FAULHABER

Communication / Function Manual

Motion Control

MCBL 300x RS
MCDC 300x RS
3564...B CS
32xx...BX4 CS
22xx...BX4 CSD

RS232

WE CREATE MOTION

EN

Imprint

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The relevant regulations regarding safety engineering and interference suppression as well as the requirements specified in this document are to be noted and followed when using the software.

Subject to change without notice.

The respective current version of this technical manual is available on FAULHABER's internet site:
www.faulhaber.com

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1 About this document

1.1 Validity of this document

This document describes:

- Quick start:
  - Initial commissioning and operation of the device with serial interface
- Communication:
  - Communication with the drive via RS232
  - Basic services provided by the Communication structure
  - Methods for accessing the parameters
  - Drive from the viewpoint of the communication system
- Function:
  - Principle of the device controller
  - Commissioning and configuring the device
  - Operating modes and functions

This manual is related to the product series of the FAUHLABER Motion Controllers and the FAULHABER Motion Control Systems. In the following these product series are termed "Motion Controller". The term "Motion Control System" will be used, only if the distinction is necessary.

This document is intended for following persons:

- Users who are commissioning a motor on the FAULHABER Motion Controller for the first time
- Software developers and project engineers with experience of interfaces
- Technicians and engineers in the application of controlled electrical drives and industrial communications systems

All data in this document relate to the standard versions of the drives. Changes relating to customer-specific versions can be found in the attached sheet.

1.2 Associated documents

For certain actions during commissioning and operation of FAULHABER products additional information from the following manuals is useful:

Manual	Description
Motion Manager 6	Operating instructions for FAULHABER Motion Manager PC software
Technical manual	Instructions for installation and use of the FAULHABER Motion Controller

These manuals can be downloaded in PDF format from the Internet page www.faulhaber.com/manuals/.

1.3 Using this document

- Read the document carefully before undertaking configuration.
- Retain the document throughout the entire working life of the product.
- Keep the document accessible to the operating personnel at all times.
- Pass the document on to any subsequent owner or user of the product.

1.4 List of abbreviations

Abbreviation	Meaning
EEPROM	Electrically Erasable Programmable Read-Only Memory
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
PWM	Pulse Width Modulation
PLC	Programmable Logic Controller
TTL	Transistor Transistor Logic

1.5 Symbols and markers

CAUTION!
Hazards to persons. Disregard may lead to minor injuries.

- Measures for avoidance

NOTICE!
Risk of damage.

- Measures for avoidance

Instructions for understanding or optimising the operational procedures

✓ Pre-requirement for a requested action

1. First step for a requested action
   - Result of a step
2. Second step of a requested action

- Result of an action
- Request for a single-step action

2 Quick start

To facilitate introduction, this chapter highlights the initial steps for commissioning and operation of FAULHABER Motion Controllers with serial interface. Additionally, the detailed documentation must be read and taken into account, particularly chap. 5.2.4, p. 63.

2.1 Commissioning using the default configuration

The following steps are necessary for commissioning using the default configuration:

1. Connect the drive unit to a 12 V – 24 V voltage source.

   For the connection cable assignment, see technical manual.

2. Connect drive unit to a serial interface of the PC (e.g. COM1) and switch on..

   For the interface assignment, see technical manual.

3. Execute configuration and motion commands via suitable software, e.g. FAULHABER Motion Manager.

ℹ Use of a USB serial adapter is recommended if the PC used does not have a serial port.

2.2 Setting node number and baud rate

The units are delivered as standard with node address 0 (NODEADR0) and with a transfer rate of 9 600 baud. The settings can be changed via the interface, e.g. with the FAULHABER Motion Manager.

Procedure when using the FAULHABER Motion Manager:

✓ Connection exists (see chap. 2.1, p. 9).

1. Select the **Configuration - Connection Parameters…** menu.
2. Select the required transfer rate and node number.
3. Press ***Send*** button.

   ↳ The settings are transferred and are permanently stored in the controller. The Motion Manager then calls up the Scan function again and the node should now be displayed with the correct node number in the Node Explorer. After switching off and on again, the drive will operate with the set configuration.

2.3 Operation via FAULHABER Motion Manager

The FAULHABER Motion Manager offers easy access to the Motion Controller’s command set. The desired node must have been activated beforehand by double clicking in Node Explorer in the case of network operation.

The FAULHABER commands described below can be entered directly in the command input line or selected from the commands menu.

In order to drive a motor via the Motion Manager, follow the procedure below:

✓ Connection exists (see chap. 2.1, p. 9).

1. Start FAULHABER Motion Manager.
2. Configure drive functions:
   - Motion control systems with electronics built onto the motor are already preset in the factory.
   - Motion Controllers with an externally connected motor must be equipped with current limitation values suitable for the motor and suitable controller parameters before being started up.

   The Motor Wizard is available in Motion Manager for selection of the motor and basic parameters suitable for the motor.

   Other settings, e.g. for the function of the fault output, can be made under the **Configuration – Drive Function** menu item, where a convenient dialog is provided (see chap. 5.2, p. 60). The configuration dialog is also available for direct access in the quick access bar of the Motion Manager.

NOTICE!

Damage to the controller and / or drive by incorrect values in the Motion Controller's settings.

- Check basic settings (see chap. 5.2.4, p. 63).

3. To operate the drive via the PC, set value presetting to digital (`SOR0`).
4. If the settings are to be permanently stored, press the ***EEPSAV*** button.
5. Activate the drive using the `EN` command.

   Select **Motion Control - Enable Drive (EN)** via the context menu of the node explorer or via the **Commands** menu

   \- or -

   enter the `EN` command in the command input field of the terminal window

   \- or -

   press ***Output stage enable*** button in the symbol bar.

6. Drive the motor velocity controlled (e.g. with 100 min^{-1}):

   Select **Motion Control - Initiate Velocity Mode (V)** via the context menu of the node explorer or via the **Commands** menu and enter 100 in the dialogue box

   \- or -

   enter the `V100` command in the command input field of the terminal window.

7. Stop the drive using the `V0` command.

8. Move the motor (e.g. relative by 10 000 increments):

   – Select **Motion Control - Load relative target position (LR)** via the context menu of the node explorer or via the **Commands** menu and enter the required value in the dialogue box

     - or -

     enter the `LR10000` command in the command input field of the terminal window.

   – Select **Motion Control - Initiate Motion (M)** via the context menu of the node explorer or via the **Commands** menu

     - or -

     enter the `M` command in the command input field of the terminal window.

9. Deactivate the drive:

   Press ***Output stage disable*** button in the symbol bar

   - or -

   press F5 key

   - or -

   select the **Motion Control - Disable Drive (DI)** menu item or execute the `DI` command.

Adjusting the controller parameters using the Tool Controller tuning

Motion Manager provides the Tool **Controller tuning**, with which the controller parameters of the velocity and positioning controller can be adjusted to the application.

NOTICE!

Material damage due to collisions.

During operation with the Tool **Controller tuning** the motor is alternately run at different speeds. Obstacles within the movement range can lead to collisions and material damage.

- Make sure that during parameter search the drive is free to move within the values that were input.

3 Functional description

3.1 Drive data

For the motor monitoring models the following parameters are required:

- Velocity constant
- Connection resistance
- Pole number for brushless motors

These values are already set for integrated units. These values are suitably preassigned for external controls by selecting a motor type in the Motion Manager's Motor Wizard.

Command	Argument	Function	Description
KN	0…16 383	Load Speed Constant	Load speed constant K_n in accordance with information in the data sheet [min^{-1}/V].
RM	10…320 000	Load Motor Resistance	Load motor resistance RM according to specification in data sheet [mΩ].
ENCRES	8…65 535	Load Encoder Resolution	Load resolution of external encoder [4 times pulse/rev].

- Sensor Type:

  The following combinations are supported as position encoder systems for brushless motors:

  - Analogue Hall sensors (3 000 Increments/revolution, fixed)
  - Analogue Hall sensors + incremental encoder (resolution depends on the incremental encoder)
  - AES encoder (e.g. AES-4096)

  An incremental encoder with selectable resolution is supported as the position encoder for DC motors.

- Resolution external encoder (ENCRES):

  If using an external incremental encoder its resolution must be given for 4 edge evaluation (4 times the pulse rate).

- Resolution internal encoder:

  If using the analogue Hall sensors of the brushless motors as position encoders, a fixed 3 000 pulses per revolution are supplied.

  MCDC only uses an external encoder, therefore the sensor type changeover is not available here. In the case of AES controllers the resolution is defined by the sensor type, an external encoder cannot be used here.

3.2 Configuration of the operating modes

The Motion Controllers can be configured for different operating modes. As standard the drive unit is delivered as a servomotor with set value presetting via the serial interface. The drive can be reconfigured by means of the corresponding FAULHABER commands.

Command	Argument	Function	Description
SOR	0…4	Source For Velocity	Source for velocity presetting. ▪ 0: Interface (Default) ▪ 1: Voltage at analogue input ▪ 2: PWM signal at analogue input ▪ 3: Current target value via analogue input ▪ 4: Target current value via analogue input with pre-setting of the direction of rotation via input polarity
CONTMOD	–	Continuous Mode	Switch back to normal mode from an enhanced mode.
STEPMOD	–	Stepper Motor Mode	Change to stepper motor mode.
APCMOD	–	Analog Position Control Mode	Position control with target value via analogue voltage.
ENCMOD	–	Encoder Mode	Change to encoder mode (not for MCDC). An external encoder serves as position detector (the current position value is set to 0).
HALLSPEED	–	Hall Sensor As Speed Sensor	Speed via Hall sensors in encoder mode (not for MCDC).
ENCSPEED	–	Encoder As Speed Sensor	Speed via encoder signals in encoder mode (not for MCDC).
GEARMOD	–	Gearing Mode	Change to gearing mode
VOLTMOD	–	Set Voltage Mode	Activate Voltage Regulator Mode.
IXRMOD	–	Set IxR Mode	Activate IxR control (MCDC only).

If the settings are to be permanently stored, the SAVE command must be executed after the configuration. This saves the current settings in the Flash data memory. From there they are reloaded when the unit is next switched on.

Alternatively, the EEPSAV command can also be executed. Both commands are identical, therefore SAVE only is used in the following.

The power stage must be activated (EN) for the drive to operate.

All commands listed further below are summarised and explained again in chap. 7, p. 80.

3.3 Position control

3.3.1 Set value presetting via the serial interface

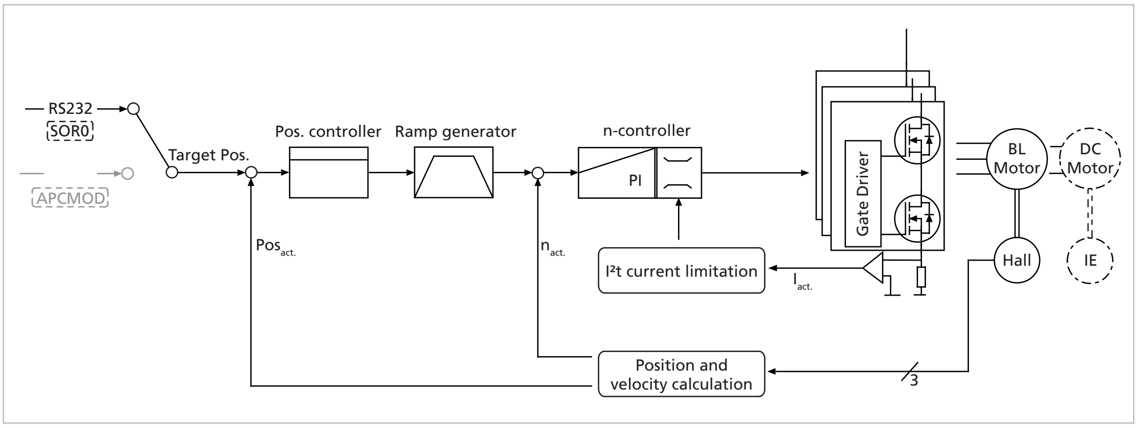


Fig. 1: Controller structure for set value presetting via the serial interface or via a sequence program

In this operating mode, target positions can be preset via the serial interface or a sequence program.

3.3.1.1 Basic settings

Operating mode CONTMOD and SOR0.

The positioning range limits can be set via the command LL and activated via APL. The proportional amplification PP and a differential term PD can be set for the position controller.

Command	Argument	Function	Description
PP	1…255	Load Position Proportional Term	Load position controller amplification.
PD	1…255	Load Position Differential Term	Load position controller D-term.
LL	$-1,8 \cdot 10^9 \ldots 1,8 \cdot 10^9$	Load Position Range Limits	Load limit positions (the drive cannot be moved out of these limits). ▪ Positive values specify the upper limit. ▪ Negative values specify the lower limit. The range limits are only active if APL = 1.
APL	0…1	Activate / Deactivate Position Limits	Activate range limits (LL) (valid for all operating modes except VOLTMOD). ▪ 1: Position limits activated ▪ 0: Position limits deactivated

Positioning beyond the range limits:

In the case of APL0 relative positioning can also be executed beyond the range limits. If the upper (1 800 000 000) or lower limit (–1 800 000 000) is exceeded, counting is continued at 0 without loss of increments.

3.3.1.2 Additional settings

Ramp generator
The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the `AC`, `DEC` and `SP` commands.

See chap. 3.8.1, p. 43.

Velocity controller / current limitation
The controller parameters `POR` and `I` of the velocity controller can be adjusted. In addition, the current limitation values `LPC` and `LCC` can be used to protect the drive against overload.

See chap. 3.4, p. 21.

3.3.1.3 Motion control commands

The positioning is executed via the FAULHABER motion control commands (see chap. 7.4, p. 89).

Command	Argument	Function	Description
`EN`	–	Enable Drive	Activate drive.
`DI`	–	Disable Drive	Deactivate drive.
`LA`	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Load Absolute Position	Load new absolute target position.
`LR`	$-2{,}14 \cdot 10^9 \ldots 2{,}14 \cdot 10^9$	Load Relative Position	Load new relative target position, in relation to last started target position. The resulting absolute target position must lie between the values given as argument.
`M`	–	Initiate Motion	Activate position control and start positioning.
`HO`	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Define Home Position	▪ Without argument: Set actual position to 0. ▪ With argument: Set actual position to specified value.
`NP`	–	Notify Position	▪ Without argument: A “p” is returned when the target position is attained. ▪ With argument: A “p” is returned if the specified position is over-travelled.
`NPOFF`	–	Notify Position Off	Notify Position command that has not yet been triggered is deactivated again.

Example:

- Load target position: `LA40000`
- Start positioning: `M`

Attainment of the target position or any intermediate position is indicated by a “p” on the serial interface if “Notify Position” is set before the start of positioning, provided that ANSW1 or ANSW2 is set.

Position resolution
If the linear Hall sensors of the brushless motors are used as position transducers, 3 000 pulses per revolution are supplied.

Complex motion profiles
More complex motion profiles can be generated through appropriate presetting of new values (maximum speed, acceleration, end position) during positioning. After a value change, simply execute a new motion start command (`M`). The commands `NP` and `NV` can be used to control the sequence.

Further information on compiling motion profiles is given in chap. 3.8.1, p. 43.

Positioning beyond the range limits
In the case of `APL0` relative positioning can also be executed beyond the range limits. If the upper (1 800 000 000) or lower limit (–1 800 000 000) is exceeded, counting is continued at 0 without loss of increments.

Digital signal target position
The entry into the target corridor can be displayed via the fault output as a digital output signal in the `POSOUT` function. The signal is not reset until a further Motion start command (`M`).

Further information on configuration is given in chap. 3.7, p. 40.

3.3.2 Analogue positioning mode (APCMOD)

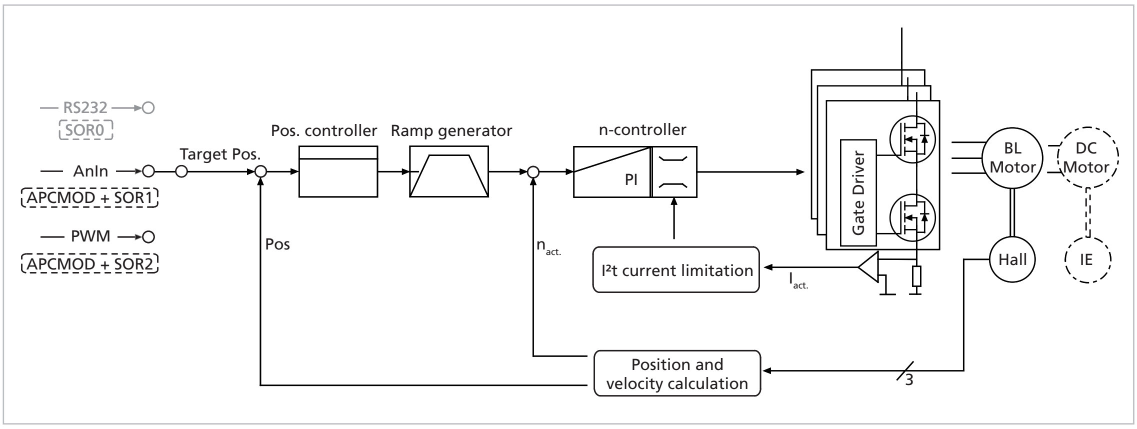


Fig. 2: Controller structure for set-point presetting via an analogue voltage

In this operating mode the target position can be preset using an analogue voltage at the AnIn input.

3.3.2.1 Basic settings

Operating mode `APCMOD` and `SOR1` or `SOR2`.

The positioning range limits can be set via the command `LL` and activated via `APL`. The proportional amplification `PP` and a differential term `PD` can be set for the position controller.

The maximum position to be approached with a voltage of 10 V can be preselected with the `LL` command. At –10 V the drive moves in the opposite direction up to the set negative range limit.

Irrespective of the preset `LL` value, the maximum position is limited to 3 000 000 in `APCMOD`.

> **i** The resolution of the analogue input is limited to 12 bit (4096 steps). The direction of rotation can be predefined with the commands `ADL` and `ADR`.

3.3.2.2 Additional settings

Ramp generator
The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the AC, DEC and SP commands.

See chap. 3.8.1, p. 43.

Velocity controller / current limitation
The controller parameters POR and I of the velocity controller can be adjusted. In addition, the current limitation values LPC and LCC can be used to protect the drive against overload.

See chap. 3.4, p. 21.

