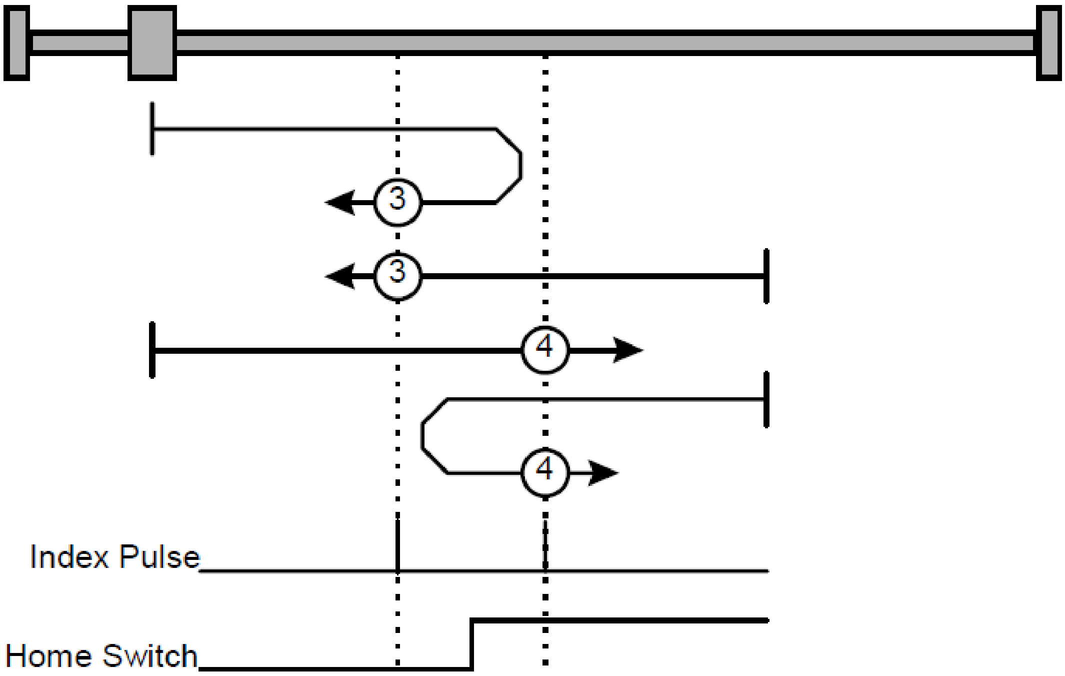
Using this method as shown in next figure, the initial direction of movement shall be rightward if the positive limit switch is inactive (here: low). The position of home shall be at the first index pulse to the left of the position where the positive limit switch becomes inactive.



Picture 37: Homing on positive limit switch and index pulse

5.2.6.13.4 Homing method: 3,4 - Homing on positive home switch and index pulse

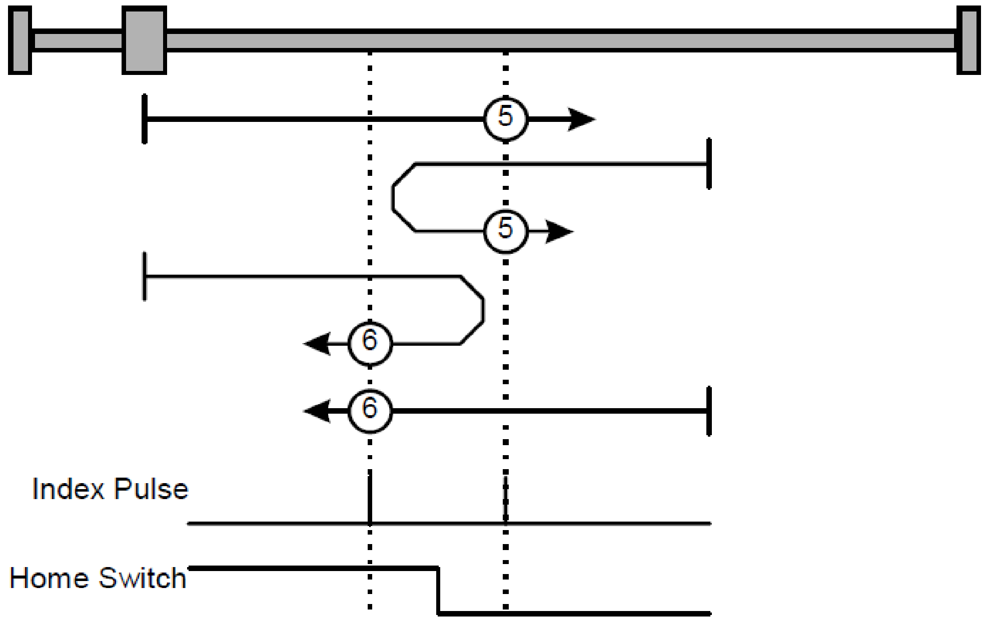
Using these methods as shown in next figure, the initial direction of movement shall be dependent on the state of the home switch. The home position shall be at the index pulse to either to the left or the right of the point where the home switch changes state. If the initial position is situated so that the direction of movement shall reverse during homing, the point at which the reversal takes place is anywhere after a change of state of the home switch.



Picture 38: Homing on positive home switch and index pulse

5.2.6.13.5 Homing method: 5,6 - Homing on negative home switch and index pulse

Using these methods as shown in next figure, the initial direction of movement shall be dependent on the state of the home switch. The home position shall be at the index pulse to either to the left or the right of the point where the home switch changes state. If the initial position is situated so that the direction of movement shall reverse during homing, the point at which the reversal takes place is anywhere after a change of state of the home switch.



Picture 39: Homing on negative home switch and index pulse

5.2.6.13.6 Homing method: 17,18 – Homing on negative/positive limit switch without index pulse

These methods are similar to methods 1 and 2 except that the home position is not dependent on the index pulse but only dependent on the relevant home or limit switch transitions.

