FAULHABER

Operating Instructions

3564K024B CC
MCBL 3003/06 C
MCDC 3003/06 C

FAULHABER GROUP
We create motion

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Firmware versions:
BL: 605.3150.51O
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The pertinent regulations regarding safety engineering and interference suppression must be complied with.

Subject to modifications.

1 Overview

1.1 General description

This document describes the functionality and operation of the following equipment with CANopen interface:

3564K024B CC
The 3564K024B CC integrates a brushless DC-Servomotor with a high-resolution absolute encoder and a motion controller in one complete drive unit.

MCBL 3003/06 C
The MCBL 3003/06 C is an external motion controller for brushless DC servomotors with linear Hall sensors, which can be operated without additional encoders.

MCDC 3003/06 C
The MCDC 3003/06 C is an external motion controller that is designed for the entire range of FAULHABER DC micro motors.

All of the motion controllers are based on a high performance digital signal processor (DSP), which enables tight control, precise positioning and very low speeds.

The following drive tasks can be performed:

- **Velocity control** with tight requirements on synchronous operation and minimal torque fluctuations. A PI controller maintains target velocities.
- **Velocity profiles** such as ramp, triangular or trapezoidal movements can be realised. Gentle starting or deceleration can easily be implemented.
- **Positioning mode:** Starting from defined positions with high resolution (1/3000 revolutions using linear Hall sensors of BL motors).
- Acquisition of **reference marks and limit switches**.
- Extended operating modes: **Stepper motor mode, Analog positioning mode, Voltage regulator, Electronic gear**, operation with **external incremental encoder.** MCDC 3003/06 C: **IxR control**.
- **Torque control** with adjustable current limitation.
- **Storage** of the set configurations.

Various inputs and outputs are available for the implementation of these tasks:

- **Set value input** for target velocity.
  Analog or PWM signals can be used. The input can also be used as digital or reference input. A frequency signal or an external incremental encoder can also be connected here.
- **Error output**(Open Collector).
  Can also be reprogrammed as rotational direction, digital or reference mark input, and as pulse or digital output.
- 1 to 3 additional **digital inputs**.

CANopen interface for integration in a CAN network with transfer rates up to 1Mbit/s. The CANopen communication profile according to DS301 V4.02 and DSP402 V2.0 according to CiA specification for slave equipment with the following services is also supported:

- 1 server SDO
- 3 transmit PDOs, 3 receive PDOs
- Static PDO mapping
- NMT with Node Guarding
- Emergency object

Transfer rates and node number are set using the network in accordance with the LSS protocol as per DSP305 V1.1, and automatic baud rate detection is also implemented.

In addition, all functions and parameters of the drive unit can be activated very easily using a special FAULHABER PDO channel. For each FAULHABER command a corresponding CAN message frame is available on the PDO channel, which enables the CAN unit to be operated similarly to the serial version. Drive parameters can be analysed very quickly with the integrated Trace function. The **FAULHABER Motion Manager 3 software** is available for Windows 95/98/ME/NT/2K/XP; this also considerably simplifies the operation and configuration of units using the CAN interface, and in addition offers a graphic online analysis function.

Fields of application
Thanks to the compact design, the units can be integrated into diverse applications with minimal wiring. The flexible connection options open up a broad field of application in all areas, for example in decentralized automation technology systems, as well as in handling devices and machine tools.

Options
A separate supply for motor and control electronics is optionally available (important for safety-critical applications), in which case the 3rd input is omitted.
Special preconfiguration of modes and parameters is possible on request.
The Motion Manager software can be downloaded free of charge from www.faulhaber-group.com.

1 Overview

1.2 Quick start

To facilitate introduction, this section highlights the initial steps for commissioning and operation of FAULHABER motion controllers with CANopen interface.

However, the detailed documentation must always be read and adhered to, particularly section 2.5 Basic Settings.

The units are delivered as standard without a valid node address (node ID = 0xFF) and with automatic baud rate detection set.

In order to set the baud rate and node address, the unit must first be configured for CAN using an appropriate configuration tool, which supports the LSS protocol according to CiA DSP305. FAULHABER Motion Manager 3, installed on a PC with supported CAN interface, can also be used for this purpose. The node address and baud rate can be set using the LSS-compatible configuration tool either in Global mode, if only one drive is connected, or in Selective mode with the serial number, if a drive is to be configured on the network (see section 2.4 Baud rate and Node ID).

If the FAULHABER Motion Manager is to be used as a configuration tool, proceed as follows:

1. Connect drive unit to the CAN interface of the PC and switch on or connect PC to the CAN network.
2. Start FAULHABER Motion Manager 3.
3. Activate CAN interface as communication interface and configure with the menu item “Terminal – Connections…”.
4. Select menu item “Configuration – Connection parameters…”.
5. Select Configuration mode:
   a. Globally configure individual drive (LSS Switch Mode Global) if only one LSS node is connected and you do not wish to input further data.
   b. Selectively configure specified node (LSS Switch Mode Selective) if a node is to be configured in the network. If the node has not been found in Node Explorer, the serial number of the drive node to be configured must be entered, otherwise the data fields are already correctly preconfigured.
6. In the next dialogue, select the desired transfer rate or “Auto” and enter the desired node address.
7. Press “Send” button.
8. The settings are transferred and permanently stored in the controller. The Motion Manager then recalls the Scan function and the node should now be displayed with the correct node number in Node Explorer. After switching off and on again, the drive will operate with the set configuration.

A CANopen node is always in “Pre-Operational” status after being switched on and must be transferred to “Operational” status before it is fully operational. No PDO communication is possible in “Pre-Operational” status, therefore no FAULHABER commands are available in this status either. In addition to the Network Management functions, only the setting of parameters in the object dictionary by means of SDO transfer is possible here (see section 4 CANopen).

1.2.1 Operation using FAULHABER Motion Manager

The FAULHABER Motion Manager offers easy access to the CANopen state machines using menus, which can either be called up using the Node Explorer context menu (right mouse button) or using the “Commands – CANopen” menu. The desired node must have been activated beforehand by double clicking in Node Explorer. The current statuses are always displayed in the status line at the bottom of the screen.

The FAULHABER commands described below can be entered directly in the command input line or selected from the Commands menu. After sending the command, a command interpreter is activated, which converts the command into a corresponding CAN message frame on PDO2.

In order to drive a motor using the Motion Manager, follow the procedure below (assuming a valid node number and matching baud rate):

1. Start network node (Start Remote Node):
   The right mouse button in Node Explorer opens a context menu, then select the entry “CANopen Network Management NMT - Start Remote Node” (or use menu “Commands – CANopen”).
   ➔ FAULHABER commands are now available!
2. Configure drive functions:
   A user-friendly dialog that enables the desired settings to be made is available under the menu item “Configuration – Drive functions…”
   For external motion controllers MCBL 3003/06 C and MCDC 3003/06 C, you must check that the correct basic settings have been made for the connected motor (see section 2.5 Basic settings). For brushless motors, the correct motor type must be set, for brushed motors the correct post-quadrature resolution must be specified for the encoder (ENCRES) under “Drive parameters”.

Depending on whether you wish to operate the drive using the standard CANopen objects or the simpler FAULHABER commands, go into the desired mode (Modes of Operation / OPMOD 1,3,6 or –1). If the settings are to be permanently stored, press the “EEPSAV” button.

3. Activate drive:

a.) FAULHABER Mode (OPMOD–1):

1. “EN” command. Input in command input field and press “Send” button or select in “Commands – Motion control – Enable drive” menu and press “Send” button.

b.) Modes of Operation / OPMOD > 0:

1. Shutdown
   Select entry “Device Control – Shutdown” using the context menu in Node Explorer or using the “Commands – CANopen” menu.
2. Switch On
   Select entry “Device Control – Switch On” using the context menu in Node Explorer or using the “Commands – CANopen” menu.

4. Drive motor (examples):
Drive motor with 100 rpm velocity control:

a.) FAULHABER Mode (OPMOD–1):
“V100” command: Enter in command input field and press “Send” button or select in “Commands – Motion control – Initiate velocity mode” menu, enter value 100 in dialogue box, press OK and “Send” button.

b.) Profile Velocity Mode (OPMOD3):
Set Target Velocity to the value 100 (Object 0x60FF).

Stop motor:

a.) FAULHABER Mode (OPMOD–1):
Command “V0”.

b.) Profile Velocity Mode (OPMOD3):
Set Target Velocity to the value 0 (Object 0x60FF) or “Disable Operation”.

Move motor relatively by 10000 increments:

c.) FAULHABER Mode (OPMOD–1):
“LR10000” command to load the relative target position, “M” command to move to loaded target position.

d.) Profile Position Mode (OPMOD1):
Set Target Position to the value 10000 (Object 0x607A). Move to Target Position (“New set-point” and set “rel” in statusword).

1.2.2 Operation using a custom interface

Start of CANopen node:

Either an individual node or the entire network is started and set to "Operational" status using the broadcast command "Start Remote Node":

11 bit identifier	2 bytes user data	
0x000	01	00

The first data byte contains the start command "Start Remote Node", the second data byte contains the node address or 0 for the entire network.

After the node has been started, all functions can be activated. The drive can now be activated and operated using the Device Control functions according to CiA DSP402 or using the FAULHABER message frames on PDO2.

The identifiers of the individual objects are allocated according to the Predefined Connection Set and are dependent on the node number (see section 4.5 NMT Network Management). These are the most important objects:

Object	Function	Identifier
TxPDO1	Statusword	0x180 + node no.
RxPDO1	Controlword	0x200 + node no.
TxPDO2	FAULHABER data	0x280 + node no.
RxPDO2	FAULHABER command	0x300 + node no.
TxSDO	Read object	0x580 + node no.
RxSDO	Write object	0x600 + node no.

In delivery status, the drives are in the operating mode *Modes of operation* = 1 (Profile Position Mode) when switched on. In this operating mode, the drive control is performed using the Device Control state machine, which is operated using the *controlword* (Object 0x6040 or RxPDO1) and queried using the *statusword* (Object 0x6041 or TxPDO1).
The following command sequence is prescribed to activate the power output stage:

1. Shutdown:
   Controlword = 0x06
2. Switch on / Enable Operation:
   Controlword = 0x0F

The drive is then in "Operation Enabled" status, in which it can be operated using the corresponding objects of the Profile Position Mode (see section 4.7 Device Control Drive Control and section 6.3.3 Profile Position Mode).

The drive can be configured both by means of SDO transfer using the objects of the object dictionary and using PDO2 with the commands of the FAULHABER channel. Not all configuration options are accessible using the object dictionary; many extended operating modes are only accessible using the FAULHABER channel (see section 6 Parameter Description).

All features of the drive can also be operated without in-depth CANopen knowledge, such as Device Control, SDO protocol and object dictionary. The FAULHABER channel on PDO2 provides an easy means of executing all supported commands. For drive control using the FAULHABER channel you must first set the operating mode to *Modes of Operation* = –1 by using the following FAULHABER command and argument:

RxPDO2: FAULHABER command "OPMOD-1"

11 bit identifier	5 bytes user data				
0x300 (768D) + Node-ID	0xFD	0xFF	0xFF	0xFF	0xFF

All FAULHABER commands can then be used for drive control in accordance with the following protocol:

RxPDO2: FAULHABER command

11 bit identifier	5 bytes user data				
0x300 (768D) + Node-ID	Command	LLB	LHB	HLB	HHB

Example: Drive node 1 at 500 rpm (command "V500"):
ID 301: 93 F4 01 00 00

All available commands are listed in section 6.4 FAULHABER Commands.

2 Installation

2.1 Connections and wiring

1.) 3564K024B CC:

The connections are indicated by colored wires and assigned as follows:

Wire	Designation	Meaning
blue	GND	GND
pink	+24V	+24 V
brown	AnIn	Analog input
white	Fault	Error output
grey	AGND	Analog GND
yellow	CAN_L	CAN-Low/RS232 RxD*
green	CAN_H	CAN-High/RS232 TxD*
red	3.In	3rd input/optional electronics supply

2.) MCBL 3003/06 C:

The connections are indicated on the terminal strips and are assigned as follows:

Supply side:	
Connection	**Meaning**
CAN_H	CAN-High / RS232 TxD*
CAN_L	CAN-Low / RS232 RxD*
AGND	Analog GND
Fault	Error output
AnIn	Analog input
+24V	+24 V
GND	GND
3.In	3rd input/optional electronics supply

Motor side:	
Connection	**Meaning**
Ph A	Motor phase A (brown)
PH B	Motor phase B (orange)
Hall C	Hall sensor C (grey)
Hall B	Hall sensor B (blue)
SGND	GND signal (black)
+5V	VCC (red)
Hall A	Hall sensor A (green)
PH C	Motor phase C (yellow)

In addition, a 9-pin SUB-D connector is attached, with the following assignment:

Pin	Meaning
2	CAN_L / RS232 RxD*
3	GND
7	CAN_H / RS232 TxD*

3.) MCDC 3003/06 C:

The connections are indicated on the terminal strips and are assigned as follows:

Supply side:	
Connection	**Meaning**
CAN_H	CAN-High / RS232 TxD*
CAN_L	CAN-Low / RS232 RxD*
AGND	Analog GND
Fault	Error output
AnIn	Analog input
+24V	+24 V
GND	GND
3.In	3rd input/optional electronics supply

Motor side:	
Connection	**Meaning**
Mot -	Motor-
Mot+	Motor+
SGND	Encoder GND
+5V	Encoder VCC
Ch B	Encoder channel B
Ch A	Encoder channel A
4. In	4th input
5. In	5th input

In addition, a 9-pin SUB-D connector is attached, with the following assignment:

Pin	Meaning
2	CAN_L / RS232 RxD*
3	GND
7	CAN_H / RS232 TxD*

* only for software update available

2 Installation

2.1 Connections and wiring

Power supply (+24 V, GND)

The power supply should provide ample current for the connected motor. Please pay attention to the polarity, as inverting the connection will destroy the internal fuse. The fuse can only be replaced at the factory!

Analog input (analog input, analog GND = AGND)

The analog input is executed as a differential input. In order to prevent a voltage drop in the supply cable, connect the analog GND to the power supply GND.

The analog input has various uses, depending on the configuration:

- Presetting of target velocity value via analog voltage
- Presetting of target velocity value via PWM signal
- Current limitation value via analog voltage
- Presetting of target position via analog voltage
- Digital input for reference and limit switches
- Connection for an external encoder (Analog input to GND: Channel A / Analog GND to GND: Channel B) in gearing or BL encoder mode.

CAN connections

The CAN wiring is established using the connections CAN-H, CAN-L and the supply GND. A serial PC interface can also be connected with the same connections, in order to perform a firmware update.

Error output

The error output has the following characteristics:

- In the absence of an error, the output pulls the output to GND (Open Collector)
- In the event of an error, the output has a 100 kΩ path to GND
- The output current is limited to roughly 30 mA, as the applied voltage should not exceed the power supply voltage (maximum U_B)
- Short-circuit proof

The error output is activated in the following situations:

- Current limiting activates
- Over-voltage protection activates (internal power bus exceeds 32 V)
- Power stage shuts down due to over temperature
- The actual velocity differs from the target by an amount greater than the set acceptable deviation (DEV)

The error output connection can also be reconfigured for other functions:

- Encoder pulse output (only MCBL…C, 3564…B CC)
- Digital output
- Limit switch input
- Rotational direction input

3rd input

This connection can be used as reference or digital input. The unit is also available with a separate logic and output stage power sections. During an emergency situation, disconnecting the supply voltage will shut down the output stage de-powering the motor. Supplying voltage independently to the third input will keep the logic section powered.

4th/5th input (MCDC only)

These inputs can be used as digital inputs.

2.1.1 Installation instructions

The place of installation must be selected so that clean and dry cooling air is available for cooling the unit. The units are intended for indoor operation. Large amounts of dust and high concentrations of chemical pollutants must be avoided. Cooling of the unit must be guaranteed, especially when installing in housings and cabinets.
As the unit cools passively with surface heat sinks, case temperatures up to 85 °C may occur. Operation is only guaranteed if the supply voltage lies within the defined tolerance ranges. Wiring should only be altered with no voltage applied to the unit.

2.1.2 Maintenance

The units are maintenance-free in principle. The air filters of cabinet units must be regularly checked and cleaned if required, depending on the quantity of dust. In the event of heavy soiling, the units themselves must be cleaned with halogen-free agents.

2.1.3 Specialised staff

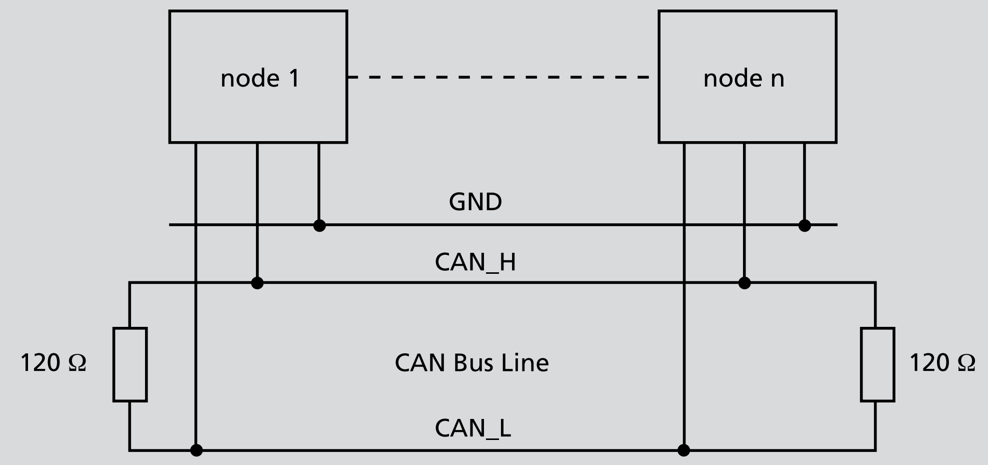
Only trained specialised staff and instructed persons with knowledge in the field of automation technology and standards and regulations such as

EMC Directive, Low Voltage Directive, Machinery Directive, VDE Regulations (such as DIN VDE 0100, DIN VDE 0113/EN 0204, DIN VDE 0160/EN 50178), Accident Prevention Regulations

may install and commission the units. This description should be carefully read and heeded prior to commissioning.

2 Installation

2.2 CAN wiring



CAN is a 2-wire bus system, to which all nodes are connect in parallel. A terminal resistance of 120 Ω must be connected to each end of the bus line. In addition to the two signal lines CAN_H and CAN_L, the nodes must be connected together by a common GND line.

The maximum line length is limited by the transfer rate and the signal propagation time:

Baud rate	Max. line length
1000 kBit/s	25 m
500 kBit/s	100 m
250 kBit/s	250 m
125 kBit/s	500 m
50 kBit/s	1000 m
20 kBit/s	2500 m
10 kBit/s	5000 m

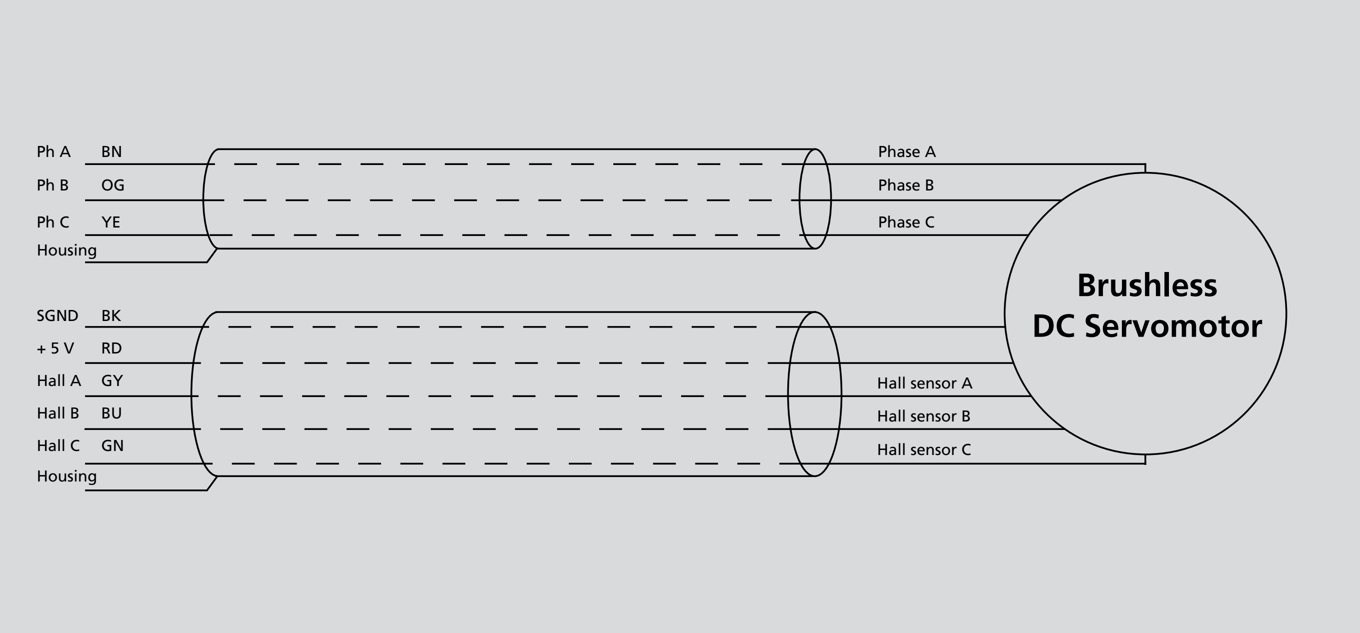
2 Installation

2.3 Motor connection

1.) MCBL 3003/06 C:

The signal lines are susceptible to interference, therefore a maximum cable length can not be specified.
For cable lengths > 300 mm the use of shielded wires is recommended.

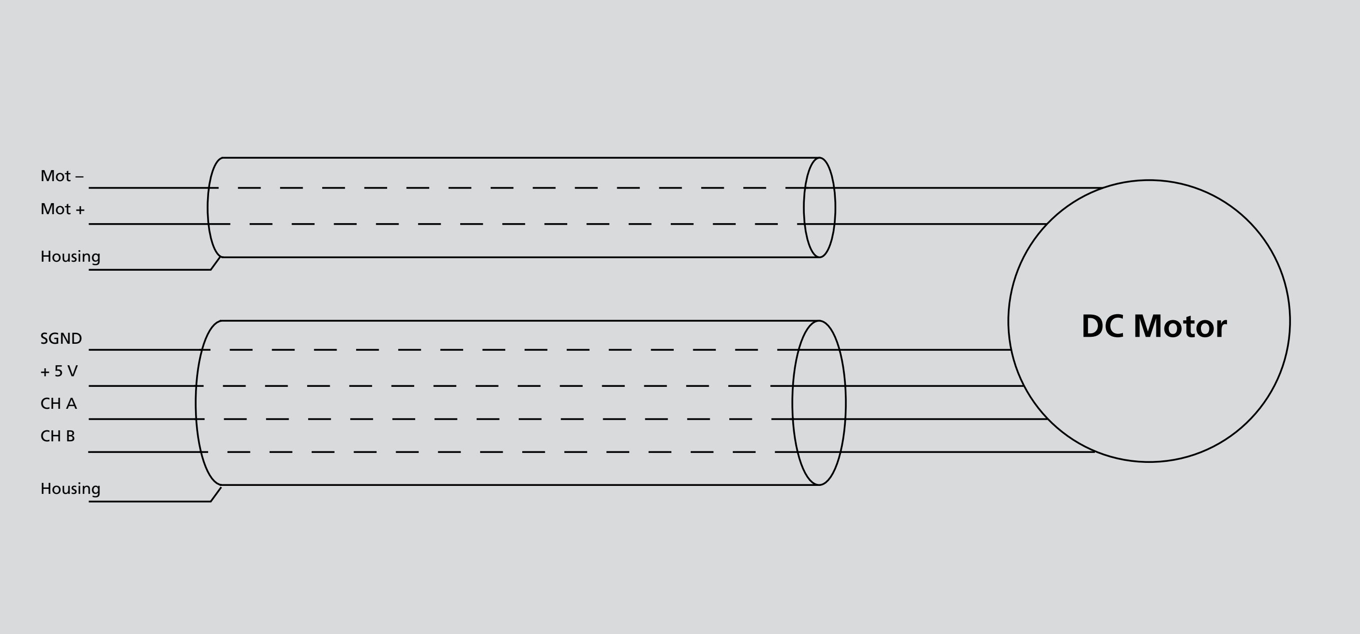
MCBL connection



2.) MCDC 3003/06 C:

The encoder lines are susceptible to interference, therefore a maximum cable length can not be specified. For cable lengths > 300 mm the use of shielded wires is recommended. When using an encoder with complementary outputs (e. g. line driver) please apply HEDL adapter board 6501.00064 from FAULHABER.

MCDC connection



2 Installation

2.4 Baud rate and Node ID

Node address and transfer rate are set using the network in accordance with the LSS protocol as per CiA DSP305 (Layer Setting Services and Protocol). A configuration tool which supports the LSS protocol – such as FAULHABER Motion Manager – is required.

The configuration tool is the LSS Master, and the drives act as LSS slaves.

LSS slaves can be configured in two ways:

1. "Switch Mode Global" switches all connected LSS slaves into configuration mode. However, only one LSS slave may be connected to set baud rate and node ID.
2. "Switch Mode Selective" switches just one LSS slave in the network into configuration mode. Vendor ID, product code, revision number, and serial number of the relevant node must be known.

The following baud rates (Bit Timing Parameters) can be set:

Baud rate	Index
1000 kBit	0
800 kBit	1
500 kBit	2
250 kBit	3
125 kBit	4
50 kBit	6
20 kBit	7
10 kBit	8

In addition, an automatic baud rate detection can be activated by sending the index value 0xFF.

The following node numbers can be set:

1 – 255.

Node ID 255 (0xFF) indicates that the node has yet to be configured, in which case the node remains in LSS-Init status until it receives a valid node number. Only then may the NMT initialization continue.

The LSS protocol also supports the reading out of LSS addresses, comprising vendor ID, product code, revision number and serial number of connected units, as well as reading out of the set node ID.

The identifiers 0x7E5 (Master) and 0x7E4 (Slave), on which the protocol is processed, are used for the LSS communication.

After configuration the set parameters are stored in the Flash memory, so that they are available again after power cycling the drive.

For activation of "Switch Mode Selective", FAULHABER controllers only use vendor ID, product code and serial number. The value 0.0 can always be assigned for revision number, as this value is ignored in the protocol.

Vendor ID: 327
Product code: 3150

For a detailed description of the LSS protocol, please see CiA document DSP 305.

If automatic baud rate detection is activated, the drive can be used in a network with any transfer rate in accordance with the above table; the network baud rate is detected after 3 message frames on the bus line at the most, and the drive adjusts accordingly. Please note that the first message frames may be lost and booting will take a little longer.