3.3.2.3 Positioning via pulse width signal (PWM) at the analogue input (SOR2)

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

Tab. 1: Meaning of the pulse duty factor on delivery

Pulse duty factor	Meaning
> 50%	Positive target position
= 50%	Target position = 0
< 50%	Negative target position

3.3.2.4 Absolute positioning within one revolution (only for BL 2 pole)

In motion control systems with brushless 2-pole motors, the initial position is absolutely initialised within one revolution after the motor is switched on (0…3 000 corresponds to 0…360° of the rotor position). 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…10 V within one revolution and to return to the correct position even after the supply has been switched off, without homing.

Function	Command
Switch over to analogue positioning	APCMOD
Hide negative range	LL-1
Fix maximum position to 1 revolution	LL3000

3.3.3 External encoder as actual position value (ENCMOD) (not for MCDC)

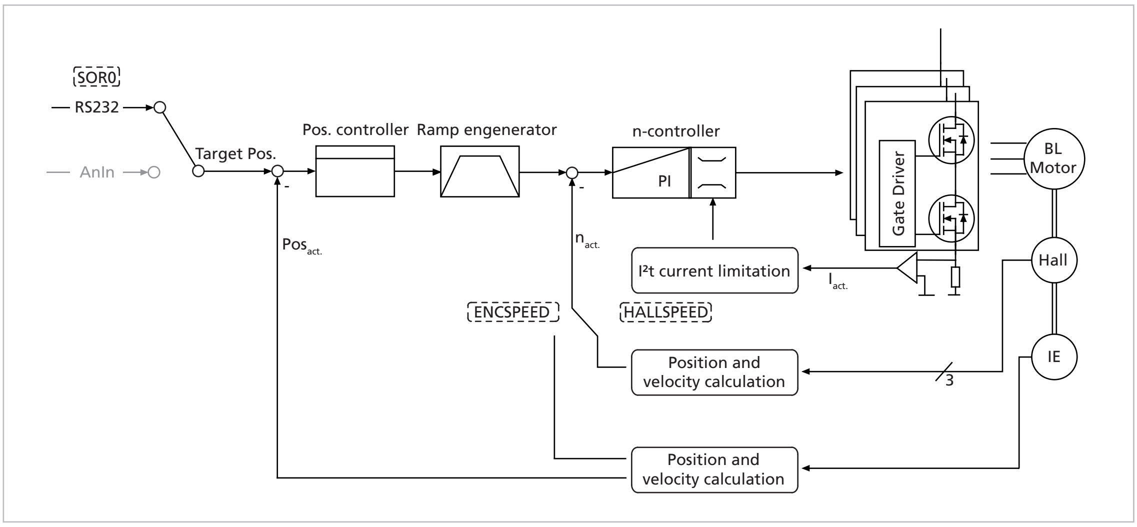


Fig. 3: Controller structure for using and external encoder as the actual value encoder

For high-precision applications, the actual values of BL motors can be derived from an external encoder.

- Depending on the application, the velocity can be derived from the encoder or from the Hall sensors.
- The external encoder can be mounted directly on the motor shaft. An encoder that is mounted to the application output (e.g. glass scale) is particularly advantageous. This allows the high precision to be set directly at the output.
- Commutation still occurs via the analogue Hall sensors.

3.3.3.1 Basic settings

Operating mode `ENCMOD` and `SOR0`.

The positioning range limits can be set via the command `LL` and activated via `APL`. The proportional amplification `PP` and a differential term `PD` can be set for the position controller.

Command	Argument	Function	Description
`PP`	1…255	Load Position Proportional Term	Load position controller amplification.
`PD`	1…255	Load Position Differential Term	Load position controller D-term.
`LL`	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Load Position Range Limits	Load limit positions (the drive cannot be moved out of these limits). ▪ Positive values specify the upper limit. ▪ Negative values specify the lower limit. The range limits are only active if `APL` = 1.
`APL`	0…1	Activate / Deactivate Position Limits	Activate range limits (`LL`) (valid for all operating modes except `VOLTMOD`). ▪ 1: Position limits activated ▪ 0: Position limits deactivated

Positioning beyond the range limits:

In the case of APL0 relative positioning can also be executed beyond the range limits. If the upper (1 800 000 000) or lower limit (–1 800 000 000) is exceeded, counting is continued at 0 without loss of increments.

Tab. 2: Settings for external encoder

Command	Argument	Function	Description
ENCMOD	–	Encoder Mode	Change to encoder mode (not for MCDC). An external encoder serves as position detector (the current position value is set to 0).
ENCSPEED	–	Encoder As Speed Sensor	Speed via encoder signals in encoder mode (not for MCDC).
HALLSPEED	–	Hall Sensor As Speed Sensor	Speed via Hall sensors in encoder mode (not for MCDC).
ENCRES	8…65 535	Load Encoder Resolution	Load resolution of external encoder [4 times pulse/rev].

3.3.3.2 Additional settings

Ramp generator

The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the AC, DEC and SP commands.

See chap. 3.8.1, p. 43.

Velocity controller / current limitation

The controller parameters POR and I of the velocity controller can be adjusted. In addition, the current limitation values LPC and LCC can be used to protect the drive against overload.

See chap. 3.4, p. 21.

3.3.3.3 Motion control commands

Positioning in the ENCMOD is executed in precisely the same way as in CONTMOD using the FAULHABER motion control commands (see chap. 7.4, p. 89).

Command	Argument	Function	Description
EN	–	Enable Drive	Activate drive.
DI	–	Disable Drive	Deactivate drive.
LA	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Load Absolute Position	Load new absolute target position.
LR	$-2{,}14 \cdot 10^9 \ldots 2{,}14 \cdot 10^9$	Load Relative Position	Load new relative target position, in relation to last started target position. The resulting absolute target position must lie between the values given as argument.
M	–	Initiate Motion	Activate position control and start positioning.
HO	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Define Home Position	▪ Without argument: Set actual position to 0. ▪ With argument: Set actual position to specified value.
NP	–	Notify Position	▪ Without argument: A “p” is returned when the target position is attained. ▪ With argument: A “p” is returned if the specified position is over-travelled.
NPOFF	–	Notify Position Off	Notify Position command that has not yet been triggered is deactivated again.

Example:

- Load target position: LA40000
- Start positioning: M

Attainment of the target position or any intermediate position is indicated by a "p" on the serial interface if "Notify Position" is set before the start of positioning, provided that ANSW1 or ANSW2 is set.

Actual value resolution
In ENCMOD the resolution of the position values depends on the resolution of the encoder.

Complex motion profiles
More complex motion profiles can be generated through appropriate presetting of new values (maximum speed, acceleration, end position) during positioning. After a value change, simply execute a new motion start command (M). The commands NP and NV can be used to control the sequence.

Further information on compiling motion profiles is given in chap. 3.8.1, p. 43.

Positioning beyond the range limits
In the case of APL0 relative positioning can also be executed beyond the range limits. If the upper (1 800 000 000) or lower limit (–1 800 000 000) is exceeded, counting is continued at 0 without loss of increments.

Digital signal target position
The entry into the target corridor can be displayed via the fault output as a digital output signal in the POSOUT function. The signal is not reset until a further Motion start command (M).

Further information on configuration is given in chap. 3.7, p. 40.

3.4 Velocity control

In velocity control mode the velocity of the drive is controlled by a PI controller. Provided the drive is not overloaded, the drive follows the presetting without deviation.

The current velocity of BL motors can be detected both from the Hall signals and via an additional encoder. An incremental encoder is always required for DC motors. One exception is IxR control (see chap. 3.6.6, p. 39).

The velocity can be preset via the serial interface or from sequence programs, via an analogue voltage preset or a PWM signal.

3.4.1 Velocity presetting via the serial interface (SOR0)

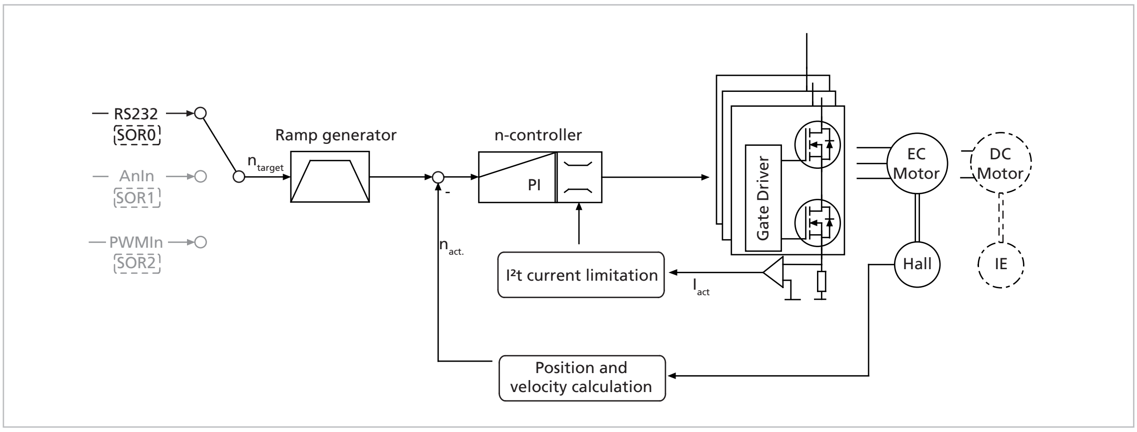


Fig. 4: Controller structure for velocity control

In this operating mode the drive can be operated by velocity controlled with set-point presetting via RS232 or from a sequence program.

3.4.1.1 Basic settings

Operating mode `CONTMOD` and `SOR0`.

The controller parameters `POR` and `I` and the sampling rate can be adjusted for the velocity controller.

Command	Argument	Function	Description
`POR`	1…255	Load Velocity Proportional Term	Load velocity controller amplification.
`I`	1…255	Load Velocity Integral Term	Load velocity controller integral term.
`SR`	1…20	Load Sampling Rate	Load sampling rate of the velocity controller as a multiple of the basic controller sampling rate according to the data sheet.

3.4.1.2 Velocity input

In BL motors the current velocity is determined in `CONTMOD` by evaluating the Hall sensor signals, which supply 3 000 pulses per revolution. In DC motors the velocity is determined using an incremental encoder whose resolution has to be set using the `ENCRES` command. DC motors without an incremental encoder can also be operated with limited accuracy in IxR mode (see chap. 3.6.6, p. 39).

Command	Argument	Function	Description
`ENCRES`	8…65 535	Load Encoder Resolution	Load resolution of external encoder [4 times pulse/rev].

3.4.1.3 Additional settings

Movement limits
With `APL1` the movement range limits set by `LL` are active in velocity controlled mode too.

Ramp generator
The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the `AC`, `DEC` and `SP` commands.

See chap. 3.8.1, p. 43.

Current limitation
The current limitation values `LPC` and `LCC` can be used to protect the drive against overload.

See chap. 3.8.3, p. 47.

3.4.1.4 Motion control commands

An overview of all motion control commands is given in chap. 7.4, p. 89.

Command	Argument	Function	Description
`EN`	–	Enable Drive	Activate drive.
`DI`	–	Disable Drive	Deactivate drive.
`V`	–30 000…30 000	Select Velocity Mode	Activate velocity mode and set specified value as target velocity (velocity control) [min^{-1}].

Example:

- Drive motor at 100 min^{-1}: `V100`

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

- Stop motor: `V0`

If the drive shall not stop at the set range limits (`LL`), `APL0` must be set.

Make sure that maximum speed `SP` is not set below the desired target velocity.

3.4.1.5 Complex motion profiles

Reaching the given speed is indicated by a “v“, if “Notify Velocity“ has been set before starting the speed mode and ANSW1 or ANSW2 is set:

Command	Argument	Function	Description
NV	–30 000…30 000	Notify Velocity	A “v” is returned when the nominal speed is reached or passed through.
NVOFF	–	Notify Velocity Off	Velocity command that has not yet been triggered is deactivated again.

3.4.2 Velocity presetting via an analogue voltage or a PWM signal (SOR1/SOR2)

In this operating mode, the drive velocity can be controlled with set value presetting via an analogue voltage (SOR1) or a PWM signal (SOR2).

3.4.2.1 Basic settings

Operating mode CONTMOD and SOR1 (AnIn) or SOR2 (PWMIn).

The controller parameters POR, I and the sampling rate can be adjusted for the velocity controller. In addition, commands are available for configuring the analogue velocity presetting.

Command	Argument	Function	Description
SP	0…30 000	Load Maximum Speed	Load maximum speed. Setting applies to all modes [min^{-1}].
MV	0…30 000	Minimum Velocity	Presetting of minimum velocity for specification via analogue voltage (SOR1, SOR2) [min^{-1}].
MAV	0…10 000	Minimum Analog Voltage	Presetting of minimum start voltage for presetting speed via analogue voltage (SOR1, SOR2) [mV].
ADL	–	Analog Direction Left	Positive voltages at the analogue input result in anticlockwise rotation of the rotor (SOR1, SOR2).
ADR	–	Analog Direction Right	Positive voltages at the analogue input result in clockwise rotation of the rotor (SOR1, SOR2).
DIRIN	–	Direction Input	Fault pin as rotational direction input.
POR	1…255	Load Velocity Proportional Term	Load velocity controller amplification.
I	1…255	Load Velocity Integral Term	Load velocity controller integral term.
SR	1…20	Load Sampling Rate	Load sampling rate of the velocity controller as a multiple of the basic controller sampling rate according to the data sheet.

3.4.2.2 Velocity input

By default, in BL motors the current speed is determined by evaluating the Hall sensor signals. Additional incremental encoders cannot be connected to BL motors for analogue velocity presetting (SOR1) or PWMIn (SOR2).

In DC motors the velocity is solely determined using the incremental encoder. DC motors without an incremental encoder can also be operated with limited accuracy in IxR mode (see chap. 3.6.6, p. 39).

3.4.2.3 Target value input

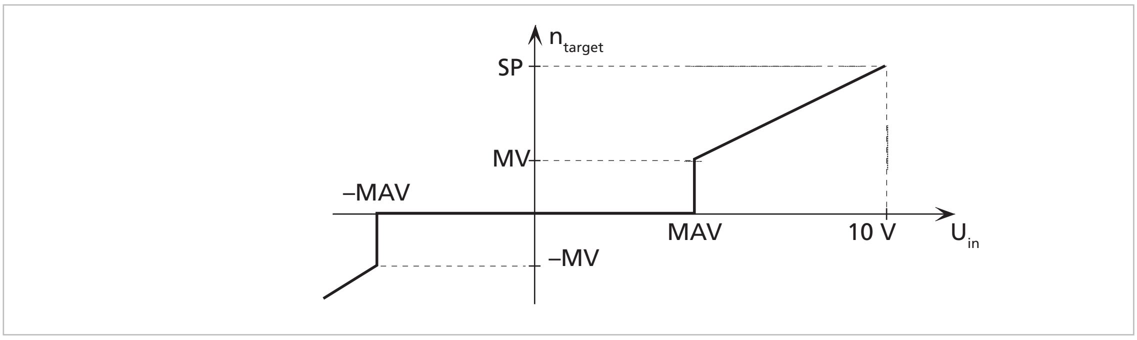


Fig. 5: Target value input

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

- `MAV100`

Advantage:

As 0 mV is usually difficult to set at the analogue input, 0 min^{-1} 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.

3.4.2.4 Additional settings

Movement limits
With `APL1` the movement range limits set by `LL` are active in velocity controlled mode too.

Ramp generator
The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the `AC`, `DEC` and `SP` commands.

See chap. 3.8.1, p. 43.

Current limitation
The current limitation values `LPC` and `LCC` can be used to protect the drive against overload.

See chap. 3.8.3, p. 47.

3.4.2.5 Set-point presetting via pulse width signal (PWM) at the analogue input (SOR2)

Tab. 3: Meaning of the pulse duty factor on delivery

Pulse duty factor	Meaning
> 50%	Clockwise rotation
= 50%	Stoppage n = 0
< 50%	Anti-clockwise rotation

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

If the drive shall not stop at the set range limits (`LL`), `APL0` must be set.

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

3.4.2.6 Input circuit

The input circuit at the analogue input is designed as a differential amplifier. If the analogue input is open, an undefined velocity can be set. The input must be connected to AGND with low-impedance or set to the voltage level of the AGND, in order to generate 0 min^{-1}.

For a circuit example, see Technical Manual.

3.4.3 External encoder as actual velocity value (ENCMOD) (not for MCDC)

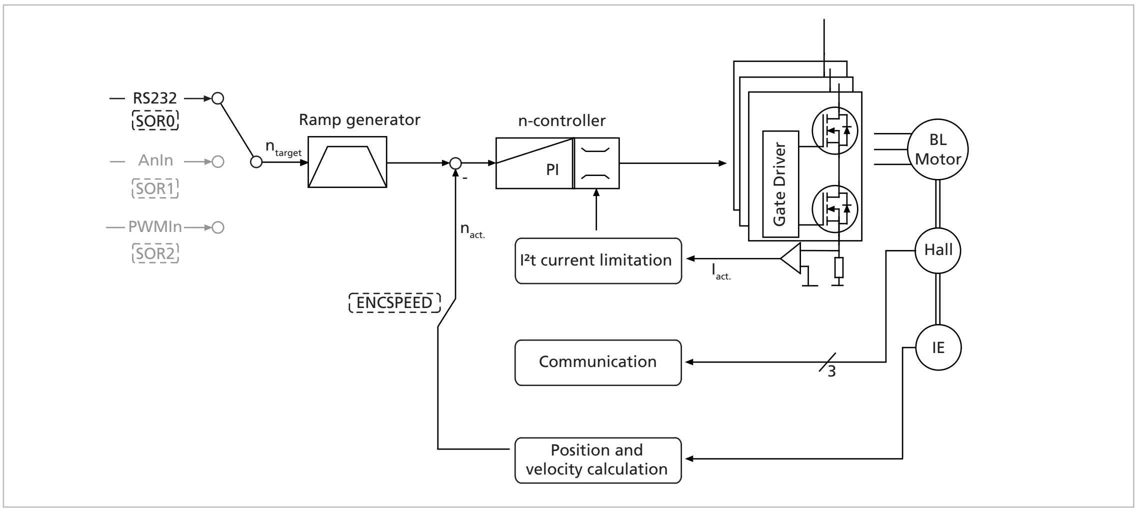


Fig. 6: Velocity control with external encoder as actual value

In this operating mode the drive can be operated by velocity controlled with set-point presetting via RS232 or from a sequence program. The velocity is evaluated via an additional encoder, external or built onto the motor. In particular, this enables a specific load speed to be controlled by an incremental encoder at the output.

ENCMOD mode is available for BL motors only. The analogue Hall sensors of the motors are also evaluated in ENCMOD mode for the motor commutation.

3.4.3.1 Basic settings

Operating mode ENCMOD and SOR0.