5.2.6.13.7 Homing method: 19,20 - Homing on positive home switch without index pulse

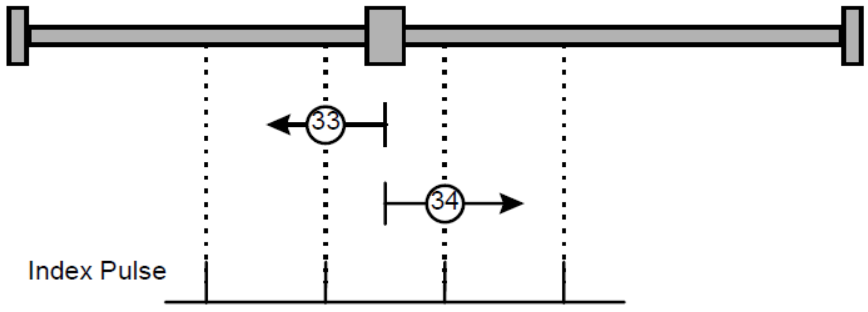
These methods are similar to methods 3 and 4 except that the home position is not dependent on the index pulse but only dependent on the relevant home or limit switch transitions.

5.2.6.13.8 Homing method: 21,22 - Homing on negative home switch and without index pulse

These methods are similar to methods 5 and 6 except that the home position is not dependent on the index pulse but only dependent on the relevant home or limit switch transitions.

5.2.6.13.9 Homing method: 33,34 - Homing on index pulse

Using these methods, the direction of homing is negative or positive respectively. The home position shall be at the index pulse found in the selected direction as shown in next figure.



Picture 40: Homing on index pulse

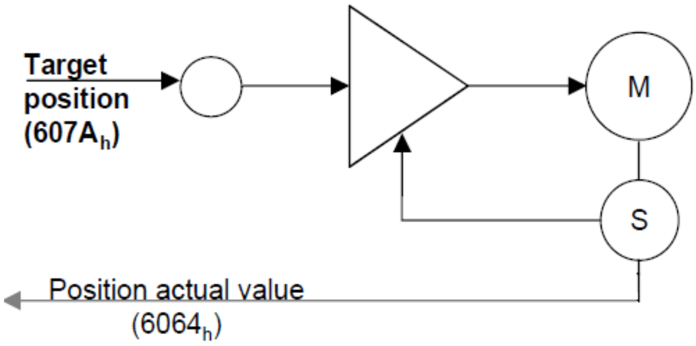
5.2.6.13.10 Homing method: 37 - Homing on current position

In this method, the current position shall be taken to be the home position.

5.2.6.14 Cyclic synchronous position mode

With the object 0x6060 Modes of operation you are able to change with the value 8 to the csp mode.

With this mode, the trajectory generator is located in the control device, not in the drive device. In cyclic synchronous manner, it provides a target position to the drive device, which performs position control, velocity control.

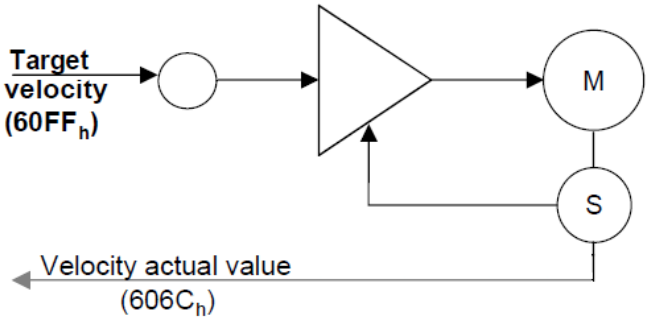


Picture 41: CSP mode

5.2.6.15 Cyclic synchronous velocity mode

With the object 0x6060 Modes of operation you are able to change with the value 9 to the csv mode.

With this mode, the trajectory generator is located in the control device, not in the drive device. In cyclic synchronous manner, it provides a target velocity to the drive device, which performs velocity control.



Picture 42: CSV mode

6 Adjustment of motor chip

All of the following explanations are mainly from the TMC262 DATASHEET (Rev. 2.14 / 2016-JUL-14) from the Company TRINAMIC Motion Control GmbH & Co. KG, and have been adapted to the SMC3. The SMC3 works with a frequency of 16MHz so one clock takes 0,0000000625s.

6.1 Register overview for adjustment

In most applications are the default register settings enough. We use three register for adjustment, which could be find in the sercos parameter or in the EtherCAT objects.

TMC Register	Sercos	EtherCAT	Features in the register
CHOPCONF	P-0-4000.0.1	0x8010:02	spreadCycle™ high-precision chopper for best current sine wave form and zero crossing
SMARTEN	P-0-4000.0.2	0x8010:03	coolStep™ load dependent current control for energy savings up to 75%
SGCSCONF	P-0-4000.0.3	0x8010:04	stallGuard2™ high precision sensorless motor load detection

Table 68: Relation of TMC Register to IDN/Object

Bit	Name	TMC Register	Comment
19	1	Register address bit	
18	0	Register address bit	
17	0	Register address bit	
16	TBL1	Blanking time	Blanking time interval, in system clock periods: %00: 16 %01: 24 %10: 36 %11: 54
15	TBL0		
14	-	-	-
13	RNDTF	Random TOFF time	Enable randomizing the slow decay phase duration: 0: Chopper off time is fixed as set by bits t_{OFF} 1: Random mode, t_{OFF} is random modulated by dN_{CLK}= -12 … +3 clocks.
12	HDEC1	Hysteresis decrement	Hysteresis decrement period setting, in system clock periods: %00: 16 %01: 32 %10: 48 %11: 64
11	HDEC0		
10	HEND3	Hysteresis end (low) value	%0000 … %1111: Hysteresis is -3, -2, -1, 0, 1, …, 12 (1/512 of this setting adds to current setting) This is the hysteresis value which becomes used for the hysteresis chopper.
9	HEND2		
8	HEND1		
7	HEND0		
6	HSTRT2	Hysteresis start value	Hysteresis start offset from HEND: %000: 1 %100: 5 %001: 2 %101: 6 %010: 3 %110: 7 %011: 4 %111: 8 Effective: HEND+HSTRT must be ≤ 15
5	HSTRT1		
4	HSTRT0		
3	TOFF3		

Bit	Name	TMC Register	Comment
2	TOFF2	Off time/MOSFET disable	Duration of slow decay phase. If TOFF is 0, the MOSFETs are shut off. If TOFF is nonzero, slow decay time is a multiple of system clock periods: N_{CLK}= 12 + (32 x TOFF) (Minimum time is 64clocks.) %0000: Driver disable, all bridges off %0001: 1 (use with TBL of minimum 24 clocks) %0010 … %1111: 2 … 15
1	TOFF1		
0	TOFF0		

Table 69: CHOPCONF -TMC Register (spreadCycle)