2 Installation

2.5 Basic settings

During initial set-up of MCDC or MCBL motion controllers, a number of basic settings must be made to configure the controller for the connected motor. Use the FAULHABER Motion Manager for easy execution of these adjustments!

Failure to observe these basic settings can result in destruction of components!

At delivery, the MCBL 3003/06 C is set to motor type 5 (2444S024B K1155) as standard. If you wish to connect another motor, you must configure the motion controller for the connected motor. The FAULHABER Motion Manager then enables the Hall sensor signals to be synchronised for smooth starting and the phase angle to be optimised for best efficiency. This process should also be carried out whenever the motor is replaced and during initial set-up ("Optimization for connected motor" in the "Configuration – Drive functions" menu).

The controller parameters and current limitation values must also be adapted to the connected motor and the application.

The MOTTYP command adjusts the controller to the relevant motor. Internal parameters are also changed for the specified values:

The values set with the MOTTYP command can be individually changed later. With the RN command, the default parameters are set according to the set motor type. If you wish to connect a motor that is not specified in the motor type list, select motor type 0 (MOTTYP0) and set the parameters k_n (speed constant) and R_m (motor resistance) in accordance with the specifications in the data sheet using the commands KN and RM.

The MCDC 3003/06 C is configured for an encoder resolution of 512 pulses (ENCRES 2048) as default. Use the command ENCRES or the Drive Parameters dialogue in the Motion Manager ("Configuration – Drive functions" menu) to configure the post-quadrature encoder resolution, which is four times the resolution of one channel per revolution.

The parameters R_m and k_n must be set to protect the power stage of the MCDC 3003/06 C during braking operation. The values are indicated in the data-sheet of the connected motor. In addition, the controller parameters and the current limit values must be configured for the connected motor and application.

If using the Fault Pin as an input (REFIN, DIRIN), the desired function must be programmed before applying external voltage to prevent destroying the input/output.

MOTTYP	Motor type	P-term (POR)	I-term (I)	PP	PD	Ii	Peak current (mA)	Continuous current (mA)
1	1628T012B K1155	12	25	24	2	40	3000	770
2	1628T024B K1155	12	22	8	10	40	3000	410
3	2036U012B K1155	6	45	10	14	50	3000	980
4	2036U024B K1155	14	25	17	6	50	3000	480
5	2444S024B K1155	7	40	16	9	50	5000	1370
6	3056K012B K1155	8	30	22	13	50	7000	1940
7	3056K024B K1155	10	40	22	12	50	3000	930
8	3564K024B K1155	8	40	12	6	50	8000	2800
9	4490H024B K1155	8	40	12	6	20	10000	6000

3 Functional Description

The motion controllers can be configured for different operating modes.

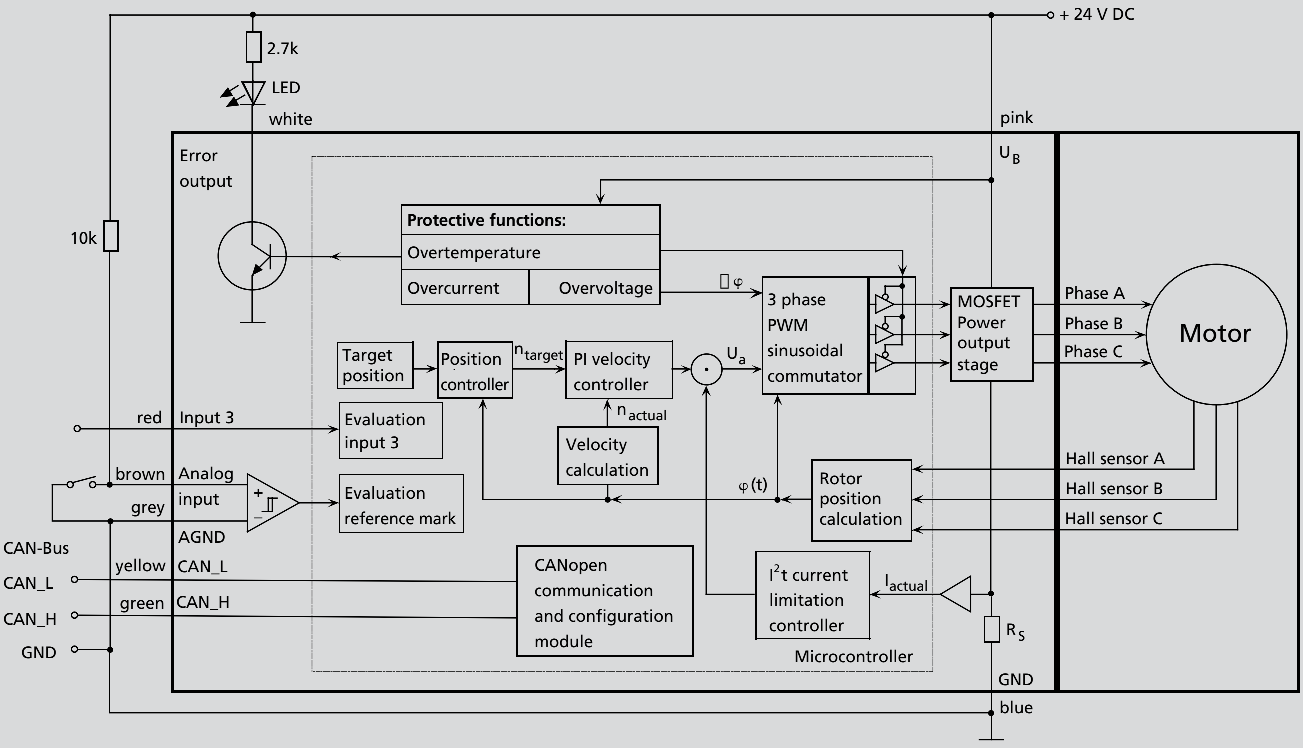
The drive unit is delivered as standard as servomotor in “Profile Position Mode” according to CiA DSP402. The drive can be reconfigured by means of the corresponding configuration commands. If the settings are to be permanently stored, the command SAVE (formerly EEPSAV) must be executed after the configuration; this saves the current settings in the flash memory, from where they will be reloaded when the unit is next switched on.

The prerequisite for operation of the drive in one of the operating modes specified here is that the unit is in “Operational” NMT status, and the power stage is activated (“Switched On” or EN). All commands and objects listed below are summarized and explained in section 6 Parameter Description. The FAULHABER commands, which are transferred as CAN message frames – as described in section 6.4 FAULHABER commands – to PDO2, are specified for each operating mode.

The FAULHABER Motion Manager 3 enables simple setting of the configuration parameters and operating modes using corresponding dialog windows. The specified commands can be entered in plain text or selected from the Commands menu. The CANopen state machines can be conveniently operated using menu selections. The current statuses are automatically displayed in the status line.

Please note that the FAULHABER commands can only be received in “Operational” status (Motion Manager menu “Commands – CANopen – Network Management NMT – Start Remote Node”).

Circuit example: 3564K024B CC with reference switch



3 Functional description

3.1 Position control

In this operating mode, target positions can be loaded with the CAN interface. Positioning can be performed in two different ways:

a.) In “Profile Position Mode” according to DSP402: *Modes of operation* or OPMOD must be set to 1. *Target Position*, profile and controller parameters are set using the object dictionary or using FAULHABER commands. In particular the acceleration values AC (0x6083) and DEC (0x6084), the maximum speed SP (0x607F), the current limitation values LPC and LCC, as well as the controller parameters POR, I, PP and PD (0x60FB and 0x60F9), must be configured for the respective application. The positioning range limits can be set using the command LL or object 0x607D. Positioning is started with the *controlword* and checked with the *statusword* (see section 6.3.3 Profile Position Mode).

b.) In FAULHABER mode: *Modes of operation* or OPMOD must be set to –1. FAULHABER operating mode CONTMOD or ENCMOD and SOR0 must be set. Profile and controller parameters are configured using the FAULHABER basic setting commands (General Parameters). In particular, the acceleration values AC and DEC, the maximum speed SP, the current limitation values LPC and LCC, as well as the controller parameters POR, I, PP and PD must be configured for the respective application. The positioning range limits can be set using the command LL and activated with APL. Position moves are made using the FAULHABER commands for motion control:

Command	Function	Description
LA	Load Absolute Position	Load new absolute target position Value range: $-1.8 \cdot 10^9 \ldots 1.8 \cdot 10^9$
LR	Load Relative Position	Load new relative target position, in relation to last started target position. The resulting absolute target position must lie between $-2.14 \cdot 10^9$ and $2.14 \cdot 10^9$.
M	Initiate Motion	Activate position control and start positioning

Example:
1.) Load target position: LA40000
2.) Start positioning: M

Attainment of the target position is indicated in both operating modes by the *statusword* on TxPDO1 (Bit 10 “Target reached”), provided that the transmission type for RxPDO1 is set to 255. (Object 0x1800).

The linear Hall sensors used as position transducers on the brushless motors (3564K024B CC, MCBL 3003/06 C) effectively produce 3000 pulses per revolution.

In the case of APL0, relative moves can also be executed beyond the range limits. If the upper (1800000000) or lower limit (–1800000000) is exceeded, counting rolls over to 0 without loss of positional information.

3.2.1 Velocity control using CAN

Velocity can be controlled using CAN in two different ways:

a.) In “Profile Velocity Mode” according to DSP402: *Modes of Operation* or OPMOD must be set to 3. Profile and controller parameters are set using the object dictionary or using FAULHABER commands. In particular, the acceleration values AC (0x6083) and DEC (0x6084), the current limitation values LPC and LCC, as well as the controller parameters POR and I (0x60F9), must be configured for the respective application. The velocity control mode is started by setting *Target Velocity* to the desired value using the object dictionary (0x60FF) and is checked with the *statusword*. The drive can be stopped with the *controlword* (Disable Operation) or by writing the value 0 to the object *Target Velocity* (see section 6.3.6 Profile Velocity Mode).

b.) In FAULHABER mode: *Modes of Operation* or OPMOD must be set to –1. FAULHABER operating mode CONTMOD or ENCMOD and SOR0 must be set. Profile and controller parameters are executed with the FAULHABER basic setting commands (General Parameters). In particular the acceleration values AC and DEC, the current limitation values LPC and LCC, as well as the controller parameters POR and I must be configured for the respective application.

The velocity control is executed with the following FAULHABER motion control command:

Command	Function	Description
V	Select Velocity Mode	Activate velocity mode and set specified value as target velocity (velocity control) Unit: rpm

Example:
Drive motor at 100 rpm: V100

In order to change the direction of rotation, simply assign a negative velocity value (e.g. V-100). V0 will stop the drive.

Make sure that APL0 is set, if you do not want the drive to stop at the set range limits (LL)! Also check that the maximum speed SP is not set below the desired target velocity.

3.2.2 Analog velocity control

This operating mode is only available in FAULHABER mode: *Modes of Operation* or OPMOD must be set to –1. FAULHABER operating mode CONTMOD and SOR1 (velocity commanded with a voltage at the analog input) or SOR2 (velocity commanded with a PWM signal at analog input) must be set.

Profile and controller parameters are configured with the FAULHABER basic setting commands (General Parameters). In particular, the acceleration values AC and DEC, the current limitation values LPC and LCC, as well as controller parameters POR and I, must be configured for the respective application. The analog velocity control can be further configured using the parameters described below:

Setting the scaling factor (maximum speed):
Target velocity at 10 V.

Command	Function	Description
SP	Load Maximum Speed	Load maximum speed. Setting applies for all modes (except VOLTMOD) Unit: rpm

Example:
Set maximum speed so that with 10 V at the analog input the target velocity is 5000 rpm: SP5000

Setting the minimum velocity:
Velocity commanded at the minimum analog voltage.

Command	Function	Description
MV	Minimum Velocity	Minimum velocity in rpm

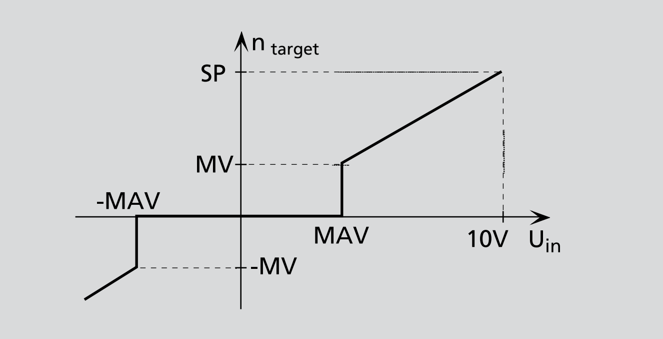
Example:
Set minimum velocity to 10 rpm: MV10

Setting the start voltage:
Minimum analog voltage which will cause the motor to spin at the minimum velocity.

Command	Function	Description
MAV	Minimum Analog Voltage	Minimum starting voltage in mV

Example:
The drive is only to start moving with voltages over 100 mV or below –100 mV at the analog input: MAV 100

Advantage:
As 0 mV is usually difficult to set at the analog input, 0 rpm is also not easy to implement. The dead band produced by the minimum start voltage prevents the motor from starting as a result of small interference voltages.



Setting the direction of rotation:

Command	Function	Description
ADL	Analog Direction Left	Positive voltages at the analog input result in counterclockwise rotation of the rotor
ADR	Analog Direction Right	Positive voltages at the analog input result in clockwise rotation of the rotor

Example:
Clockwise rotation in the case of positive voltages: ADR

The error output (fault pin) can also be reconfigured as a digital rotational direction input:

Command	Function	Description
DIRIN	Direction Input	Use fault pin as rotational direction input

Level and direction:

Low: ... Left-hand rotation
(corresponding to ADL command)

High: ... Right-hand rotation
(corresponding to ADR command)

The level at the rotational direction input is dominant to the settings made with ADR and ADL.

3 Functional Description

3.2 Velocity control

Velocity control using a pulse width modulated (PWM) signal at the analog input (SOR2):

Default duty cycle at the analog input:

- Greater than 50 % causes clockwise rotation
- Equal to 50 % keeps the motor stationary
- Less than 50 % causes counterclockwise rotation

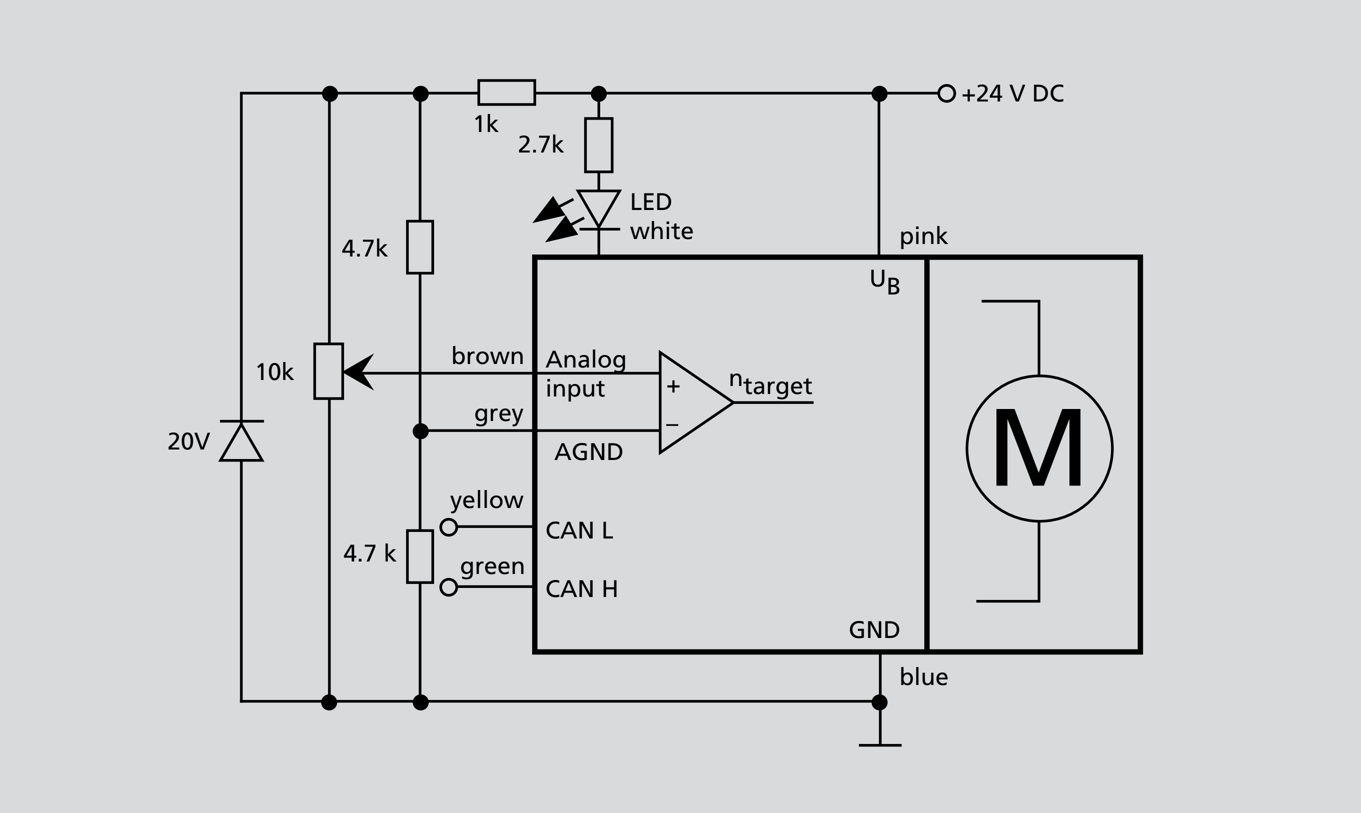
The commands SP, MV, MAV, ADL and ADR can also be used here.

Make sure that APL0 is set, if you do not want the drive to stop at the set range limits (LL)!

Note on input circuit:

The circuit for the analog input is designed as a differential amplifier. If the analog input is open, an unexpected velocity may be possible. The input must be set to the voltage level of AGND or rather be connected to AGND with low-impedance, in order to generate 0 rpm.

Simple velocity control using a potentiometer, circuit example with 3564K024B CC:



3 Functional Description

3.3 Homing and limit switches

Available inputs for homing and limit switches:

- AnIn
- Fault
- 3. In
- 4. In and 5. In (MCDC only)

In brushless motors the zero crossing of the Hall sensor signals is also available as index pulse, appearing once per revolution. The index pulse of an external encoder can also be connected to the fault pin; this allows for a very repeatable system.

The AnIn and Fault connections are designed as interrupt inputs, which means that they are edge-triggered. All other inputs are not edge-triggered, so that the signal should last at least 100 µs long to be reliably detected. The maximum reaction time to level changes at all inputs is 100 µs.

Set levels of digital inputs:

Command	Function	Description
SETPLC	Set PLC-Inputs	Digital inputs PLC-compatible (24 V level)
SETTTL	Set TTL-Inputs	Digital inputs TTL-compatible (5 V level)

The signal level of the digital inputs can be set using the above commands:

PLC (Default): Low: 0...7.0 V / High: 12.5 V...U_B
TTL: Low: 0...0.5 V / High: 3.5 V...U_B

Configure fault pin as reference or limit switch input:

Command	Function	Description
REFIN	Reference Input	Fault pin as reference or limit switch input

The limit switch functions for the fault pin are only accepted if REFIN is activated (setting must be saved with SAVE or EEPSAV)!

Important: Configure the fault pin as an input before applying external voltage!

Homing can be performed in two different ways:

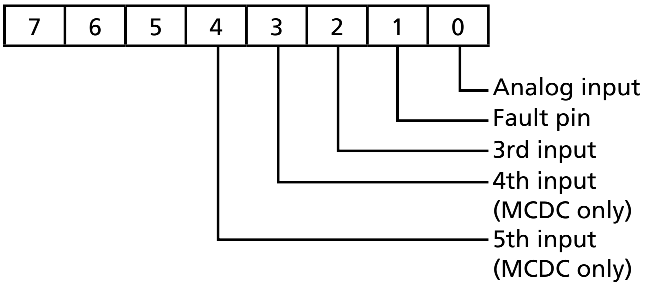
a.) In “Homing mode” according to DSP402:
Modes of operation or OPMOD must be set to 6. *Homing Method, Homing Offset, Homing Speed* and *Homing Acceleration* are set using the object dictionary (objects 0x6098, 0x607C, 0x6099 and 0x609A). The homing sequence is started with the *controlword* and checked with the *statusword* (see section 6.3.4 Homing Mode). The function of the inputs is set using object 0x2310 (see section 6.2 Manufacturer-specific Objects).

b.) In FAULHABER Mode:
Modes of operation or OPMOD must be set to –1. The function of the inputs and the homing behaviour is set with the FAULHABER commands described below. A previously stored homing sequence is then started with the following FAULHABER commands:

Command	Function	Description
GOHOSEQ	Go Homing Sequence	Execute FAULHABER homing sequence. A homing sequence is executed (if programmed) irrespective of the current mode.
GOHIX	Go Hall Index	Move brushless motor to Hall zero point (Hall index) and set actual position value to 0 (not available on MCDC)
GOIX	Go Encoder Index	Move to the encoder index at the fault pin and set actual position value to 0 (DC motor or ext. encoder).

Configuration of homing and limit switches in FAULHABER mode:

The following commands use the following bit mask for configuration of the limit switch functions:



Set or delete the bit at the position of the required input for each command.

Polarity and limit switch function:

Command	Function	Description
HP	Hard Polarity	Define effective edge and polarity of respective limit switches: 1: Rising edge and high level effective. 0: Falling edge and low level effective.
HB	Hard Blocking	Activate Hard-Blocking function for relevant limit switch.
HD	Hard Direction	Presetting of direction of rotation which is blocked by HB of the respective limit switch. 1: Clockwise rotation blocked 0: Counterclockwise rotation blocked

The Hard-Blocking function provides reliable protection against overshooting of the range limit switch. If the HB limit switch is activated, then the direction of rotation set with HD will be blocked, i.e. the drive can only move out of the limit switch. The speed stays at 0 rpm if target velocities are in the wrong direction.

Example:

Setting of the Hard-Blocking function for fault pin and 4th input:
$2^1 + 2^3 = 2 + 8 = 10$ ➔ HB10

Definition of homing behaviour:

Command	Function	Description
SHA	Set Home Arming for Homing Sequence	Homing behaviour (GOHOSEQ): Set position value to 0 at edge of respective limit switch.
SHL	Set Hard Limit for Homing Sequence	Homing behaviour (GOHOSEQ): Stop motor at edge of respective limit switch.
SHN	Set Hard Notify for Homing Sequence	Homing behaviour (GOHOSEQ): Send message to Master (statusword bit 14=1) at edge of respective limit switch.

In order to be able to execute a homing sequence with the command GOHOSEQ, a homing sequence must be defined for a specific limit switch!

If the drive is already located in the limit switch when GOHOSEQ is called, it attempts to move out of the switch. As the speed defined in HOSP would only drive the mechanics further into the switch, the same velocity as set in HOSP is used, but in the opposite direction.

Example:

The following commands configure the drive to stop the motor, set the actual position to 0, and notify the Master when input 3 transitions to a high state.

```
HP4
SHA4
SHL4
SHN4
```

Homing Speed:

Command	Function	Description
HOSP	Load Homing Speed	Load speed and direction of rotation for homing (GOHOSEQ, GOHIX). Unit: rpm

Example: HOSP-100

Direct programming using HA, HL and HN commands:

Command	Function	Description
HA	Home Arming	Set the position value to 0 and delete corresponding HA bit at edge of respective limit switch. Setting is not saved.
HL	Hard Limit	Stop motor and delete corresponding HL bit at edge of respective limit switch. Setting is not saved.
HN	Hard Notify	Send message to Master (statusword bit 14=1) and delete corresponding HN bit at edge of respective limit switch. Setting is not saved.

These special commands can be used to define actions that are to be triggered at an edge of the relevant input, independently of a homing sequence. A programmed limit switch function will remain effective until the preselected edge occurs. The programming can be changed with a new command before an edge occurs.

The settings are not saved with the SAVE command, so all limit switches are inactive again after power cycling.

HL/SHL command:

Positioning mode: When the edge occurs, the motor positions itself on the reference mark with maximum acceleration.

Velocity controller mode: The motor is decelerated at the set deceleration value when the edge occurs, i. e. it goes beyond the reference mark. Using a positioning command (LA0, M) allows the system to return gracefully to the reference mark. This method has the advantage of no abrupt changes in motion.

3 Functional Description

3.4 Extended operating modes

The extended operating modes are only available in FAULHABER mode:

Modes of Operation or OPMOD must be set to –1.

Use the CONTMOD command to revert from an extended operating mode to normal mode.

3.4.1 Stepper motor mode

Command	Function	Description
STEPMOD	Stepper Motor Mode	Change to stepper motor mode

In stepper motor mode, the analog input acts as frequency input. The error output must be configured as rotational direction input if the direction of rotation is to be changed using a digital signal. Alternatively, the direction of rotation can also be preset using the commands ADL and ADR.

Command	Function	Description
DIRIN	Direction Input	Fault pin as rotational direction input

The drive moves a configurable number of degrees for each pulse at the analog input, and thus simulates the function of a stepper motor.

There are a number of considerable advantages in comparison with a real stepper motor:

- The number of steps per revolution is easily programmable and is only limited by the resolution of the encoder
- The individual step is easily configurable
- There is no detent torque
- The full dynamics of the motor can be used
- The motor is very quiet
- Because of the encoder, there is no loss of steps even under extreme loads
- There is no current draw when the motor reaches position
- The system only consumes the energy it needs
- The control electronics are already integrated in the 3564K024B CC

Input:
Maximum input frequency: 400 kHz

Level: 5 V TTL or 24 V PLC-compatible, depending on configuration.

Stepper motor mode enables position-accurate velocity control; any rational ratios can be set for input frequency to motor speed using step width and step number, in accordance with the following formula:

$$\text{Revolutions} = \text{Pulses} \cdot \frac{STW}{STN}$$

Revolutions	...Revolutions commanded of the motor
Pulses	...Number of pulses at the frequency input (= number of steps)
STW	...Step width (step width factor = number of steps per pulse at frequency input)
STN	...Step number (number of steps = number of steps per revolution)

Value range of STN and STW: 0 to 65535

Command	Function	Description
STW	Load Step Width	Load step width for step motor and gearing mode
STN	Load Step Number	Load number of steps per revolution for step motor and gearing mode

Example:
Motor should turn 1/1000th of a revolution for each input pulse:
STW1
STN1000

The direction of rotation can be predefined with the commands ADL and ADR, or using an external signal at the fault pin (DIRIN command).

The acceleration and speed parameters (AC, DEC, SP) are effective in stepper motor mode. These permit gentle starting and stopping. The position range limits set using LL can also be activated with the APL1 command.