The controller parameters POR and I and the sampling rate can be adjusted for the velocity controller.

Command	Argument	Function	Description
POR	1…255	Load Velocity Proportional Term	Load velocity controller amplification.
I	1…255	Load Velocity Integral Term	Load velocity controller integral term.
SR	1…20	Load Sampling Rate	Load sampling rate of the velocity controller as a multiple of the basic controller sampling rate according to the data sheet.

3.4.3.2 Velocity input

The external incremental encoder's resolution must be specified with 4 edge evaluation using the ENCRES parameter.

In addition to ENCMOD mode, velocity evaluation on the basis of the encoder must be activated using the ENCSPEED command.

Command	Argument	Function	Description
ENCMOD	–	Encoder Mode	Change to encoder mode (not for MCDC). An external encoder serves as position detector (the current position value is set to 0).
ENCSPEED	–	Encoder As Speed Sensor	Speed via encoder signals in encoder mode (not for MCDC).
HALLSPEED	–	Hall Sensor As Speed Sensor	Speed via Hall sensors in encoder mode (not for MCDC).
ENCRES	8…65 535	Load Encoder Resolution	Load resolution of external encoder [4 times pulse/rev].

3.4.3.3 Additional settings

Movement limits
With APL1 the movement range limits set by LL are active in velocity controlled mode too.

Ramp generator
The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the AC, DEC and SP commands.

See chap. 3.8.1, p. 43.

Current limitation
The current limitation values LPC and LCC can be used to protect the drive against overload.

See chap. 3.8.3, p. 47.

3.4.3.4 Motion control commands

An overview of all motion control commands is given in chap. 7.4, p. 89.

Command	Argument	Function	Description
EN	–	Enable Drive	Activate drive.
DI	–	Disable Drive	Deactivate drive.
V	–30 000…30 000	Select Velocity Mode	Activate velocity mode and set specified value as target velocity (velocity control) [min^{-1}].

Example:

- Drive motor at 100 min^{-1}: V100

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

If the drive shall not stop at the set range limits (LL), APL0 must be set.

Make sure that maximum speed SP is not set below the desired target velocity.

3.4.3.5 Complex motion profiles

Reaching the given speed is indicated by a "v", if "Notify Velocity" has been set before starting the speed mode and ANSW1 or ANSW2 is set:

Command	Argument	Function	Description
NV	–30 000…30 000	Notify Velocity	A "v" is returned when the nominal speed is reached or passed through.
NVOFF	–	Notify Velocity Off	Velocity command that has not yet been triggered is deactivated again.

3.5 Homing and limit switches

Homing on limit switches can be used to re-initialise the absolute position of an application after switching on.

After switching on, or by giving the GOHOSEQ command, previously defined homing is performed up to the set limit switch and then the actions defined for it are performed. The ramp generator settings for maximum acceleration and the movement limits are taken into account.

3.5.1 Limit switch connections and switching level

The following connections can be used as reference and limit switch inputs:

- AnIn
- Fault
- 3rd input
- 4th, 5th input (MCDC only)

In BL motors the zero crossing of the Hall sensor signals is also available as index pulse. The index pulse occurs once or twice per revolution depending on the motor type (two or four pole). The index pulse of an external encoder can also be connected to the fault pin, enabling the actual position to be exactly zeroed.

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 must be at least 500 µs to be reliably detected. The maximum reaction time to level changes at all inputs is 500 µs.

Digital input configuration

Command	Argument	Function	Description
SETPLC	–	Set PLC-Threshold	Digital inputs PLC-compatible (24 V level).
SETTTL	–	Set TTL-Threshold	Digital inputs TTL-compatible (5 V level).
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. The setting must be saved with SAVE.

NOTICE!

Damage to the electronics

The electronics can be damaged if a voltage is applied to the fault pin while it is not configured as input.

- Configure the fault pin as input first before applying external voltage.

3.5.2 Motion control commands

The function of the inputs and the homing behaviour are set using the FAULHABER commands described in chap. 3.5.3, p. 29. A previously configured homing is then started with the following FAULHABER commands.

An overview of all motion control commands is given in chap. 7.4, p. 89.

Command	Argument	Function	Description
GOHOSEQ	–	Go Homing Sequence	Execute FAULHABER homing sequence. A homing sequence is executed (if programmed) irrespective of the current mode..
POHOSEQ	0…1	Power-On Homing Sequence	Start homing automatically after power-on: ▪ 0: No homing after power-on ▪ 1: Power-On Homing Sequence is activated
FHIX	–	Find Hall Index	For BL 4-pol motors only (not for MCDC): Move BL 4-pole motor to Hall zero point (Hall index) and set action position value to 0. In the case of 4-pol motors, two Hall zero points, each opposite, are present within a revolution. The respective nearest index is approached.
GOHIX	–	Go Hall Index	For BL 2-pol motors only (not for MCDC): Move BL 2-pol motor to Hall zero point (Hall index) and set actual position value to 0.
GOIX	–	Go Encoder Index	Move to the encoder index at the Fault pin and set actual position value to 0.

If the drive is already located in the limit switch when GOHOSEQ is invoked, first of all it moves out of the switch, in the opposite direction to that specified for HOSP. The same applies to the Power On Homing Sequence (POHOSEQ).

Homing or index runs should start with an actual velocity close to 0 min^{-1}. If the actual velocity clearly differs from 0 min^{-1} when starting the homing or index run, it is not guaranteed that the set acceleration and deceleration ramp values are respected at the subsequent homing or index run.

3.5.3 Configuration of homing and limit switch inputs

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

Bit:	0	1	2	3	4	5	6	7
Input:	Analogue input	Fault-Pin	3rd input	4th input (only MCDC)	5th input (only MCDC)	–	–	–

- Set the bit at the position of the required input for each command and assign the resulting numeric value to the commands described below.

3.5.3.1 Polarity and limit switch function

Limit switches can respond to the rising or falling edge (or level).

In addition, the hard blocking function can be configured for the limit switches. The hard blocking function provides reliable protection against overshooting of the range limit switch. If the drive is located in an HB limit switch, then the direction of rotation set with HD will be blocked, i.e. the drive can only move further out of the limit switch.

The speed stays at 0 min^{-1}, if the target velocity is preset in the wrong direction.

Command	Argument	Function	Description
HP	Bitmask	Hard Polarity	Define valid edge and polarity of respective limit switches: ▪ 1: Rising edge and high level effective ▪ 0: Falling edge and low level effective
HB	Bitmask	Hard Blocking	Activate Hard Blocking function for relevant limit switch.
HD	Bitmask	Hard Direction	Presetting of direction of rotation that is blocked with HB of respective limit switch: ▪ 1: Clockwise direction blocked ▪ 0: Anticlockwise direction blocked

Example:

Setting of the Hard-Blocking function for Fault pin and 4th input:

- $2^1+2^3 = 2 + 8 = 10$: HB10

3.5.3.2 Definition of homing behaviour

In order to be able to execute a homing sequence with the command GOHOSEQ or as POHOSEQ, a homing sequence must be defined for a specific limit switch. Definition of the hard blocking behaviour is an additional option.

Command	Argument	Function	Description
SHA	Bitmask	Set Home Arming for Homing Sequence	Homing behaviour (GOHOSEQ): Set position value to 0 at edge of respective limit switch.
SHL	Bitmask	Set Hard Limit for Homing Sequence	Homing behaviour (GOHOSEQ): Stop motor at edge of respective limit switch.
SHN	Bitmask	Set Hard Notify for Homing Sequence	Homing behaviour (GOHOSEQ): Send a character to RS232 at edge of respective limit switch.

These settings must be saved with SAVE so that they are available immediately after switching on.

Example:

Homing with 3rd input as reference input (rising edge):

HP4 Low level or falling edge was evaluated at AnIn and at the fault pin.

The rising edge is evaluated at the 3rd input.

SHA4 Activate a homing sequence for 3rd input (all others are in bit mask = 0).

Action: Set Pos = 0 on reaching the limit switch.

SHL4 Activate a homing sequence for 3rd input (all others are in bit mask = 0).

Action: Stop motor

SHN4 Activate a homing sequence for 3rd input (all others are in bit mask = 0).

Action: Notify via RS232

3.5.3.3 Homing Speed

Command	Argument	Function	Description
HOSP	–30 000…30 000	Load Homing Speed	Load speed [min^{-1}] and direction of rotation for homing (GOHOSEQ, GOHIX, GOIX).

Example:

Homing with 100 min^{-1} and negative direction of rotation:

- HOSP-100

3.5.3.4 Direct programming via HA, HL and HN commands

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.

Command	Argument	Function	Description
HA	Bitmask	Home Arming	Set position value to 0 and delete relevant HA bit at edge of respective limit switch. Setting is not saved.
HL	Bitmask	Hard Limit	Stop motor and delete relevant HL bit at edge of respective limit switch. Setting is not saved.
HN	Bitmask	Hard Notify	Send a character to RS232 and delete relevant HN bit at edge of respective limit switch. Setting is not saved.

The settings are not saved with the SAVE command, therefore all configured limit switches are inactive again after power-on.

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 acceleration value when the edge occurs, i.e. it goes beyond the reference mark. The reference mark can be precisely approached with a subsequent positioning command (command `M`).

Advantage: No abrupt motion changes.

HN/SHN command

Hard Notify (`HN`) and Set Hard Notify (`SHN`) return values to the RS232 interface:

Connection	Return value
AnIn	h
Fault	f
3rd input	t
4th input (MCDC only)	w
5th input (MCDC only)	x

3.6 Enhanced operating modes

The CONTMOD command can be used to revert from an enhanced operating mode to normal mode.

3.6.1 Stepper motor mode

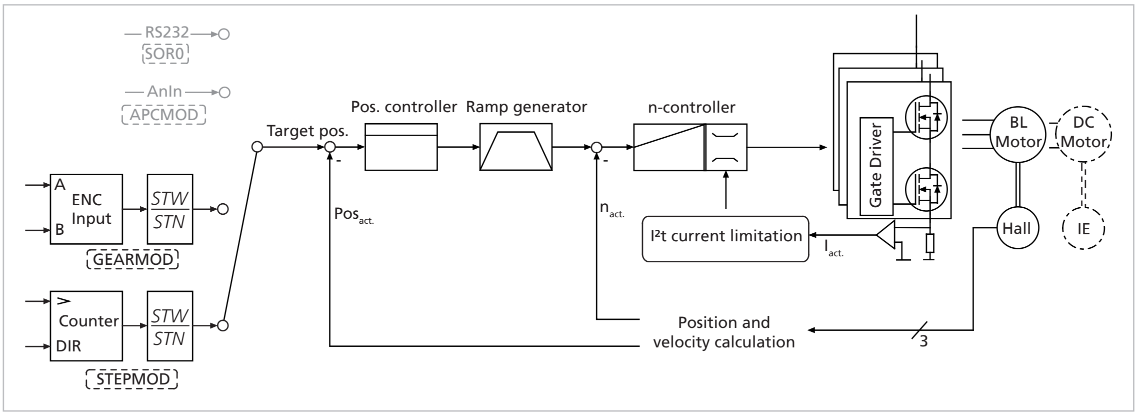


Fig. 7: Controller structure in stepper motor mode

In stepper motor mode the drive moves one programmable angle further for each pulse at the analogue 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 freely programmable and of a very high resolution (encoder resolution)
- The individual step widths are freely programmable
- No detent torque
- The full dynamics of the motor can be used
- The motor is very quiet
- The motor monitors actual position so that no steps are lost (even with maximum dynamics)
- No motor current flows in settled state (actual position reached)
- High efficiency

3.6.1.1 Basic settings

In stepper motor mode, the analogue input acts as frequency input. The error output must be configured as rotational direction input if the direction of rotation is to be changed via a digital signal.

Alternatively, the direction of rotation can also be preset via the commands ADL and ADR.

Command	Argument	Function	Description
STEPMOD	–	Stepper Motor Mode	Change to stepper motor mode.
DIRIN	–	Direction Input	Fault pin as rotational direction input.
ADL	–	Analog Direction Left	Positive voltages at the analogue input result in anti-clockwise rotation of the rotor (SOR1, SOR2).
ADR	–	Analog Direction Right	Positive voltages at the analogue input result in clock-wise rotation of the rotor (SOR1, SOR2).

3.6.1.2 Input

Maximum input frequency: 400 kHz

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

The number of steps of the emulated stepper motor can be set to virtually any required settings using the following formula:

$$\text{Revolutions} = \text{pulses} \cdot \frac{\mathtt{STW}}{\mathtt{STN}}$$

Revolutions: revolutions generated on the drive

Traversing distance: traversing distance of the linear motor in mm

Pulses: number of pulses at the frequency input (= number of steps)

Command	Argument	Function	Description
STW	1…65 535	Load Step Width	Load step width for step motor and gearing mode.
STN	1…65 535	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 signal:

- STW1
- STN1000

3.6.1.3 Additional settings

Movement limits

With APL1 the movement range limits set by LL are active in stepping mode too.

Ramp generator

The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the AC, DEC and SP commands.

Current limitation

The current limitation values LPC and LCC can be used to protect the drive against overload.

3.6.2 Gearing mode (electronic gear)

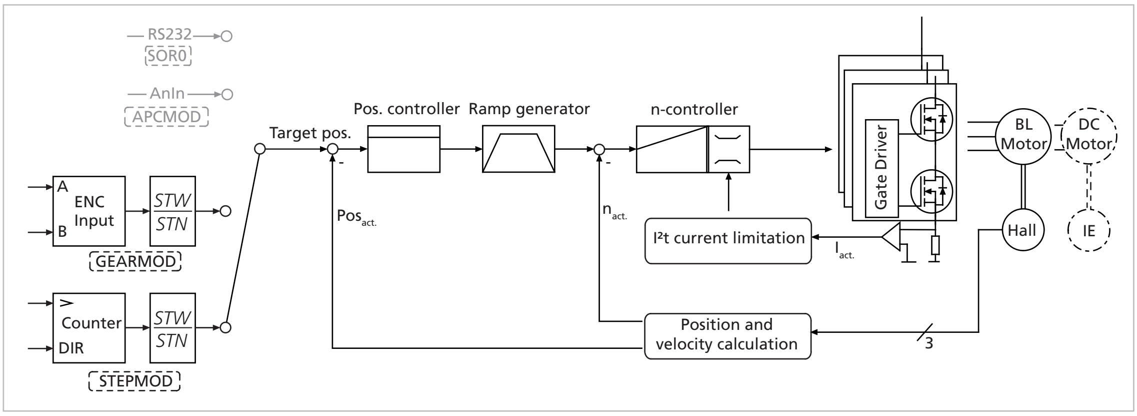


Fig. 8: Controller structure in gearing mode

Gearing mode enables the use of an external encoder as set-point source for the position. This enables several drives to be synchronised. If the direction of rotation is to be changed by a digital signal, the function of the fault pin must be reconfigured as a rotational direction input.

Alternatively, the direction of rotation can be preset via the commands ADL and ADR.

3.6.2.1 Basic settings

Command	Argument	Function	Description
GEARMOD	–	Gearing Mode	Change to gearing mode
DIRIN	–	Direction Input	Fault pin as rotational direction input.

3.6.2.2 Input

The two channels of an external encoder are connected to connections AnIn and AGND which may need to be connected to the 5 V encoder supply via a 2,7 kΩ pull-up resistor.

The gear ratio between the count of the external encoder and the resulting movement of the motor can be set using the following formula:

$$\text{Revolutions} = \text{pulses} \cdot \frac{\mathtt{STW}}{\mathtt{STN}}$$

Revolutions: revolutions generated on the drive

Traversing distance: traversing distance of the linear motor in mm

Pulses: number of pulses at the frequency input (= number of steps)

Command	Argument	Function	Description
`STW`	1…65 535	Load Step Width	Load step width for step motor and gearing mode.
`STN`	1…65 535	Load Step Number	Load number of steps per revolution for step motor and gearing mode.

Example:
Motor has to move one revolution at 1 000 pulses of the external encoder:

- `STW1`
- `STN1000`

3.6.2.3 Additional settings

Movement limits
The range limits set with `LL` are also active in gearing mode with `APL1`.

Ramp generator
The slopes of the acceleration and deceleration ramps, and the maximum speed can be defined using the `AC`, `DEC` and `SP` commands.

See chap. 3.8.1, p. 43.

Current limitation
The current limitation values `LPC` and `LCC` can be used to protect the drive against overload.

See chap. 3.8.3, p. 47.

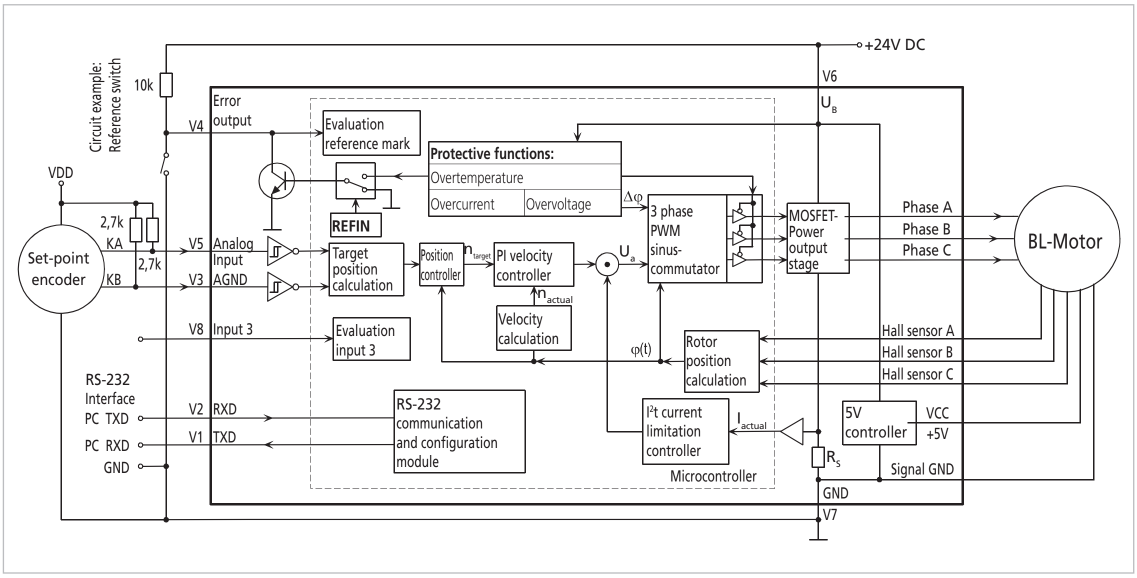


Fig. 9: Circuit example, gearing mode for MCBL 3003/06 S

3.6.3 Voltage regulator mode

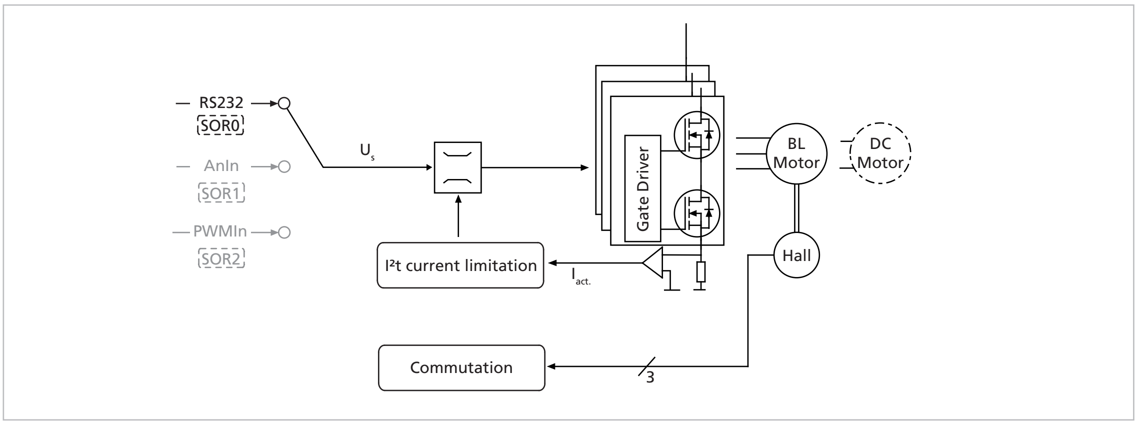


Fig. 10: Controller structure in voltage regulator mode

In voltage regulator mode a motor voltage is output proportional to the preset value. Current limitation remains active.