Bit	Name	TMC Register	Comment
19	1	Register address bit	
18	0	Register address bit	
17	1	Register address bit	
16	-		
15	SEIMIN	Minimum coolStep current	0: ½ CS current setting 1: ¼ CS current setting
14	SEDN1	Current decrement speed	Number of times that the stallGuard2 value must be sampled equal to or above the upper threshold for each decrement of the coil current: %00: 32 %01: 8 %10: 2 %11: 1
13	SEDN0		
12	-		
11	SEMAX3	Upper coolStep threshold as an offset from the lower threshold	If the stallGuard2 measurement value SG is sampled equal to or above (SEMIN+SEMAX+1) x 32 enough times, then the coil current scaling factor is decremented.
10	SEMAX2		
9	SEMAX1		
8	SEMAX0		
7	-		
6	SEUP1	Current increment size	Number of current increment steps for each time that the stallGuard2 value SG is sampled below the lower threshold: %00: 1 %01: 2 %10: 4 %11: 8
5	SEUP0		
4	-		
3	SEMIN3	Lower coolStep threshold/coolStep disable	If SEMIN is 0, coolStep is disabled. If SEMIN is nonzero and the stallGuard2 value SG falls below SEMIN x 32, the coolStep current scaling factor is increased.
2	SEMIN2		
1	SEMIN1		
0	SEMIN0		

Table 70: SMARTEN -TMC Register (coolStep)

Bit	Name	TMC Register	Comment
19	1	Register address bit	
18	1	Register address bit	
17	0	Register address bit	

Bit	Name	TMC Register	Comment
16	SFILT	stallGuard2 filter enable	0: Standard mode, fastest response time. 1: Filtered mode, updated once for each four fullsteps to compensate for variation in motor construction, highest accuracy.
15	-		
14	SGT6	stallGuard2 threshold value	The stallGuard2 threshold value controls the optimum measurement range for readout and stall indicator output (SG_TST). A lower value results in a higher sensitivity and less torque is required to indicate a stall. The value is a two's complement signed integer. Values below -10 are not recommended. Range: -64 to +63
13	SGT5		
12	SGT4		
11	SGT3		
10	SGT2		
9	SGT1		
8	SGT0		
7	-		
6	-		
5	-		
4	CS4	Current scale	This setting is not allowed to overwrite, because the desired current in P-0-4000.0.10 or in 0x8010:A is almoust calculated and set into this CS register. The user should read this value only after setting the right desired current, and use the CS value for the calculation of $Hysteresis\ Start$ in **Fehler! Verweisquelle konnte nicht gefunden werden.**.
3	CS3		
2	CS2		
1	CS1		
0	CS0		

Table 71: SGCSCONF -TMC Register (stallGuard)

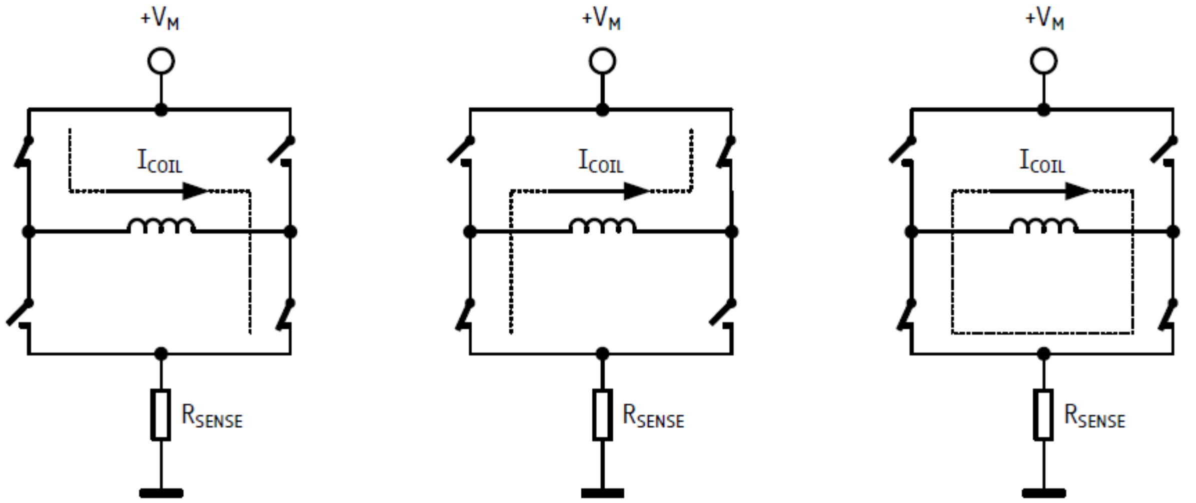
6.2 Tool: TMC26x Configurator V1.01

Use the TMC26x Configuration V1.01 Tool to read or write the register values, but don´t use other settings, that are not mentioned in this documentation. First write your desired current value and then read all the default values over your master befor youyou're your needed register bits.

6.3 Configuration of the most important motor setting

Before you improve the motor parameter you should disabled the in the register SMARTEN the coolStep (for automatic energy saving), by setting SEMIN to 0.

The currents through both motor coils are controlled using choppers. The choppers work independently of each other. Next figure shows the three chopper phases:



Picture 43: chopper phase

Although the current could be regulated using only on phases and fast decay phases, insertion of the slow decay phase is important to reduce electrical losses and current ripple in the motor. The duration of the slow decay phase is specified in a control parameter and sets an upper limit on the chopper frequency. The current comparator can measure coil current during phases when the current flows through the sense resistor, but not during the slow decay phase, so the slow decay phase is terminated by a timer. The on phase is terminated by the comparator when the current through the coil reaches the target current. The fast decay phase may be terminated by either the comparator or another timer.

When the coil current is switched, spikes at the sense resistors occur due to charging and discharging parasitic capacitances. During this time, typically one or two microseconds, the current cannot be measured. Blanking is the time when the input to the comparator is masked to block these spikes.

There is only one chopper modes available: a high-performance chopper algorithm called spreadCycle. The spreadCycle mode cycles through four phases: on, slow decay, fast decay, and a second slow decay.