3.4.2 Gearing mode (electronic gearing)

Using gearing mode forces the attached motor to follow an external encoder.

Command	Function	Description
GEARMOD	Gearing Mode	Change to gearing mode

The two channels of an external encoder are connected to AnIn and AGND, which may need to be connected to the 5 V encoder supply using a 2.7 kΩ pull-up resistor.

The gear ratio can be set in accordance with the following formula:

$$\text{Revolutions} = \text{Pulses} \cdot \frac{STW}{STN}$$

Revolutions	...Revolutions commanded of the motor
Pulses	...Post-quadrature encoder pulses
STW	...Step width (step width factor = number of steps per encoder pulse)
STN	...Step number (number of steps = number of steps per revolution)

Value range of STN and STW: 0 to 65535

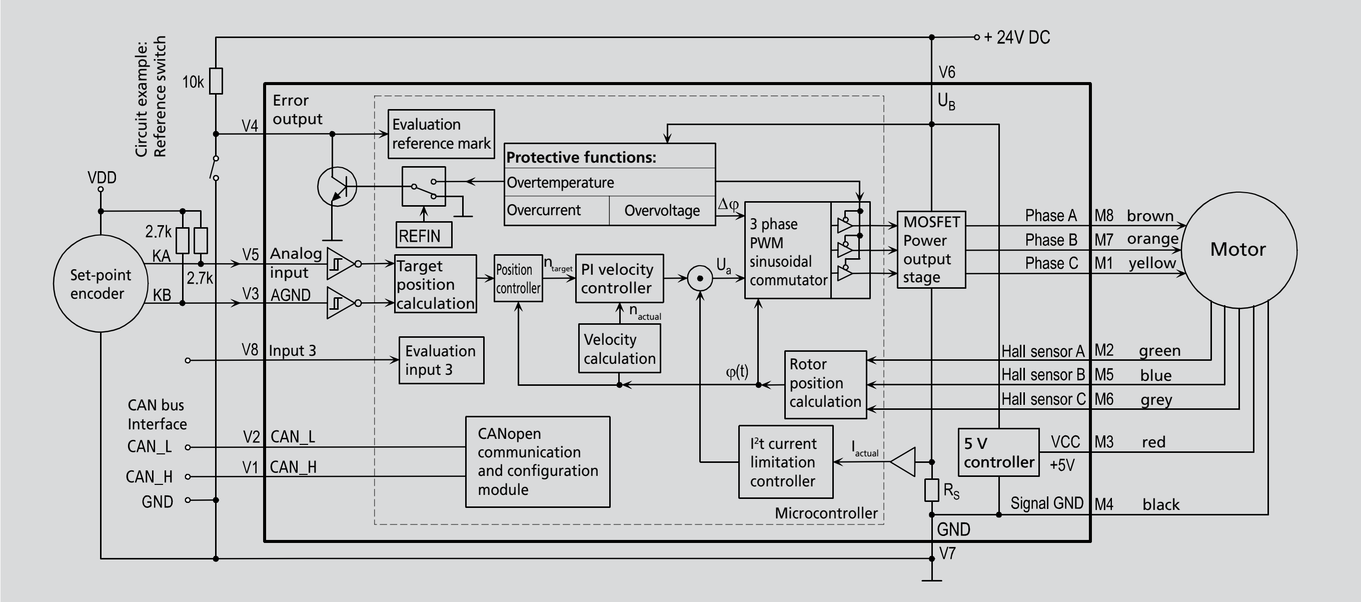
Command	Function	Description
STW	Load Step Width	Load step width for stepper motor and gearing mode
STN	Load Step Number	Load number of steps per revolution for stepper motor and gearing mode

Example:
Motor has to move one revolution at 1000 pulses of the external encoder:
STW1
STN1000

The direction of rotation can be predefined with the commands ADL and ADR, or using an external signal at the fault pin (DIRIN command).

The acceleration and speed parameters (AC, DEC, SP) are effective in gearing mode. These permit gentle starting and deceleration. The position range limits set via LL can also be activated with the APL1 command.

Circuit example gearing mode for MCBL 3003/06 C



3 Functional Description

3.4 Extended operating modes

3.4.3 Analog positioning mode

In analog positioning mode, the position can be commanded using a potentiometer or an external analog voltage.

Command	Function	Description
APCMOD	Analog Position Control Mode	Change to position control via analog voltage

The full-scale deflection at 10 V is set using the LL command. At –10 V the drive will move the motor an equal distance, but in the opposite direction.

Command	Function	Description
LL	Load Position Range Limits	Load limit positions (the drive does not move out of these limits in positioning mode, positive values specify the upper limit and negative values specify the lower limit). APCMOD: Position value at 10 V

Irrespective of the preset LL value, the maximum position is limited to 3 000 000 in APCMOD. Note: The resolution of the analog input is limited to 12 bit (4096 steps).

The direction of rotation can be predefined with the commands ADL and ADR. The acceleration and speed paramaters (AC, DEC, SP) are effective in APCMOD. These permit gentle starting and stopping.

Velocity control using a pulse width modulated (PWM) signal:

If SOR2 is set in APCMOD, the pulse duty factor of a PWM signal can be used as command position.

Default duty cycle at the analog input:

- Greater than 50 % commands a positive position
- Equal to 50 % commands target position = 0
- Less than 50 % commands a negative position

Absolute positioning within one revolution:

Thanks to the linear Hall sensors, the absolute position can be recorded within one revolution on brushless motors. This means that even if the power supply is disconnected, the position determination supplies the correct position value after restarting (if the rotor has only been turned within one revolution).

The following commands enable the drive to be accurately positioned in the voltage range 0 V to 10 V within one revolution and to return to the correct position even after the power has been cycled, without homing (not available with the MCDC):
APCMOD ...change to analog positioning
LL3000 ...fix maximum position at 1 revolution

3.4.4 Dual-loop PID control mode (not available on MCDC)

For high-precision applications, an external encoder on the end effector may be used to accurately control the system. A word of caution is in order. Any backlash in the system may lead to an unstable system causing damage to mechanical components!

- The resolution of the system is dependent upon the resolution of the external encoder.
- The motor velocity may be controlled by using the Hall sensors or the external encoder.
- The external encoder may be directly linked to the motor shaft, but systems using an encoder on the end effector will realize even more significant benefits like higher precision.
- Hall sensors are still used for commutation.

Command	Function	Description
ENCMOD	Encoder Mode	Change to encoder signals mode (not for MCDC). An external encoder signal serves as position transducer (the current position value is set to 0)
HALLSPEED	Hall sensor as speed sensor	Hall sensors used to control motor speed (not for MCDC)
ENCSPEED	Encoder as speed sensor	External encoder used to control motor speed (not for MCDC)

The two channels of the external encoder signals are connected to AnIn and AGND, which may need to be connected to the 5 V encoder supply using a 2.7 kΩ pull-up resistor.

The maximum limit position (value preset with the LL command) covers the value range from 0 to 1800000000 for the positive and 0 to –1800000000 for the negative limit position.

Input:
Maximum input frequency: 400 kHz
Level: low 0...0.5 V / high 3.5 V… U_B

Set encoder resolution:

Command	Function	Description
ENCRES	Load Encoder Resolution	Load resolution of external encoder. Value range: 0 to 65535 (4 times pulse/rev)

Example:
External encoder with 512 pulses: ENCRES2048

Set ENCRES to the post-quadrature value of the encoder resolution, which is four times the resolution of one channel per revolution.

3.4.5 Voltage regulator mode

To regulate the power supply to an effectively lower DC voltage, configure the drive using the command VOLTMOD. While current limiting is still active, the drive will hold a constant voltage proportional to power supply. This allows, for example, testing a brushed motor at different voltages with a fixed voltage power supply.

Command	Function	Description
VOLTMOD	Set Voltage Mode	Activate voltage regulator mode
U	Set Output Voltage	Output motor voltage. Value: –32767...32767 (corresponds to -Uv...+Uv)

Three options exist to control the output voltage: CAN, analog input voltage, and PWM.

Using CAN requires first setting SOR0.
The command U sets the output voltage proportional to the supply voltage. A value of 32767 passes the full power supply voltage to the motor. A value of 0 passes 0 V to the motor. A value of –32767 passes the full power supply voltage inverted.

Using an analog voltage requires first setting SOR1.
The input analog voltage will scale the output voltage to the motor. A value of 10 V passes the full power supply voltage to the motor. A value of 0 V passes 0 V to the motor. A value of –10 V passes the full power supply voltage inverted.

Using a PWM signal requires first setting SOR2.
A 100 % duty cycle passes the full power supply voltage to the motor. A 50 % duty cycle passes 0 V to the motor. A 0 % duty cycle passes the full power supply voltage inverted.

3.4.6 Analog control of current limit

The command SOR3 allows the drive to change current limiting by using the analog input. A 10 V signal allows the drive to induce as much current as is limited by the setting for LPC. In this mode, the I^2t calculation stops and the LCC setting has no effect. Setting LPC beyond what the motor can sustain may cause permanent damage!

The motion controller only measures the magnitude of the input voltage. A negative input voltage will not cause reverse direction of rotation.

3.4.7 IxR control for DC controllers

For speed-controlled applications with DC motors without an encoder, an IxR control is available on the MCDC. In this mode, the motor speed is determined via an internal motor model. Consequently, the encoder and the associated wiring can be omitted. However, control quality and accuracy are considerably restricted. This mode is mainly suited for higher speeds and larger motors in the FAULHABER range.

Command	Function	Description
IXRMOD	Set IxR Mode	Activate IxR control (MCDC only)
RM	Load Motor Resistance	Load motor resistance R_M as found on the spec sheet Unit: mOhm
KN	Load Speed Constant	Load speed constant k_n as found on the spec sheet Unit: rpm/V

3 Functional Description

3.5 Special functions of the error connection

The fault output pin can be configured to act as an input or an output. Use the appropriate command found in the following table to configure the pin for the desired functionality.

Command	Function	Description
ERROUT	Error Output	Fault pin as error output
ENCOUT	Encoder Output	Fault pin as pulse output (not available on the MCDC)
DIGOUT	Digital Output	Fault pin as digital output. The output initializes to low logic (pulled to GND)
DIRIN	Direction Input	Fault pin as rotational direction input
REFIN	Reference Input	Fault pin as reference or limit switch input

The REFIN and DIRIN functions have already been explained in the relevant sections.

Fault pin as error output:

In ERROUT mode the output is set as soon as one of the following errors occurs:

– One of the set current limitation values (LPC, LCC) is exceeded

– Set maximum permissible speed deviation (DEV) is exceeded

– Overvoltage detected

– Maximum coil or MOSFET temperature exceeded

In order to hide the transient occurrence of errors during the acceleration phase, for example, an error delay can be set which specifies how long an error must be present before it is displayed at the error output:

Command	Function	Description
DCE	Delayed Current Error	Delayed error output for ERROUT in 1/100 sec.

Example:
Only display error after 2 seconds: DCE200

If one of the above errors occurs, a corresponding Emergency Object is sent to the CAN network!
Please consider the error mask in object 0x2320.
Only it is set at 1, the error status will be send.
See also chapter 6.2 Manufacturer-specific objects under FAULHABER fault register.

Fault pin as pulse output (not for MCDC):

In the ENCOUT mode the fault pin is used as pulse output, which outputs an adjustable number of pulses per revolution. The pulses are derived from the Hall sensor signals of the BL motors and are limited to 4000 pulses per second.

Command	Function	Description
LPN	Load Pulse Number	Preset pulse number for ENCOUT. Value range: 1 to 255

Example:
Output 16 pulses per revolution at the fault pin: LPN16
In the case of 5000 rpm, 5000/60 · 16 = 1333 pulses per second are output.

For speeds that would generate more than the maximum possible pulse number at the set LPN value, the maximum number is output. The set pulses are precisely achieved, but the timing does not necessarily have to exactly agree (delays possible). Position determination via pulse counting is therefore possible, provided that no change occurs in the direction of rotation and the maximum possible pulse number is not exceeded.

Fault pin as digital output:

In DIGOUT mode, the error connection can be used as universal digital output. The digital output can be set or deleted via the following commands.

Command	Function	Description
CO	Clear Output	Set digital output DIGOUT to low level
SO	Set Output	Set digital output DIGOUT to high level
TO	Toggle Output	Switch digital output DIGOUT

3.6.1 Sinusoidal commutation

The 3564K024B CC and the MCBL 3003/06 C are characterised by a so-called sinus commutation. This means that the preset rotating field is always ideally positioned in relation to the rotor. As a result, torque fluctuations can be reduced to a minimum, even at very low speeds. In addition, the motor runs particularly quietly.

In the current version, the sinus commutation has been extended by a so-called flat-top modulation, which enables 15 % more modulation. As a result, higher no-load speeds are possible. With the SIN0 command, the system can even be set so that over 30 % more modulation is possible.
In this mode, the sinus commutation in the upper speed range switches over to a block commutation. This full modulation enables the complete speed range of the motor to be utilised.

Command	Function	Description
SIN	Sinus Commutation	1: Only sinusoidal commutation 0: Block commutation in the upper speed range (full modulation possible)

3.6.2 Current controller and I^2t current limitation

The FAULHABER motion controllers are equipped with an integral current controller, which enables implementation of a moment limitation.

The following parameters can be set:

Command	Function	Description
LPC	Load Peak Current Limit	Load peak current Value range: 0 to 12000 mA
LCC	Load Continuous Current Limit	Load continuous current Value range: 0 to 12000 mA
CI	Load Current Integral Term	Load integral term for current controller Value range: 1…255

1.) Peak current

FAULHABER command:
LPC8000 ➔ set peak current to 8000 mA

The current is limited to the peak current, provided that the thermal current model calculates a non-critical temperature.

2.) Continuous current

FAULHABER command:
LCC2800 ➔ set continuous current to 2800 mA

If the thermal current model reaches a critical temperature, limit is set to continuous current.

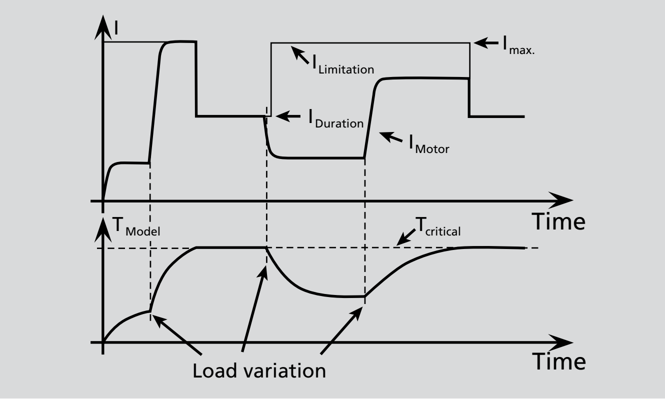
Mode of operation of the current controller:

When the motor starts, the peak current is preset as the set-point for the current controller. As the load increases, the current in the motor constantly increases until it finally reaches the peak current. The current controller then comes into operation and limits the current to this set-point.

A thermal current model operating in parallel calculates a model temperature from the actually flowing current. If this model temperature exceeds a critical value, continuous current is switched to and the motor current is regulated to this. Only when the load becomes so small that the temperature falls below the critical model temperature is peak current permitted again.

The aim of this so-called I^2t current limitation is to prevent heating of the motor beyond the thermally permissible temperature through appropriate selection of the continuous current. On the other hand, a high load should be temporarily possible in order to enable very dynamic movements.

Functioning of the I^2t current limitation:



3.6.3 Overtemperature protection

If the MOSFET temperature of the external controllers or the coil temperature of the 3564K024B CC exceeds a preset limit value, the motor is switched off. The following conditions must be fulfilled in order to reactivate the motor:

- Temperature below a preset limit value
- Target velocity set to 0 rpm
- Actual motor speed less than 50 rpm

Note on determination of the coil temperature:
The housing temperature is measured and the power loss concluded from the current measurement. The MOSFET or coil temperature is calculated from these values via a thermal model. In most applications, this method represents a thermal motor protection device.

3.6.4 Undervoltage monitoring

If the supply voltage falls below the lower voltage threshold, the power stage is switched off. The motion controller remains active. When the voltage returns within the permissible range, the power stage is switched on again immediately.

3.6.5 Overvoltage regulation

If the motor is operated as a generator, it produces energy. Usually power supply units are not able to feed this energy back into the power line. Consequently, the supply voltage at the motor increases, and depending on the speed, the permissible maximum voltage may be exceeded.

In order to avoid severe damage to components, the 3564K024B CC and the MCBL 3003/06 C contain a controller which adjusts the rotor displacement angle if a limit voltage (32 V) is exceeded. The MCDC 3003/06 C contains a ballast circuit which is activated if a limit voltage (32 V) is exceeded. As a result, the energy generated in the motor is converted, and the voltage of the electronics remains limited to 32 V. This method protects the drive during generating operation and rapid braking.

3.6.6 Adjustment of the controller parameters

The controller parameters are already preset for common applications. However, in order to optimally adapt the controller to the respective application, the controller parameters must be optimized. Various theoretical and practical adjustment rules exist, but these will not be described in more detail here. A simple, practical method of adjusting the controller is explained below.

The digital controller operates at a sampling rate of 100 µs. When needed the sampling rate can be increased up to 2 ms.

The following controller parameters are available:

Command	Function	Description
POR	Load Velocity Proportional Term	Load velocity controller amplification. Value range: 1 – 255. Corresponds to object 0x60F9
I	Load Velocity Integral Term	Load velocity controller integral term. Value range: 1 – 255. Corresponds to object 0x60F9
PP	Load Position Proportional Term	Load position controller amplification. Value range: 1 – 255. Corresponds to object 0x60FB
PD	Load Position D-Term	Load position controller D-term. Value range: 1 – 255. Corresponds to object 0x60FB
SR	Load Sampling Rate	Load sampling rate of the velocity controller as a multiplier of 100 µs. Value Range: 1...20 ms/10

Possible procedure:

a.) Set parameters of velocity controller:

1.) First of all you have to choose the right sampling rate for the velocity controller depending on the encoder resolution. With less encoder pulses you need a lower sampling rate (i.e. ENCRES256 -> SR18). For BL motors with internal encoder (3000 pulses) the maximum sampling rate SR1 (100 µs) is recommended.

Set initial configuration:

- Controller amplification = 8; POR8
- Integral term = 20; I20
- Speed at 1/3 of the maximum application speed (example V1000)
- Set acceleration to highest value of application (example AC10000)

2.) Increase controller amplification (step width 5, less subsequently); POR 13

3.) Preset velocity jump from 1/3 of maximum speed to 2/3 (example V2000)

4.) Velocity jump from 2/3 to 1/3 and monitor behaviour (example V1000)

5.) Repeat steps 2 to 4, until the controller becomes unstable. Then reduce controller amplification until stability is reliably ensured.

6.) Follow steps 2 to 5 with integral term

b.) Set parameters of position controller:

1.) Set initial configuration

- Default value for P term: 8; PP8
- Default value for D term: 15; PD15

2.) Motion profiles appropriate for the application must now be run. If the system does not function stably with these settings, stability can be achieved by reducing the I term of the velocity controller or reducing the P term of the position controller.

3.) The P term of the position controller can now be increased until the system becomes unstable, in order to optimise the motion profile.

4.) The stability can then be restored through the following measures:

- Increasing the D term of the position controller (example: PD20)
- Reducing the I term of the velocity controller

4 CANopen

4.1 Introduction

- CANopen is a standard software protocol based on CAN hardware (Controller Area Network).
- The international CAN organisation CAN in Automation e.V. (CiA) defines the communication profile in DS301 (description of the communication structure and the methods for parameter access, control and monitoring functions).
- Device profiles are specified for the various devices, such as DSP402 for drives and DS401 for I/O devices (general device description from the user's viewpoint).
- Public data are managed via the object dictionary (parameter table, access to entries via index and sub-index).
- There are two data communication objects:
  – PDOs (process data objects for control and monitoring)
  – SDOs (service data objects for access to the object dictionary)
- Further objects are available for network management, node guarding and synchronisation.
- CANopen supports up to 127 nodes per network segment with transfer rates up to 1 MBit/s.
- The communication is message-related; each communication object receives its own 11 bit identifier.

The FAULHABER motion controllers support the CANopen communication profile according to CiA DS301 V4.
The following communication objects are supported:

– 3 transmit PDOs
– 3 receive PDOs
– 1 server SDO
– 1 emergency object
– NMT with node guarding (no heartbeat)
– No SYNC, no time stamp object

The identifier configuration of the CANopen objects is defined according to the "Predefined Connection Set" (see section 4.5 NMT Network Management). The data assignment of the PDOs is permanently preset (static PDO Mapping).

Many manufacturers offer CANopen libraries for PC and PLC systems through which the individual objects can be easily accessed, without having to deal with the internal structure.

FAULHABER Motion Manager 3 also enables easy access to the individual objects via a graphic user interface.

4 CANopen

4.2 PDOs (Process Data Objects)

PDOs correspond to a CAN message frame with up to 8 bytes and are used for the transfer of process data, i.e. control and monitoring of the device behaviour. The PDOs are designated from the viewpoint of the field device. Receive PDOs (RxPDOs) are received by the field device and contain e.g. control data, while Transmit PDOs (TxPDOs) are sent by the field device and contain e.g. monitoring data.

PDOs can only be transmitted if the device is in "Operational" status (see section 4.5 NMT (Network Management)).

PDO communication modes:

- Event-controlled: Data are sent by the device automatically after a change.
- Remote Request (RTR): Data are sent after a request message frame.
- Synchronised (not supported): Data are sent after receipt of a SYNC object.

FAULHABER motion controllers provide the following PDOs:

- Receive PDO1: controlword according to DSP402
- Transmit PDO1: statusword according to DSP402
- Receive PDO2: FAULHABER command
- Transmit PDO2: FAULHABER request data (RTR)
- Receive PDO3: FAULHABER trace configuration
- Transmit PDO3: FAULHABER trace data (RTR)

RxPDO1: Controlword

11 bit identifier	2 bytes user data	
0x200 (512D) + Node-ID	LB	HB

Contains the 16 bit controlword according to CiA DSP402, which controls the state machine of the drive unit.
The PDO refers to the object index 0x6040 in the object dictionary. The bit division is described in section 6.3.1 Device Control.

TxPDO1: Statusword

11 bit identifier	2 bytes user data	
0x180 (384D) + Node-ID	LB	HB

Contains the 16 bit statusword according to CiA DSP402, which displays the status of the drive unit. The PDO refers to the object index 0x6041 in the object dictionary. The bit division is described in section 6.3.1 Device Control.

4 CANopen

4.2 PDOs (Process Data Objects)

RxPDO2: FAULHABER command

11 bit identifier	5 bytes user data				
0x300 (768D) + Node-ID	Command	LLB	LHB	HLB	HHB

Provides the FAULHABER channel for the transmission of manufacturer-specific commands. All parameters and control commands of the drive unit can be transmitted using this PDO. 5 bytes are always transferred: the first byte specifies the command and the following 4 bytes specify the argument as a Long Integer value. A description of the commands is given in section 6.4 **FAULHABER Commands**.

TxPDO2: FAULHABER data

11 bit identifier	6 bytes user data					
0x280 (640D) + Node-ID	Command	LLB	LHB	HLB	HHB	Error

FAULHABER channel for request commands. A request (RTR) on this PDO provides the data requested with the previously sent command. 6 bytes are always transferred: the first byte specifies the command and the following 4 bytes the desired value as a Long Integer, followed by an error code. The Error byte can also be used to check whether a Transmit command has been successfully executed (1 = command successfully executed, for further error codes see section 6.4 **FAULHABER Commands**).

RxPDO3: Trace configuration

11 bit identifier	5 bytes user data				
0x400 (1024D) + Node-ID	Mode1	Mode2	TC	Packets	Period

This PDO serves for setting Trace mode, which allows internal parameters to be read out quickly. The data configuration looks like this:

Byte 0: Mode for Parameter 1
Byte 1: Mode for Parameter 2
Byte 2: Transfer with time code [1/0]
Byte 3: Number of packets to be transmitted per request (default:1)
Byte 4: Time interval between packets (default: 1 ms)

The possible operating modes for parameters 1 and 2 are described in section 5.2 **Trace**.

TxPDO3: Trace data

11 bit identifier	3 to 8 bytes user data							
0x380 (896D) + Node-ID	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7

A request (RTR) on this provides the Trace data according to the setting made via RxPDO3 (see section 5.2 **Trace**).

4.3 SDO (Service Data Object)

The Service Data Object allows parameters to be read and written in the object dictionary (OD). Access occurs via the 16 bit index and the 8 bit subindex. The motion controller acts as server in this case, i.e. it provides data at the client's (PC, PLC) request (upload) and receives data from the client (download).

Byte0	Byte1-2	Byte3	Byte4
Command Specifier	16 bit index	8 bit subindex	1-4 byte parameter data

➔ Entry in the object dictionary

There are 2 different SDO transfer modes:
– Expedited Transfer: Transfer of maximum 4 bytes
– Segmented Transfer: Transfer of more than 4 bytes

As a maximum of 4 data bytes are transferred with FAULHABER motion controllers except for version and device name requests, only Expedited Transfer is described here.