With this mode, it is possible to use a higher level controller. The controller then serves only as a power amplifier.

3.6.3.1 Basic settings

Command	Argument	Function	Description
VOLTMOD	–	Set Voltage Mode	Activate Voltage Regulator Mode.
U	–32 767…32 767	Set Output Voltage	Output motor voltage (corresponds to $–U_B…+U_B$) for SOR0 only in VOLTMOD.

3.6.3.2 Input

SOR0 (RS232)	SOR1 (AnIn)	SOR2 (PWMIn)	U_{MOT}
U-32767	–10 V	0 %	$-U_B$
U0	0 V	50 %	0
U32767	10 V	100 %	$+U_B$

3.6.3.3 Additional settings

The current limitation values `LPC` and `LCC` can be used to protect the drive against overload.

3.6.4 Current control with analogue current presetting - fixed direction of rotation (SOR3)

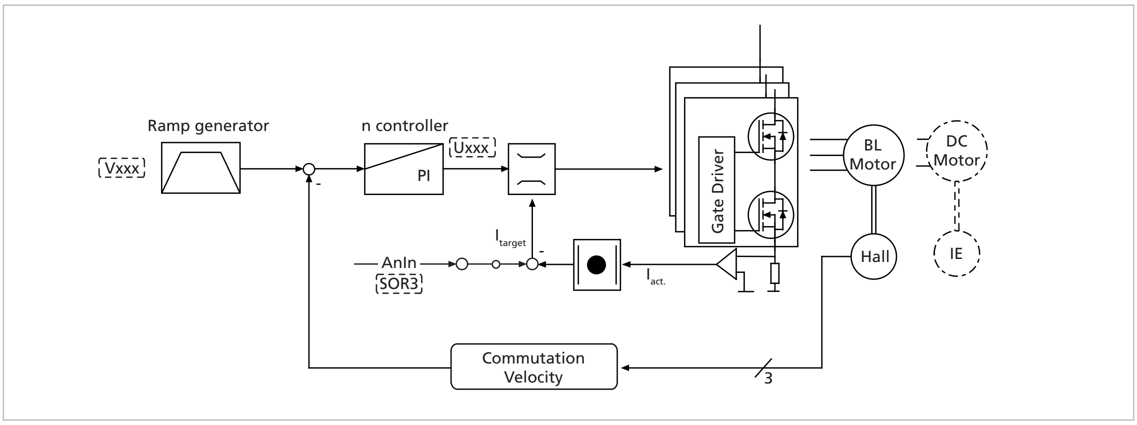


Fig. 11: Controller structure for analogue current presetting with fixed preset direction of rotation

You can switch to analogue target current presetting with the `SOR3` command. In this way, both in velocity mode and in voltage regulator mode, current amount can be limited proportional to the voltage at the analogue input. The set current is weighted with the maximum current LPC.

The motor is activated either in velocity mode by a previously fixed target velocity, or in voltage regulator mode via a voltage value. The error output must be configured as rotational direction input if the direction of rotation is to be changed via a digital signal.

3.6.4.1 Basic settings

Command	Argument	Function	Description
`SOR`	3	Source For Velocity	Current target value via analogue input.
`LPC`	0…12 000	Load Peak Current Limit	Load peak current [mA].

3.6.4.2 Input

If 10 V are present at the analogue input, the current is accordingly limited to the maximum current set with LPC.

Even if negative voltages are present at the analogue input, the current is limited to the amount of the applied voltage. Negative target current presettings therefore have no effect on the direction of rotation.

SOR3 (AnIn)	I_{max}	n_{max}
–10 V	LPC	SP
0 V	0	SP
10 V	LPC	SP

NOTICE!

Risk of destruction

In current control mode with analogue current presetting the internal I^2t current limitation is deactivated.

- Set a suitable maximum current.

3.6.5 Current control with analogue current presetting - direction of rotation depending on current target value (SOR4)

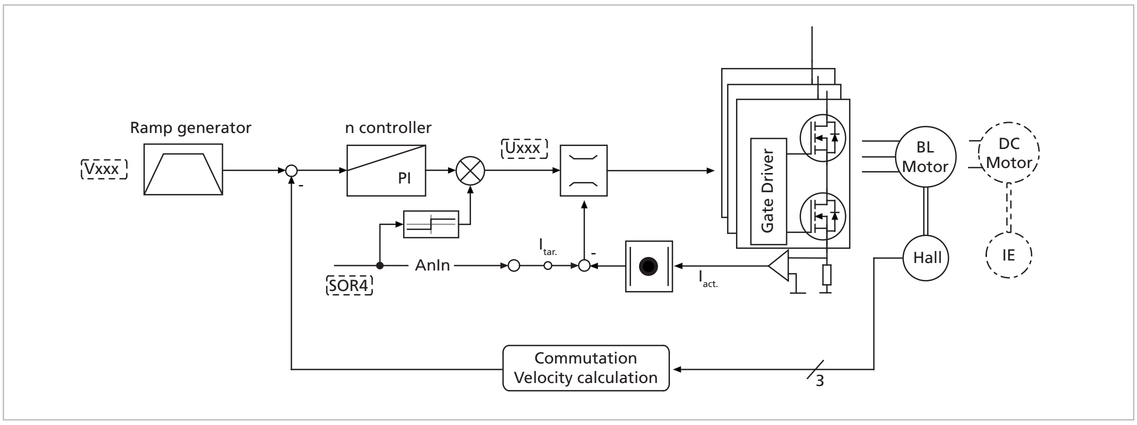


Fig. 12: Controller structure for analogue current presetting with direction of rotation depending on current target value

You can switch to analogue target current presetting with the SOR4 command. In this way, both in velocity mode and in voltage regulator mode, current amount can be limited proportional to the voltage at the analogue input. The set current is weighted with the maximum current LPC.

The motor is activated either in velocity mode by a previously fixed target velocity, or in voltage regulator mode via a voltage value. The direction of rotation is determined from the sign of the current target value.

This mode corresponds to direct current control.

3.6.5.1 Basic settings

Command	Argument	Function	Description
SOR	4	Source For Velocity	Target current value via analogue input with presetting of the direction of rotation via input polarity.
LPC	0…12 000	Load Peak Current Limit	Load peak current [mA].

3.6.5.2 Input

If 10 V are present at the analogue input, the current is accordingly limited to the maximum current set with LPC.

SOR4 (AnIn)	I_{max}	n_{max}
–10 V	LPC	–SP
0 V	0	SP
10 V	LPC	SP

NOTICE!

Risk of destruction

In current control mode with analogue current presetting the internal I^2t current limitation is deactivated.

- Set a suitable maximum current.

3.6.6 IxR control for MCDC

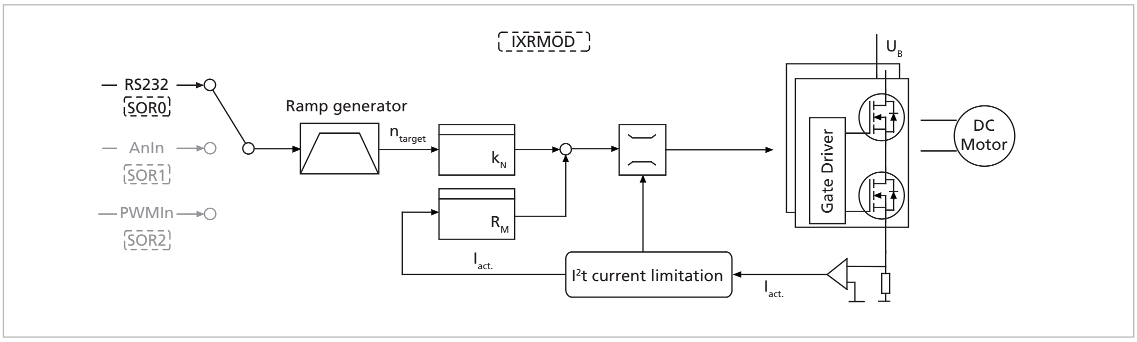


Fig. 13: Controller structure in IxR mode

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.

3.6.6.1 Basic settings

Command	Argument	Function	Description
IXRMOD	–	Set IxR Mode	Activate IxR control (MCDC only).
RM	10…320 000	Load Motor Resistance	Load motor resistance RM according to specification in data sheet [mΩ].
KN	0…16 383	Load Speed Constant	Load speed constant K_n in accordance with information in the data sheet [min^{-1}/V].

In stationary mode the following formula applies to the voltage at the DC motor:

$$U_M = R_M \cdot I_A + \frac{n}{k_N}$$

At constant terminal voltage U_M the speed falls under load.

Vice versa, if R_M and k_N are known, the voltage applied to the motor can be increased depending on the target velocity and the measured motor current so that the voltage drop is approximately compensated at the winding resistor.

3.6.6.2 Setting rules

Synchronisation of the no-load speed via k_N

Synchronisation of the velocity under load via R_M

- Velocity increases under load: R_M is set too high
- Velocity drops too far under load: R_M is set too low

3.7 Special fault output functions

The error connection (fault pin) can be configured as input or output for different tasks:

Command	Argument	Function	Description
ERROUT	–	Error Output	Fault pin as error output.
ENCOUT	–	Encoder Output	Fault pin as pulse output (not for MCDC).
DIGOUT	–	Digital Output	Fault pin as digital output. The output is set to low level.
DIRIN	–	Direction Input	Fault pin as rotational direction input. ▪ Velocity control (see chap. 3.4, p. 21) ▪ Stepper motor mode (see chap. 3.6.1, p. 32) ▪ Gearing mode (see chap. 3.6.2, p. 34) ▪ Voltage regulator mode (see chap. 3.6.3, p. 36) ▪ Current control with analogue current presetting (see chap. 3.6.4, p. 37 and chap. 3.6.5, p. 38)
REFIN	–	Reference Input	Fault pin as reference or limit switch input. ▪ Homing and limit switches (see chap. 3.5, p. 27)
POSOUT	–	Position Output	Fault pin as digital output for display of the condition: “target position reached”.

3.7.1 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

3.7.2 Additional settings

Delayed signalling
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	Argument	Function	Description
DCE	0…65 535	Delayed Current Error	Delayed error output for ERROUT [1/100 s].

Example:
Wait 2 seconds before displaying error:

- DCE200

Error notification via RS232
If one of the above errors occurs, automatic notification with an “r” can be implemented by setting “Notify Error”, provided ANSW1 or ANSW2 is set:

Command	Argument	Function	Description
NE	0…1	Notify Error	Notification in the event of errors: ▪ 1: An “r” is returned if an error occurs ▪ 0: No error notification

3.7.3 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.

- In 2 pole motors the value is limited to max. 4 000 pulses per second.
- In 4 pole motors the value is limited to max. 2 000 pulses per second.
- In MCBL 300x RS AES the LPN value is limited to 32.

Command	Argument	Function	Description
LPN	1…255 1…32 for MCBL AES	Load Pulse Number	Preset pulse number for ENCOUT.

Example:
Output 16 pulses per revolution at the fault pin:

- `LPN16`

In the case of 5000 min^{-1}, 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 do not necessarily sync with the rotor position (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.

3.7.4 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 cleared via the following commands:

Command	Argument	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.

3.8 Technical information

3.8.1 Ramp generator

In all modes, apart from voltage regulator mode and current control, the set-point is controlled by the ramp generator.

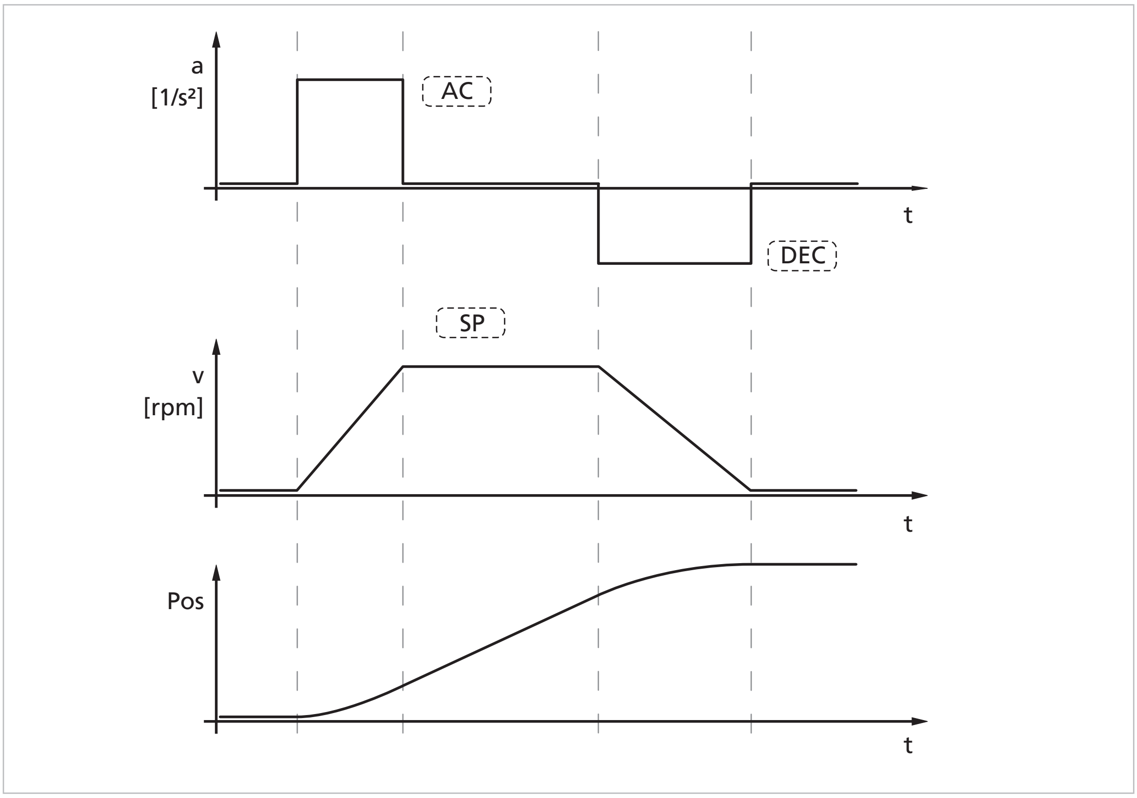


Fig. 14: Basic ramp generator function

This can be used to separately set the parameters for maximum acceleration (AC), maximum delay (DEC) and maximum speed (SP) for specific applications.

3.8.1.1 Basic settings

Command	Argument	Function	Description
AC	0…30 000	Load Command Acceleration	Load acceleration value [1/s^2].
DEC	0…30 000	Load Command Deceleration	Load deceleration value [1/s^2].
SP	0…30 000	Load Maximum Speed	Load maximum speed. Setting applies to all modes [min^{-1}].

3.8.1.2 Ramp generator in velocity mode

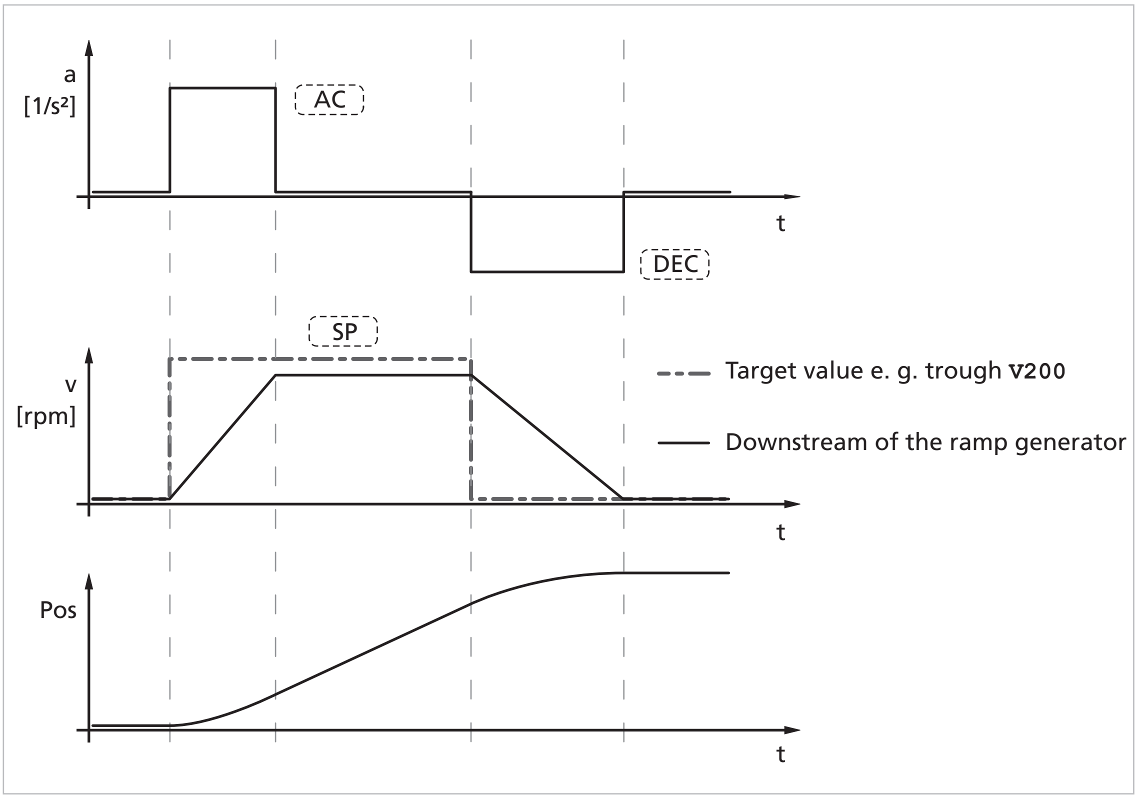


Fig. 15: Intervention of the ramp generator in velocity mode

In velocity mode the ramp generator acts like a filter on the target velocity. The target value is limited to the maximum speed value (`SP`) and target value changes are limited according to the deceleration and acceleration ramps (`AC` and `DEC`).