Two parameters are used for controlling the chopper mode:

Parameter	Description	Setting	Comment
TOFF	Off time. This setting controls the duration of the slow decay time and limits the maximum chopper frequency. For most applications an off time within the range of 5µs to 20µs will fit. If the value is 0, the MOSFETs are all shut off and the motor can freewheel. A value of 1 to 15 sets the number of system clock cycles in the slow decay phase to: $NCLK$ = ($TOFF$ * 32) + 12 The SD-Time is	0 1… 15	Chopper off. Off time setting. (1 will work with minimum blank time of 24 clocks.)

Parameter	Description	Setting	Comment
	t_{SD} = 1/16MHz * $NCLK$ **Automata usese 16MHz clock.**		
TBL	Blanking time. This time needs to cover the switching event and the duration of the ringing on the sense resistor. For most low-current applications, a setting of 16 or 24 is good. For high-current applications, a setting of 36 or 54 may be required. **Automata usese 16MHz clock.**	0	16 system clock cycles
		1	24 system clock cycles
		2	36 system clock cycles
		3	54 system clock cycles

Table 72: Important paramters for the motor chip

The spreadCycle chopper algorithm is a precise and simple to use chopper mode which automatically determines the optimum length for the fast-decay phase. Several parameters are available to optimize the chopper to the application.

Each chopper cycle is comprised of an on phase, a slow decay phase, a fast decay phase and a second slow decay phase. The slow decay phases limit the maximum chopper frequency and are important for low motor and driver power dissipation. The hysteresis start setting limits the chopper frequency by forcing the driver to introduce a minimum amount of current ripple into the motor coils. The motor inductance limits the ability of the chopper to follow a changing motor current. The duration of the on phase and the fast decay phase must be longer than the blanking time, because the current comparator is disabled during blanking. This requirement is satisfied by choosing a positive value for the hysteresis as can be estimated by the following calculation:

$$dI_{COILBLANK} = V_M * \frac{t_{BLANK}}{L_{COIL}}$$

$$dI_{COILSD} = R_{COIL} * I_{COIL} * \frac{2 * t_{SD}}{L_{COIL}}$$

Picture 44: Formula for different current

(e.g. $dI_{COILBLANK}$ = 24V * 0,0000015/0,0128H = 0,0028A)

(e.g. dI_{COILSD} = 2,6Ω * 8A * 2 * 0,00001875s/0,0128H = 0,061A)

where:

$dI_{COILBLANK}$ is the coil current change during the blanking time.

dI_{COILSD} is the coil current change during the slow decay time.

t_{SD} is the slow decay time. (e.g. 1/16MHz * (9*32+12) = 0,00001875s)

t_{BLANK} is the blanking time (as set by TBL). (e.g. 1/16MHz * 24 system clock cycles = 0,0000015s)

V_M is the motor supply voltage. (for SMC3 24V or 48V)

I_{COIL} is the peak motor coil current at the maximum motor current setting CS. (SMC3 has always 8A)

R_{COIL} and L_{COIL} are motor coil inductance and motor coil resistance.

With this, a lower limit for the start hysteresis setting can be determined:

$$Hysteresis\ Start \geq (dI_{COILBLANK} + dI_{COILSD}) * \frac{2 * 248}{I_{COIL}} * \frac{CS + 1}{32}$$

Picture 45: Formula for Hysteresis Start

(e.g. $Hysteresis\ Start$ = (0,0028A+0,061A) * 2*248/8A * (CS+1)/32) = 1)

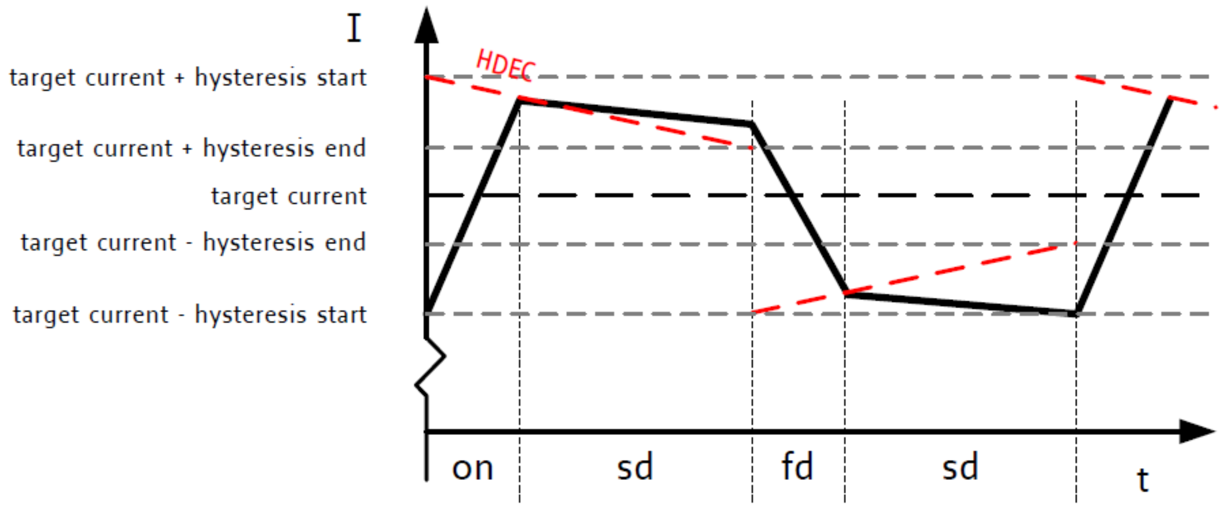
The CS value you should read out from the register SGCSCONF after you write your desired motor currten in P-0-4000.0.10 or in 0x8000:A.

Now the user has to write into the HEND (Register value of CHOPCONF) the value $Hysteresis\ Start$ – 1. (e.g. HEND = 0)

Now the user has to write into the HSTR (Register value of CHOPCONF) a value $Hysteresis\ Start$ - $Hysteresis\ Start$ + 3. (e.g. HSTR = 3)

As experiments show, the setting is quite independent of the motor, because higher current motors typically also have a lower coil resistance. Choosing a medium default value for the hysteresis (for example, effective HSTRT+HEND=10) normally fits most applications. The setting can be optimized by experimenting with the motor: A too low setting will result in reduced microstep accuracy, while a too high setting will lead to more chopper noise and motor power dissipation.