The message frames are always 8 bytes and structured as follows:

Reading OD entries: Client ➔ Server, Upload Request

11 bit identifier	8 bytes user data							
0x600 (1536D) + Node-ID	0x40	Index LB	Index HB	Subindex	0	0	0	0

Server ➔ Client, Upload Response

11 bit identifier	8 bytes user data							
0x580 (1408D) + Node-ID	0x4x	Index LB	Index HB	Subindex	LLB (D0)	LHB (D1)	HLB (D2)	HHB (D3)

Byte0 (0x4x) specifies the number of valid data bytes in D0-D3 and the transfer type and is coded as follows for Expedited Transfer (≤ 4 data bytes):

– 1 data byte in D0:	Byte0 = 0x4F	– 2 data bytes in D0-D1:	Byte0 = 0x4B
– 3 data bytes in D0-D2:	Byte0 = 0x47	– 4 data bytes in D0-D3:	Byte0 = 0x43

Writing OD entries: Client -> Server, Download Request

11 bit identifier	8 bytes user data							
0x600 (1536D) + Node-ID	0x2x	Index LB	Index HB	Subindex	LLB (D0)	LHB (D1)	HLB (D2)	HHB (D3)

Byte0 (0x2x) specifies the number of valid data bytes in D0-D3 and the transfer type and is coded as follows for Expedited Transfer (≤ 4 data bytes):

– 1 data byte in D0:	Byte0 = 0x2F	– 2 data bytes in D0-D1:	Byte0 = 0x2B
– 3 data bytes in D0-D2:	Byte0 = 0x27	– 4 data bytes in D0-D3:	Byte0 = 0x23

If no specification of the number of data bytes is necessary: Byte0 = 0x22

Server ➔ Client, Download Response

11 bit identifier	8 bytes user data							
0x580 (1408D) + Node-ID	0x60	Index LB	Index HB	Subindex	0	0	0	0

Termination of the SDO protocol in the event of error:
Client ➔ Server

11 bit identifier	8 bytes user data							
0x600 (1536D) + Node-ID	0x80	Index LB	Index HB	Subindex	Error0	Error1	Error2	Error3

Server ➔ Client

11 bit identifier	8 bytes user data							
0x580 (1408D) + Node-ID	0x80	Index LB	Index HB	Subindex	Error0	Error1	Error2	Error3

Error3: Error class
Error2: Error code
Error1: Additional error code HB
Error0: Additional error code LB

Error class	Error code	Additional code	Description
0x05	0x03	0x0000	Toggle bit unchanged
0x05	0x04	0x0001	SDO Command Specifier invalid or unknown
0x06	0x01	0x0000	Access to this object is not supported
0x06	0x01	0x0002	Attempt to write to a Read_Only parameter
0x06	0x02	0x0000	Object not present in the object dictionary
0x06	0x04	0x0041	Object cannot be mapped in PDO
0x06	0x04	0x0042	Number and/or length of mapped objects would exceed PDO length
0x06	0x04	0x0043	General parameter incompatibility
0x06	0x04	0x0047	General internal error in device
0x06	0x06	0x0000	Access terminated due to hardware error
0x06	0x07	0x0010	Data type or parameter length do not agree or are unknown
0x06	0x07	0x0012	Data type does not agree, parameter length too large
0x06	0x07	0x0013	Data type does not agree, parameter length too small
0x06	0x09	0x0011	Subindex not available
0x06	0x09	0x0030	General value range error
0x06	0x09	0x0031	Value range error: Parameter value too large
0x06	0x09	0x0032	Value range error: Parameter value too small
0x06	0x0A	0x0023	Resource not available
0x08	0x00	0x0021	Access not possible due to local application
0x08	0x00	0x0022	Access not possible due to current device status

4 CANopen

4.4 Emergency Object (Error Message)

The Emergency Object informs other bus subscribers of errors that have occurred.
The Emergency Object is always 8 bytes in size and structured as follows:

11 bit identifier	8 bytes user data							
0x80 (128D) + Node-ID	Error0 (LB)	Error1 (HB)	Error-Reg.	0	0	0	0	0

The first two bytes contain the 16 bit error code, the third byte contains the error register, the following 5 bytes can contain a manufacturer-specific additional code.

The error register identifies the error type. The possible error Typees are described in the OD under Index 0x1001 (e.g. Bit 4 = Communication Error).

The general errors are listed in the following error code table
(e.g. Error0=0x10, Error1=0x82: Error 0x8210: PDO not processed due to length error):

Emergency Error Codes

Error Code (hex)	Meaning
0000	no error
1000	generic error
2000	current
2300	current, device output side
2310	continuous over current
3000	voltage
3200	voltage inside the device
3210	over voltage
4000	temperature
4200	device temperature
4210	over temperature
5000	device hardware
5500	data storage
5530	flash memory error
6000	device software
6100	internal software
8000	monitoring
8100	communication
8110	CAN overrun (objects lost)
8120	CAN in error passive mode
8130	life guard error or heartbeat error
8140	recovered from bus off
8150	transmit COB-ID collision
8200	protocol error
8210	PDO not processed due to length error
8220	PDO length exceeded
8400	velocity speed controller (deviation)
8600	positioning controller
8611	following error

4 CANopen

4.5 NMT (Network Management)

After power-on and successful initialisation, the FAULHABER motion controllers are automatically in "Pre-Operational" state. In this state, communication with the device can only occur via service data objects (SDOs) – as well as NMT messages – in order to make or request parameter settings. The FAULHABER motion controllers are supplied with sensible default settings for all objects, so that as a rule no further parameterisation is necessary at system start. Usually, any necessary parameter settings are performed once, e.g. with the help of the FAULHABER Motion Manager, and then stored permanently in the data flash memory. These settings are then available immediately after system start.

A single CAN message is sufficient to start a CANopen device:
Start Remote Node:

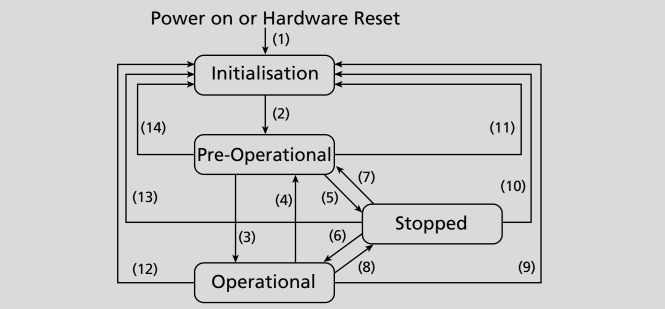
11 bit identifier	2 bytes user data	
0x000	0x01	Node-ID

Or, to start the entire network:
Start All Remote Nodes:

11 bit identifier	2 bytes user data	
0x000	0x01	0x00

The devices are then in "Operational" state. The device is now fully functional and can be operated via PDOs.

The status diagram is shown below:



(1)	At Power on the initialisation state is entered autonomously
(2)	Initialisation finished – enter PRE-OPERATIONAL automatically
(3),(6)	Start_Remote_Node indication
(4),(7)	Enter PRE-OPERATIONAL_State indication
(5),(8)	Stop_Remote_Node indication
(9),(10),(11)	Reset_Node indication
(12),(13),(14)	Reset_Communication indication

In "Stopped" ("Prepared") state, the device is in error status and can no longer be operated via SDO and PDOs. Only NMT messages are received, in order to produce a status change. Status changes can be performed with the help of the NMT services:

An NMT message frame always consists of 2 bytes on the identifier 0x000:

11 bit identifier	2 bytes user data	
0x000	CS	Node-ID

CS: Command Specifier
Node ID: Node address (0 = all nodes)

The possible values for the Command Specifier CS are listed in the following table:

State transition	Command specifier cs	Explanation
(1)	–	The initialisation state is entered autonomously at power on.
(2)	–	The Pre-Operational state is entered automatically after initialisation, and the boot-up message is sent.
(3), (6)	cs = 0x01 (1D)	Start_Remote_Node. Starts the device and releases PDO transmission.
(4), (7)	cs = 0x80 (128D)	Enter_Pre-Operational. Stops PDO transmission, SDO still active.
(5), (8)	cs = 0x02 (2D)	Stop_Remote_Node. Device goes into error state, SDO and PDO switched off.
(9), (10), (11)	cs = 0x81 (129D)	Reset_Node. Performs a reset. All objects are reset to Power-On defaults.
(12), (13), (14)	cs = 0x82 (130D)	Reset_Communication. Performs a reset of the communication functions.

4 CANopen

4.5 NMT (Network Management)

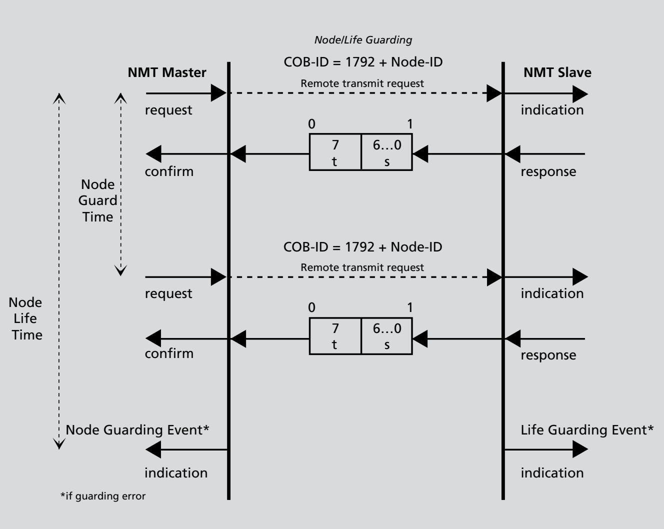
Boot-Up message:
After the initialisation phase, the FAULHABER motion controller sends the boot-up message, a CAN message with one data byte (Byte0 = 0x00), on the identifier of the Node-Guarding message (0x700 + Node ID):

11 bit identifier	1 byte user data
0x700 (1792D) + Node-ID	0x00

The Boot-Up message signals the end of the initialisation phase of a newly activated module, which can then be configured and started.

Node Guarding:
The current device status can be requested with the Node-Guarding Object. The Master sends a request (request message frame) to the Guarding Identifier of the monitored node by setting a remote frame. The node then responds with the Guarding message, which contains the current node status and a toggle bit.

The following diagram describes the Node-Guarding protocol:



t: Toggle Bit. Initially 0, changes its value in each Guarding frame.

s: Status:

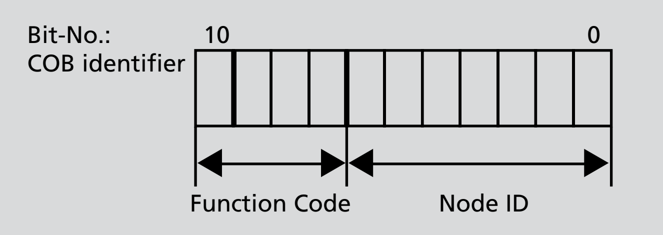
s = 0x04 (4D): Stopped (Prepared)

s = 0x05 (5D): Operational

s = 0x7F (127D): Pre-Operational

Identifier distribution:

CANopen provides default identifiers for the most important objects in the "Predefined Connection Set". These consist of a 7-bit node address (Node ID) and a 4-bit function code, in accordance with the following diagram:



The FAULHABER motion controllers only operate with these default identifiers!

Object	Function code (binary)	Resulting COB-ID	Communication Parameters at Index
NMT	0000	0	–
SYNC	0001	128 (80h)	1005h
TIME STAMP	0010	256 (100h)	1012h

Object	Function code (binary)	Resulting COB-ID	Communication Parameters at Index
EMER-GENCY	0001	129 (81h) – 255 (FFh)	1014h, 1015h
PDO1 (tx)	0011	385 (181h) – 511 (1FFh)	1800h
PDO1 (rx)	0100	513 (201h) – 639 (27Fh)	1400h
PDO2 (tx)	0101	641 (281h) – 767 (2FFh)	1801h
PDO2 (rx)	0110	769 (301h) – 895 (37Fh)	1401h
PDO3 (tx)	0111	897 (381h) – 1023 (3FFh)	1802h
PDO3 (rx)	1000	1025 (401h) – 1151 (47Fh)	1402h
SDO (tx)	1011	1409 (581h) – 1535 (5FFh)	1200h
SDO (rx)	1100	1537 (601h) – 1663 (67Fh)	1200h
NMT Error Control	1110	1793 (701h) – 1919 (77Fh)	

4.6 Entries in the object dictionary

The configuration parameters are managed in the CANopen Object dictionary.
The Object dictionary is divided into three areas:

1. Communication parameters (Index 0x1000 – 0x1FFF)
2. Manufacturer-specific area (Index 0x2000 – 0x5FFF)
3. Standardised device profiles (0x6000 – 0x9FFF)

The 1st area contains the objects according to DS301, the 2nd area is reserved for manufacturer-specific objects, and the 3rd area contains the objects according to DSP402 supported by the FAULHABER motion controllers.

Each object can be referenced via its index and sub-index (SDO protocol).

Overview of the available objects:

a.) Communication objects according to DS301:

Index	Object (Symbolic Name)	Name	Type	Attrb.
0x1000	VAR	device type	UNSIGNED32	ro
0x1001	VAR	error register	UNSIGNED8	ro
0x1003	ARRAY	pre-defined error field	UNSIGNED32	ro
0x1008	VAR	manufacturer device name	Vis-String	const
0x1009	VAR	manufacturer hardware version	Vis-String	const
0x100A	VAR	manufacturer software version	Vis-String	const
0x100C	VAR	guard time	UNSIGNED16	rw
0x100D	VAR	life time factor	UNSIGNED8	rw
0x1010	ARRAY	store parameters	UNSIGNED32	rw
0x1011	ARRAY	restore default parameters	UNSIGNED32	rw
0x1014	VAR	COB-ID EMCY	UNSIGNED32	ro
0x1018	RECORD	Identity Object	Identity (23h)	ro
		Server SDO Parameter		
0x1200	RECORD	1st Server SDO parameter SDO	Parameter (22h)	ro
		Receive PDO Communication Parameter		
0x1400	RECORD	1st receive PDO Parameter PDO	CommPar (20h)	rw
0x1401	RECORD	2nd receive PDO Parameter PDO	CommPar (20h)	rw
0x1402	RECORD	3rd receive PDO Parameter PDO	CommPar (20h)	rw
		Receive PDO Mapping Parameter		
0x1600	RECORD	1st receive PDO mapping PDO	Mapping (21h)	ro
0x1601	RECORD	2nd receive PDO mapping PDO	Mapping (21h)	ro
0x1602	RECORD	3rd receive PDO mapping PDO	Mapping (21h)	ro
		Transmit PDO Communication Parameter		
0x1800	RECORD	1st transmit PDO Parameter PDO	CommPar (20h)	rw
0x1801	RECORD	2nd transmit PDO Parameter PDO	CommPar (20h)	rw
0x1802	RECORD	3rd transmit PDO Parameter PDO	CommPar (20h)	rw
		Transmit PDO Mapping Parameter		
0x1A00	RECORD	1st transmit PDO mapping PDO	Mapping (21h)	ro
0x1A01	RECORD	2nd transmit PDO mapping PDO	Mapping (21h)	ro
0x1A02	RECORD	3rd transmit PDO mapping PDO	Mapping (21h)	ro

b.) Drive profile objects according to DSP402:

Index	Name	Type	Attrb.	Meaning
0x6040	controlword	Unsigned16	rw	Drive control
0x6041	statusword	Unsigned16	ro	Status display
0x6060	modes of operation	Integer8	wo	Operating mode changeover
0x6061	modes of operation display	Integer8	ro	Set operating mode
0x6062	position demand value	Integer32	ro	Last target position
0x6063	position actual value	Integer32	ro	Actual position in increments
0x6064	position actual value	Integer32	ro	Actual position scaled
0x6067	position window	Unsigned32	rw	Target position window
0x6068	position window time	Unsigned16	rw	Time in target position window
0x6069	velocity actual sensor value	Integer32	ro	Current speed value
0x606B	velocity demand value	Integer32	ro	Target speed
0x606C	velocity actual value	Integer32	ro	Current speed value
0x606D	velocity window	Unsigned16	rw	End speed window
0x606E	velocity window time	Unsigned16	rw	Time in end speed window
0x606F	velocity threshold	Unsigned16	rw	Speed threshold value
0x6070	velocity threshold time	Unsigned16	rw	Time below speed threshold value
0x607A	target position	Integer32	rw	Target position
0x607C	homing offset	Integer32	rw	Reference point offset
0x607D	software position limit	ARRAY	rw	Area limits
0x607E	polarity	Unsigned8	rw	Polarity (direction of rotation)
0x607F	max profile velocity	Unsigned32	rw	Maximum speed
0x6081	profile velocity	unsigned32	rw	Maximum speed
0x6083	profile acceleration	Unsigned32	rw	Acceleration value
0x6084	profile deceleration	Unsigned32	rw	Braking ramp value
0x6085	quick stop deceleration	Unsigned32	rw	Quick stop braking ramp value
0x6086	motion profile type	Integer16	ro	Motion profile
0x6093	position factor	ARRAY	rw	Position factor
0x6096	velocity factor	ARRAY	rw	Speed factor
0x6097	acceleration factor	ARRAY	rw	Acceleration factor
0x6098	homing method	Integer8	rw	Homing method
0x6099	homing speed	ARRAY	rw	Homing speed
0x609A	homing acceleration	Unsigned32	rw	Homing acceleration
0x60F9	velocity control parameter set	ARRAY	rw	Parameters for speed controller
0x60FA	control effort	Integer32	ro	Controller output
0x60FB	position control parameter set	ARRAY	rw	Parameters for position controller
0x60FF	target velocity	Integer32	rw	Target speed
0x6510	drive data	RECORD	rw	Drive information

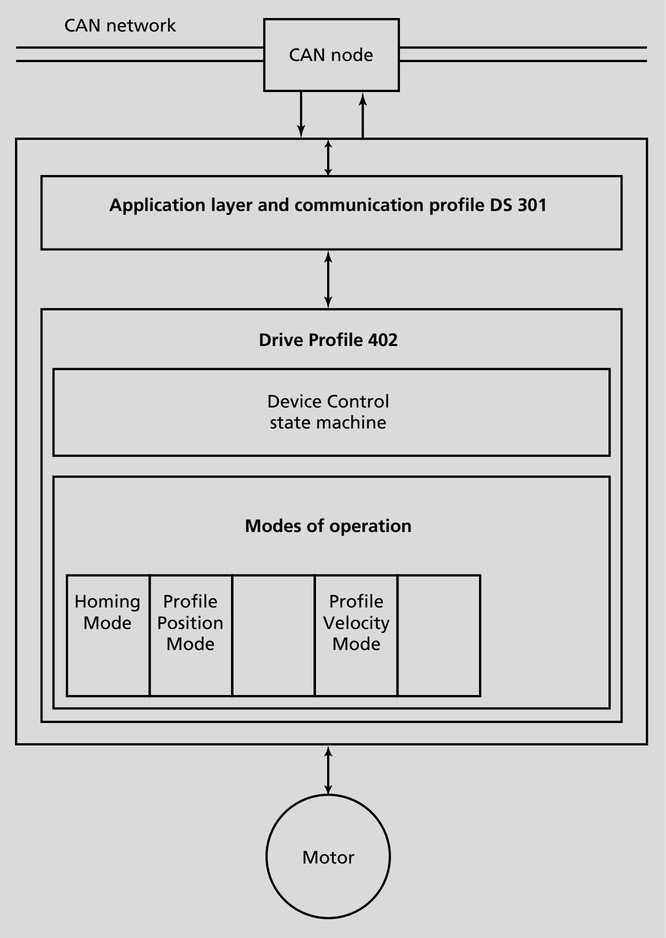
A detailed description of the individual objects is provided in section 6 Parameter Description.

4 CANopen

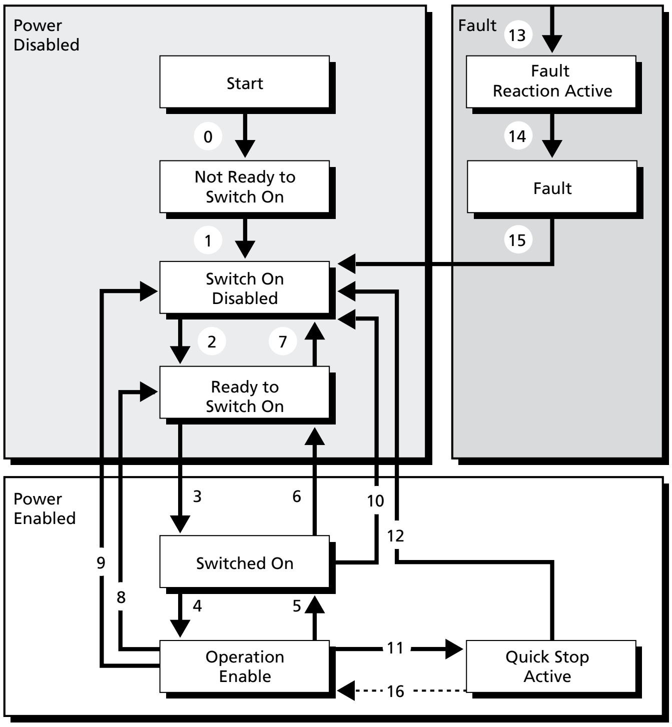
4.7 Drive control (Device control)

The FAULHABER motion controllers support drive control according to CiA DSP402. This device profile for drives is based on the CiA DS301 communication profile and provides standardised objects for drive control and configuration.

In addition to “Device Control”, the operating modes “Profile Position Mode”, “Profile Velocity Mode” and “Homing Mode” are also supported.



The drive behaviour is mapped in CANopen via a state machine. The states can be controlled with the *controlword* and displayed with the *statusword*:



After switch on and successful initialisation, the FAULHABER drive is immediately in “Switch On Disabled” state.

A state change can only be performed when the device is in “Operational” state (see section 4.5 NMT (Network Management)).

The “Shutdown” command puts the drive in the “Ready to Switch On” state (transition 2).

The “Switch On” command then switches on the power stage. The drive is now enabled and is in “Switched On” state (transition 3).

The “Enable Operation” commands puts the drive in the “Operation Enabled” state, the drive’s normal operating mode (transition 4). The “Disable Operation” command returns the drive to the “Switched On” state and serves e.g. to terminate a running operation (transition 5).

The state changes shown in the diagram are executed by the following commands:

Command	Transitions
Shutdown	2,6,8
Switch on	3
Disable Voltage	7,9,10,12
Quick Stop	7,10,11
Disable Operation	5
Enable Operation	4,16
Fault Reset	15

The commands for executing state changes are executed through a special bit combination in the *controlword*. The *controlword* is located in the Object dictionary under Index 0x6040 and is generally transmitted with PDO1.

The meaning of the individual bits of the *controlword* is explained in section 6.3.1 Device Control.

In the event of state changes, the FAULHABER motion controller in its default setting automatically sends the current *statusword* on PDO1. The current state can also be requested at any time via a remote request on PDO1. The *statusword* is located in the Object dictionary under Index 0x6041.

The meaning of the individual bits of the *statusword* is explained in section 6.3.1 Device Control.

5 Extended CAN Functions

5.1 The FAULHABER channel

A special FAULHABER channel is available on PDO2, via which all commands of the motion controller can be simply executed.

For each FAULHABER command there is a corresponding CAN frame with which the CAN unit can be operated, similarly to the serial variant. All functions and parameters of this drive unit can be accessed via this channel.

Section 6.4 FAULHABER Commands contains a complete description of the FAULHABER commands.

5.2 Trace

It is possible to trace operating data via PDO3, i.e. to read data out online in a resolution of up to 1 ms. After setting the desired trace type via RxPDO3, the values can be requested in succession by means of requests to TxPDO3 (see section 4.2 PDOs (Process Data Objects)).

Trace configuration:

RxPDO3:

Byte	Function
0	Mode for parameter 1
1	Mode for parameter 2 255 = No second parameter
2	Transmission with time code 1 = With time code 0 = Without time code
3	Number of data packets to be transmitted per request Default: 1
4	Time interval between packets [ms] Default: 1ms

The following values are available for parameters 1 and 2:

0: Actual speed [Integer16, rpm]
1: Target speed [Integer16, rpm]
2: Controller output [Integer16]
4: Motor current [Integer16, mA]
44: Housing temperature [Unsigned16, °C]
46: Coil temperature [Unsigned16, °C]
200: Actual position [Integer32, Inc]
201: Target position [Integer32, Inc]

Data request:

Depending on the mode set for parameters 1 and 2, 3 to 8 bytes are sent back on TxPDO3 after a request (RTR) on TxPDO3:

1.) Mode1 between 0 and 15,
Mode2 at 255 (inactive)

➔ 3 byte ... 1st byte: Low byte data
2nd byte: High byte data
3rd byte: Time code

The data are in Integer16 format.

2.) Mode1 between 16 and 199,
Mode2 at 255 (inactive)

➔ 3 byte ... Coding as in 1.)

The data are in Unsigned16 format.

3.) Mode1 between 200 and 255,
Mode2 at 255 (inactive)

➔ 5 byte ... 1st byte: Lowest byte data
2nd byte: Second byte data
3rd byte: Third byte data
4th byte: Highest byte data
5th byte: Time code

The data are in Integer32 format.

4.) Mode1 corresponding to 1.), 2.) or 3.) and
Mode2 less than 255:

➔ 5 to 8 byte ... Byte 1 to 2 (4):
Data bytes of Mode1
Byte 3 (5) to 4 (6) (8):
Data bytes of Mode2
Byte 5 (7): Time code

The data bytes of Mode2 are coded as for Mode1.

The time code corresponds to a multiple of the time basis of 1 ms and defines the time interval to the last transmission. If 2 Integer32 parameters are requested, there is no more space for the time code in the CAN frame, and configuration parameter 2 must therefore be set to 0 (transfer without time code). The time measurement must then occur in the Master.

6 Parameter Description

6.1 Communication Objects according to DS301

Device Type

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1000	0	device type	Unsigned32	ro	No	Specification of the device type

Contains information on the device type, divided into two 16-bit fields:

Byte: MSB LSB

Additional Information	Device Profile Number

Device Profile Number = 0x192 (402D)

Error Register

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1001	0	error register	Unsigned8	ro	No	Error register

Internal device errors are displayed in this byte as follows:

Bit	M/O	Meaning
0	M	generic error
1	O	current
2	O	voltage
3	O	temperature
4	O	communication error (overrun, error state)
5	O	device profile specific
6	O	reserved (always 0)
7	O	manufacturer specific

Pre-defined Error Field (error memory)

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1003	0	number of errors	Unsigned8	ro	No	No. of stored errors
	1	standard error field	Unsigned32	ro	No	Last error
	2	standard error field	Unsigned32	ro	No	Further error…

The error memory contains the description of the last occurring error.
The standard error field is divided into two 16-bit fields:

Byte: MSB LSB

Additional Information	Error Code

Errors are reported by the Emergency Object. The meaning of the individual error codes is described in section 4.4 **Emergency Object (Error Message)**.

The error memory is deleted by writing a "0" to Subindex 0. If no error has occurred since switch on, then the object only consists of Subindex 0 with the entry 0.

6 Parameter Description

6.1 Communication Objects according to DS301

Manufacturer Device Name

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1008	0	manufacturer device name	Vis-String	const.	No	Device name

Use the Segmented SDO protocol to read out the device name, as it can be larger than 4 bytes.

Manufacturer Hardware Version

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1009	0	manufacturer hardware version	Vis-String	const.	No	Hardware version

Use the Segmented SDO protocol to read out the hardware version, as it can be larger than 4 bytes.

Manufacturer Software Version

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x100A	0	manufacturer software version	Vis-String	const.	No	Software version

Use the Segmented SDO protocol to read out the software version, as it can be larger than 4 bytes.

Guard Time

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x100C	0	guard time	Unsigned16	rw	0	Monitoring time for Node Guarding

Specification of Guard Time in milliseconds, 0 switches the monitoring off.

Life Time Factor

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x100D	0	Life time factor	Unsigned8	rw	0	Time factor for lifeguarding

The Life Time Factor multiplied by the Guard Time gives the Life Time for the Node Guarding Protocol (see section 4.5 NMT (Network Management)). 0 switches Lifeguarding off.