Notification of the higher level control

Reaching the given speed is indicated by a "v", if "Notify Velocity" has been set before starting the speed mode and `ANSW1` or `ANSW2` is set.

3.8.1.3 Ramp generator in positioning mode

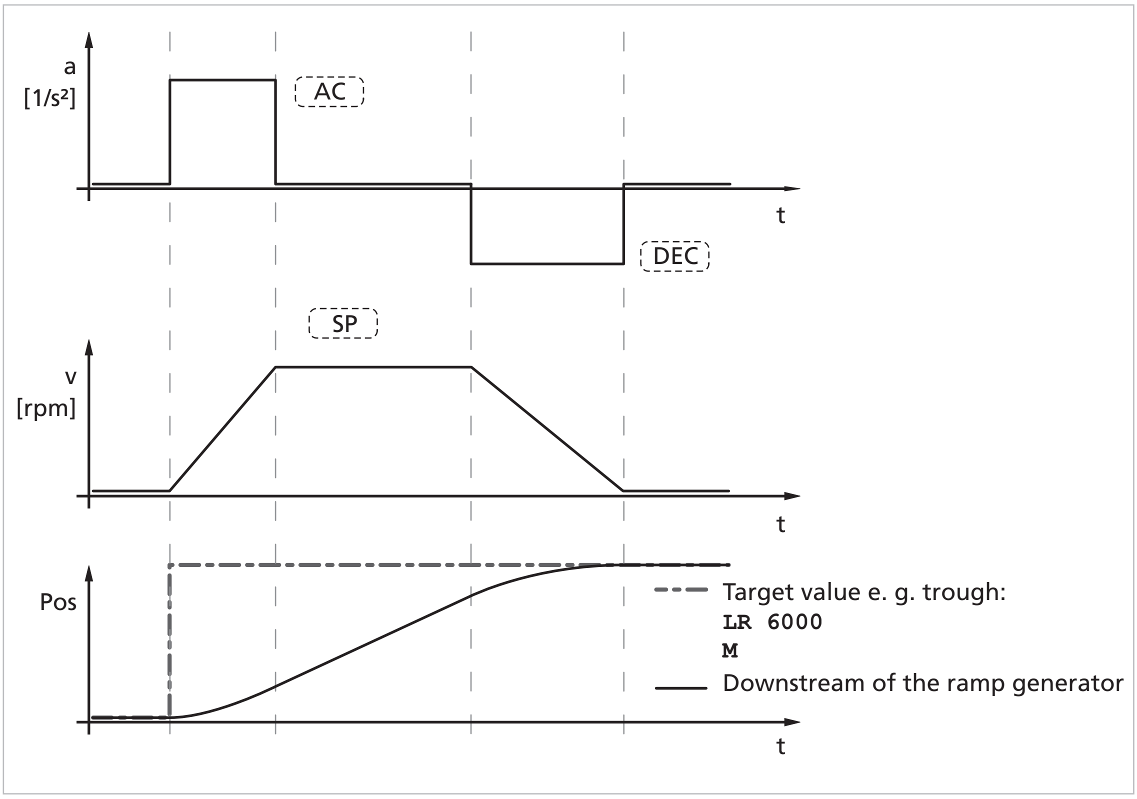


Fig. 16: Intervention of the ramp generator in positioning mode

In positioning mode a preset speed is determined by the position controller from the difference between the target position and actual position.

In the ramp generator, the preset speed output by the position controller is limited to the maximum speed value (SP) and accelerations are limited according to the acceleration ramp (AC).

In positioning mode the deceleration process is not extended as, before reaching the limit position, the speed has to be reduced so that the target position can be reached without overshooting.

According to the equation of motion:

$$2a \cdot s = v^2 \rightarrow v_{max} = \sqrt{2a \cdot s}$$

a: acceleration [m/s²]

v: velocity [m/s]

s: remaining distance [m]

the maximum speed v_{max} must be limited proportional to the remaining distance.

The allowable deceleration ramp, or rather the technically possible ramp depending on the motor and the inertia of the load, is set here using the parameter DEC.

Notification of the higher level control

Attainment of the target position or any intermediate position is indicated by a “p” on the serial interface if “Notify Position” is set before the start of positioning, provided that ANSW1 or ANSW2 is set.

3.8.1.4 Complex motion profiles

More complex motion profiles can be generated through appropriate presetting of new values (maximum speed, acceleration, end position) during positioning.

After a value change, simply execute a new motion start command (`M`). The commands `NP` and `NV` can be used to control the sequence.

The complex profile can be generated either by a higher level control or autonomously via a sequence program. Notes on design of the sequence programs are given in chap. 6, p. 72.

Command	Argument	Function	Description
`NP`	–	Notify Position	▪ Without argument: A "p" is returned when the target position is attained. ▪ With argument: A "p" is returned if the specified position is over-travelled.
`NPOFF`	–	Notify Position Off	Notify Position command that has not yet been triggered is deactivated again.
`NV`	–30 000…30 000	Notify Velocity	A "v" is returned when the nominal speed is reached or passed through.
`NVOFF`	–	Notify Velocity Off	Velocity command that has not yet been triggered is deactivated again.

Example:
Complex speed profile with notify by the drive:

Start	Update a)	Update b)	Update c)	Update d)
LA[POS3]	AC[AC2]	AC[AC1]	SP[SP2]	DEC[DEC4]
AC[AC1]	NV[V2]	NP[POS1]	DEC[DEC3]	NP[POS3]
SP[SP1]	M	M	NP[POS2]	M
NV[NV1]			M	
M				

Drive response:

V = V1	V = V2	POS = POS1	POS = POS2	POS = POS3
v	v	p	p	p

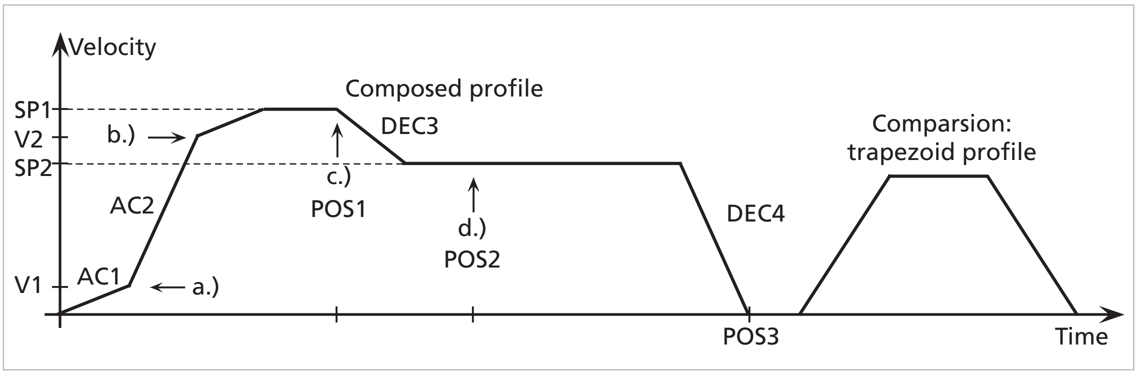


Fig. 17: Example of complex motion profile in comparison with trapezoidal profile

3.8.2 Sinus commutation

The outstanding feature of FAULHABER motion controllers for linear motors is their so-called sinus commutation. This means that the preset magnetic field is always ideally positioned relative to the cage bar. As a result, force fluctuations can be reduced to a minimum, even at very low speeds. In addition, the motor runs particularly quietly.

The sinus commutation is further enhanced by so-called flat-top modulation, which enables more modulation. As a result, higher no-load speeds are possible..

The `SIN0` command can even be used to set the system so that the sinus commutation switches to block commutation in the upper speed range. This full modulation enables the complete speed range of the motor to be utilised.

Command	Argument	Function	Description
`SIN`	0…1	Sinus Commutation	1: No block commutation within the upper velocity range (default) 0: Block commutation within the upper velocity range (full modulation) (not for MCDC)

3.8.3 Current controller and I^2t current limitation

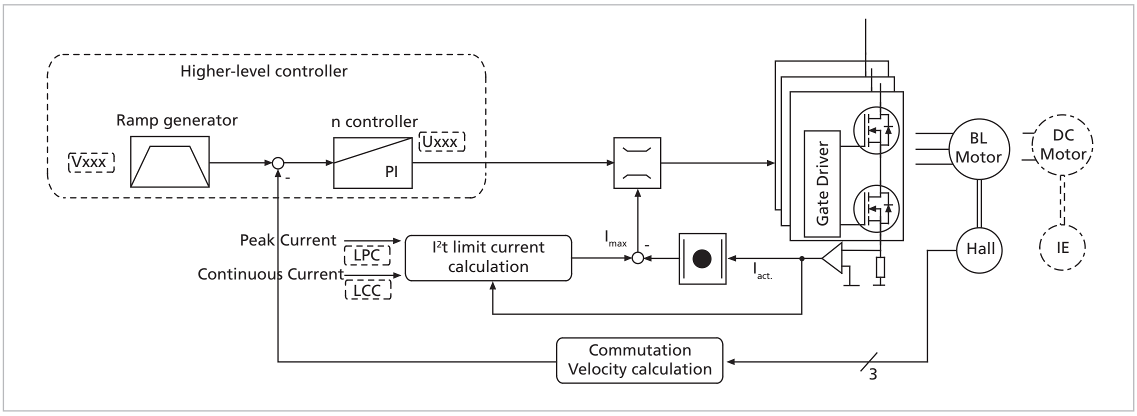


Fig. 18: Intervention of the current limiting controller

The FAULHABER Motion Controllers are equipped with an integral current controller, which enables torque limitation.

The current controller operates as a limitation controller. Depending on the previous loading, the I^2t current limitation limits to the allowable peak current or continuous current. As soon as the motor current exceeds the currently allowed maximum value the current controller limits the voltage.

Due to its design as a current limiting controller, current control in the thermally relaxed state has no effect on the dynamic of the velocity control. The time response of this limitation can be adjusted using the parameter `CI`.

The default values for `CI` limit the current to the allowable value after around 5 ms.

3.8.3.1 Basic settings

Command	Argument	Function	Description
LPC	0…12 000	Load Peak Current Limit	Load peak current [mA].
LCC	0…12 000	Load Continuous Current Limit	Load continuous current [mA].
CI	1…255	Load Current Integral Term	Load integral term for current controller.

3.8.3.2 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 limiting is not to heat the motor above the thermally allowable temperature by selecting a suitable continuous current. On the other hand, a high load should be temporarily possible in order to enable very dynamic movements.

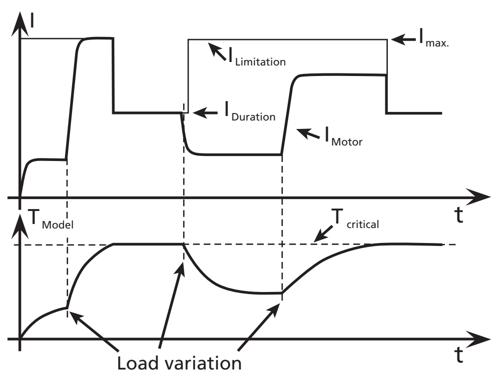


Fig. 19: Function of the I^2t current limitation

3.8.4 Overtemperature protection

If the MOSFET temperature of the external controllers or the coil temperature of the drives with integrated controller 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 min^{-1}
- Actual motor speed < 50 min^{-1}

When determining 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.

3.8.5 Under-voltage 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.

3.8.6 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. For this reason, the supply voltage at the motor increases, and depending on the speed, the allowable maximum voltage may be exceeded.

In order to avoid irreparable damage to components, FAULHABER motion controllers for brushless motors contain a controller which adjusts the displacement angle if a limit voltage (32 V) is exceeded. Motion controllers for DC motors contain 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.

3.8.7 Setting the controller parameters

The preset controller parameters must be optimised in order to optimally adjust the controller to the respective application.

The digital controller operates at a sampling rate according to the data sheet. If necessary the sampling rate can be increased to the given multiple of the basic controller sampling rate via `SR`.

Default behaviour

Without further settings, the gain set in the parameter `POR` is effective for the speed controller.

In positioning mode the gain set via the parameter `POR` is increased within the target corridor by the value of the parameter `PD`. This enables faster adjustment to the stoppage in the target position without having to over-stimulate the controller during the transient phenomena. To this end, the parameter `PD` must be set carefully and should typically be a maximum of 50% of the base value `POR`. Otherwise there is a risk of instability.

Available controller parameters

Command	Argument	Function	Description
POR	1…255	Load Velocity Proportional Term	Load velocity controller amplification.
I	1…255	Load Velocity Integral Term	Load velocity controller integral term.
PP	1…255	Load Position Proportional Term	Load position controller amplification.
PD	1…255	Load Position Differential Term	Load position controller D-term.
SR	1…20	Load Sampling Rate	Load sampling rate of the velocity controller as a multiple of the basic controller sampling rate according to the data sheet.

In the case of integrated units these values are already preset, however, they can be adjusted to the driving load using the Motion Manager's Motor Wizard. These values are suitably preassigned for external controls by selecting a motor type in the Motion Manager's Motor Wizard.

The **Controller tuning** tool can be used to further adjust several controller parameters, in order to optimally adjust the controller to the respective application.

Possible procedure

1. Perform the default settings of the Motor Wizard.

2. Optimise velocity controller:
   - Use the **Controller tuning** tool to make velocity jumps between 1/3 and 2/3 of the maximum velocity and at the same time increase the controller gain `POR` gradually, until the controller becomes unstable.
   - Reduce the controller gain again until reliable stability exists.

   Under certain circumstances it may be necessary to optimise the integral term I accordingly.

3. Optimise position controller:
   - Specify appropriate motion profiles for the application using the **Controller tuning** tool.
   - 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.
   - Increase the P term of the position controller gradually up to the system's stability limit.
   - Restore the stability either by increasing the D term of the position controller or by reducing the I term of the velocity controller.

3.8.8 Special mode for position control

The `SR` command can be used to activate a special position control mode. To this end, the value 100 must be added to the required `SR` setting.

Example:
Required setting SR10 with special mode:

- `SR110`

If this mode is activated, the parameter `POR` is successively reduced in a position-controlled application as soon as the drive is within the target corridor (can be set using the `CORRIDOR` command). This enables a much "gentler" stoppage to be achieved after reaching the target position. As soon as the drive is removed from the set target position, `POR` is immediately increased again to the set value.

The *Gain scheduling* function only becomes active at sampling rates with a factor larger than 3 (sampling rate > 3).

4 Protocol description

An extensive set of ASCII commands is available for configuring and operating FAULHABER Motion Controllers. The structure of the command telegrams is described in the following.

The drive can also be operated independently of the RS232 interface if the desired function, such as velocity or position controller, has been previously programmed via analogue input, stepper motor or electronic gear.

4.1 Command frame

Structure of the ASCII commands:

[Node number]	Command	[Argument]	CR

- The node number is optional and is only required if several drives are being operated on one interface.
- The command consists of a letter character string.
- The optional argument consists of an ASCII numeric value.
- The end is always a CR character (Carriage Return, ASCII decimal code 13). Space characters are ignored, and no distinction is made between upper and lower case.

4.2 Response frame

The response to query commands or asynchronous events is also an ASCII character string, followed by a CR character (Carriage Return, ASCII decimal code 13) and an LF character (Line Feed, ASCII decimal code 10).

Response	CR	LF

The response frames do not contain a node number.

In bus mode you must therefore ensure that the response of the contacted node is received before a new command is sent.

Example: Actual position query

- Transmit: `POS[CR]`
- Receive: `98956[CR][LF]`

Example: Drive nodes at 500 min^{-1}

- Transmit: `V500[CR]`

Response behaviour settings

As a default, the send commands are not acknowledged. However, the ANSW command can be used to change the response behaviour:

Command	Argument	Function	Description
ANSW	0…7	Answer Mode	0: No asynchronous responses 1: Allow asynchronous responses 2: All commands with confirmation and asynchronous responses 3: Debug mode, sent commands are returned (cannot be used if configuring with Motion Manager) 4…7: analogous to 0…3, but responses resulting from a command in the sequence program are not sent (cannot be set via Motion Manager)

Possible answers to a pure send command if ANSW2 is set:

- OK, when the command has been successfully executed
- Unknown command
- Invalid parameter
- Command not available
- Overtemperature – drive disabled

Example:

- Transmit: V500[CR]
- Receive: OK[CR][LF]

Possible answers to SAVE and EEPSAV commands:

- EEPROM writing done, after successful saving of the current settings in the data Flash memory
- Flash defect, if the save has failed

ℹ If data is sent simultaneously by several devices, communication disturbance (interference) occurs.

- Do **not** send unaddressed query commands in network mode (see chap. 4.3.2, p. 54), as otherwise all units will answer simultaneously and the message frames will mix.
- Make sure that asynchronous (sporadic) responses are **not** sent simultaneously by several devices.
- Switch off command acknowledgement if using unaddressed send commands.

Example: debug mode

- Activate debug mode: ANSW3
- Transmit: V100
- Receive: v,100: OK

4.3 Pre-conditions for communication

The units are delivered as standard without a valid node address (NODEADR0) and with a transfer rate of 9 600 baud. The settings can be changed via the interface, e.g. with the FAULHABER Motion Manager (see chap. 2.3, p. 10).

A change of the node number and Baud rate is acknowledged with the last setting for the node number and Baud rate.

4.3.1 Operation of an individual Motion Controller

1. Establish a connection with a host interface (typically a PC or PLC).
   - Connect the Tx data cable on the host side with the Rx pin of the drive
   - Connect the Rx data cable on the host side with the Tx pin of the drive (null modem cable)
2. Configure the host interface to match the drive settings (see chap. 4.4, p. 55):
   - The same Baud rate
   - 8 data bits, no parity, 1 stop bit, no flow control
3. Switch on the Motion Controller.