The hysteresis principle could in some cases lead to the chopper frequency becoming too low, for example when the coil resistance is high compared to the supply voltage. This is avoided by splitting the hysteresis setting into a start setting (HSTRT+HEND) and an end setting (HEND). An automatic hysteresis decrementer (HDEC) interpolates between these settings, by decrementing the hysteresis value stepwise each 16, 32, 48, or 64 system clock cycles. At the beginning of each chopper cycle, the hysteresis begins with a value which is the sum of the start and the end values (HSTRT+HEND), and decrements during the cycle, until either the chopper cycle ends or the hysteresis end value (HEND) is reached. This way, the chopper frequency is stabilized at high amplitudes and low supply voltage situations, if the frequency gets too low. This avoids the frequency reaching the audible range.



Picture 46: spreadCycle chopper mode showing the coil current during a chopper cycle

Three parameters control spreadCycle mode:

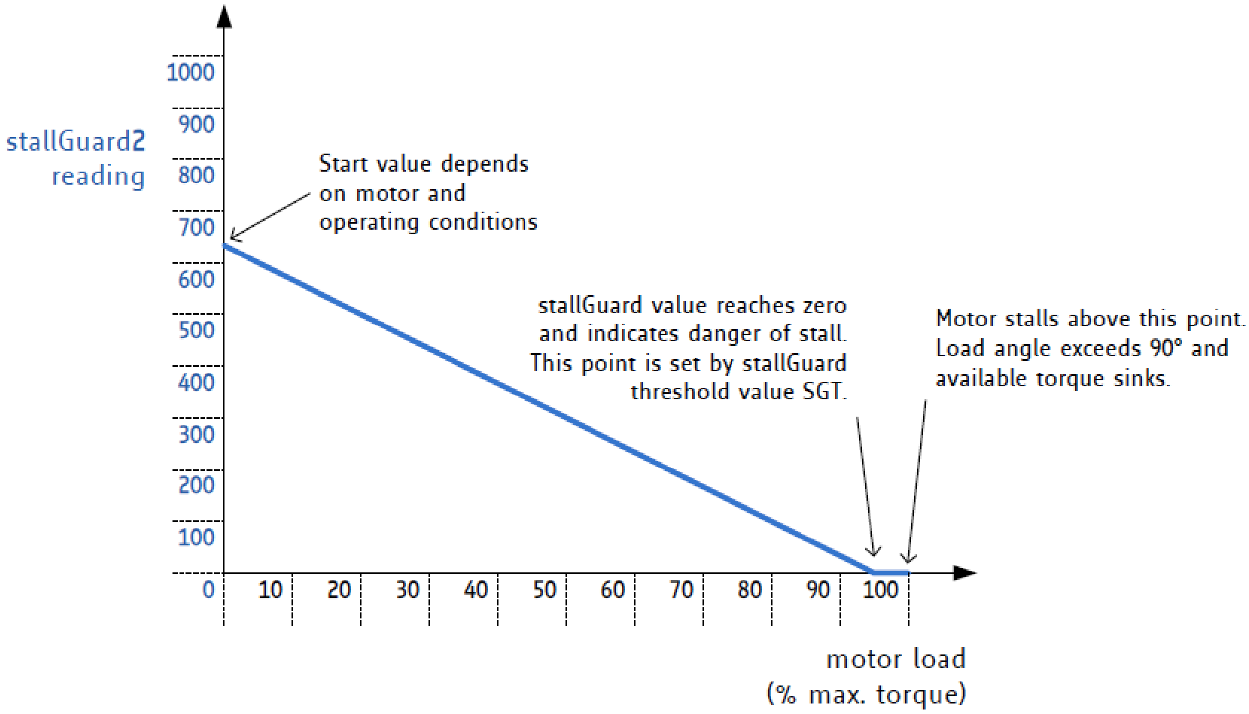
Parameter	Description	Range	Comment
HSTART	*Hysteresis start* setting. Please remark, that this value is an offset to the hysteresis end value HEND.	1…8	This setting adds to HEND.
HEND	*Hysteresis end* setting. Sets the hysteresis end value after a number of decrements. Decrement interval time is controlled by HDEC.	-3…12	-3..-1: negative HEND 0: zero HEND 1…12: positive HEND
HDEC	*Hysteresis decrement* setting. This setting determines the slope of the hysteresis during on time and during fast decay time.	0…3	0: fast decrement 3: very slow decrement

Table 73: spreedCycle parameter

6.4 stallGuard2 (load measurement)

The stallGuard2 provides an accurate measurement of the load on the motor. It can be used for stall detection as well as other uses at loads below those which stall the motor, such as coolStep loadadaptive current reduction.

The stallGuard2 measurement value changes linearly over a wide range of load, velocity, and current settings, as shown in next Figure. At maximum motor load, the value goes to zero or near to zero. This corresponds to a load angle of 90° between the magnetic field of the coils and magnets in the rotor. This also is the most energy-efficient point of operation for the motor.



Picture 47: stallGuard2 load measurement SG as a function of load

Two parameters control stallGuard2 and one status value is returned in P-0-.4002.4.0 or 0x2024.

Parameter	Description	Setting	Comment
SGT	7-bit signed integer that sets the stallGuard2 threshold level for asserting the SG_TST output and sets the optimum measurement range for readout. Negative values increase sensitivity, and positive values reduce sensitivity so more torque is required to indicate a stall. Zero is a good starting value. Operating at values below - 10 is not recommended.	0	indifferent value
		+1… +63	less sensitivity
		-1… -64	higher sensitivity
SFILT	Mode bit which enables the stallGuard2 filter for more precision. If set, reduces the measurement frequency to one measurement per four fullsteps. If cleared, no filtering is performed. Filtering compensates for mechanical asymmetries in the construction of the motor, but at the expense of response time. Unfiltered operation is recommended for rapid stall detection. Filtered operation is recommended for more precise load measurement.	0	standard mode
		1	filtered mode

Table 74: stallGuard2 parameter

6.4.1 Tuning the stallGuard threshold

Due to the dependency of the stallGuard2 value SG from motor-specific characteristics and application-specific demands on load and velocity the easiest way to tune the stallGuard2 threshold SGT for a specific motor type and operating conditions is interactive tuning in the actual application.

The procedure is:

1. Operate the motor at a reasonable velocity for your application and monitor SG.

2. Apply slowly increasing mechanical load to the motor. If the motor stalls before SG reaches zero, decrease SGT. If SG reaches zero before the motor stalls, increase SGT. A good SGT starting value is zero. SGT is signed, so it can have negative or positive values.