Store Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1010	0	largest sub-index supported	Unsigned8	ro	3	Number of storage options
	1	save all parameters	Unsigned32	rw	1	Saves all parameters
	2	save communication parameters	Unsigned32	rw	1	Only save communication parameters
	3	save application parameters	Unsigned32	rw	1	Only save application parameters

This object stores configuration parameters in the non-volatile flash memory.
A read access provides information on the storage options.

The storage process is triggered by writing the signature “save” to the relevant subindex:

Signature	MSB			LSB
ISO 8859 (“ASCII”)	e	v	a	s
hex	65h	76h	61h	73h

The object corresponds to the FAULHABER command SAVE.

Attention: The command may not be executed more than 10,000 times, as otherwise the function of the Flash memory can no longer be guaranteed.

Restore Default Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1011	0	largest subindex supported	Unsigned8	ro	3	Number of restore options
	1	restore all default parameters	Unsigned32	rw	1	Loads all default parameters
	2	restore default communication parameters	Unsigned32	rw	1	Only load default communication parameters
	3	restore default application parameters	Unsigned32	rw	1	Only load default application parameters

This object loads the default configuration parameters (status at delivery).
A read access provides information on the restore options.
The restore process is triggered by writing the signature “load” to the relevant subindex:

Signature	MSB			LSB
ASCII	d	a	o	l
hex	64h	61h	6Fh	6Ch

The parameters are only set to the default values at the next boot-up (reset).
If the default parameters are to be definitively saved, a save command must be executed after the reset.

COB-ID Emergency Message

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1014	0	COB-ID EMCY	Unsigned32	ro	0x80 + Node-ID	CAN Object Identifier of the Emergency Object

Identity Object

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1018	0	Number of entries	Unsigned8	ro	4	Number of object entries
	1	Vendor ID	Unsigned32	ro	327	Manufacturer ID number (Faulhaber: 327)
	2	Product code	Unsigned32	ro	3150	Product ID number
	3	Revision number	Unsigned32	ro		Version number
	4	Serial number	Unsigned32	ro		Serial no.

6 Parameter Description

6.1 Communication Objects according to DS301

Server SDO Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1200	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	COB-ID Client ➔ Server (rx)	Unsigned32	ro	0x600 + Node-ID	CAN Object Identifier for Server RxSDO
	2	COB-ID Server ➔ Client (tx)	Unsigned32	ro	0x580 + Node-ID	CAN Object Identifier for Server TxSDO

Receive PDO1 Communication Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1400	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	COB-ID	Unsigned32	ro	0x200 + Node-ID	CAN Object Identifier for RxPDO1
	2	transmission type	Unsigned8	ro	255	PDO transmission type

Receive PDO2 Communication Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1401	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	COB-ID	Unsigned32	ro	0x300 + Node-ID	CAN Object Identifier for RxPDO2
	2	transmission type	Unsigned8	ro	255	PDO transmission type

Receive PDO3 Communication Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1402	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	COB-ID	Unsigned32	ro	0x400 + Node-ID	CAN Object Identifier for RxPDO3
	2	transmission type	Unsigned8	ro	255	PDO transmission type

Receive PDO1 Mapping Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1600	0	Number of entries	Unsigned8	ro	1	Number of object entries
	1	1st object to be mapped	Unsigned32	ro	0x60400010	Reference to 16-bit controlword (0x6040)

Receive PDO2 Mapping Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1601	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	1st object to be mapped	Unsigned32	ro	0x23010108	Reference to 8-bit FAULHABER command
	2	2nd object to be mapped	Unsigned32	ro	0x23010220	Reference to 32-bit command argument

6 Parameter Description

6.1 Communication Objects according to DS301

Receive PDO3 Mapping Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1602	0	Number of entries	Unsigned8	ro	5	Number of object entries
	1	1st object to be mapped	Unsigned32	ro	0x23030108	Reference to 8-bit Trace Mode for Parameter 1
	2	2nd object to be mapped	Unsigned32	ro	0x23030208	Reference to 8-bit Trace Mode for Parameter 2
	3	3rd object to be mapped	Unsigned32	ro	0x23030308	Reference to 8-bit Trace time code setting
	4	4th object to be mapped	Unsigned32	ro	0x23030408	Reference to 8-bit Trace value “Number of packets”
	5	5th object to be mapped	Unsigned32	ro	0x23030508	Reference to 8-bit Trace value “Time interval”

Transmit PDO1 Communication Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1800	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	COB-ID	Unsigned32	ro	0x180 + Node-ID	CAN Object Identifier for TxPDO1
	2	transmission type	Unsigned8	rw	255	PDO transmission type: asynchronous

Transmit PDO2 Communication Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1801	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	COB-ID	Unsigned32	ro	0x280 + Node-ID	CAN Object Identifier for TxPDO2
	2	transmission type	Unsigned8	rw	253	PDO transmission type: asynchronous, only on request (RTR)

Transmit PDO3 Communication Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1802	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	COB-ID	Unsigned32	ro	0x380 + Node-ID	CAN Object Identifier for TxPDO3
	2	transmission type	Unsigned8	ro	253	PDO transmission type: asynchronous, only on request (RTR)

6 Parameter Description

6.1 Communication Objects according to DS301

Transmit PDO1 Mapping Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1A00	0	Number of entries	Unsigned8	ro	1	Number of object entries
	1	1st object to be mapped	Unsigned32	ro	0x60410010	Reference to 16-bit statusword (0x6041)

Transmit PDO2 Mapping Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1A01	0	Number of entries	Unsigned8	ro	3	Number of object entries
	1	1st object to be mapped	Unsigned32	ro	0x23010108	Reference to 8-bit FAULHABER command
	2	2nd object to be mapped	Unsigned32	ro	0x23020120	Reference to 32-bit value
	3	2nd object to be mapped	Unsigned8	ro	0x23020208	Reference to 8-bit error code

Transmit PDO3 Mapping Parameters

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x1A02	0	Number of entries	Unsigned8	ro	3	Number of object entries
	1	1st object to be mapped	Unsigned32	ro	0x23040120	Reference to 32-bit Trace value of Parameter 1
	2	2nd object to be mapped	Unsigned32	ro	0x23040220	Reference to 32-bit Trace value of Parameter 2
	3	3rd object to be mapped	Unsigned32	ro	0x23040308	Reference to 8-bit time code

6 Parameter Description

6.2 Manufacturer-specific objects

FAULHABER command

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2301	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	command	Unsigned8	rw	0	Command byte for FAULHABER channel
	2	argument	Unsigned32	rw	0	Argument for FAULHABER command

This object is written via RxPDO2 and always contains the last transmitted FAULHABER command.

Return value of FAULHABER command

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2302	0	Number of entries	Unsigned8	ro	2	Number of object entries
	1	value	Unsigned32	ro	0	Return value of FAULHABER command
	2	error	Unsigned8	ro	0	Error code: 1=OK, for further errors see **FAULHABER Commands**

The content of this object is requested by means of a Request (RTR) on TxPDO2 and supplies the return value for commands on the FAULHABER channel.

Trace configuration

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2303	0	Number of entries	Unsigned8	ro	5	Number of object entries
	1	mode1	Unsigned8	rw	0	Trace mode for Parameter 1
	2	mode2	Unsigned8	rw	0	Trace mode for Parameter 2
	3	time code	Unsigned8	rw	1	Data with time code
	4	packets	Unsigned8	rw	1	Number of packets to be transmitted per request
	5	period	Unsigned8	rw	1	Time interval between packets

This object is written via RxPDO3 and always contains the last transmitted Trace setting.

Trace data

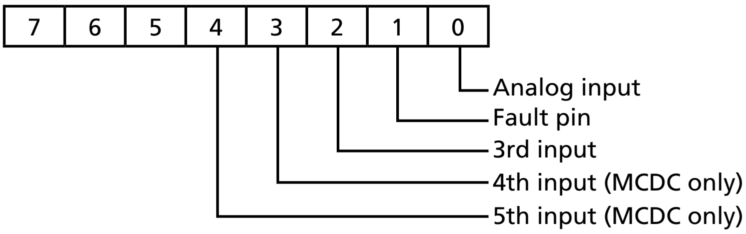
Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2304	0	Number of entries	Unsigned8	ro	3	Number of object entries
	1	value1	Unsigned32	ro	0	Last value of Parameter 1
	2	value2	Unsigned32	ro	0	Last value of Parameter 2
	3	time code	Unsigned8	ro	0	Last time code value

The content of this object is requested by means of a Request (RTR) on TxPDO3 and supplies the Trace data for the set parameters. The last requested values are always temporarily stored.

Limit switch setting

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2310	0	Number of entries	Unsigned8	ro	5	Number of object entries
	1	Negative Limit	Unsigned8	rw	0	Lower limit switch
	2	Positive Limit	Unsigned8	rw	0	Upper limit switch
	3	Homing	Unsigned8	rw	0	Homing switch*
	4	Notify	Unsigned8	rw	0	Notify switch**
	5	Polarity	Unsigned8	rw	7	Polarity of switch 1: Pos. edge valid 0: Neg. edge valid

The function of the digital inputs can be set according to the following bit mask:



Upon reaching the upper or lower limit switch, the drive is stopped and can only be moved out of the limit switch again in the opposite direction (Hard Blocking).

* Homing switches are only active in DSP402 Homing Mode; Polarity and Notify are not taken into account here, and the position value is reset after execution of homing.

** Notify switches indicate activation with the statusword and setting of bit14. You can then query which switch has triggered with Object 0x2311.

The settings of this object change simultaneously with the settings of the FAULHABER parameters HB, HD, HA, HN and HP!

Notify switch

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2311	0	Triggered switch	Unsigned8	ro	0	Triggered switch

This object can be used to query which switch has triggered in accordance with the above bit mask after receipt of a statusword message with bit14 set. Reading the object resets bit14 in the statusword again.

FAULHABER fault register

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2320	0	Number of entries	Unsigned8	ro	3	Number of object entries
	1	Internal fault register	Unsigned16	ro	0	Current internal fault 0=No fault
	2	Emergency mask	Unsigned16	rw	0xFF	Faults that trigger an emergency message frame
	3	Fault mask	Unsigned16	rw	0	Faults that are treated as DSP402 errors and influence the state machine (error state)
	4	Errout mask	Unsigned16	rw	0xFF	Faults that set the error output

This object describes the treatment of internal faults.

The errors are coded as follows and can be masked by adding the required error Types:

0x1000 - Software overflow

0x0100 - CAN error

0x0010 - NVRAM error

0x0004 - Overvoltage

0x0008 - Temperature error

0x0001 - Current limit active

0x0002 - Speed deviation

Set baud rate

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x2400	0	Baud rate	Unsigned8	ro	0xFF	Set baud rate

You can use this object to query which baud rate is set. The index of the set baud rate or 0xFF is returned if AutoBaud is set:

Baud rate	Index	Baud rate	Index
1000 KBit	0	125 KBit	4
800 KBit	1	50 KBit	6
500 KBit	2	20 KBit	7
250 KBit	3	10 KBit	8
		AutoBaud	0xFF

6.3.1 Device Control

The objects in this range serve to control and display the drive behaviour.

Controlword

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6040	0	controlword	Unsigned16	rw	0	Drive control

The controlword serves to control the drive state machine and is generally transmitted by means of RxPDO1. The individual bits of the controlword have the following meaning:

Bit	Function	Commands for Device Control State Machine						
		Shut-down	Switch on	Disable Voltage	Quick Stop	Disable Operation	Enable Operation	Fault Reset
0	Switch on	0	1	X	X	1	1	X
1	Enable Voltage	1	1	0	1	1	1	X
2	Quick Stop	1	1	X	0	1	1	X
3	Enable Operation	X	X	X	X	0	1	X
4	New set-point / Homing operation start							
5	Change set immediately							
6	abs / rel							
7	Fault reset							0->1
8	Halt							
9	0							
10	0							
11	0							
12	0							
13	0							
14	0							
15	0							

Function	Description
New set-point	0: Do not set new target position 1: Set new target position
Change set immediately	0: Finish current positioning and start a new positioning 1: Interrupt current positioning and start a new positioning
abs/rel	0: *Target Position* is an absolute value 1: *Target Position* is a relative value
Fault reset	0->1: Reset fault
Halt	0: Motion can be executed 1: Stop drive

The necessary command sequence at the start of a positioning, a speed control operation or a homing sequence is explained subsequently in the section for the respective operating mode.

Statusword

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6041	0	Statusword	Unsigned16	ro	0	Status display

The statusword serves to display the current state of the drive state machine and is generally transmitted automatically in the event of status changes, by means of TxPDO1.

The individual bits of the statusword have the following meaning:

Bit	Function	Commands for Device Control State Machine							
		Not Ready to Switch On	Switch On Disabled	Ready to Switch On	Switched On	Operation Enabled	Quick stop active	Fault reaction active	Fault
0	Ready to Switch On	0	0	1	1	1	1	1	0
1	Switched On	0	0	0	1	1	1	1	0
2	Operation Enabled	0	0	0	0	1	1	1	0
3	Fault	0	0	0	0	0	0	1	1
4	Voltage Enabled	X	X	X	X	X	X	X	X
5	Quick Stop	X	X	1	1	1	0	X	X
6	Switch On Disabled	0	1	0	0	0	0	0	0
7	Warning								
8	0								
9	Remote								
10	Target Reached								
11	Internal limit active								
12	Set-point acknowledge/ Speed / Homing attained								
13	Homing Error								
14	Hard Notify								
15	0								

Function	Description
Warning	not used
Remote	not used
Target Reached	0: Target Position/Target Velocity not yet reached 1: *Target Position/Target Velocity* reached. (Halt = 1: Drive has reached speed 0)
Set-point acknowledge	0: No new target position adopted yet (Profile Position Mode) 1: New target position adopted
Homing attained	0: Homing sequence not yet complete 1: Homing sequence successfully completed
Speed	0: Speed unequal to 0 (Profile Velocity Mode) 1: Speed 0
Homing Error	0: No error 1: Error
Hard Notify	0: No limit switch has triggered 1: A Notify switch has triggered (see Object 0x2311 for which input has triggered)

Bit 10 (Target Reached) is set when the drive has reached its target position in Profile Position Mode, or has reached its target velocity in Profile Velocity Mode. Presetting a new set-point deletes the bit.

Bit 11 (Internal Limit Active) indicates that a range limit has been reached (Position Range Limit or Limit Switch).

Bit 12 (Set-point acknowledge/Speed) is set after receipt of a new positioning command (controlword with New Set-Point) and reset when New Set-Point is reset in the controlword (handshake for positioning command). The bit is set at velocity 0 in Profile Velocity Mode.

Modes of operation

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6060	0	Modes of operation	Integer8	wo	1	Operating mode changeover

The following values are available:

1 Profile Position Mode (Position Control)
3 Profile Velocity Mode (Velocity Control)
6 Homing Mode (Homing)
-1 FAULHABER Specific Operating Mode

The individual operating modes are described in more detail later in this section. Modes 1 to 6 automatically switch the drive into Normal Mode (CONTMOD) with digital set-point presetting (SOR0). The object corresponds to the FAULHABER OPMOD command.

Modes of operation display

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6061	0	Modes of operation display	Integer8	ro	1	Display of set operating mode

The set operating mode can be queried here. The return value corresponds to the values of Object 0x6060. The object corresponds to the FAULHABER GOPMOD command.

6.3.2 Factor Group

The objects in this range serve for conversion between internal values and user-defined physical values.

Position Factor

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6093	0	number of entries	Unsigned8	ro	2	Number of object entries
	1	numerator	Unsigned32	rw	1	Dividend (numerator) of position factor
	2	feed_constant	Unsigned32	rw	1	Divisor (denominator) of position factor

$$\text{position\_factor} = \frac{\text{position\_encoder\_resolution} \cdot \text{gear\_ratio}}{\text{feed\_constant}}$$

The desired position unit for Profile Position Mode can be set with this factor (default: encoder resolution). The internal position values are divided by the position_factor in order to produce the desired physical values.

Velocity Factor

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6096	0	number of entries	Unsigned8	ro	2	Number of object entries
	1	numerator	Unsigend32	rw	1	Dividend (numerator) of velocity factor
	2	divisor	Unsigend32	rw	1	Divisor (denominator) of velocity factor

$$\text{velocity\_factor} = \frac{\text{position\_encoder\_resolution}}{\text{velocity\_encoder\_resolution}}$$

The desired velocity unit can be set with this factor (default: 1/min). The internal velocity values are divided by the velocity_factor in order to produce the desired physical values.

Acceleration Factor

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6097	0	number of entries	Unsigned8	ro	2	Number of object entries
	1	numerator	Unsigend32	rw	1	Dividend (numerator) of acceleration factor
	2	divisor	Unsigend32	rw	1	Divisor (denominator) of acceleration factor

$$\text{acceleration\_factor} = \frac{\text{velocity\_units} \cdot \text{velocity\_encoder\_factor}}{\text{acceleration\_units} \cdot \text{sec}}$$

The desired acceleration unit can be set with this factor (default: $1/s^2$)

Polarity

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x607E	0	polarity	Unsigned8	rw	0	Polarity (direction of rotation)

The direction of rotation can generally be changed with this object:
Bit 7 = 1: Neg. direction of rotation in positioning mode
Bit 6 = 1: Neg. direction of rotation in velocity mode

6.3.3 Profile Position Mode

The objects in this range are available for Positioning Mode.

Target Position

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x607A	0	target position	Integer32	rw	0	Target position

The Target Position is the position to which the drive is to move in Profile Position Mode. To do this, it uses the current settings for velocity, acceleration etc. The presetting occurs in user-defined units, according to the specified Position Factor. The Target Position can be interpreted relatively or absolutely, depending on the type of positioning that is preset via the controlword.
The object corresponds to the FAULHABER command LA or LR.

Software Position Limit

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x607D	0	number of entries	Unsigned8	ro	2	Number of object entries
	1	min position limit	Integer32	rw	see spec.	Lower positioning range limit
	2	max position limit	Integer32	rw	see spec.	Upper positioning range limit

The range limits specified here in relation to the reference position cannot be exceeded. The presetting occurs in user-defined units, according to the specified Position Factor. The object corresponds to the FAULHABER command LL.

6 Parameter Description

6.3 Objects of the DSP402 profile

Max Profile Velocity

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x607F	0	max profile velocity	Unsigned32	rw	see spec.	Maximum velocity
0x6081	0	profile velocity	Unsigned32	rw	see spec.	Maximum velocity

Maximum velocity during a positioning. The presetting occurs in user-defined units, according to the specified Velocity Factor. The object corresponds to the FAULHABER command SP.

Profile Acceleration

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6083	0	profile acceleration	Unsigned32	rw	see spec.	Acceleration value

The presetting occurs in user-defined units, according to the specified Acceleration Factor. The object corresponds to the FAULHABER command AC.

Profile Deceleration

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6084	0	profile deceleration	Unsigned32	rw	see spec.	Braking ramp value

The presetting occurs in user-defined units, according to the specified Acceleration Factor. The object corresponds to FAULHABER command DEC.

Quick Stop Deceleration

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6085	0	quick stop deceleration	Unsigned32	rw	30000	Braking ramp value for Quick Stop

The presetting occurs in user-defined units, according to the specified Acceleration Factor.

Motion Profile Type

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6086	0	motion profile type	Integer16	ro	0	Type of motion profile

Only Motion Profile type 0 is supported: Linear ramp (trapezoidal profile).

Control Effort

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x60FA	0	control effort	Integer32	ro	0	Controller output

The object corresponds to FAULHABER command GRU.

Position Control Parameter Set

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x60FB	0	number of entries	Unsigned16	ro	2	Number of object entries
	1	gain	Unsigned16	rw	see spec.	Position controller P-term
	2	D constant	Unsigned16	rw	see spec.	Position controller D-term

Position controller parameters. The object corresponds to FAULHABER commands PP and PD. Parameters P and I of the speed controller in object 0x60F9 (section Profile Velocity Mode) also influence the behaviour of the position controller!

6 Parameter Description

6.3 Objects of the DSP402 profile

Two methods can be used to preset target positions:

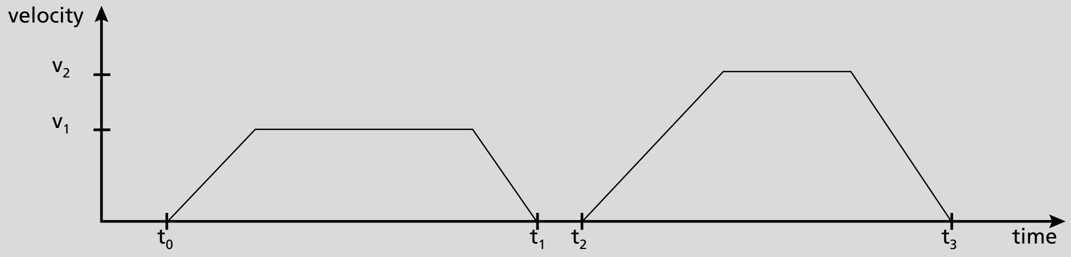
- Individual set-points:
  After reaching the target position, the drive informs the Master that it has reached the target and can then move to a new target position. The speed is usually 0 before a new positioning is started.
- A sequence of set-points:
  After reaching one target position, the drive immediately moves to the next – previously assigned – target position. This results in a continuous movement, without the need to decelerate the drive to speed 0 in between.

Both methods are controlled by the temporal sequence of bits 4 and 5 (*New Set-point, Change Set immediately*) of the controlword and bit 12 (*Set-point acknowledge*) of the statusword. These bits enable preparation of a new set-point while an old movement instruction is still being executed, via a handshake mechanism.

Procedure for individual positionings:

Prerequisite: NMT state “Operational”, drive state “Operation enabled” and Modes of Operation (0x6060) set to Profile Position Mode (1).

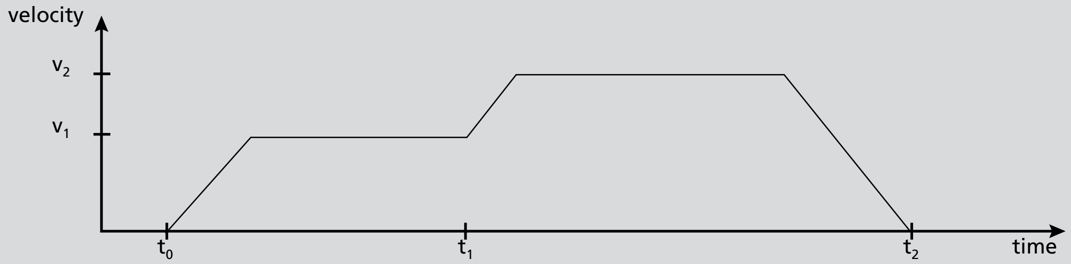
1. Set Target Position (0x607A) to the desired value.
2. In the controlword set bit 4 (*New set-point*) to “1”, bit 5 (*Change set immediately*) to “0”, and bit 6 (*abs/rel*) depending on whether absolute or relative positioning is required.
3. Drive responds with bit 12 (*Set-point acknowledge*) set in the statusword and commences positioning.
4. The drive indicates that it has reached the target position via the statusword with bit 10 set (*Target reached*). An existing or new positioning instruction can now be started (*New set-point*).



Procedure for a sequence of set-points:

Prerequisite: NMT state “Operational”, drive state “Operation Enabled” and Modes of Operation (0x6060) set to Profile Position Mode (1).

1. Set Target Position (0x607A) to the desired value.
2. In the controlword set bit 4 (*New set-point*) and bit 5 (*Change set immediately*) to “1”, and bit 6 (*abs/rel*) depending on whether absolute or relative positioning is required.
3. Drive responds with bit 12 (*Set-point acknowledge*) set in the statusword and commences positioning.
4. A new positioning instruction can now be started (*New set-point*); with relative positionings, the new target position is added to the last target position. The drive then moves to the new target position immediately.
5. The end of positioning is indicated by the statusword with set bit 10 (*Target reached*).



6.3.4 Homing Mode

The objects in this range are available for Homing Mode. After switch-on, a homing sequence must generally be executed in order to reset the position value on the homing limit switch.

Homing Offset

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x607C	0	Homing Offset	Integer32	rw	0	Zero point displacement from the reference position

Homing Method

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6098	0	Homing Method	Integer8	rw	20	Homing Method

All Homing Methods defined in DSP402 V2 are supported:

1 to 14: Homing with index pulse (if present)
17 to 30: Homing without index pulse
33, 34: Homing at index pulse (if present)
35: Homing at current position

Methods 1 and 17: Homing at lower limit switch (Negative Limit Switch)

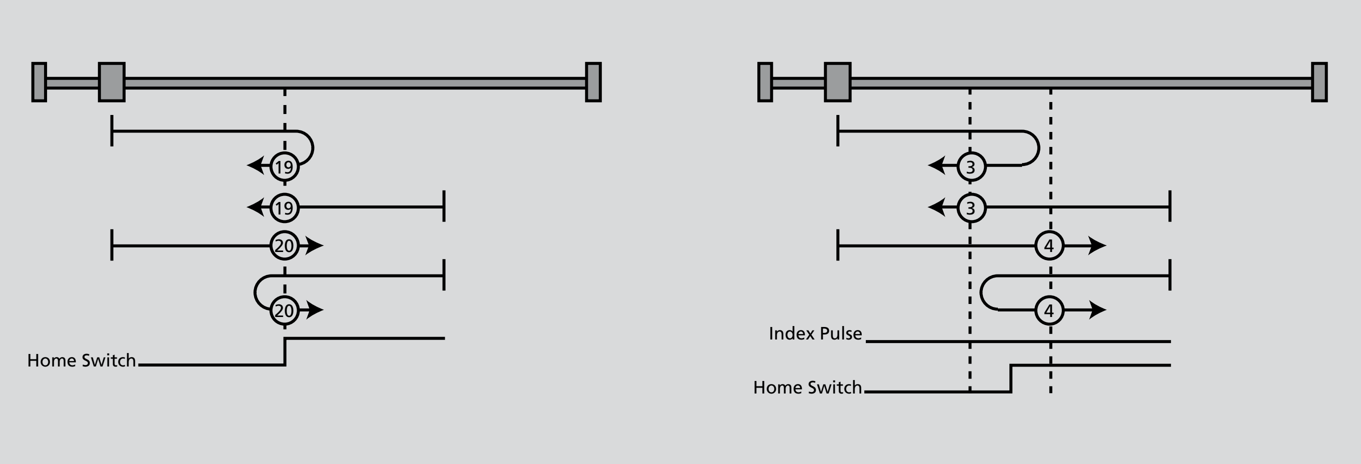
If the limit switch is inactive, the drive initially moves in the direction of the lower limit switch until its positive edge is detected. If the limit switch is active, the drive moves up out of the limit switch until the negative edge is detected. With Method 1 the drive then moves to the next index pulse at which the Home position is set.

Methods 2 and 18: Homing at upper limit switch (Positive Limit Switch)

If the limit switch is inactive, the drive initially moves in the direction of the upper limit switch until its positive edge is detected. If the limit switch is active, the drive moves down out of the limit switch until the negative edge is detected. With Method 2 the drive then moves to the next index pulse at which the Home position is set.