↳ Communication will be established. The drive will report a boot-up message at the last Baud rate setting.

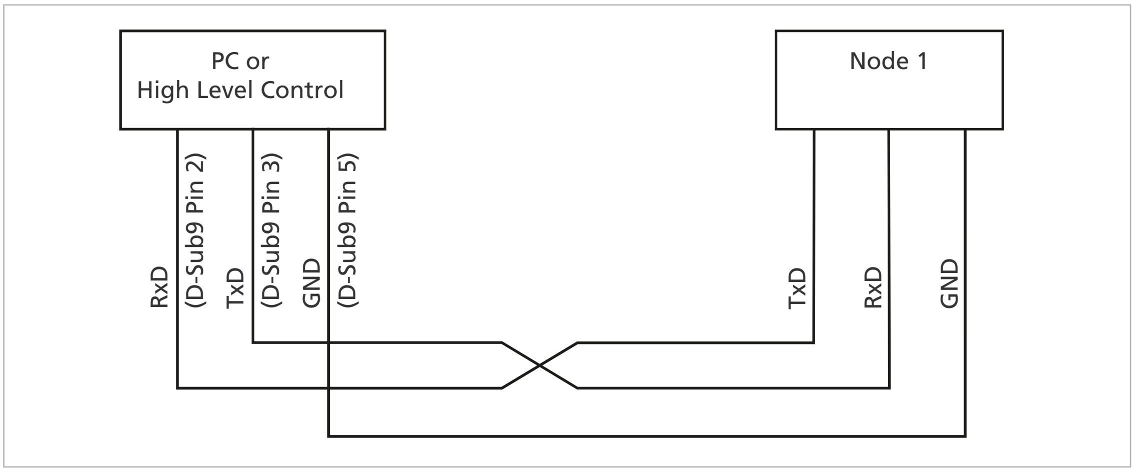


Fig. 20: Wiring between PC/controller and a drive

4.3.2 RS232 network operation

Multiple Motion Controllers can be operated on a single RS232 host interface.

- Connect the Tx cables and Rx cables to the controller in parallel.

When they are in network operation the drives may not send any asynchronous messages, because these can interfere with communications with another drive. Asynchronous responses can be deactivated via `ANSW0`.

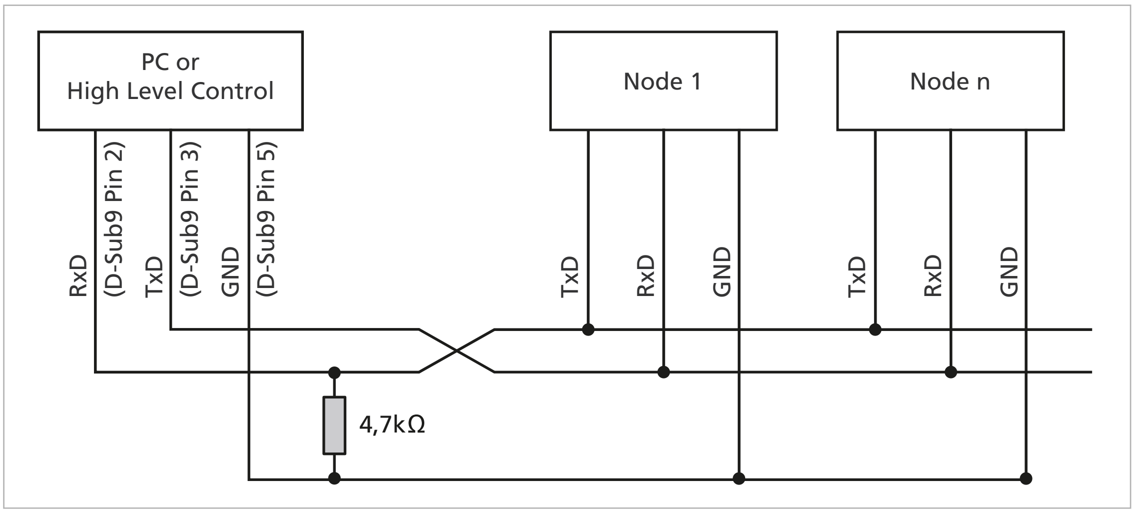


Fig. 21: Wiring with several Motion Control systems in RS232 network operation

4.4 Communication settings

Baud rate

The following RS232 transfer rates can be set:

Command	Argument	Function	Description
BAUD	600 Bit/s (not supported by Motion Manager) 1 200 bit/s 2 400 bit/s 4 800 bit/s 9 600 bit/s (default) 19 200 bit/s 38 400 bit/s 57 600 bit/s 115 200 bit/s	Select baud rate	Transfer rate for RS232 interface

The baud rate can be set via the interface using the BAUD command, if a connection already exists with the drive node.

Example: BAUD 19200

Serial network and node number

The node numbers 1 to 255 can be set.

To prepare the units for network operation, they must be individually connected to the PC and set to the required node address, e.g. with help of the FAULHABER Motion Manager. In order to address the individual drives in the network, the node number must be specified before each ASCII command to be sent.

Example: 3V100

Commands without a node number are adopted by all drive nodes in the network (Broadcast).

Command	Argument	Function	Description
NODEADR	0…255	Define Node Address	Set node number.
NET	0…1	Set Network Mode	Activate RS232 multiplex mode for network operation. 0: No network operation, single drive on an RS232 1: Network operation activated

Example: Set drive unit to node number 3

NODEADR3

Example: Activate network operation

NET1

4.5 Trace

An efficient trace function is available via an additional binary interface. This allows up to 2 values to be read out online in a resolution of up to 3 ms.

In order to be able to use the binary interface, it must first have been opened for the desired node with the `BINSEND1` command.

Command	Argument	Function	Description
`BINSEND`	0…1	Open Binary Interface	1: Open binary interface 0: Close binary interface

The FAULHABER Motion Manager provides a user-friendly means of setting and evaluating the trace functions.

4.5.1 Configuring Trace

- Set the binary transmit mode for parameter 1/2 (curve 1/2).

  2 binary characters are sent in direct success: [Command][Mode1/2]

  The relevant value is switched to, depending on the value of Mode1/2:

Command	Function
200	Set binary transmit mode for parameter 1
202	Set binary transmit mode for parameter 2

Mode1/2	Parameter	Type	Unit
0	Actual velocity	Integer16	min^{-1}
1	Target velocity	Integer16	min^{-1}
2	Controller output	Integer16	–
4	Motor current	Integer16	mA
44	Housing temperature	Unsigned16	°C
46	Coil temperature	Unsigned16	°C
200	Current position	Integer32	Inc
201	Target position	Integer32	Inc
255	Mode2 only: No second parameter is sent (basic setting for power-on)	–	–

4.5.2 Requesting data

Following a mode adjustment with the 200 or 202 command it is necessary to wait for at least 2 ms before requesting valid data.

- Request a data package with 201.
- Depending on the set mode 3, 5, 7 or 9 bytes are sent back to the PC:

Mode1	Mode2	Number of bytes	Received data	Type
0…15	255	3	1. Byte: Low byte data 2. Byte: High byte data 3. Byte: Time code	Integer16
16…199	255	3	1. Byte: Low byte data 2. Byte: High byte data 3. Byte: Time code	Unsigned16
200…255	255	5	1. Byte: Lowest byte data 2. Byte: Second byte data 3. Byte: Third byte data 4. Byte: Highest byte data 5. Byte: Time code	Integer32
0…15	0…15	5	1.Byte…2.Byte: Data bytes of Mode1 3.Byte…4.Byte: Data bytes of Mode2 5. Byte: Time code	Integer16 Integer16
0…15	16…199	5	1.Byte…2.Byte: Data bytes of Mode1 3.Byte…4.Byte: Data bytes of Mode2 5. Byte: Time code	Integer16 Unsigned16
0…15	200…255	7	1.Byte…2.Byte: Data bytes of Mode1 3.Byte…6.Byte: Data bytes of Mode2 7. Byte: Time code	Integer16 Integer32
16…199	0…15	5	1.Byte…2.Byte: Data bytes of Mode1 3.Byte…4.Byte: Data bytes of Mode2 5. Byte: Time code	Integer16 Integer16
16…199	16…199	5	1.Byte…2.Byte: Data bytes of Mode1 3.Byte…4.Byte: Data bytes of Mode2 5. Byte: Time code	Unsigned16 Unsigned16
16…199	200…255	7	1.Byte…2.Byte: Data bytes of Mode1 3.Byte…6.Byte: Data bytes of Mode2 7. Byte: Time code	Unsigned16 Integer32
200…255	0…15	7	1.Byte…4.Byte: Data bytes of Mode1 5.Byte…6.Byte: Data bytes of Mode2 7. Byte: Time code	Integer32 Integer16
200…255	16…199	7	1.Byte…4.Byte: Data bytes of Mode1 5.Byte…6.Byte: Data bytes of Mode2 7. Byte: Time code	Integer32 Unsigned16
200…255	200…255	9	1.Byte…4.Byte: Data bytes of Mode1 5.Byte…8.Byte: Data bytes of Mode2 9. Byte: Time code	Integer32 Integer32

The time code corresponds to a multiple of the time basis of 1 ms and defines the time interval to the last transmission.

5 Commissioning

The drive unit must be connected to a PC via the RS232 interface in order to make the basic settings for commissioning.

Connection of the RS232 interface is described in the technical manual. For the communication setup, the same transfer rate must be set for all nodes.

5.1 Basic settings

In the case of external motion controllers, several basic settings have to be made during the initial start-up to adjust the controller to the connected motor.

If drive units are integrated, these basic settings are made in the factory. It is only necessary to adjust to the respective application.

NOTICE!

Damage to components

- Perform the basic settings described in the following.

The following basic settings must be made for external motion controllers:

- Motor type or motor data (`KN`, `RM`) of the connected motor
- Resolution of an external encoder (`ENCRES`), if used
- Current limitation values (`LCC`, `LPC`), adjusted to the motor type and application
- Controller parameters (`POR`, `I`, `PP`, `PD`), adjusted to the motor type and application

In addition, FAULHABER Motion Manager can be used to synchronise the Hall sensor signals for smooth start-up and optimisation of the phase angle for the best efficiency.

The configuration must then be adjusted to the respective application for all motion controllers (integrated and external). In particular, the following basic settings are important:

- Operating mode
- Current limiting values
- Controller parameters
- Function of the digital inputs/outputs

NOTICE!

Damage to components

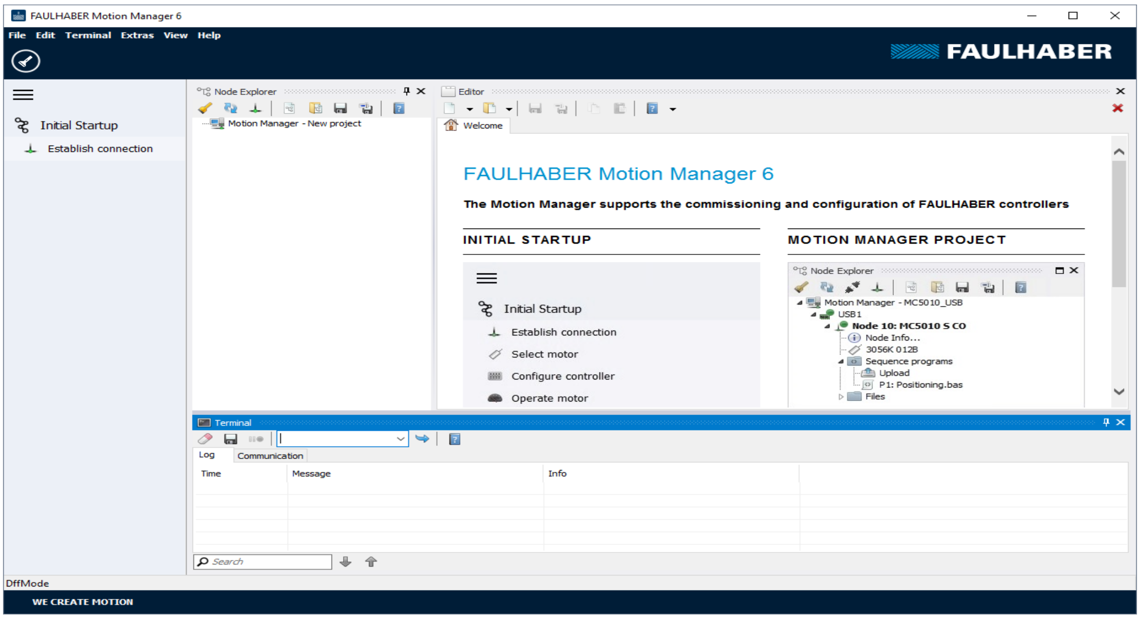
- If using the Fault Pin as input (`REFIN`, `DIRIN`) program the desired function before applying external voltage.

Configuration of these parameters with the help of the FAULHABER Motion Manager is explained in greater detail in the following chapter.

5.2 Configuration using Motion Manager

FAULHABER Motion Manager PC software provides a simple option for configuring the drive unit and for performing initial tests and optimisation.

The software is available for Microsoft Windows and can be downloaded free of charge from the FAULHABER internet site: www.faulhaber.com.



Motion control systems with electronics built onto the motor are already pre-parameterised in the factory.

Motion controllers with an externally connected motor must be equipped with current limitation values suitable for the motor and suitable controller parameters before being started up.

The motor selection wizard is available for selecting the motor and the suitable basic parameters.

Other settings, e.g. for the function of the fault pin, can be made under the **Configuration – Drive Functions** menu item, where a convenient dialog is provided (see chap. 5.2.3, p. 63). The configuration dialog is also available for direct access in the quick access bar of the Motion Manager.

The tool **Controller tuning**, with which the controller parameters of the speed and positioning controller can be adjusted to the application, is also provided.

5.2.1 Establish connection

In order to communicate with the control in question, a connection with the control must be established by the PC on which the Motion Manager is installed. A wizard is available for setting up the communication connection via a one of the supported interfaces. The wizard appears automatically when a new project is created. It can be called up at any time by pressing the ***Establish connection*** button in the quick access toolbar or via the **Terminal** menu.

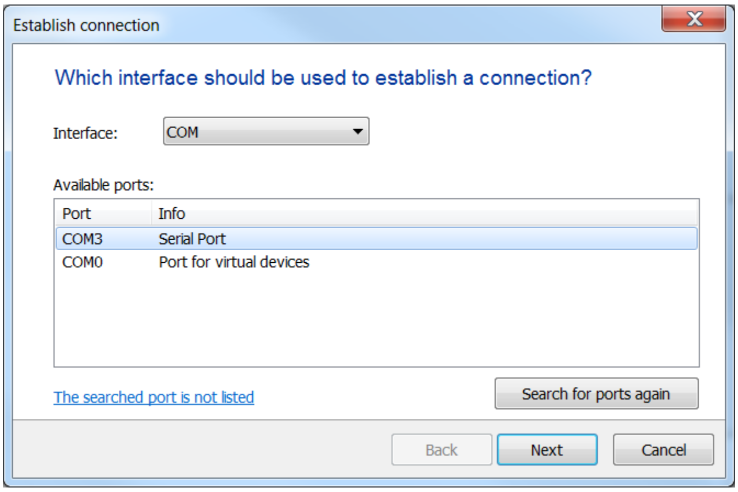
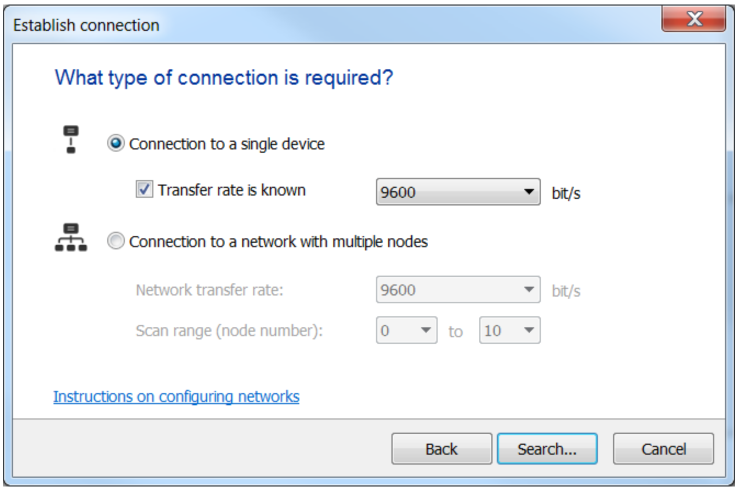


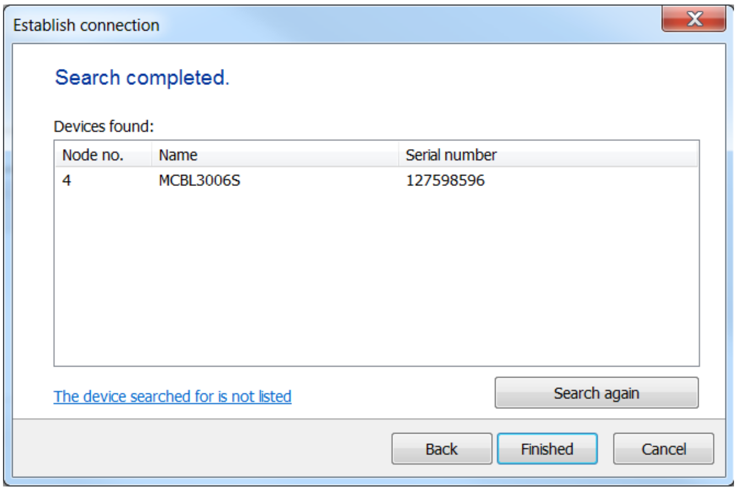
Fig. 22: Connection wizard

1. Select the COM interface.
2. Under **Available ports** select the desired interface connection.
3. Press ***Next*** button.

4. Select device family **Motion Controller V2.x**.
5. Press ***Next*** button.



6. Select the connection type and the transfer rate.
7. Press ***Search...*** button.
   - ↳ Motion Manager will find and display devices, which are set to a suitable transfer rate.



8. Press ***Finished*** button.

5.2.2 Selecting the motor

External motion controllers must be adjusted to the connected motor. The wizard for motor selection is provided for this purpose; it can be opened via the quick access toolbar of the Motion Manager or via **Configuration** under **Initial Startup - Select motor**.

After selecting the required FAULHABER motor from a list and setting the sensor type used, as well as entering an inertia factor for the load to be operated, in addition to the motor and current limiting values, suitable controller parameters are also determined and transferred to the drive.