3. The optimum setting is reached when SG is between 0 and 400 at increasing load shortly before the motor stalls, and SG increases by 100 or more without load. SGT in most cases can be tuned together with the motion velocity in a way that SG goes to zero when the motor stalls and the stall output SG_TST is asserted. This indicates that a step has been lost.

6.4.2 Further stallGuard informations

Across a range of velocities, on-the-fly adjustment of the stallGuard2 threshold SGT improves the accuracy of the load measurement SG. This also improves the power reduction provided by coolStep, which is driven by SG. Linear interpolation between two SGT values optimized at different velocities is a simple algorithm for obtaining most of the benefits of on-the-fly SGT adjustment.

Motors with a high detent torque show an increased variation of the stallGuard2 measurement value SG with varying motor currents, especially at low currents. For these motors, the current dependency might need correction in a similar manner to velocity correction for obtaining the highest accuracy.

Motors working over a wide temperature range may require temperature correction, because motor coil resistance increases with rising temperature. This can be corrected as a linear reduction of SG at increasing temperature, as motor efficiency is reduced.

The stallGuard2 measurement value SG is updated with each full step of the motor. This is enough to safely detect a stall, because a stall always means the loss of four full steps. In a practical application, especially when using coolStep, a more precise easurement might be more important than an update for each fullstep because the mechanical load never changes instantaneously from one step to the next. For these applications, the SFILT bit enables a filtering function over four load measurements. The filter should always be enabled when high-precision measurement is required. It compensates for variations in motor construction, for example due to misalignment of the phase A to phase B magnets. The filter should only be disabled when rapid response to increasing load is required, such as for stall detection at high velocity.

To safely detect a motor stall, a stall threshold must be determined using a specific SGT setting. Therefore, you need to determine the maximum load the motor can drive without stalling and to monitor the SG value at this load, for example some value within the range 0 to 400. The stall threshold should be a value safely within the operating limits, to allow for parameter stray.

stallGuard2 does not operate reliably at extreme motor velocities: Very low motor velocities (for many motors, less than one revolution per second) generate a low back EMF and make the measurement unstable and dependent on environment conditions (temperature, etc.). Other conditions will also lead to extreme settings of SGT and poor response of the measurement value SG to the motor load.

Very high motor velocities, in which the full sinusoidal current is not driven into the motor coils also lead to poor response. These velocities are typically characterized by the motor back EMF reaching the supply voltage.

6.5 coolStep (load adaptive current control)

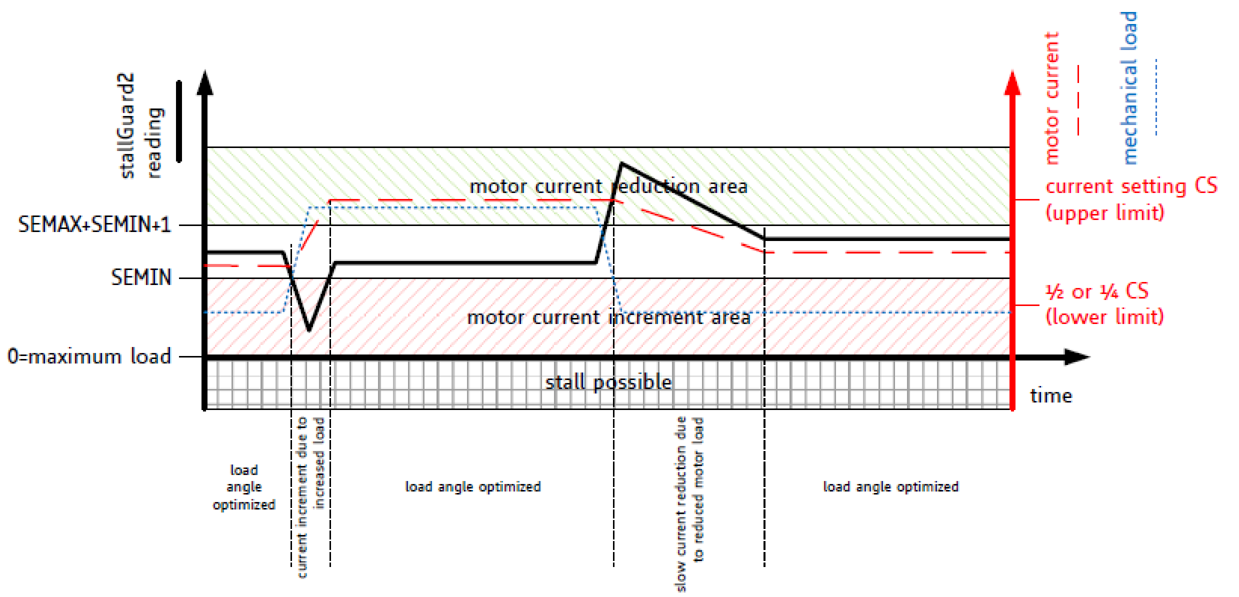
coolStep allows substantial energy savings, especially for motors which see varying loads or operate at a high duty cycle. Because a stepper motor application needs to work with a torque reserve of 30% to 50%, even a constant-load application allows significant energy savings because coolStep automatically enables torque reserve when required. Reducing power consumption keeps the system cooler, increases motor life, and allows reducing cost in the power supply and cooling components.

coolStep is controlled by several parameters, but two are critical for understanding how it works:

Parameter	Description	Setting	Comment
SEMIN	4-bit unsigned integer that sets a lower threshold. If SG goes below this threshold, coolStep increases the current to both coils. The 4-bit SEMIN value is scaled by 32 to cover the lower half of the range of the 10-bit SG value.	0… 15	lower stallGuard threshold: SEMINx32
SEMAX	4-bit unsigned integer that controls an upper threshold. If SG is sampled equal to or above this threshold enough times, coolStep decreases the current to both coils. The upper threshold is (SEMIN + SEMAX + 1) x 32.	0… 15	upper stallGuard threshold: (SEMIN+SEMAX+1)x32
SEUP	Number of increments of the coil current for each occurrence of an SG measurement below the lower threshold.	0… 3	step width is: 1, 2, 4, 8
SEDN	Number of occurrences of SG measurements above the upper threshold before the coil current is decremented.	0… 3	number of stallGuard measurements per decrement: 32, 8, 2, 1
SEIMIN	Mode bit that controls the lower limit for scaling the coil current. If the bit is set, the limit is ¼ CS. If the bit is clear, the limit is ½ CS.	0 1	Minimum motor current: 1/2 of CS 1/4 of CS

Table 75: Parameter for coolStep

Next Figure shows the operating regions of coolStep. The black line represents the SG measurement value, the blue line represents the mechanical load applied to the motor, and the red line represents the current into the motor coils. When the load increases, SG falls below SEMIN, and coolStep increases the current. When the load decreases and SG rises above (SEMIN + SEMAX + 1) x 32 the current becomes reduced.