Methods 3, 4 and 19, 20: Homing at a positive Homing switch (Positive Home Switch)

Depending on the status of the Homing switch, the drive moves in one or the other direction until it reaches the falling (3,19) or rising (4, 20) edge. The Homing switch only has one rising edge in the direction of the upper limit switch. The FAULHABER parameter HP for the limit switch used is simultaneously set to 1 (rising edge).



6 Parameter Description

6.3 Objects of the DSP402 profile

Methods 5, 6 and 21, 22
Homing at a negative Homing switch (Negative Home Switch)

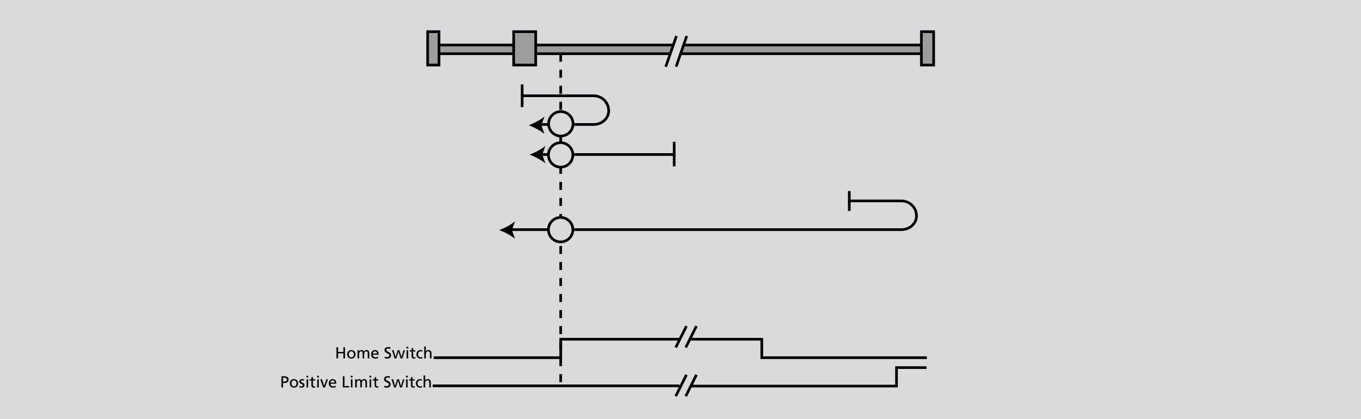
Depending on the status of the Homing switch, the drive moves in one or the other direction until it reaches the falling (5,21) or rising (6, 22) edge. The Homing switch only has one falling edge in the direction of the upper limit switch. The FAULHABER parameter HP for the limit switch used is simultaneously set to 0 (falling edge).

Methods 7 to 14 and 23 to 30:
Homing at the Homing switch (Home Switch)

These methods use a limit switch that is only active within a defined path range.
A distinction is made in respect of the reaction to the two edges.

With methods 7 to 14, after detection of the edge the drive continues until the index pulse at which the Homing position is set.

Methods 7 and 23: Homing at bottom of falling edge.
Start in positive direction if switch is inactive.



Methode 8 and 24: Homing at the top of rising edge.
Start in positive direction if switch is inactive.

Methods 9 and 25: Homing at top of rising edge.
Start always in positive direction.

Methods 10 and 26: Homing at top of falling edge.
Start always in positive direction.

Methods 11 and 27: Homing at top of falling edge.
Start in negative direction if switch is inactive.

Methods 12 and 28: Homing at top of rising edge.
Start in negative direction if switch is inactive.

Methods 13 and 29: Homing at bottom of rising edge.
Start always in negative direction.

Methods 14 and 30: Homing at bottom of falling edge.
Start always in negative direction.

Methods 33 and 34: Homing at index pulse
Drive moves in negative (33) or positive (34) direction until the index pulse.

Method 35: The position counter is reset at the current position.

Homing speed

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6099	0	Number of entries	Unsigned32	ro	2	Number of entries
	1	Speed during search for switch	Unsigned32	rw	400	Speed during search for switch
	2	Speed during search for zero	Unsigned32	rw	100	Speed during search for zero point

The data are provided in user-defined units, according to the specified Velocity Factor.

Homing acceleration

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x609A	0	Homing acceleration	Unsigned32	rw	50	Acceleration during homing

The presetting is made in user-defined units, according to the specified Acceleration Factor.

Procedure for a homing sequence:

Prerequisite: NMT state “Operational”, drive state “Operation enabled” and Modes of Operation (0x6060) set to Homing Mode (6).

1. Set Homing Mode (0x6098), Homing Speed (0x6099) and Homing Acceleration (0x609A) to the desired value.
2. In the controlword set bit 4 (*Homing operation start*) to “1” to start the homing sequence.
3. Drive responds with bit 12 (*Homing attained*) set in the statusword when the homing sequence is complete. If an error occurs during the homing sequence, bit 13 (*Homing error*) is set in the statusword.

An in-progress homing sequence can be interrupted by writing a “0” to bit 4 in the controlword.

6.3.5 Position Control Function

The objects in this range are used to monitor positioning operation.

Position Demand Value

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6062	0	position demand value	Integer32	ro	0	Preset value for target position

Position Actual Value

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6063	0	position actual value	Integer32	ro	0	Current actual position (increments)

The internal encoder increments are output. The object corresponds to the FAULHABER command POS.

Position Actual Value

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6064	0	position actual value	Integer32	ro	0	Current actual position (scaled)

Output occurs in user-defined units, according to the specified position factor.

Position Window

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6067	0	position window	Unsigned32	rw	40	Target position window

Symmetrical area around the target position which is used for the “Target Reached” message. Presetting is in user-defined units, according to the specified Position Factor. The object corresponds to the FAULHABER command CORRIDOR.

Position Window Time

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6068	0	position window time	Unsigned16	rw	200	Time in target position window

If the drive stays within the range of the position window for at least the time set here in milliseconds, bit 10 is set in the statusword (Target Reached).

6.3.6 Profile Velocity Mode

The objects in this range are available for speed control operation.

Velocity sensor actual value

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6069	0	velocity sensor actual value	Integer32	ro	0	Current velocity value

The output occurs in user-defined units, in accordance with the specified Velocity Factor.
The object corresponds to the FAULHABER command GN.

Velocity demand value

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x606B	0	velocity demand value	Integer32	ro	0	Target velocity

The output occurs in user-defined units, in accordance with the specified Velocity Factor.
The object corresponds to the FAULHABER command GV.

Velocity actual value

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x606C	0	velocity actual value	Integer32	ro	0	Current velocity value

Identical value to 0x6069, with use of the integrated analog Hall sensors for velocity recording. The output occurs in user-defined units, in accordance with the specified Velocity Factor. The object corresponds to the FAULHABER command GN.

Velocity Window

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x606D	0	velocity window	Unsigned16	rw	20	End velocity window

Velocity range around the target speed, which is used to identify the attained end velocity. The presetting occurs in user-defined units, in accordance with the specified Velocity Factor.

Velocity Window Time

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x606E	0	velocity window time	Unsigned16	rw	200	Time in end velocity window

If the drive stays within the velocity range of the Velocity Window for at least the time set here in milliseconds, bit 10 is set in the statusword (Target Reached).

Velocity Threshold

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x606F	0	velocity threshold	Unsigned16	rw	20	Velocity threshold value

Velocity range around 0 which is used to detect standstill. Presetting occurs in user-defined units, in accordance with the specified Velocity Factor.

Velocity Threshold Time

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6070	0	velocity threshold time	Unsigned16	rw	0	Time below velocity threshold value

If the drive stays below the velocity threshold value for at least the time set here in milliseconds, bit 12 is set in the statusword (Speed = 0).

Target Velocity

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x60FF	0	target velocity	Integer32	rw	0	Target velocity

Target velocity is a nominal speed for the velocity controller. Presetting occurs in user-defined units, in accordance with the specified Velocity Factor. The object corresponds to the FAULHABER command V.

Velocity Control Parameter Set

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x60F9	0	number of entries	Unsigned16	ro	2	Number of object entries
	1	gain	Unsigned16	rw	see spec.	Velocity controller P-term
	2	integration time constant	Unsigned16	rw	see spec.	Velocity controller I-term

Parameters of the velocity controller.
The object corresponds to the FAULHABER commands POR and I.

6.3.7 Common Entries

Drive Data

Index	Subindex	Name	Type	Attrb.	Default value	Meaning
0x6510	0	number of entries	Unsigned8	ro	1	Number of object entries
	1	motor type	Signed32	rw	8	Set motor type 0...9 BL motor –1 DC motor

The motor type to which the control is set can be queried or set here (MCDC: only reading possible).
The object corresponds to the FAULHABER command MOTTYP/GMOTTYP.

The acceleration setting in object 0x6083 (section Profile Position Mode) is also valid in both directions for the velocity control mode when the target velocity is changed!

Start drive in velocity-controlled mode:

Prerequisite: NMT state “Operational”, drive state “Operation enabled” and Modes of Operation (0x6060) set to Profile Velocity Mode (3).

Set Target Velocity (0x60FF) to the desired velocity value.

Stop drive in velocity-controlled mode:

Set Target Velocity (0x60FF) to velocity value 0 or set bit 3 to 0 in the controlword (“Disable Operation”).

6 Parameter Description

6.4 FAULHABER commands

The drive can be configured and controlled very easily with the FAULHABER commands. All supported ASCII commands of the serial variant are available as CAN message frames on PDO2. The first byte always contains the HEX value of the command, and the following 4 bytes can contain data:

RxPDO2: FAULHABER command

11 bit identifier	5 bytes user data				
0x300 (768D) + Node-ID	Command	LLB	LHB	HLB	HHB

To configure the drive via the FAULHABER channel the device must be in "Operational" NMT state.

Some of the parameters can also be set via the object dictionary, but others only via the FAULHABER channel.

Certain parameters can only be set and used in the FAULHABER operating mode *Modes of Operation* = –1 (object 0x6060 or command OPMOD), as they have a direct influence on the drive behaviour.

The reaction to FAULHABER commands depends on the transmission type set for TxPDO2 (OD index 0x1801):

a.) transmission type = 253

After sending the command on RxPDO2 a request (RTR) must be executed on TxPDO2 to get the answer of query commands or to check transmit commands.

b.) transmission type = 255

The commands are immediately answered on TxPDO2. 6 bytes are always returned: the first byte specifies the command and the following 4 bytes the desired value as a Long Integer (for transmit commands: 0), followed by an error code:

TxPDO2: FAULHABER data

11 bit identifier	5 bytes user data					
0x280 (640D) + Node-ID	Command	LLB	LHB	HLB	HHB	Error

Error	Explanation
1	Command successfully executed
-2	EEPROM writing done
-4	Overtemperature – drive disabled
-5	Invalid parameter
-7	Unknown command
-8	Command not available
-13	Flash defect

Example:

Query actual position of node 3 (Command "POS"):

Transmit Id 303: 40 00 00 00 00
Request Id 283
Receive Id 283: 40 A0 86 01 00 01

➔ Actual position = 100000D

6.4.1 Basic setting commands

The commands listed here are used for the configuration of basic setting parameters, which are stored in the Flash data memory with the SAVE / EEPSAV command and reloaded from here after switch-on.

6.4.1.1 Commands for special FAULHABER operating modes

Only available in FAULHABER mode (*Modes of operation* = OPMOD = -1)

Command	Hex value	Data	Function	Description
OPMOD	0xFD	0	Operation Mode	CANopen operating mode: -1: FAULHABER mode 1: Profile Position Mode 3: Profile Velocity Mode 6: Homing Mode Corresponds to object 0x6060 (modes of operation)
SOR	0x8E	0-3	Source For Velocity	Source for velocity presetting 0: CAN interface (default) 1: Voltage at analog input 2: PWM signal at analog input 3: Current limitation value via analog input
CONTMOD	0x06	0	Continuous Mode	Switch back from an extended mode to normal mode
STEPMOD	0x46	0	Stepper Motor Mode	Switch to stepper motor mode
APCMOD	0x02	0	Analog Position Control Mode	Switch to position control via analog voltage
ENCMOD	0x10	0	Encoder Mode	Switch to encoder mode (not for MCDC). An external encoder serves as position detector (the current position value is set to 0)
HALLSPEED	0x3B	0	Hall Sensor as Speed Sensor	Speed via Hall sensors in encoder mode (not for MCDC)
ENCSPEED	0x12	0	Encoder as Speed Sensor	Speed via encoder signals in encoder mode (not for MCDC)
GEARMOD	0x1D	0	Gearing Mode	Switch to gearing mode
VOLTMOD	0x49	0	Set Voltage Mode	Activate voltage regulator mode
IXRMOD	0x50	0	Set IxR Mode	Activate lxR control (only MCDC)

6.4.1.2 Parameters for basic settings

Command	Hex value	Data	Function	Description
ENCRES	0x70	Value	Load Encoder Resolution	Load resolution from external encoder. Value range: 0 to 65535 (4 times pulse/rev)
MOTTYP	0x84	0-9	BL Motor Type	Setting for connected BL motor (MCBL only). 0: BL special motor according to KN and RM 1: 1628T012B K1155 2: 1628T024B K1155 3: 2036U012B K1155 4: 2036U024B K1155 5: 2444S024B K1155 6: 3056K012B K1155 7: 3056K024B K1155 8: 3564K024B K1155 9: 4490H024B K1155
KN	0x9E	Value	Load Speed Constant	Load speed constant K_n according to specifications in data sheet. Unit: rpm/V. (Only necessary for MOTTYP0 or DC motor)
RM	0x9F	Value	Load Motor Resistance	Load motor resistance R_M according to specification in data sheet. Unit: mOhm. (Only necessary for MOTTYP0 or DC motor)
STW	0x77	Value	Load Step Width	Load step width for step motor and gearing mode Value range: 0…..65535
STN	0x64	Value	Load Step Number	Load number of steps per revolution for step motor and gearing mode Value range: 0…..65535
MV	0x85	Value	Minimum Velocity	Presetting of minimum velocity in rpm for velocity presetting via analog voltage (SOR1, SOR2) Value range: 0…..32767
MAV	0x83	Value	Minimum Analog Voltage	Presetting of minimum start voltage in mV for velocity presetting via analog voltage (SOR1, SOR2) Value range: 0…..10000
ADL	0x00	0	Analog Direction Left	Positive voltages at the analog input result in counter-clockwise rotation of the rotor (SOR1, SOR2)
ADR	0x01	0	Analog Direction Right	Positive voltages at the analog input result in clockwise rotation of the rotor (SOR1, SOR2)
SIN	0xA0	0-1	Sinus Commutation	1: No block commutation in the upper velocity range (default) 0: Block commutation in the upper velocity range (full modulation) (not with MCDC)

6 Parameter Description

6.4 FAULHABER commands

6.4.1.3 General parameters

Command	Hex value	Data	Function	Description
LL	0xB5	Value	Load Position Range Limits	Load limit positions (the drive cannot be moved out of these limits). Positive values specify the upper limit and negative values the lower. The range limits are only active if APL1 is set. Value range: -1.8 · 10^9…+1.8 · 10^9 Corresponds to object 0x607D
APL	0x03	0-1	Activate / Deactivate Position Limits	Activate range limits (LL) (valid for all operating modes). 1: Position limits activated 0: Position limits deactivated
SP	0x8F	Value	Load Maximum Speed	Load maximum speed. Value range: 0 to 32767 rpm. Setting applies for all modes. Corresponds to object 0x607F
AC	0x65	Value	Load Command Acceleration	Load acceleration value. Value range: 0 to 30000 r/s². Corresponds to object 0x6083
DEC	0x6D	Value	Load Command Deceleration	Load deceleration value. Value range: 0 to 30000 r/s². Corresponds to object 0x6084
SR	0xA4	Value	Sampling Rate	Load sampling rate of the velocity controller as a multiplier of 100 µs. Value Range: 1...20 ms/10
POR	0x89	Value	Load Velocity Proportional Term	Load velocity controller amplification. Value range: 1…255. Corresponds to object 0x60F9
I	0x7B	Value	Load Velocity Integral Term	Load velocity controller integral term. Value range: 1…255. Corresponds to object 0x60F9
PP	0x9B	Value	Load Position Proportional Term	Load position controller amplification. Value range: 1…255. Corresponds to object 0x60FB
PD	0x9C	Value	Load Position Differential Term	Load position controller D-term. Value range: 1…255. Corresponds to object 0x60FB
CI	0xA2	Value	Load Current Integral Term	Load integral term for current controller. Value range: 1…255
LPC	0x81	Value	Load Peak Current Limit	Load peak current. Value range: 0 to 12000 mA
LCC	0x80	Value	Load Continuous Current Limit	Load continuous current. Value range: 0 to 12000 mA
DEV	0x6F	Value	Load Deviation	Load maximum permissible deviation of actual velocity from target velocity (deviation) Value range: 0…32767
CORRIDOR	0x9D	Value	Load Corridor	Window around the target position. Value range: 0…65535 Corresponds to object 0x6067

6 Parameter Description

6.4 FAULHABER commands

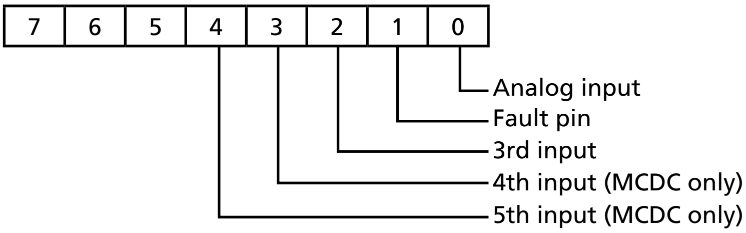
6.4.1.4 Configuration of fault pin and digital inputs

Command	Hex value	Data	Function	Description
ERROUT	0x14	0	Error Output	Fault pin as error output
ENCOUT	0x11	0	Encoder Output	Fault pin as pulse output (not with MCDC)
DIGOUT	0x0A	0	Digital Output	Fault pin as digital output. The output is set to low level.
DIRIN	0x0C	0	Direction Input	Fault pin as rotational direction input
REFIN	0x41	0	Reference Input	Fault pin as reference or limit switch input
DCE	0x6B	Value	Delayed Current Error	Delayed error output for ERROUT in 1/100 sec. Value range: 1…65535
LPN	0x82	Value	Load Pulse Number	Preset pulse number for ENCOUT Value range: 1…255
CO	0x05	0	Clear Output	Set digital output DIGOUT to low level
SO	0x45	0	Set Output	Set digital output DIGOUT to high level
TO	0x55	0	Toggle Output	Switch digital output DIGOUT
SETPLC	0x51	0	Set PLC inputs	Digital inputs PLC-compatible (24 V level)
SETTTL	0x52	0	Set TTL inputs	Digital inputs TTL-compatible (5 V level)

6.4.1.5 Configuration of homing and limit switches in FAULHABER mode

Command	Hex value	Data	Function	Description
HP	0x79	Value	Hard Polarity	Define valid edge and polarity of respective limit switches: 1: Rising edge or high level valid. 0: Falling edge or low level valid.
HB	0x73	Value	Hard Blocking	Activate Hard Blocking function for relevant limit switch.
HD	0x74	Value	Hard Direction	Presetting of direction of rotation that is blocked with HB of respective limit switch. 1: Clockwise rotation blocked 0: Counterclockwise rotation blocked
SHA	0x8A	Value	Set Home Arming for Homing Sequence	Homing behaviour (GOHOSEQ): Set position value to 0 at edge of respective limit switch.
SHL	0x90	Value	Set Hard Limit for Homing Sequence	Homing behaviour (GOHOSEQ): Stop motor at edge of respective limit switch.
SHN	0x9A	Value	Set Hard Notify for Homing Sequence	Homing behaviour (GOHOSEQ): Send message to Master at edge of respective limit switch (statusword bit 14=1).
HOSP	0x78	Value	Load Homing Speed	Load speed and direction of rotation for homing (GOHOSEQ, GOHIX, GOIX). Value range: -32767 to 32767 rpm.
HA	0x72	Value	Home Arming	Set position value to 0 and delete relevant HA bit at edge of respective limit switch. Setting is not stored.
HL	0x75	Value	Hard Limit	Stop motor and delete relevant HL bit at edge of respective limit switch. Setting is not stored.
HN	0x76	Value	Hard Notify	Send message to Master (statusword bit 14=1) and delete relevant HN bit at edge of respective limit switch. Setting is not stored.

Limit switch bit mask:



6.4.2 Query commands for basic settings

6.4.2.1 Operating modes and general parameters

Command	Hex value	Data	Function	Description
GOPMOD	0xFE	0	Get Operation Mode	Display current CANopen operating mode: -1: FAULHABER mode 1: Profile Position Mode 3: Profile Velocity Mode 6: Homing Mode Corresponds to object 0x6061 (modes of operation display)
CST	0x58	0	Configuration Status	Set operating mode. Return value binary coded (LSB=Bit 0): Bit 0-2, Reserved Bit 3-4, Velocity presetting: 0:SOR0 (CAN interface) 1:SOR1 (Analog voltage) 2:SOR2 (PWM signal) 3:SOR3 (current limitation value) Bit 5-6, reserved Bit 7-9, FAULHABER mode: 0:CONTMOD 1:STEPMOD 2:APCMOD 3:ENCMOD / HALLSPEED 4:ENCMOD / ENCSPEED 5:GEARMOD 6:VOLTMOD 7:IXRMOD Bit 10, Power amplifier: 0:Disabled (DI) 1:Enabled (EN) Bit 11, Position controller: 0:Switched off 1: Switched on Bit 12, Analog direction of rotation: 0:ADL 1:ADR Bit 13, Position Limits APL: 0:Deactivated 1:Activated Bit 14, Sinus commutation SIN: 0:Permit block commutation 1:Do not permit block commutation

6 Parameter Description

6.4 FAULHABER commands

Command	Hex value	Data	Function	Description
GMOD	0x28	0	Get Mode	Set FAULHABER mode: 0: CONTMOD 1: STEPMOD 2: APCMOD 3: ENCMOD / HALLSPEED 4: ENCMOD / ENCSPEED 5: GEARMOD 6: VOLTMOD 7: IXRMOD
GENCRES	0x1E	0	Get Encoder Resolution	Set encoder resolution ENCRES
GMOTTYP	0x29	0	Get Motor Type	Set motor type 0-9 (MOTTYP) -1: DC motor
GKN	0x4D	0	Get Speed Constant	Speed constant for MOTTYP0 or DC motor in rpm/V
GRM	0x4E	0	Get Motor Resistance	Motor resistance for MOTTYP0 or DC motor in mOhm
GSTW	0x39	0	Get Step Width	Set step width STW
GSTN	0x38	0	Get Step Number	Set step number per revolution STN
GMV	0x2A	0	Get Minimum Velocity	Set minimum speed MV in rpm
GMAV	0x27	0	Get Minimum Analog Voltage	Set minimum start voltage value MAV in mV
GPL	0x31	0	Get Positive Limit	Set positive limit position LL Corresponds to object 0x607D
GNL	0x2C	0	Get Negative Limit	Set negative limit position LL Corresponds to object 0x607
GSP	0x36	0	Get Maximum Speed	Set maximum speed SP in rpm. Corresponds to object 0x6081
GAC	0x15	0	Get Acceleration	Set acceleration value AC in r/s². Corresponds to object 0x6083
GDEC	0x1B	0	Get Deceleration	Set deceleration value DEC in r/s². Corresponds to object 0x6084
GSR	0x56	0	Get Sampling Rate	Set sampling rate of velocity controller in ms/10
GPOR	0x33	0	Get Velocity Prop. Term	Set amplification value of velocity controller POR Corresponds to object 0x60F9
GI	0x26	0	Get Velocity Integral Term	Set integral term of velocity controller I Corresponds to object 0x60F9
GPP	0x5D	0	Get Position Prop. Term	Set amplification value of position controller PP Corresponds to object 0x60FB
GPD	0x5E	0	Get Position D-Term	Set D-term of position controller PD Corresponds to object 0x60FB
GCI	0x63	0	Get Current Integral Term	Set integral term of current controller CI
GPC	0x30	0	Get Peak Current	Set peak current PC in mA
GCC	0x18	0	Get Continuous Current	Set continuous current CC in mA
GDEV	0x1C	0	Get Deviation	Set deviation value DEV
GCORRIDOR	0x62	0	Get Corridor	Set window around target position Corresponds to object 0x6067

6.4.2.2 Configuration of fault pin and digital inputs

Command	Hex value	Data	Function	Description
IOC	0x5C	0	I/O Configuration	Set input/output configuration. Return value binary coded (LSB=Bit 0): Bit 0-7, FAULHABER Hard Blocking: 0-7: Function active for input 1-3 Bit 8-15, FAULHABER Hard Polarity: 0-7: Rising edge at input 1-3 Bit 16-23, FAULHABER Hard Direction: 0-7: Clockwise rotation stored at input 1-3 Bit 24, State of digital output: 0: Low 1: High Bit 25, Level of digital inputs: 0: TTL level (5V) 1: PLC level (24V) Bit 26-28, Function of fault pin: 0: ERROUT 1: ENCOUT 2: DIGOUT 3: DIRIN 4: REFIN
GDCE	0x1A	0	Get Delayed Current Error	Set value of error output delay DCE
GPN	0x32	0	Get Pulse Number	Set pulse number LPN

6.4.2.3 Configuration of homing in FAULHABER mode

Command	Hex value	Data	Function	Description
HOC	0x5B	0	Homing Configuration	Set homing configuration. Return values binary coded (LSB = Bit 0): Bit 0-7, SHA setting for input 1-8 Bit 8-15, SHN setting for input 1-8 Bit 16-23, SHL setting for input 1-8 (input 6-8: Reserved)
GHOSP	0x24	0	Get Homing Speed	Set homing speed in rpm

6.4.3 Miscellaneous commands

Command	Hex value	Data	Function	Description
SAVE	0x53	0	Save Parameters, (EEPSAV)	Save current parameters and configuration setting to Flash memory. The drive will also start with these settings when next switched on. Corresponds to object 0x1010. Attention: Command must not be executed more than 10,000 times, as otherwise the function of the Flash memory can no longer be guaranteed.
RESET	0x59	0	Reset	Restart drive node. Corresponds to NMT Reset Node.
RN	0x44	0	Reset Node	Set parameters to original values (ROM values) (current, acceleration, controller parameters, maximum speed, limit positions…).
FCONFIG	0xD0	0	Factory Configuration	All configurations and values are reset to the delivery status. The drive is deactivated after this command. The drive is only reactivated (with the ROM values) when the supply is reconnected.

6.4.4 Motion control commands

The commands executed here are only available in FAULHABER mode (*Modes of operation* = -1).