Refer to the Motion Manager instruction manual for details of how to use the wizard for motor selection.

5.2.3 Configuring the drive

The Motor Wizard has already set sensible default settings for the motor/sensor combination selected.

A configuration dialog with several pages for further drive configuration and adjustment to the required application is available in the Motion Manager's quick access bar or under the menu item: **Configuration – Drive Functions…**.

No settings are transferred to the drive until the ***Send*** button is pressed. The current state of the drive is also read back and the dialog is updated accordingly. Invalid combinations of settings are corrected at the same time, as they are not accepted by the drive.

The settings are permanently saved in the drive using the ***EEPSAV*** button.

5.2.4 Making basic settings

Within the scope of the commissioning, the following parameters are set in the **Basic Settings** tab:

- Operating mode
- Type of set-point presetting
- Optimisation for Hall sensors
- Controller mode
- Power-on state
- Communication settings

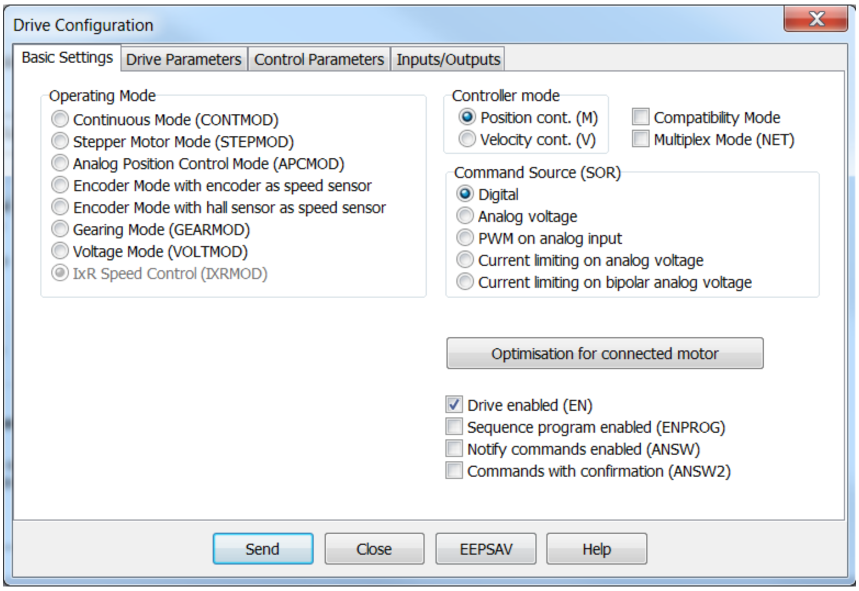


Fig. 23: Basic settings for the motor and encoder type

Optimisation for Hall sensors

A button, with which a wizard for optimisation to the connected motor can be started, is available for adjusting Hall sensor signals and phase angles to the connected motor for externally connected BL motors with analogue Hall sensors.

Ensure that the motor can freely rotate before starting the encoder optimisation.

Controller mode

FAULHABER Motion Controllers support the following main types of operation:

- Position control as servo drive
- Velocity control

The controller mode is partly automatically selected depending on the chosen operating mode.

Operating mode

In addition to the controller mode, variations of the operation can also be selected.

The following options are available:

Operating mode	Description
CONTMOD	Default setting for the selected controller mode. For BL motors the actual velocity and actual position in CONTMOD are determined by the motor's Hall sensors. For DC motors the actual velocity and actual position are determined by the motor's incremental encoder (corresponds to ENCMOD). ▪ CONTMOD for position control: See chap. 3.3.1, p. 14 ▪ CONTMOD for velocity control: See chap. 3.4.1, p. 21
STEPMOD	Position control. The target position is derived from the number of steps at the AnIn input (see chap. 3.6.1, p. 32).
APCMOD	Position control. The target position is preset by an analogue voltage at the AnIn input (see chap. 3.3.2, p. 16.
ENCMOD with ENCSPEED	Position control or velocity control with evaluation of the external encoder for the actual velocity too. ▪ ENCMOD for position control: see chap. 3.3.3, p. 18 ▪ ENCMOD for velocity control: see chap. 3.4.3, p. 25
ENCMOD with HALLSPEED	Position control with evaluation of an external encoder and the Hall signals for the actual speed of BL motors (see chap. 3.3.3, p. 18).
GEARMOD	Position control. The target position is determined using the number of steps of an external encoder (see chap. 3.6.2, p. 34.
VOLTMOD	Direct presetting of a voltage amplitude at the motor (see chap. 3.6.3, p. 36).
IxRMOD	Velocity control without sensors for DC motors (see chap. 3.6.6, p. 39).

Set-point presetting

The set-value presetting must be chosen in one of the following ways to match the selected type of operation and controller mode:

- Presetting via the serial interface or from a sequence program
- Set-point presetting for position or velocity via an analogue voltage
- Set-point presetting for position or velocity via a PWM voltage
- Set-point presetting for the limit current via an analogue voltage

Power-on state

- In the default state the drive's power stage is initially inactive after power-on.

  The power stage can be automatically activated after power-on by selecting the **Drive enabled (EN)** checkbox.

- In the default state, a sequence program is not worked through after the drive is switched on (power-on).

  A sequence program stored in the drive can be automatically started immediately after power-on by selecting the **Program sequence enabled (ENPROG)** checkbox.

Communication settings

- The **Multiplex-Modus (NET)** checkbox is used to activate the selected drive for network mode.
- The **Asynchronous Responses (ANSW)** checkbox can be used to suppress asynchronous responses of the selected drive. They are enabled in the default state.
- The **Commands with confirmation (ANSW2)** checkbox can be used to suppress the confirmation frames for the commands sent to the drive. They are activated in the default state.

5.2.5 Setting the drive parameters

The **Drive Parameters** tab is used to make additional settings for the encoder and chosen type of operation.

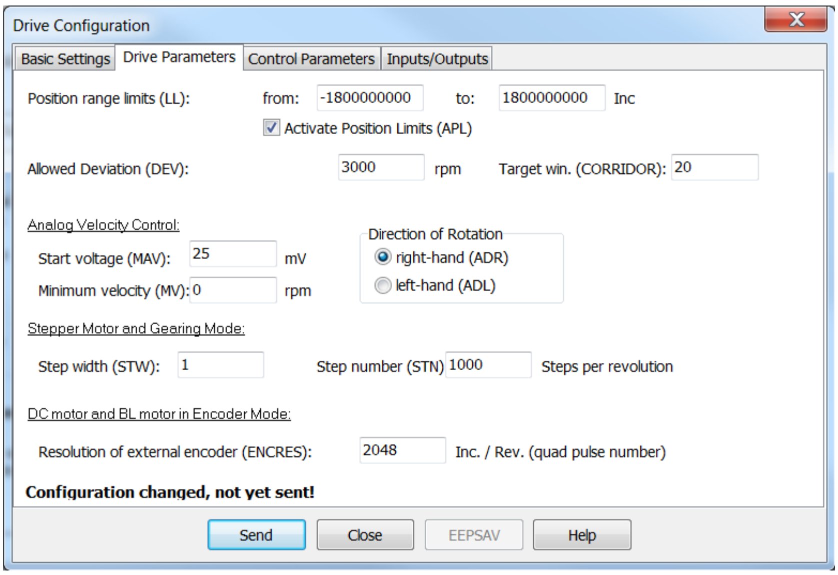


Fig. 24: Additional settings for the chosen type of operation

Encoder resolution

If an incremental encoder attached to the motor is to be evaluated its effective resolution for 4 edge evaluation must be given.

Set-point presetting in Stepper Mode or Gearing Mode

For set-point presetting in Stepper Mode and in Gearing Mode the conversion from step count of the external presetting to number of motor revolutions must be given.

Example:

Motor has to perform one revolution at 1 000 pulses of the external encoder or at 1 000 steps:

- STW1
- STN1000

Detailed notes on using these parameters are given in the chapters with the functional description of Stepper Mode and Gearing Mode (see chap. 3.6.1, p. 32 and chap. 3.6.2, p. 34).

Velocity presetting via an analogue voltage

For presetting a velocity via an analogue voltage, a threshold value (MAV) can be preset, from which the target value is evaluated starting with the minimum velocity (MV).

Detailed notes on using these parameters is given in chap. 3.4.2, p. 23.

Positioning range limits

In various types of operation the movement range can be monitored and limited. The limits of this movement rage can be given in increments of the actual position using the parameter LL.

Range monitoring is activated by the APL1 command.

Maximum allowable velocity deviation and target corridor

The parameter CORRIDOR defines a range by which the target position within which the „Target position reached“ flag is set. If required, the target position is signalled asynchronously by a *Notify*.

Within this corridor the D term of the position controller is active and the ramp generator is inactive.

The parameter DEV can be used to preset a maximum allowable controller deviation for the velocity controller. If this barrier is exceeded for longer than set using the parameter DCE in the **Inputs/Outputs** tab, an error is signalled via the fault pin or on the serial interface.

5.2.6 Setting the controller parameters

The changes to the default set controller and current limitation parameters can be made in the **Controller Parameters** tab of the drive configuration dialog.

In addition, under the **Configuration – Controller Parameters…** menu item, there is another dialogue in which the online parameters can be changed and the result can be observed directly or can be recorded using the trace function in Motion Manager.

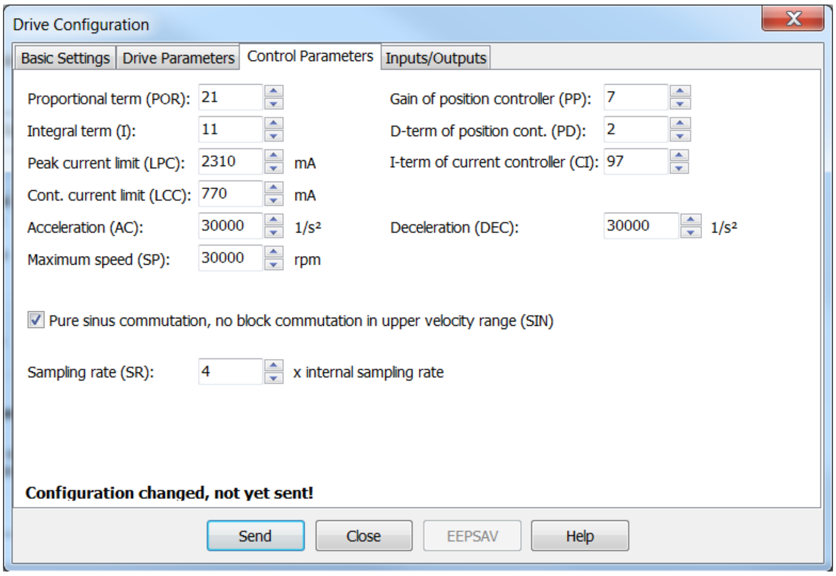


Fig. 25: Settings for the controller

Commutation settings for BL motors

By default the motion controller for BL motors uses pure sinus commutation. This means the motor runs with the lowest possible losses and noise.

Alternatively, at higher velocities it is possible to also allow overriding of the output signals similar to block commutation. This enables the complete speed range of the motor to be utilised.

On changing between pure sinus commutation and operation with block commutation in the upper velocity range the controller amplification also increases.

Current controller (`LCC`, `LPC`, `CI`)

The `LCC` parameter can be used to give the thermally allowable continuous current for the application.

Motors and the Motion Controller can be overloaded within certain limits. Therefore, higher currents can also be allowed for dynamic processes. The maximum peak current value is given via the `LPC` parameter.

Depending on the drive's load, the internal current monitoring limits the output current to the peak current (`LPC`) or the allowable continuous current (`LCC`).

NOTICE!

Destruction of the motor

- Do **not** set the thermally allowable continuous current (`LCC`) higher than the thermally allowable continuous current of the motor according to its data sheet.
- Do **not** set the peak current (`LPC`) higher than the maximum peak output current of the existing electronics.

The current controller of the Motion Controller operates as a current limiting controller and therefore in an unlimited case has no effect on the dynamics of the velocity control. The speed of the limiting can be set using the parameter CI. If using the default values for your motor, the current is limited to the allowable value after around 5 ms.

If a FAULHABER motor was selected via the Motor Wizard, parameters are already set with which the motor can be operated safely.

Further details are given in chap. 3.8.3, p. 47.

Velocity controller (`I`, `POR`, `SR`)

The velocity controller is designed as a PI controller. The following parameters can be set:

- Sampling rate `SR` as multiples of the basic sampling rate of the drive
- Proportional gain `POR`
- Integral component `I`

If a FAULHABER motor was selected via the Motor Wizard, parameters are already set with which the motor can be operated.

If the motor is exposed to additional loads, the inertia of the load must be compensated for by a higher proportional term and if necessary slower sampling. In most applications the integral term can remain unchanged.

Further notes see chap. 3.8.7, p. 49.

Ramp generator (`AC`, `DEC`, `SP`)

The ramp generator limits the velocity change at the input of the velocity controller via the `AC` and `DEC` parameters and the maximum default speed via the `SP` parameter.

The `AC` and `SP` parameters can be freely selected depending on the application. The `DEC` parameter is used to specify the deceleration behaviour in positioning mode. For large loads, the deceleration ramp must be limited using the Profile Deceleration parameter, in order to achieve dead beat (overshoot-free) run-in in the target position.

Further notes see chap. 3.8.1, p. 43.

Position controller (`PP`, `PD`)

The position controller is designed as a proportional controller. An additional D term also acts, but only within the target corridor (see **Drive Parameters** tab).

The proportional term uses the position deviation in increments to calculate the maximum default velocity for the secondary velocity controller. The ramp generator is used to additionally limit the acceleration and maximum velocity.

Dead beat run-in in the target position can be preferentially achieved by adjusting the deceleration ramp to the load. For a well-attenuated transient condition in the limit position, the parameter `PP` must be reduced proportionally to the load inertia.

Further notes see chap. 3.8.7, p. 49.

5.2.7 Setting inputs/outputs and use

The **Inputs/Outputs** tab of the drive configuration dialog can be used to specify the function of the digital inputs and outputs and to define the homing settings.

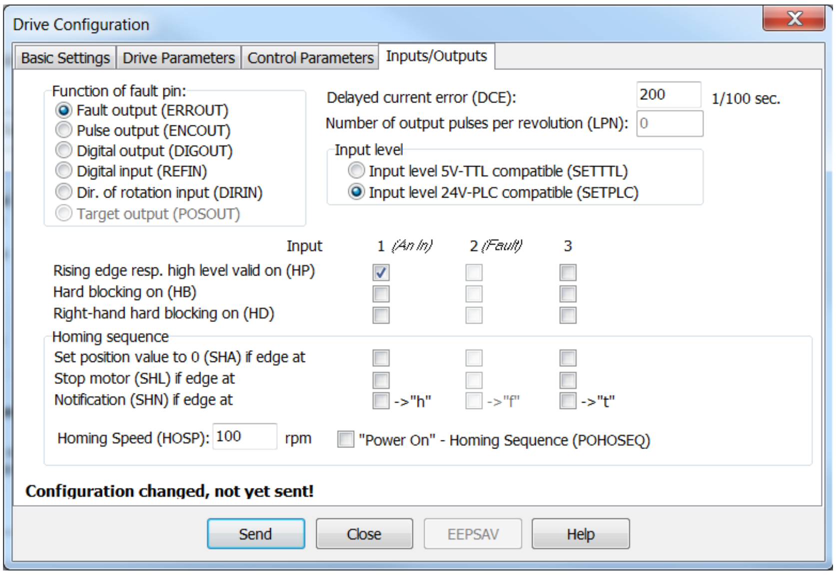


Fig. 26: Configuration of inputs/outputs

Input level and edge

The switching thresholds of the digital inputs are either directly 5 V TTL compatible or are adjusted to the switching level of 24 V PCS outputs.

In addition, it is also possible to select which level is to be used as the active level for each input and to what extent the input is to be used as a limit switch (HB / HD).

Function of the fault pin

The fault pin can be used both as an input and as an output.

NOTICE!

Destruction of the motor

- Do **not** connect 24 V to the fault pin, if the fault pin is configured as a digital output (ERROUT / DIGOUT / ENCOUT).

The other settings for the 2nd input can only be made if the fault pin is configured as the reference or rotational direction input.

For the default function as a fault output, the delay time can be specified via the `DCE` parameter in order to suppress the response, e.g. to individual short overcurrent pulses.

For the function as pulse output, the number of pulses per revolution of the motor can be set using the parameter `LPN`.

In the `POSOUT` function the output displays the entry into the target corridor as a digital signal (low means “target position is reached“).

Homing
Use as a reference switch can be set for each of the available inputs.

Either the actual position can be set to 0 by an edge at the selected input (`SHA`), the motor can be stopped (`SHL`) or a message can be set to the higher level control (`SHN`). The actions can be combined.

Homing defined in this way can be executed by the `GOHOSEQ` command or automatically after switching on if `POHOSEQ` is set.

5.2.8 Managing the data set

Saving parameters
The settings of a drive can be saved as a backup or as a file for configuration of other drives.

The Motion Manager provides the option of reading out the current drive configuration and saving it.

Transferring parameters to the drive
In the Motion Manager, previously saved parameter files can be opened, edited if necessary and transferred to the drive.

ℹ Run the `SAVE` or `EEPSAV` command to permanently save a transferred parameter set in the drive.

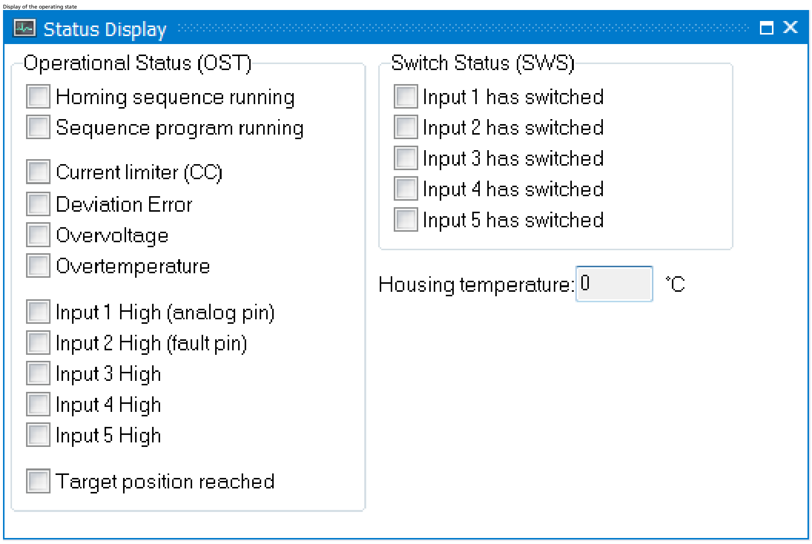
5.2.9 Diagnosis

The status display is used for continuous checking of the main operating states.