Picture 48: coolStep adapts motor current to the load

Before tuning coolStep, first tune the stallGuard2 threshold level SGT, which affects the range of the load measurement value SG. coolStep uses SG to operate the motor near the optimum load angle of +90°.

The current increment speed is specified in SEUP, and the current decrement speed is specified in SEDN. They can be tuned separately because they are triggered by different events that may need different responses. The encodings for these parameters allow the coil currents to be increased much more quickly than decreased, because crossing the lower threshold is a more serious event that may require a faster response. If the response is too slow, the motor may stall. In contrast, a slow response to crossing the upper threshold does not risk anything more serious than missing an opportunity to save power.

coolStep operates between limits controlled by the current scale parameter CS and the SEIMIN bit.

For fast response to increasing motor load, use a high current increment step SEUP. If the motor load changes slowly, a lower current increment step can be used to avoid motor current oscillations. If the filter controlled by SFILT is enabled, the measurement rate and regulation speed are cut by a factor of four.

7 FAQs

7.1 Can I use stepper motors with eight strands?

In an eight strands stepper motor consists each phase of two separated coils. With this construct you have the possibility to connect the separated coils in a serial or parallel connection. The serial connection will be used when the SMC3 can´t create enough current but you need nevertheless a high torque value. But this is only for slow velocities possible. The parallel connection is the standard and will be used when the SMC3 could generated the desired current and is for fast velocities.

7.2 Can I use unipolar stepper motors?

The unipolar stepper motor has six strands. You can connect the unipolar motor like a bipolar motor on the smc3, please refer to chapter 4.3.6.

7.3 Do I need speed monitoring?

This is only needed when working with very expensive tools or operator protecting. When the stepper motor is correct dimensioned, then it is an absolute reliable drive element.

7.4 What happen when stepper can´t follow the rotating field?

The motor goes ballistics and can´t follow further and after more lose steps the motor stalls.

7.5 What happen to the energy while breaking?

First of all the motor becomes a generator. That means energy goes to the power supply and the supply voltage is increasing. This could lead to an illegal high supply voltage and damage the power supply. Therefore is an enough big capacitator needed, that should be dimension. And it is also needed a distance to the voltage limit value ore an active circuitry to discharge surplus energy and heat.

7.6 What start/stop frequency is sensible?

This depends on the load of the motor and the extern mechanical inertance that is fixed on the motor. In any case it must not be too high, because the motor could not follow the immediately velocity override. Too low frequency can create a resonance in the mechanical system, and prevent fast position cycles.

7.7 Why is heat development increasing with higher velocity?

With higher velocity are also more reversions of polarity and therefore more resistive and magnetic losses.

7.8 Advantage of current lowering

In standstill is only a holding torque needed and this is created with mostly with low current. The power dissipation is quadratic to the current ($I^2 * R$), and therefore a current lowering of 25% reducing the power dissipation of the half.

7.9 Why is the current consumption increasing of the power supply when voltage is decreasing?

The energy conservation applies here. The equation of continuity say, when you need the same power and decrease the voltage, so must the current increasing proportional.

7.10 Stepper motor can´t start without a load

The stepper motor is part of synchronous motors. The rotor follows the magnetic field in narrow limits due to a very high stiffness. This stiffness is in the stepper motors favored and is the reason for oscillation in the natural resonance frequency. (Most nearly 100Hz) If the motor work near this frequency could the motor lose steps.

7.11 How can I reduce resonance appearance?

- Decrease of current

  This makes the stepper motor less stiff, but also less oscillation of the system

- Working with more steps

  The more steps the higher the frequency and lower the resonance

- Steeper acceleration ramp

  Thus, the motor is driven faster through the critical region.

7.12 Error when SMC3 comes to OP or CP4

When you want to switch in to OP in EtherCAT of in CP4 in Sercos, you get immediately an error. The reason for this is that the power connection to the contact X6 is missing, or the power supply is not strong enough..

7.13 Error 0x01 in EtherCAT

If you get an error 0x01 in object 0x1001, then you have no connection to the motor because of unplugged cable. You get no error in the StatusWord and you can´t reset the error with controlword 0x6040 bit 0x80. You can reset the error only by connected motor cable and switched on and off the X6 voltage. Or you connect the motor cable and start a movement in a safe direction till the error delete by itself.

8 Firmware update in Fallback

There are two ways to activate the Fallback mode.

- While starting the SMC3 you should press the button min. 2 sec to have a static ip address allocation.
- While starting the SMC3 you should press the button min. 4 sec to have a dynamic ip address allocation.

The SMC3 can be updated in Fallback mode. Following requirements must be met:

- Fallback mode must be aktive
- A link must be present on port 1
- The computer from which the update is to be made must be able to reach the SMC3 on the interface 1. For this, SMC3 can either be connected directly to the network interface of the computer or the SMC3 is connected to a network, from which the computer can reach it.
- When Fallback mode with dynamic ip address is active, a DHCP server must be available.
- On the computer with which the update is to be made a TFTP client must be installed
- An update file (SMC3.ocf) must be available. This file contains the Logicware and the application.

In the following table the configuration parameter of the Fallback mode with static ip address are described. These parameter can not be changed.

Parameter	Value	Notice
MAC Address	*(unique for the device, not changeable)*	
IP Address	192.168.100.100	
Subnet-Mask	255.255.255.0	
Gateway Address	0.0.0.0	

Table 76: IP-Configuration in Fallback mode with static ip address

When the SMC3 is used in Fallback mode with dynamic address, it requests the ip configuration from the DHCP server.
To run an update a command console has to be opened and following instructions has to be executed.

Fallback (static IP Address):

```
tftp -i 192.168.100.100 SMC3.ocf
```

Fallback (dynamic IP Address):

```
tftp -i <DHCP server assigned ip address> PUT SMC3.ocf
```

or

```
tftp -i SMC3 PUT SMC3.ocf
```

The variant using the hostname only works in DHCP mode!!