Command	Hex value	Data	Function	Description
DI	0x08	0	Disable Drive	Deactivate drive
EN	0x0F	0	Enable Drive	Activate drive
M	0x3C	0	Initiate Motion	Activate position control and start positioning
LA	0xB4	Value	Load Absolute Position	Load new absolute target position Value range: $-1.8 \cdot 10^9$ ... $1.8 \cdot 10^9$
LR	0xB6	Value	Load Relative Position	Load new relative target position, in relation to last started target position. Resulting absolute target position must be between $-2.14 \cdot 10^9$ and $2.14 \cdot 10^9$.
V	0x93	Value	Select Velocity Mode	Activate velocity mode and set specified value as target velocity. (Velocity control) Value range: –32767...32767 rpm
U	0x92	Value	Set Output Voltage	Output PWM value in VOLTMOD Value range: –32767...32767 (corresponds to –Uv...+Uv)
GOHOSEQ	0x2F	0	Go Homing Sequence	Execute FAULHABER homing sequence. A homing sequence is executed (if programmed) independently of the current mode
GOHIX	0x2E	0	Go Hall Index	Move BL motor to Hall zero point (Hall index) and set actual position value to 0 (not for MCDC)
GOIX	0xA3	0	Go Encoder Index	Move to the Encoder Index at the fault pin and set actual position value to 0 (DC motor or ext. encoder)
HO	0xB8	0 / Value	Define Home-Position	Data = 0: Set actual position to 0. Otherwise: Set actual position to specified value. Value range: $-1.8 \cdot 10^9$ ...$1.8 \cdot 10^9$

6.4.5 General query commands

Command	Hex value	Data	Function	Description
POS	0x40	0	Get Actual Position	Current actual position Corresponds to object 0x6063
TPOS	0x4B	0	Get Target Position	Target position of last started positioning Corresponds to object 0x6062
GV	0x3A	0	Get Velocity	Current target velocity in rpm Corresponds to object 0x60FF
GN	0x2B	0	Get N	Current actual velocity in rpm Corresponds to object 0x6069
GU	0x5F	0	Get PWM Voltage	Set PWM value in VOLTMOD
GRU	0x60	0	Get Real PWM Voltage	Current controller output value
GCL	0x10	0	Get Current Limit	Current limitation current in mA
GRC	0x34	0	Get Real Current	Current actual current in mA
TEM	0x47	0	Get Temperature	Current housing temperature in °C
OST	0x57	0	Operation Status	Display current operating status. Return value binary coded (LSB = Bit 0): Bit 0: Homing running Bit 1-3: Reserved Bit 4: Current limitation active Bit 5: Deviation error Bit 6: Overvoltage Bit 7: Overtemperature Bit 8: Status input 1 Bit 9: Status input 2 Bit 10: Status input 3 Bit 11: Status input 4 Bit 12: Status input 5 Bit 13-15: Res. for further inputs Bit 16: Position attained
SWS	0x5A	0	Switch Status	Temporary limit switch settings. Return value binary coded (LSB = Bit 0): Bit 0-7: HA setting for input 1-8 Bit 8-15: HN setting for input 1-8 Bit 16-23: HL setting for input 1-8 Bit 24-31: Specifies which limit switch 1-8 has already switched (is reset again when the respective input is reset).

7 Appendix

7.1 Electromagnetic compatibility (EMC)

The FAULHABER motion controllers MCBL 3003/06 C, MCDC 3003/06 C and 3564K024B CC have been checked and tested in accordance with EMC directive 89/336/EEC for compliance with EMC protective requirements.

In nominal operation the system fulfils the requirements of the following standards:

EMC emissions within the limits of the basic technical standards for emitted interference in the industrial sector EN 61000-6-4 (August 2002)

EMC immunity in accordance with the basic technical standards for interference resistance in the industrial sector EN 61000-6-2 (August 2002), tested for:

- Electrostatic discharges ESD with 4 kV (contact discharge) and 8 kV (atmospheric discharge) in accordance with EN 61000-4-2 (December 2001)
- HF fields in accordance with EN 61000-4-3 (November 2003)
- Rapid transients in accordance with EN 61000-4-4 (July 2002)
- Transient voltages in accordance with EN 61000-4-5 (December 2001)
- Conducted disturbance variables, induced by high-frequency fields in accordance with EN 61000-4-6 (December 2001)
- Magnetic field with power engineering frequencies in accordance with EN 61000-4-8 (December 2001)

The following conditions must be fulfilled for compliance with the requirements:

- Operation in accordance with the technical data and the operating instructions
- The supply line must be led through a suitable ferrite tube with two windings (e.g. Würth Elektronik no.: 742 700 90), as close as possible to the control.

Supporting measures for conducted interferences:
Further suppression measures are required, in order to comply with the limit values on the DC connecting line that are prescribed for AC supply points in accordance with the above-specified standard (EN 61000-6-4).
In addition to the ferrite tube, a current-compensated choke (e.g. Würth Elektronik no.: 744 825 605) with electrolytic capacitor 470 µF must be installed in the supply line, as close as possible to the control.

7.1.1 Intended use

The units are developed, manufactured, tested and documented in compliance with the pertinent standards.

If used as intended, the units do not give rise to any risks for people or property. Intended use assumes that the units are used exclusively as described here and that all safety instructions and regulations are complied with.

Intended use also includes observance of the pertinent regulations in respect of safety (Machinery Directive) and radio shielding (EMC Directive) when using the units.

Electronic devices are not fail-safe in principle. The user must ensure that, in the event of failure of the device, the drive is put into a safe condition.

Dr. Fritz Faulhaber GmbH & Co. KG cannot accept any liability for direct or consequential damages resulted from misuse of the units.

7.1.2 CE marking

The devices fulfil the requirements of DIN EN 61000-6-2 regarding immunity to interference in the industrial sector and of DIN EN 61000-6-4 in relation to emitted interference in the industrial sector.

Protection against contact may need to be provided around the units in order to comply with the Machinery Directive. Depending on loading, temperatures above 85 °C can occur on the device surface.

There are no requirements from the Low Voltage Directive, as the operating voltage may not reach 50 V or over at any point in time.

In order to fulfil the necessary standards for CE marking, the line lengths from and to the motion controller must not exceed 3 meters. All connecting lines must comply with the state-of-the-art and all additional connection and installation regulations in this description.

Additional circuits and measures such as e.g. ferrite tube, suppressor diodes and shield connection may be required to comply with special requirements.

7 Appendix

7.2 Default configuration

The standard configuration parameters with which the units are delivered are listed below. These settings can also be reloaded at any time with the command FCONFIG, followed by a hardware reset.

For the default values of the CANopen objects not listed here, please see the Parameter Description. Baud rate and Node ID are each set to 0xFF, i.e. automatic baud rate recognition and invalid node number.

3564K024B CC:

FAULHABER command	CANopen object	Description
CONTMOD		Normal operation
APL0		Position limits deactivated
SOR0		Velocity presetting via CAN
MOTTYP8		Motor type 3564K024B
ERROUT		Fault pin = Error output
HP7		All inputs react to rising edge
HB0, HD0		No Hard Blocking limit switch defined
HOSP100		Homing Speed = 100 rpm
SHA0, SHL0, SHN0		No FAULHABER homing sequence defined
ADR		Analog direction of rotation right
LPC8000		Peak current limitation = 8 A
LCC2800		Continuous current limitation = 2.8 A
AC30000	0x6083	Acceleration = 30000 r/s²
DEC30000	0x6084	Deceleration ramp = 30000 r/s²
SR1		Sampling rate = 100 µs
I40	0x60F9	I-term of velocity controller
POR8	0x60F9	P-term of velocity controller
PP12	0x60FB	P-term of position controller
PD6	0x60FB	D-term of position controller
CI50		I-term of current controller
SP12000	0x607F	Limitation of maximum velocity to 12000 rpm
MV0		Minimum analog velocity
MAV25		Minimum analog voltage
LL1800000000	0x607D	Upper positioning range limit
LL-1800000000	0x607D	Lower positioning range limit
LPN16		Numeric value for pulse output
STW1		Step width for special operation
STN1000		Step number for special operation
ENCRES2048		Resolution of external encoder
DEV30000		Do not monitor deviation error
DCE200		Error delay 2 sec.
CORRIDOR20	0x6067	Target corridor for positionings
SIN1		Do not permit block commutation
SETPLC		Digital inputs PLC-compatible
OPMOD1	0x6060	Operating mode: “Profile Position Mode”
DI		Power power stage deactivated
V0		Nominal speed value = 0 rpm

MCBL 3003/06 C:

FAULHABER command	CANopen object	Description
CONTMOD		Normal operation
APL0		Position limits deactivated
SOR0		Velocity presetting via CAN
MOTTYP5		Motor type 2444S024B K1155
ERROUT		Fault pin = Error output
HP7		All inputs react to rising edge
HB0, HD0		No Hard Blocking limit switch defined
HOSP100		Homing Speed = 100 rpm
SHA0, SHL0, SHN0		No FAULHABER homing sequence defined
ADR		Analog direction of rotation right
LPC5000		Peak current limitation = 5 A
LCC1370		Continuous current limitation = 1.37 A
AC30000	0x6083	Acceleration = 30000 r/s²
DEC30000	0x6084	Deceleration ramp = 30000 r/s²
SR1		Sampling rate = 100 µs
I40	0x60F9	I-term of velocity controller
POR7	0x60F9	P-term of velocity controller
PP16	0x60FB	P-term of position controller
PD9	0x60FB	D-term of position controller
CI50		I-term of current controller
SP30000	0x607F	Limitation of maximum velocity to 30000 rpm
MV0		Minimum analog velocity
MAV25		Minimum analog voltage
LL1800000000	0x607D	Upper positioning range limit
LL-1800000000	0x607D	Lower positioning range limit
LPN16		Numeric value for pulse output
STW1		Step width for special operation
STN1000		Step number for special operation
ENCRES2048		Resolution of external encoder
DEV30000		Do not monitor deviation error
DCE200		Error delay 2 sec.
CORRIDOR20	0x6067	Target corridor for positionings
SIN1		Do not permit block commutation
SETPLC		Digital inputs PLC-compatible
OPMOD1	0x6060	Operating mode: “Profile Position Mode”
DI		Power power stage deactivated
V0		Nominal speed value = 0 rpm

7 Appendix

7.2 Default configuration

MCDC 3003/06 C:

FAULHABER command	CANopen-object	Description
CONTMOD		Normal operation
APL0		Position limits deactivated
SOR0		Velocity presetting via CAN
ERROUT		Fault pin = error output
HP31		All inputs react to rising edge
HB0, HD0		No Hard Blocking limit switch defined
HOSP100		Homing speed = 100 rpm
SHA0, SHL0, SHN0		No FAULHABER homing sequence defined
ADR		Analog direction of rotation right
LPC10000		Peak current limitation = 10 A
LCC5000		Continuous current limitation = 5 A
AC30000	0x6083	Acceleration = 30000 r/s²
DEC30000	0x6084	Deceleration ramp = 30000 r/s²
SR1		Sampling rate = 100 µs
I50	0x60F9	I-term of velocity controller
POR10	0x60F9	P-term of velocity controller
PP10	0x60FB	P-term of position controller
PD5	0x60FB	D-term of position controller
CI40		I-term of current controller
SP30000	0x607F	Limitation of maximum velocity to 30000 rpm
MV0		Minimum analog velocity
MAV25		Minimum analog voltage
LL1800000000	0x607D	Upper positioning range limit
LL-1800000000	0x607D	Lower positioning range limit
LPN16		Numeric value for pulse output
STW1		Step width for special operation
STN1000		Step number for special operation
ENCRES2048		Resolution of external encoder
DEV30000		Deviation error not monitored
DCE200		Error delay 2 sec.
CORRIDOR20	0x6067	Target corridor for positionings
SETPLC		Digital inputs PLC-compatible
OPMOD1	0x6060	Operating mode: “Profile Position Mode”
RM3300		Motor resistance = 3.3 Ω
KN398		Velocity constant = 398 rpm/V
DI		Power power stage deactivated
V0		Nominal speed value = 0 rpm

Notes

NEW

Brushless DC-Servomotor 50 mNm

with integrated Motion Controller and CAN interface

For combination with
Gearheads:
30/1, 32/3, 38/1, 38/2

Series 3564K024B CC

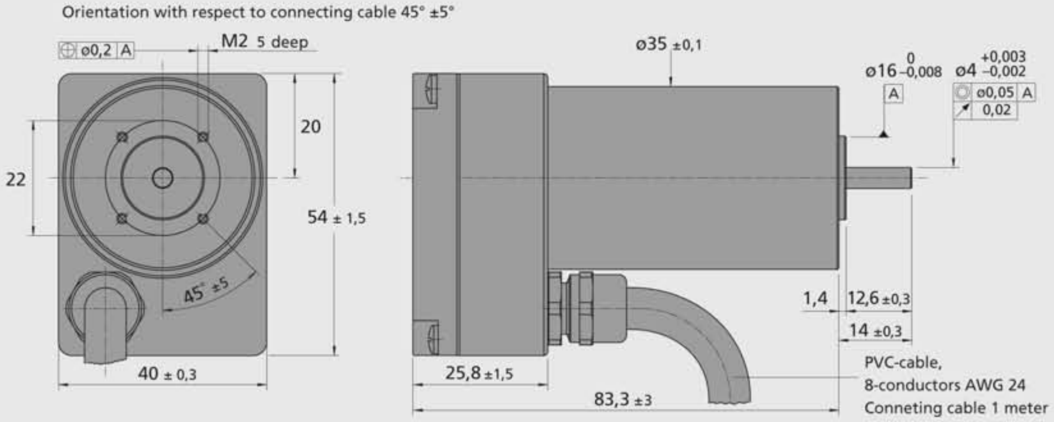
	3564 K		024 B CC	
Nominal voltage	U_N		24	Volt
Output power	$P_{2\,max.}$		90	W
Efficiency	$\eta_{max.}$		80	%
No-load speed	n_o		10 500	rpm
No-load current	I_o		0,28	A
Peak torque for 8 A	M_P		160	mNm
Friction torque:				
– static	C_o		1,10	mNm
– dynamic	C_v		$2{,}4 \cdot 10^{-4}$	mNm/rpm
Torque constant	k_M		20,2	mNm/A
Current constant	k_I		0,05	A/mNm
Slope of n/M curve	$\Delta n/\Delta M$		31	rpm/mNm
Mechanical time constant	τ_m		11	ms
Rotor inertia	J		34	gcm^2
Angular acceleration	$\alpha_{max.}$		109	$\cdot 10^3 rad/s^2$
Thermal resistance	$R_{th\,1} / R_{th\,2}$	2,5 / 6,3		K/W
Thermal time constant	τ_{w1} / τ_{w2}	23 / 1 175		s
Operating temperature range		– 5 ... + 85		°C
Shaft bearings		ball bearings, preloaded		
Shaft load max.:				
– radial at 3000 rpm (7,4 mm from mounting flange)		108		N
– axial at 3000 rpm (push-on only)		50		N
– axial at standstill (push-on only)		131		N
Shaft play:				
– radial	≤	0,015		mm
– axial	=	0		mm
Housing material		aluminium, black anodized		
Weight with electronics		440		g
Direction of rotation		electronically reversible		

Recommended values				
Speed range [1]	n_e		5 - 12 000	rpm
Torque up to [2]	$M_{e\,max.}$		50	mNm
Current up to [2]	$I_{e\,max.}$		2,80 [3]	A

[1] Power rating of 44 Watt at 8 400 rpm and 50 mNm
[2] thermal resistance $R_{th\,2}$ by 55% reduced

[3] This is a preset value and can be changed over the interface

scale reduced



3564K024B CC

Connection

Wires	Function
blue	GND
pink	+ 24 V
brown	Connection No. 1
white	Connection No. 2
grey	Analog GND
yellow	CAN_L (RS232 RXD)
green	CAN_H (RS232 TXD)
red	Connection No. 3

Caution:
be sure to connect motor supply terminals to the correct polarity. Motor electronics are protected against polarity reversal by an internal fuse. In case of damage due to polarity reversal, this internal fuse can only be replaced at the factory.

For notes on technical data and lifetime performance refer to "Technical Information".

Specifications subject to change without notice.

Motion Controller

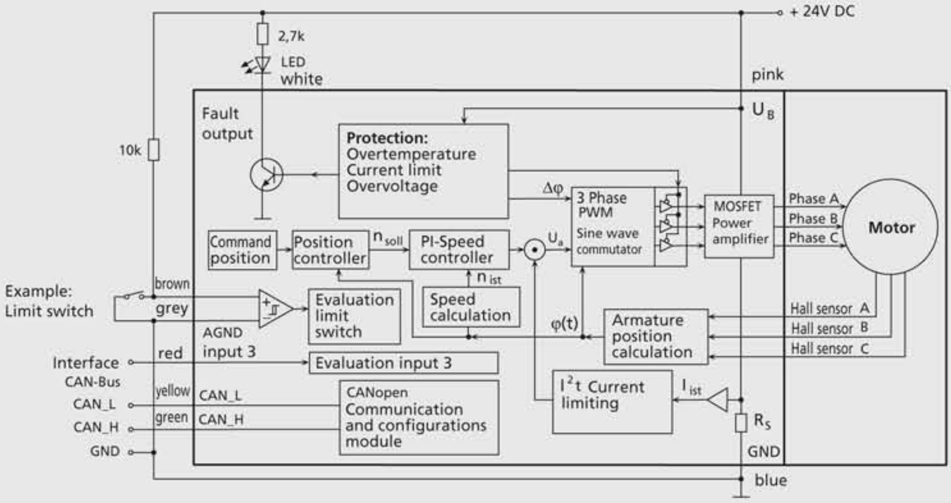
Supply voltage [1]	U_B		12 ... 30	V DC
Peak current [2]	$I_{max.}$		8	A
Input/output (see connection No. 1, 2 and 3)			3	
Connection No. 1 (brown)				
– Speed command analog input		voltage range	±10	V
– Speed command PWM input		frequency range	100 ... 2 000	Hz
		pulse duty factor 50%	0	rpm
– Digital input		input resistance	5	kΩ
– External encoder	$f_{max.}$		400	kHz
– Step frequency input	$f_{max.}$		400	kHz
Connection No. 2 (white)				
– Fault output		no error	switched to GND	
– Digital output		open collector	max. U_B / 30 mA	
– Digital input		input resistance	100	kΩ
Connection No. 3 (red)				
– Digital input		input resistance	22	kΩ
– Electronic supply voltage [1]	U_B		12 ... 30	V DC
Encoder:				
– Scanning rate			100	µs
– Resolution internal encoder			3 000	per turn

The signal level of the digital inputs can be set using the above commands:
Standard (SPS): Low 0...7V / High 12,5V...U_B, TTL: Low 0...0,5V / High 3,5V...U_B

[1] A separate supply for motor and drive electronic is optional available (important for safety-relevant applications), here escapes the digital input, connection 3 (red).

[2] Preset value. Can be changed over the interface.

Position control



Brushless DC-Servomotor with integrated Motion Controller

General description

The 3564K024B CC combines an electronically commutated DC-Servomotor, a high-resolution **absolute encoder** and a programmable **position and speed controller** with **CAN interface**, based on a high-capacity digital signal processor (DSP), within a complete drive unit.

This intelligent EC servomotor performs the following drive functions:

- **Speed control** from 5 to 12 000 rpm with superior performance specifications as regards synchronous operation and minimal torque fluctuations. A PI controller ensures observance of set-point speeds.
- **Speed profiles** such as ramp, triangular or trapezoidal movements are possible. Gentle acceleration or deceleration can be implement ed without problem.
- **Positioning mode**: Positioning with a resolution of 1/3 000 revolutions. Acquisition of **reference marks and end position switches**.
- **Stepper motor mode**, **electronic gear** or operation with external **incremental encoder** for high-precision applications.
- **Torque control** through current regulation.
- **Self-protection** against excess temperature in the case of high loading, against over-voltage during generator operation and against under-voltage.
- **Storage** of the set configuration.

Various inputs and outputs are available for implementation of these functions:

- **Set-point input** for speed presetting.
  Analogue or PWM signal can be used. The input can also read in a reference mark signal. Depending on mode, a frequency signal or external incremental encoder can also be connected.
- **Error output** (Open Collector).
  Can also be reprogrammed as a rotational direction or reference mark input.
- Additional **digital input**.

CAN interface for integration into a CAN network with transfer rates up to 1Mbit/s. The CANopen communication profile according to DS301 V4.02 and DSP402 V2.0 in accordance with the CiA specification is supported for slave devices with the following services:

– 1 Server SDO
– 3 Transmit PDOs, 3 Receive PDOs
– Static PDO Mapping
– NMT with Node Guarding
– Emergency Object

Transfer rate and node no. are set via the network in accordance with the LSS protocol according to DSP305 V1.11, and automatic baud rate detection is also implemented.

In addition, all functions and parameters of the drive unit can be very easily activated via a special FAULHABER PDO channel. For each FAULHABER command a corresponding CAN message frame is available on the PDO channel, enabling operation of the CAN unit analogously to the serial variant. Drive parameters can be analysed very quickly via the integrated trace function.

For Windows 95/98/ME/NT/2K/XP the **"FAULHABER Motion Manager"** software is available; this considerably simplifies operation and configuration of the units via the CAN interface and also enables graphic online analysis of the operating data.

Fields of application

Thanks to the integrated technology, the drive can be used in a range of different areas with minimal wiring effort. The flexible connection options open up a broad field of application in all areas, for example in decentralised systems of automation technology, as well as in pick-and-place machines and machine tools.

Options

An adapter board can also be ordered, to enable immediate commissioning of the 3564K024B CC.

Separate supply of motor and control electronics is possible (important for safety-relevant applications); in this case the 3rd input is not required.

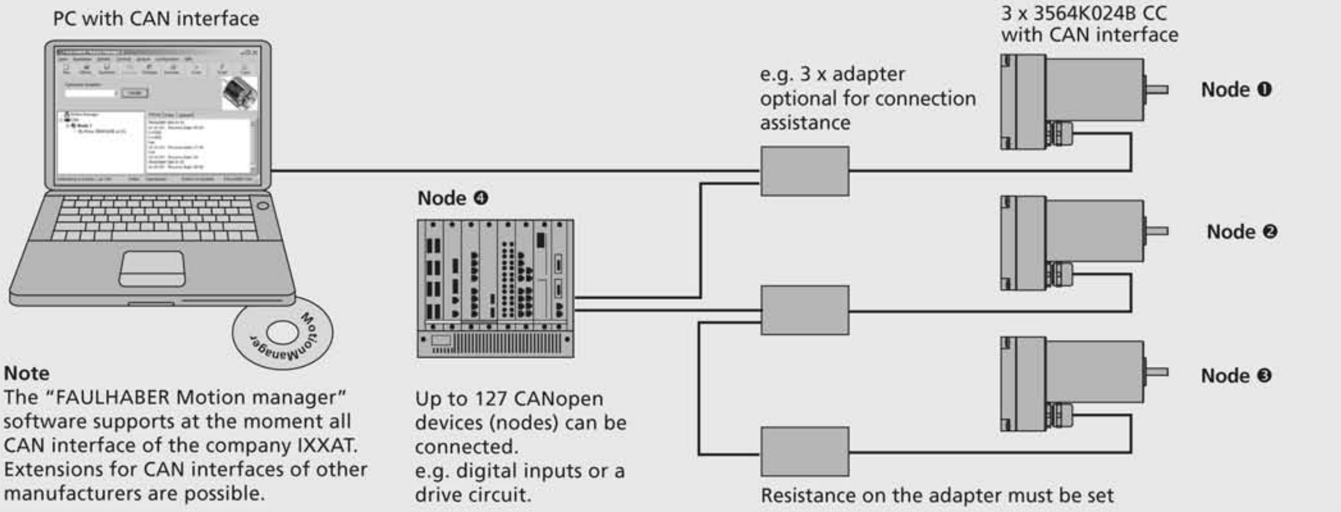
Special preconfiguration of modes and parameters is possible on request.

The Motion Manager program is available on request or on the Internet.

Note

Detailed operating instructions on installation and commissioning are provided with the brushless DC-Servomotor.

Connection diagram



Note
The "FAULHABER Motion manager" software supports at the moment all CAN interface of the company IXXAT. Extensions for CAN interfaces of other manufacturers are possible.

Up to 127 CANopen devices (nodes) can be connected.
e.g. digital inputs or a drive circuit.

Notes

NEW

Motion Controller

4-Quadrant PWM
with CAN interface

For combination with:
Brushless DC-Servomotors
with option K1155

Series MCBL 3003/06 C

		MCBL 3003 C	MCBL 3006 C	
Power supply	U_B	12 ... 30	12 ... 30	V DC
PWM switching frequency	f_{PWM}	78,12	78,12	kHz
Efficiency	η	95	95	%
Max. continuous output current [1]	I_{dauer}	3	6	A
Max. peak output current	I_{max}	10	10	A
Total standby current	I_{el}	0,06	0,06	A
Speed range		5 ... 30 000	5 ... 30 000	rpm
Scanning rate	N	100	100	µs
Encoder resolution with Hall Sensors		≤ 3 000	≤ 3 000	lines/rev.
Resolution with external encoder		≤ 65 535	≤ 65 535	lines/rev.
Input/output (partially free configurable)		3	3	
Operating temperature range		0 ... + 70	0 ... + 70	°C
Storage temperature		– 25... + 85	– 25 ... + 85	°C
Housing material		without housing	aluminium, black anodized	
Weight		18	160	g

[1] at 22°C ambient temperature

Connection information				
Connection "CANH", "CANL":			CAN-High / CAN-Low	
Interface			CAN	
Communication profile			CANopen	
Max. transfer speed rate			1	Mbit/s
Connection "AGND":				
– analog ground			analog GND	
– digital input	external encoder		channel B	
		R_{In}	10	kΩ
		f	≤ 400	kHz
Connection "Fault":				
– digital input		R_{In}	100	kΩ
– digital output (open collector)		U	≤ U_B	V
		I	≤ 30	mA
		clear	switched to GND	
		set	high-impedance	
	fault output	no error	switched to GND	
		error	high-impedance	
	signal output	f	≤ 2	kHz
		resolution	1...255	lines/rev.
Connection "AnIn":			"AGND" as GND	
– analog input	set speed value	U_{In}	± 10	V
– digital input	PWM set speed value	f	100 ... 2 000	Hz
		T	50% ≙ 0 rpm	
	external encoder		channel A	
		f	≤ 400	kHz
	step frequency input	f	≤ 400	kHz
		R_{In}	5	kΩ
Connection "+24V":		U_B	12 … 30	V DC
Connection "GND":			ground	
Connection "3. In":				
– digital input		R_{In}	22	kΩ
– electronic supply voltage [2]		U_B	12 … 30	V DC

[2] Optional on request

Connection information

Connection "Ph A", "Ph B", "Ph C":					
Motor connection	Ph A		Phase A	brown [1]	
	Ph B		Phase B	orange [1]	
	Ph C		Phase C	yellow [1]	
		U_{Out}	0 … U_B		V
PWM switching frequency		f_{PWM}	78,12		kHz
Connection "Hall A", "Hall B", "Hall C":					
Hall sensor input	Hall A		Hall sensor A	green [1]	
	Hall B		Hall sensor B	blue [1]	
	Hall C		Hall sensor C	grey [1]	
		U_{In}	≤ 5		V
Connection "SGND":					
Signal GND			Signal ground	black [1]	
Connection "+5V":					
Output voltage for external use [2]		U_{Out}	5	red [1]	V DC
Load current		I_{Out}	≤ 60		mA

[1] Color identification for brushless DC-Servomotor

[2] E.g. Hall sensor

D-SUB-connector information

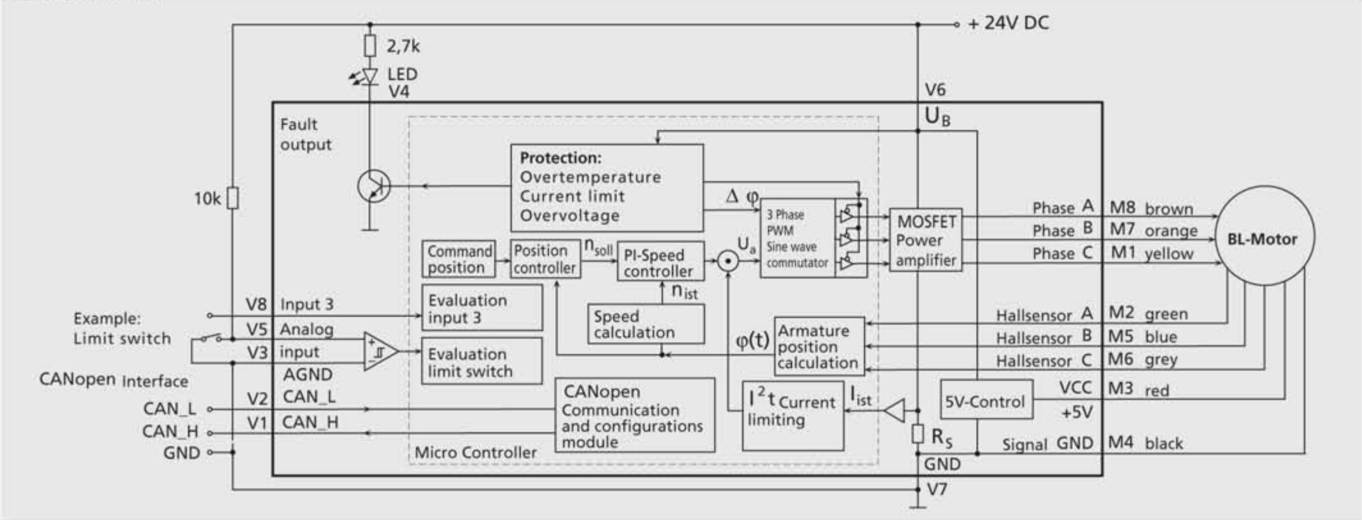
Connection D-SUB-connector:			
Pin 2	CAN_L		CAN-Low
Pin 3	GND		Ground
Pin 7	CAN_H		CAN-High

Digital inputs general information

- PLC, default	high	12,5 … U_B	V
	low	0 … 7	V
- TTL	high	3,5 … U_B	V
	low	0 … 0,5	V

The signal level (PLC or TTL) of the digital inputs can be set over the interface (see instruction manual).

Position control



Specifications subject to change without notice

Motion Controller

General description

The MCBL 3003/06 C is designed for brushless DC-Servomotors with linear Hall sensors. Ultra-low speeds and high positioning resolutions (1/3000 revolutions) are thus possible without the need for an additional encoder. The motors have a sinusoidal current, resulting in a constant torque over the entire circumference. This means that the motors run particularly quietly, and efficiency is also increased.

Maximum performance:

- **PI speed controller** with superior performance specifications in respect of synchronous operation and minimal torque fluctuations.
- **Speed profiles** such as e.g. ramp, triangular or trapezoidal movements. More complex profiles can also be implemented.
- **Positioning** with high resolution, including **limit switches and zero referencing**.
- **Operation as torque controller** through current regulation.
- **Extended** operating modes:

  - Stepper motor mode
  - Gearing mode (electronic gear)
  - Analogue positioning mode (position control with analogue voltage)
  - Voltage regulator mode
  - Analogue target current presetting
  - External encoder as absolute encoder

Latest technology in micro format:

- High efficiency
- Power amplifier with very high PWM frequency
- Power MOSFETs with minimal on-resistance
- Unique thermal protection device determines MOSFET silicon temperature
- High-capacity 16 bit signal processor

Versatile communication:

- **Set-point input** for speed presetting. Processes analogue and PWM signals. The input can also be used for a frequency or reference mark signal.
- **Error output** (Open Collector). Can also be programmed as a rotational direction or reference mark input.
- **Additional** digital input
- **CANopen interface** for integration into a CAN network with transfer rates up to 1Mbit/s

Programming made easy

The MCBL 30003/06 C supports the CANopen communication profile according to DS301 V4.02 and DSP402 V2.0 in accordance with the CiA specification for slave devices with the following services:
- 1 Server SDO
- 3 Transmit PDOs, 3 Receive PDOs
- Static PDO Mapping
- NMT with Node Guarding
- Emergency Object

The transfer rate and node no. are set via the network in accordance with the LSS protocol according to DSP305 V1.11, and automatic baud rate detection is also implemented. In addition, all functions and parameters of the drive unit can be very easily activated via a special FAULHABER PDO channel. For each FAULHABER command a corresponding CAN message frame is available on the PDO channel, enabling the CAN unit to be operated analogously to the serial variant.

For Windows operating systems the "**FAULHABER Motion Manager**" software is available. This considerably simplifies operation and configuration and also enables graphic online analysis of the operating data.

Fields of application

The Motion Controller can be used in many different areas. Thanks to the highly flexible connection options, this device is suitable for a diverse range of applications, for example in decentralised systems of automation technology, as well as in pick-and-place machines and machine tools.

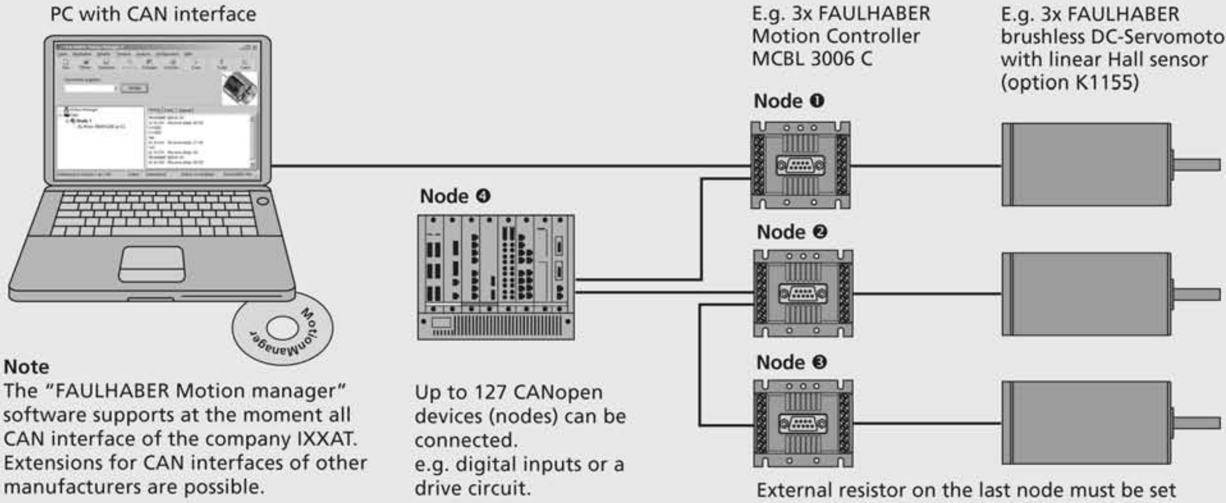
Options

- Separate supply of motor and control electronics is optionally possible (important for safety-relevant applications); in this case the 3rd input is not required.
- Special preconfiguration of modes and parameters is possible on request.
- The "**FAULHABER Motion Manager**" software is available on request or on the Internet.

Note

Detailed operating instructions on installation and commissioning are provided with the Motion Controller.

Connection diagram


PC with CAN interface
E.g. 3x FAULHABER Motion Controller MCBL 3006 C
E.g. 3x FAULHABER brushless DC-Servomotor with linear Hall sensor (option K1155)
Node ❶
Node ❷
Node ❸
Node ❹
MotionManager

Note
The "FAULHABER Motion manager" software supports at the moment all CAN interface of the company IXXAT. Extensions for CAN interfaces of other manufacturers are possible.

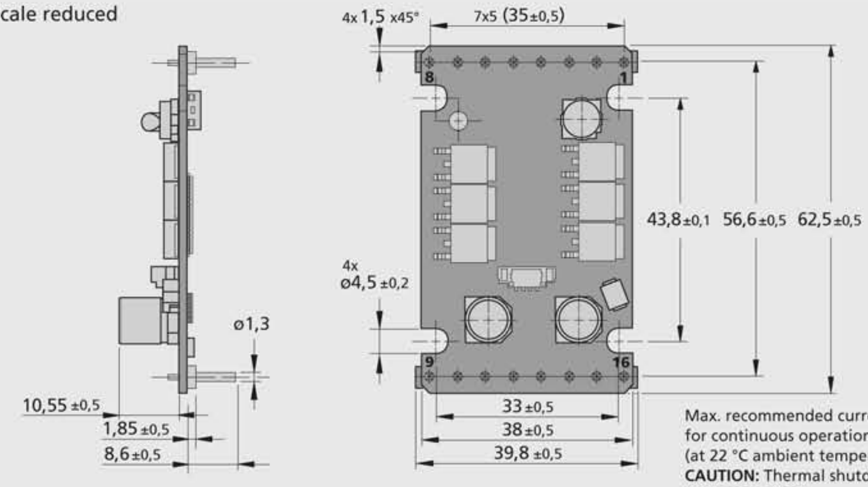
Up to 127 CANopen devices (nodes) can be connected.
e.g. digital inputs or a drive circuit.

External resistor on the last node must be set

Specifications subject to change without notice

Dimensional drawing and connection information for MCBL 3003 C

Scale reduced



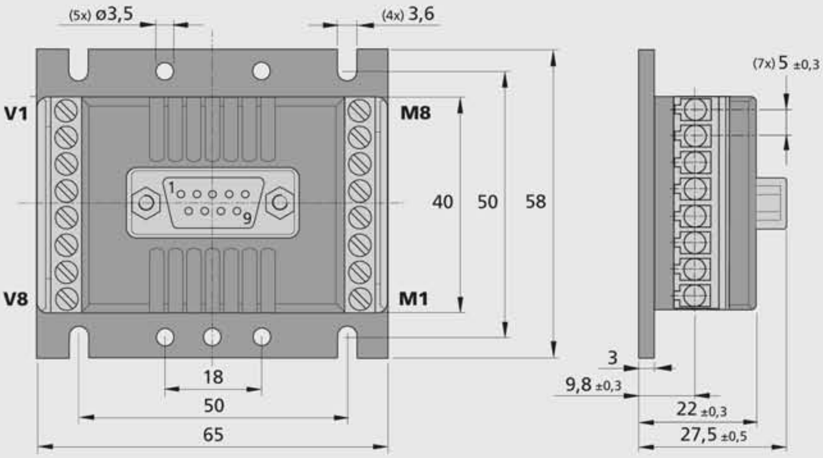
Max. recommended current for continuous operation: 3A (at 22 °C ambient temperature)
CAUTION: Thermal shutdown is NOT guaranteed!

Connection

Pin	Function
1	Ph C
2	Hall A
3	+ 5V
4	SGND
5	Hall B
6	Hall C
7	Ph B
8	Ph A
9	CAN_H
10	CAN_L
11	AGND
12	Fault
13	AnIn
14	+ 24V
15	GND
16	3. In

Dimensional drawing and connection information for MCBL 3006 C

Scale reduced



Motor connection

No.	Function
M1	Ph C
M2	Hall A
M3	+ 5V
M4	SGND
M5	Hall B
M6	Hall C
M7	Ph B
M8	Ph A

Supply connection

No.	Function
V1	CAN_H
V2	CAN_L
V3	AGND
V4	Fault
V5	AnIn
V6	+ 24V
V7	GND
V8	3. In

Specifications subject to change without notice

NEW

Motion Controller

4-Quadrant PWM
with CAN interface

For combination with:
DC-Micromotors

Series MCDC 3003/06 C

		MCDC 3003 C	MCDC 3006 C	
Power supply	U_B	12 ... 30	12 ... 30	V DC
PWM switching frequency	f_{PWM}	78,12	78,12	kHz
Efficiency	η	95	95	%
Max. continuous output current [1]	I_{dauer}	3	6	A
Max. peak output current	I_{max}	10	10	A
Total standby current	I_{el}	0,06	0,06	A
Speed range		5 ... 30 000	5 ... 30 000	rpm
Scanning rate	N	100	100	µs
Encoder resolution with Hall Sensors		≤ 65 535	≤ 65 535	lines/rev.
Input/output (partially free configurable)		5	5	
Operating temperature range		0 ... + 70	0 ... + 70	°C
Storage temperature		– 25... + 85	– 25 ... + 85	°C
Housing material		without housing	aluminium, black anodized	
Weight		18	160	g

[1] at 22°C ambient temperature

Connection information				
Connection "CANH", "CANL":			CAN-High / CAN-Low	
Interface			CAN	
Communication profile			CANopen	
Max. transfer speed rate			1	Mbit/s
Connection "AGND":				
– analog ground			analog GND	
– digital input	external encoder		channel B	
		R_{In}	10	kΩ
		f	≤ 400	kHz
Connection "Fault":				
– digital input		R_{In}	100	kΩ
– digital output (open collector)		U	≤ U_B	V
		I	≤ 30	mA
		clear	switched to GND	
		set	high-impedance	
	fault output	no error	switched to GND	
		error	high-impedance	
Connection "AnIn":			"AGND" as GND	
– analog input	set speed value	U_{In}	± 10	V
– digital input	PWM set speed value	f	100 ... 2 000	Hz
		T	50% ≙ 0 rpm	
	external encoder		channel A	
		f	≤ 400	kHz
	step frequency input	f	≤ 400	kHz
		R_{In}	5	kΩ
Connection "+24V":		U_B	12 … 30	V DC
Connection "GND":			ground	
Connection "3. In":				
– digital input		R_{In}	22	kΩ
– electronic supply voltage [2]		U_B	12 … 30	V DC
Connection "4. In":				
– digital input		R_{In}	22	kΩ
Connection "5. In":				
– digital input		R_{In}	22	kΩ

[2] Optional on request

Specifications subject to change without notice

Connection information

Connection "Mot -", "Mot +":				
Motor connection	Mot -		Motor -	
	Mot +		Motor +	
		U_{Out}	0 … U_B	V
PWM switching frequency		f_{PWM}	78,12	kHz
Connection "Ch A", "Ch B":				
Hall sensor input	CH A		encoder channel A	
	CH B		encoder channel B	
Integrated pullup resistance + 5V		R	2,2	kΩ
		f	≤ 400	kHz
Connection "SGND":				
Signal GND			signal ground	
Connection "+5V":				
Output voltage for external use [1]		U_{Out}	5	V DC
Load current		I_{Out}	≤ 60	mA

[1] E.g. encoder

D-SUB-connector information

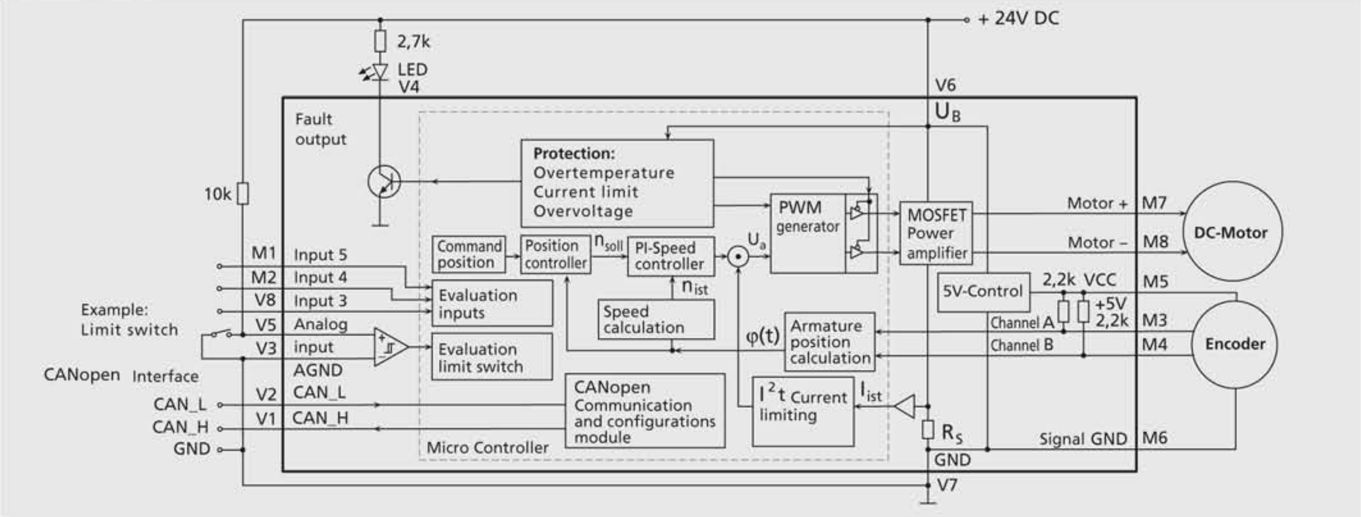
Connection D-SUB-connector:			
Pin 2	CAN_L		CAN-Low
Pin 3	GND		Ground
Pin 7	CAN_H		CAN-High

Digital inputs general information

- PLC, default	high	12,5 … U_B	V
	low	0 … 7	V
- TTL	high	3,5 … U_B	V
	low	0 … 0,5	V

The signal level (PLC or TTL) of the digital inputs can be set over the interface (see instruction manual).

Position control



Specifications subject to change without notice

Motion Controller

General description

The MCDC 3003/06 C is the perfect controller for the entire range of FAULHABER DC-Micromotors. In conjunction with the proven IE2-512 encoders, they are capable of achieving a positioning resolution of 0.18°. A special ballast circuit protects the electronics from over-voltage during braking in generator mode.

Maximum performance:

- **PI speed controller** with superior performance specifications in respect of synchronous operation and minimal torque fluctuations.
- **Speed profiles** such as e.g. ramp, triangular or trapezoidal movements. More complex profiles can also be implemented.
- **Positioning** with high resolution, including **limit switches and zero referencing**.
- **Operation as torque controller** through current regulation.
- **Extended** operating modes:

  - Stepper motor mode
  - Gearing mode (electronic gear)
  - Analogue positioning mode (position control with analogue voltage)
  - Voltage regulator mode
  - Analogue target current presetting
  - IxR control

Latest technology in micro format:

- High efficiency
- Power amplifier with very high PWM frequency
- Power MOSFETs with minimal on-resistance
- Unique thermal protection device determines MOSFET silicon temperature
- High-capacity 16 bit signal processor

Versatile communication:

- **Set-point input** for speed presetting. Processes analogue and PWM signals. The input can also be used for a frequency or reference mark signal.
- **Error output** (Open Collector). Can also be programmed as a rotational direction or reference mark input.
- **Additional** digital inputs
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- 1 Server SDO
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- Static PDO Mapping
- NMT with Node Guarding
- Emergency Object

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For Windows operating systems the **"FAULHABER Motion Manager"** software is available. This considerably simplifies operation and configuration and also enables graphic online analysis of the operating data.

Fields of application

The Motion Controller can be used in many different areas. Thanks to the highly flexible connection options, this device is suitable for a diverse range of applications, for example in decentralisied systems of automation technology, as well as in pick-and-place machines and machine tools.

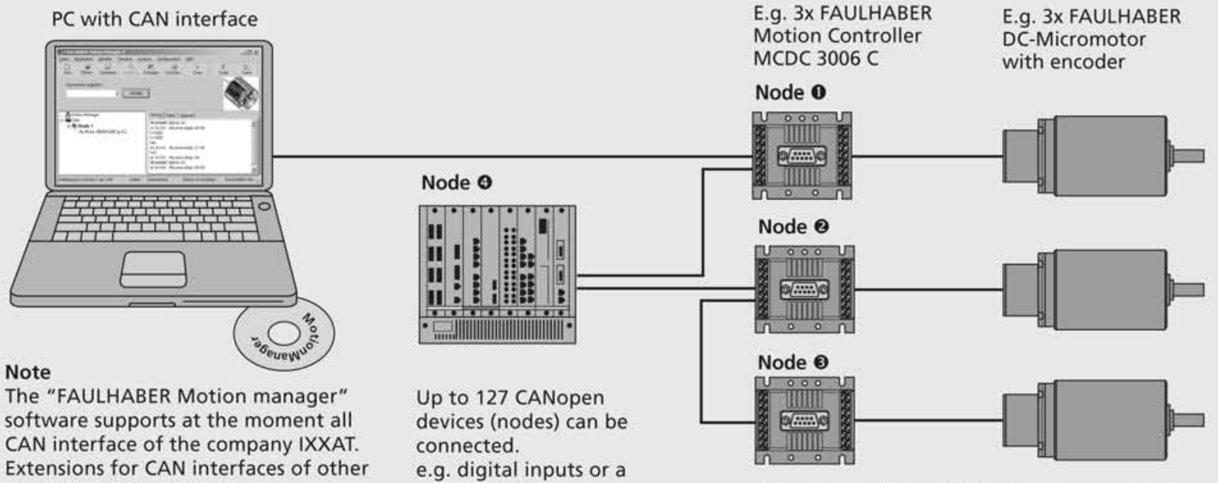
Options

- Adapter for IE2 or HEDL encoder
- Separate supply of motor and control electronics is optionally possible (important for safety-relevant applications); in this case the 3rd input is not required.
- Special preconfiguration of modes and parameters is possible on request.
- The **"FAULHABER Motion Manager"** software is available on request or on the Internet.

Note

Detailed operating instructions on installation and commissioning are provided with the Motion Controller.

Connection diagram


PC with CAN interface
E.g. 3x FAULHABER Motion Controller MCDC 3006 C
E.g. 3x FAULHABER DC-Micromotor with encoder
Node ❶
Node ❹
Node ❷
Node ❸
MotionManager

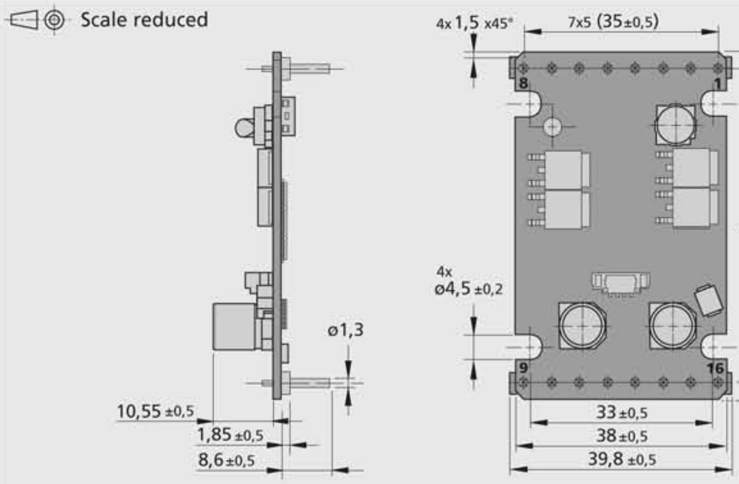
Note
The "FAULHABER Motion manager" software supports at the moment all CAN interface of the company IXXAT. Extensions for CAN interfaces of other manufacturers are possible.

Up to 127 CANopen devices (nodes) can be connected.
e.g. digital inputs or a drive circuit.

External resistor on the last node must be set

Specifications subject to change without notice

Dimensional drawing and connection information MCDC 3003 C

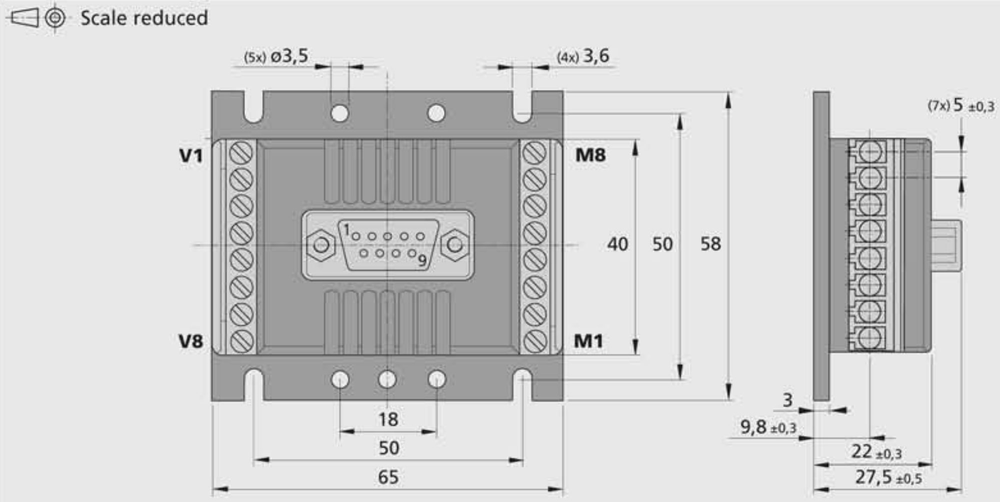


Max. recommended current
for continuous operation: 3A
(at 22 °C ambient temperature)
CAUTION: Thermal shutdown is
NOT guaranteed!

Connection

Pin	Function
1	5. In
2	4. In
3	Ch A
4	Ch B
5	+ 5V
6	SGND
7	Mot +
8	Mot –
9	CAN_H
10	CAN_L
11	AGND
12	Fault
13	AnIn
14	+ 24V
15	GND
16	3. In

Dimensional drawing and connection information MCCD 3006 C



Motor connection

No.	Function
M1	5. In
M2	4. In
M3	Ch A
M4	Ch B
M5	+ 5V
M6	SGND
M7	Mot +
M8	Mot –

Supply connection

No.	Function
V1	CAN_H
V2	CAN_L
V3	AGND
V4	Fault
V5	AnIn
V6	+ 24V
V7	GND
V8	3. In

Specifications subject to change without notice

Notes

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