The state of the update process is shown by the LEDs.

In the following table the possible error messages of the TFTP servers are shown.

Error	Description
Unknown transfer ID.: Wrong filename or extension: '<name of the received file>', '<extension of the received file>' expected 'smc3.ocf'	The wrong file for update was choosen.
Unknown transfer ID.: Wrong Block#: <received block number>, expected: <expected block number>	The received block number doesn't match with the expected block number.
Unknown transfer mode.: Allowed transfer mode: octet, used transfer mode: <used transfer mode>	File was not transmitted in binary mode.
Disk full or allocation exceeded.	Not enough dynamic storage fort he reception of the file.
Illegal TFTP operation: Awaiting filename: filename' but received 'filename'	The expected filename doesn't match with the received filename.
Illegal TFTP operation: Read Request not supported.	Reading files over TFTP is not supported
Illegal TFTP operation: <Code number>	The received TFTP op code is not supported
Access violation.: Ongoing transmission in progress.	The simultaneous transmission of multiple files is not supported.

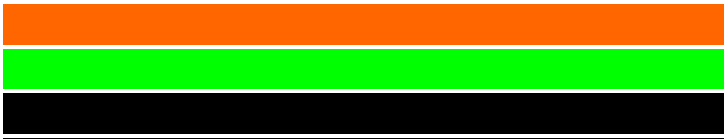
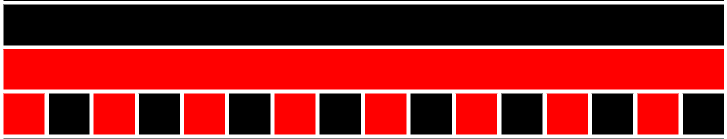
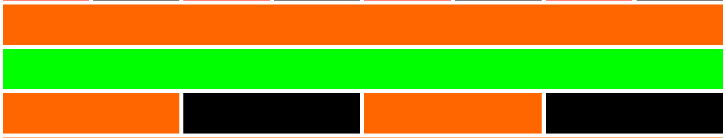
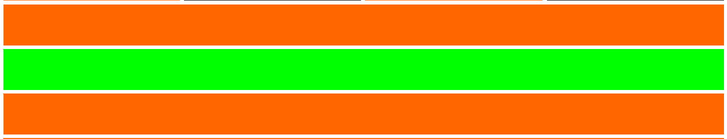
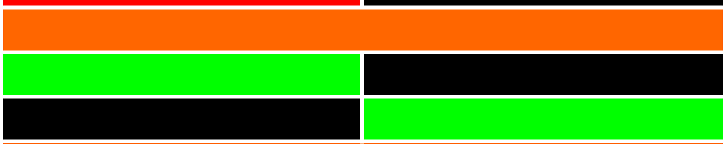
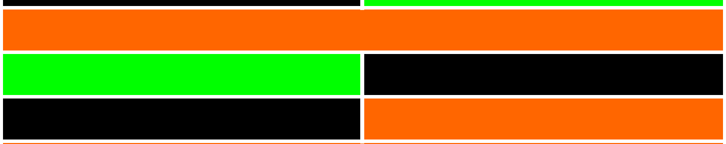
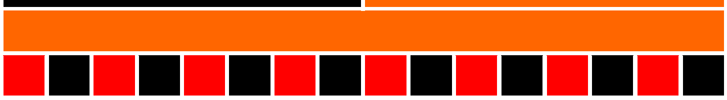
Table 77: TFTP server error messages

8.1 Fallback factory setting

If you need a factory setting, this means a default setting of all parameters, then you should press the button for 8 seconds while the smc3 is booting. The DIAG3 LED signals the factory setting and its meanings.

8.2 Fallback LED-Codes

The DIAG2 LED is orange shining for dynamic IP and orange flashing (frequency 0,5Hz) for static IP. In the following table all LED-Codes are shown for the static variant. All other LED-Codes, for flashing with a higher frequency (exception), stands for the orange flashing DIAG2 LED.

State/Error	DIAG2 BUS LED DIAG3
no error	
FB_LED_CODE_FLASH_LAYOUT_FAILED: The flash layout could not be find out, an access on the flash is not able. It works now with default values.	
FB_LED_CODE_APP_INFO_RD_FAILED: The application info could not be read out of the flash.	
FB_LED_CODE_WAITING_FOR_LINK: The application is waiting on a link on port 1.	
FB_LED_CODE_LINK_OK_WAITING_FOR_IP: Link ok, the application is waiting on an IP address allocation.	
FB_LED_CODE_IP_OK: An IP address was allocated.	
FB_LED_CODE_TSE_INIT_FAILED: The ethernet interface could not be init.	
FB_LED_CODE_TFTP_INIT_FAILED: The TFTP-Server could not be init.	
FB_LED_CODE_FILE_TRANS_IN_PROGRESS There are currently transmitted data.	
FB_LED_CODE_FLASH_UPDATE: The transmitted data is currently stored in flash.	
FB_LED_CODE_FLASH_UPDATE_FAILED: The transmitted data could not be stored in flash.	

State/Error	DIAG2 BUS LED DIAG3
FB_LED_CODE_FLASH_UPDATE_OK: The transferred data could be successfully stored in Flash.	
FB_LED_CODE_SERCOS_START_FAILED: The SIII application could not be started.	
FB_LED_CODE_ETHERCAT_START_FAILED: The ECAT application could not be started.	
FB_LED_CODE_EXCEPTION_UNKNOWN: There is an unknown exception occurred. The application execution is aborted.	
FB_LED_CODE_EXCEPTION_DIVISION: It is a division by zero occurred. The application execution is aborted.	
FB_LED_CODE_EXCEPTION_MISALIGNED: It was carried out an access to a non-aligned address. The application execution is aborted.	
FB_LED_CODE_EXCEPTION_STANDARD: It has occurred a default exception. The application execution is aborted.	
FB_LED_CODE_FACTORY_SETTING: The erasing of all configuration data is started.	
FB_LED_CODE_FACTORY_SETTING_FAILD: The configuration data could not be erased.	
FB_LED_CODE_FACTORY_SETTING_FINISHED: The erasing of all configuration data was successful.	
	< -- 1 sec ----------------------------------- >

Table 78: Fallback Led-codes