Internal states, error flags and the state of the digital inputs are signalled. In addition, the internally measured housing temperature, the Statusword and further actual values are displayed.

The display is updated by Motion Manager via cyclical querying of the state data.

Display of the operating state



Internal states
The following partially autonomous states of the Motion Controller are displayed:

- Course of homing
- Active sequence program

Other internal states are the error flag and the housing temperature.

The current limiting flag is set if the maximum current has been set to continuous current (`LCC`) by the I^2t monitoring.

States of digital inputs
The state of the digital inputs is displayed as On or Off depending on the level setting.

Status of the limit switches
The display indicates whether one of the limit switches has switched, even if the assigned input is already back in the idle state.

5.2.10 Trace function

Motion Manager provides the tool **Graphic Analysis** as an additional diagnosis tool with which the internal parameters can be graphically recorded. This enables the dynamic behaviour of the drive to be monitored, which is useful, e.g. for optimisation of the controller parameters.

6 Sequence programs

Sequence programs that are stored directly in the data flash memory of the controller and executed from there can be created for stand-alone applications or for partially autonomous sequences.

The sequence programs can be created and transferred with the FAULHABER Motion Manager, but it is also possible to use a standard text editor and to subsequently transfer the programs with the Motion Manager or a terminal program.

During a program sequence commands can still be sent via the RS232. Almost all ASCII commands can be used in motion programs.

The command PROGSEQ can also be used in the network with a preceding node number. The subsequent command must be send also with a preceding node number. The addressed node stores all received instructions thereby, between the commands PROGSEQ and END.

Command	Argument	Function	Description
PROGSEQ [...] END	–	Program Sequence	Defines the start and end of the sequence program. All commands sent to PROGSEQ are not executed, but transferred to the sequence program memory. An END marks the end of the sequence program. All commands after END are directly executed again. There is no SAVE command necessary for saving the program sequence. Command must not be executed more than 10 000 times, as otherwise the function of the Flash memory can no longer be guaranteed. These commands do not have to be entered in the FAULHABER Motion Manager, as they are automatically attached by the “Transfer program file...” function. **Note:** The Xon/Xoff protocol must be used to transfer lengthy program sequences.
GPROGSEQ	1	Get Program Sequence	Reads out and sends back the stored program sequence. Each program line is output in lower case letters, ending with a CR character. At the end of the program, the "end:" line is sent with details of the program length in bytes followed by a CR and LF character. GPROGSEQ1: Reads out the program sequence and indicates at which program line the program counter is currently located („PC--“).
ENPROG	–	Enable Program	Execution of the program is released, i.e. the sequence is started. This status can be permanently stored with SAVE/EEPSAV, so that the drive starts up with the stored program sequence immediately after power-on.
DIPROG	–	Disable Program	Deactivate program execution.
RESUME	–	Resume	Continue program sequence after DIPROG at the point at which it was interrupted.
MEM	–	Memory	Return available program memory in Word.

6.1 Control of sequence programs

There are a number of additional commands for controlling programs which are only useful within sequence programs and are consequently only available there.

The following commands stop the sequence until the relevant position is reached:

Command	Function	Sequence
NP	Notify Position	Stops at the next `M` or `V` command, until the relevant position is reached.
HN	Hard Notify	Stops at the `GOHOSEQ` command or at the next `M` or `V` command, until the limit switch is overtravelled.
NV	Notify Velocity	Stops at the next `M` or `V` command, until the relevant speed is reached.
GOHIX	Go Hall Index	Stops at the `GOHIX` command, until the Hall null position is reached.

If there are several Notify conditions, the first fulfilled condition effects continuation of the program.

Additional commands for use within sequence programs:

Command	Argument	Function	Description
`DELAY`	0…65 535	Delay	Stop sequence for a defined time [1/100 s].
`TIMEOUT`	0…65 535	Timeout	With Notify commands, only wait for the specified time and then continue the sequence again. Can also be used via RS232: Send an “o” if Notify condition has not been fulfilled.
`JMP`	0…255	Jump	Jump to the given address (can also be used via RS232).
`JMPGx`	0…255	Jump if greater than x	Jump to the specified address if result of last query command is greater than variable x (A, B, C).
`JMPLx`	0…255	Jump if less than x	Jump to the specified address if result of last query command is less than variable x (A, B, C).
`JMPEx`	0…255	Jump if equal x	Jump to specified address if result of last query command is equal to variable x (A, B, C).
`JPH`	0…255	Jump if Hard-Input activated	Jump to the specified address if the analogue input is active (`HP` determines the polarity).
`JPF`	0…255	Jump if Fault-Input activated	Jump to the specified address if the Fault Pin input is active (HP determines the polarity). Fault Pin must be configured as input (`REFIN`).
`JPT`	0…255	Jump if 3. Input activated	Jump to the specified address if the 3rd input is active (`HP` determines the polarity).
`JPD` (MCDC only)	0…255	Jump if 4. Input activated	Jump to the specified address if the 4th input is active (`HP` determines the polarity).
`JPE` (MCDC only)	0…255	Jump if 5. Input activated	Jump to the specified address if the 5th input is active (`HP` determines the polarity).
`SETx`	–2 147 483 648… 2 147 483 647 (Int32)	Set Variable x	▪ Without argument: Result of last query command is loaded into the variable. ▪ Set variable x (A, B, C) to the specified value.
`GETx`	–	Get Variable x	Query content of variable x (A, B, C).
`ADDx`	–2 147 483 648… 2 147 483 647 (Int32)	Add to Variable x	Add or subtract variable x (A, B, C) with given value.

Command	Argument	Function	Description
SETARGx	–	Set argument	Set value of variable x (A, B, C) as argument for the next command (if no argument is given there).
DxJNZ	0…255	Decrement x, Jump if not Zero	Decrease the value of variable x (A, B, C) by one and jump to specified address if the value is not 0.
ERI	0…255	Error Interrupt	An error interrupt is activated from execution of this command. This means that if an error subsequently occurs (overvoltage, current limitation, …), then the sequence branches to the specified address. The error handling mode is ended if a JMP or RETI command is executed.
RETI	–	Return Error Interrupt	Return from an error handling routine. **Important:** the interrupted command is not continued, even if it was not completed at the time of interruption.
DIERI	–	Disable Error Interrupt	The ERI command is deactivated, i.e. in the event of an error the program does not jump to the error handling routine.
CALL	0…255	Call Subroutine	Call a subroutine at specified address.
RET	–	Return from Subroutine	Return from a subroutine. **Important:** only one subroutine level is possible, i.e. no subroutines can be called within subroutines.
A	0…255	Define Address	Definition of current position as entry address for jump commands.

6.2 Response behaviour settings

As a default, the send commands are not acknowledged. However, the ANSW command can be used to change the response behaviour:

Command	Argument	Function	Description
ANSW	0…7	Answer Mode	0: No asynchronous responses 1: Allow asynchronous responses 2: All commands with confirmation and asynchronous responses 3: Debug mode, sent commands are returned (cannot be used if configuring with Motion Manager) 4…7: analogous to 0…3, but responses resulting from a command in the sequence program are not sent (cannot be set via Motion Manager)

6.3 Explanations of the commands and functions

6.3.1 Jump commands

The program sequence can be specifically controlled with the jump commands.

The JMP command can also be used from the RS232. This is useful in cases where different program routines are to be called from the computer.

Example:

```
A1
JMP1       ;Endless loop
A2         ;Program sequence 2 (can only be called by JMP2 from the RS232 interface)
LA10000
NP
M
JMP1       ;Return to endless loop
A3         ;Program sequence 3 (can only be called by JMP3 from the RS232 interface)
LA-10000
NP
M
JMP1       ;Return to endless loop
```

The program sequences according to A2 or A3 can only be called by a JMP2 or JMP3 command from the RS232 interface. A JMP2 from the RS232 interface results in the drive moving to position 10 000 and stopping there.

The DxJNZ commands serve to form loops with a predefined number of cycles.

Example:

Move by the same relative position 5 times.

```
SETA5      ;Set variable A to the value 5
A2         ;Define jump address 2
LR100      ;Load relative position
NP         ;Notify Position
M          ;Start positioning
DAJNZ2     ;Decrease A by 1 and jump to address 2, provided that variable A is not yet 0.
```

The commands JPH, JPF and JPT enable jumps that are only executed if the relevant input is active. This means that programs can be called via external switches.

The commands JMPGx, JMPLx, JMPEx enable jumps that refer to the result of the last query command.

Example:

```
SETA100

GN

JMPLA3
```

The command JMPLA3 jumps to address 3 if the velocity value returned with GN is less than 100 min^{-1} (value of variable A).

Entry addresses are defined via command A. In the case of a jump, the sequence is continued at this point.

The value range for jump commands extends from 0 to 255. Accordingly, a maximum of 256 different entry points can be defined with JMP, JPx, ERI and CALL.

6.3.2 Error Interrupt

During execution of the ERI command, nothing happens initially. Only if an error situation subsequently occurs does the sequence jump immediately to the specified address. This enables sensible continuation of the program in the event of error.

The RETI command enables you to return to the position at which the sequence was interrupted. Note that the interrupted command is no longer executed, but is continued with the next command.

No new error interruption can take place within the error handling routine. The error handling status is cancelled as soon as the RETI or JMP command is executed. After this, the commands are interrupted again if an error occurs. It should therefore be ensured that the error situation disappears in the error handling routine. Otherwise, the error handling call will be repeated.

6.3.3 Homing

The HN-/SHN command enables you to stop the sequence until the limit switch is reached. In order to correctly execute the GOHOSEQ command within a sequence, it is essential to set the SHN command accordingly when defining the homing sequence. This is necessary particularly if you wish to use the Power-On Homing sequence (POHOSEQ1).

6.3.4 Notify commands

Notify commands can be used to generate complicated motion profiles.

Example:

```
LA100000
SP5000
AC50
NV1000
M
AC100
NV2000
M
AC50
NP
M
```

With this sequence, the acceleration is increased during boot-up at 1 000 min^{-1}. It is decreased again at 2 000 min^{-1}.

The `NP` command without argument stops the sequence until the target position is reached.

6.3.5 CALL command

The `CALL` command enables subroutines to be called from different points, any number of times. You can only jump back from a subroutine again with the `RET` command.

All commands are permitted within a subroutine except for a repeated `CALL` command.

6.3.6 General information

If a sequence program is completely processed (no jump at the end of a program), then an "n" is sent to the RS232, if `ANSW1` or `ANSW2` is set.

In order to generate an endless program (useful for standalone operation), a jump command is required at the end of the program.

6.3.7 Memory size

The sequence programs are stored in binary coding in the Flash memory; 2 bytes are stored for each command, and 0 to 4 bytes for the argument. The maximum memory size available for sequence programs is 6 656 bytes (3 328 words).

6.3.8 Example: positioning routines called via RS232

The program enables the calling of different routines from the RS232 interface:

Routine	Description
JMP2	Homing Sequence. First move to a limit switch and then to the Hall sensor zero point (Hall index), in order to obtain the most precise reference point possible.
JMP3	Move to position 0 and stop there.
JMP4	Attempt to approach a position with low current limitation. As there may be an obstacle in the way in the application, the target position may not be attained. The motor should be stopped after 5 s, in any event. (Further evaluation occurs in the higher level control).
JMP5	1 000 cycles with following sequence: 10 revolutions forwards, 1 s pause, 5 revolutions back again and then 0.5 s pause.

Configuration

```
SOR0        ;Digital velocity presetting via RS232
LR0         ;Set current position as target position
M           ;Switch to position control (motion 0)
SHA1        ;Homing Sequence with Notify at AnIn
SHN1
SHL1
HOSP200     ;Homing speed 200 min⁻¹
HP1         ;Rising edge at limit switch effective
ENPROG      ;Start motion program after power-on
ANSW0       ;No asynchronous responses
EEPSAV      ;Save configuration
```

Program

```
A1
JMP1        ;Endless loop
A2          ;Entry point for homing sequence (JMP2)
GOHOSEQ     ;Homing to reference switch
GOHIX       ;Subsequent homing to Hall sensor zero point (Hall index)
JMP1        ;Return to endless loop
A3          ;Entry point for routine 1 (JMP3)
LA0         ;Set target position to 0
NP          ;Notify at target position (sequence stops until target position is reached)
M           ;Start positioning
JMP1        ;Return to endless loop
```

```
A4          ;Entry point for routine 2 (JMP4)
LPC500      ;Set current limitation values to 500 mA (continuous current # peak current)
LA1000000
NP
TIMEOUT500 ;Continue sequence after 5 s, even if position has not yet been attained
M           ;Start positioning
VO          ;Stop motor
LR0
M           ;Switch back to positioning mode
JMP1        ;Return to endless loop
A5          ;Entry point for routine 3 (JMP5)
SETA1000    ;Predefine variable A
A6          ;Entry point for loop
LR30000
NP
M
DELAY100
LR-15000
NP
M
DELAY50
DAJNZ6      ;Repeat loop 5 times
JMP1        ;Return to endless loop
```

The individual routines are called from the serial interface by sending the commands `JMP2`, `JMP3`, etc.

If the sequence is to wait until the end of a motion command (`M`, `GOHOSEQ`, etc.), a Notify (`NP` or `SHN1` in the Homing Sequence configuration) must be set first of all.

7 Parameter description

7.1 Basic setting commands

7.1.1 Commands for special operating modes

Command	Argument	Function	Description
SOR	0…4	Source For Velocity	Source for velocity presetting. ▪ 0: Interface (Default) ▪ 1: Voltage at analogue input ▪ 2: PWM signal at analogue input ▪ 3: Current target value via analogue input ▪ 4: Target current value via analogue input with presetting of the direction of rotation via input polarity
CONTMOD	–	Continuous Mode	Switch back to normal mode from an enhanced mode.
STEPMOD	–	Stepper Motor Mode	Change to stepper motor mode.
APCMOD	–	Analog Position Control Mode	Position control with target value via analogue voltage.
ENCMOD	–	Encoder Mode	Change to encoder mode (not for MCDC). An external encoder serves as position detector (the current position value is set to 0).
HALLSPEED	–	Hall Sensor As Speed Sensor	Speed via Hall sensors in encoder mode (not for MCDC).
ENCSPEED	–	Encoder As Speed Sensor	Speed via encoder signals in encoder mode (not for MCDC).
GEARMOD	–	Gearing Mode	Change to gearing mode
VOLTMOD	–	Set Voltage Mode	Activate Voltage Regulator Mode.
IXRMOD	–	Set IxR Mode	Activate IxR control (MCDC only).

7.1.2 Parameters for basic setting

Command	Argument	Function	Description
ENCRES	8…65 535	Load Encoder Resolution	Load resolution of external encoder [4 times pulse/rev].
KN	0…16 383	Load Speed Constant	Load speed constant K_n in accordance with information in the data sheet [min^{-1}/V].
RM	10…320 000	Load Motor Resistance	Load motor resistance RM according to specification in data sheet [mΩ].
STW	1…65 535	Load Step Width	Load step width for step motor and gearing mode.
STN	1…65 535	Load Step Number	Load number of steps per revolution for step motor and gearing mode.
MV	0…30 000	Minimum Velocity	Presetting of minimum velocity for specification via analogue voltage (SOR1, SOR2) [min^{-1}].
MAV	0…10 000	Minimum Analog Voltage	Presetting of minimum start voltage for presetting speed via analogue voltage (SOR1, SOR2) [mV].
ADL	–	Analog Direction Left	Positive voltages at the analogue input result in anti-clockwise rotation of the rotor (SOR1, SOR2).
ADR	–	Analog Direction Right	Positive voltages at the analogue input result in clock-wise rotation of the rotor (SOR1, SOR2).
SIN	0…1	Sinus Commutation	1: No block commutation within the upper velocity range (default) 0: Block commutation within the upper velocity range (full modulation) (not for MCDC)
NET	0…1	Set Network Mode	Activate RS232 multiplex mode for network operation. 0: No network operation, single drive on an RS232 1: Network operation activated
BAUD	600, 1 200, 2 400, 4 800, 9 600, 19 200, 38 400, 57 600, 115 200	Select Baudrate	Specify transfer rate for RS232 interface.
NODEADR	0…255	Define Node Address	Set node number.
ANSW	0…7	Answer Mode	0: No asynchronous responses 1: Allow asynchronous responses 2: All commands with confirmation and asynchronous responses 3: Debug mode, sent commands are returned (cannot be used if configuring with Motion Manager) 4…7: analogous to 0…3, but responses resulting from a command in the sequence program are not sent (can-not be set via Motion Manager)
POLNUM	2, 4	Pole Number	Number of magnetic poles of the connected motor (not for MCDC). 2: Two-pole motor 4: Four-pole motor (e.g. BX4)
SENSTYP	4	Sensor Type	Setting of the connected AES encoder (only for MCBL AES). 4: AES-4096 Further types available on request.

7.1.3 General parameters

Command	Argument	Function	Description
LL	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Load Position Range Limits	Load limit positions (the drive cannot be moved out of these limits). ▪ Positive values specify the upper limit. ▪ Negative values specify the lower limit. The range limits are only active if APL = 1.
APL	0…1	Activate / Deactivate Position Limits	Activate range limits (LL) (valid for all operating modes except VOLTMOD). ▪ 1: Position limits activated ▪ 0: Position limits deactivated
SP	0…30 000	Load Maximum Speed	Load maximum speed. Setting applies to all modes [min^{-1}].
AC	0…30 000	Load Command Acceleration	Load acceleration value [$1/s^2$].
DEC	0…30 000	Load Command Deceleration	Load deceleration value [$1/s^2$].
SR	1…20	Load Sampling Rate	Load sampling rate of the velocity controller as a multiple of the basic controller sampling rate according to the data sheet.
POR	1…255	Load Velocity Proportional Term	Load velocity controller amplification.
I	1…255	Load Velocity Integral Term	Load velocity controller integral term.
PP	1…255	Load Position Proportional Term	Load position controller amplification.
PD	1…255	Load Position Differential Term	Load position controller D-term.
CI	1…255	Load Current Integral Term	Load integral term for current controller.
LPC	0…12 000	Load Peak Current Limit	Load peak current [mA].
LCC	0…12 000	Load Continuous Current Limit	Load continuous current [mA].
DEV	0…30 000	Load Deviation	Load maximum permissible deviation of actual velocity from target velocity (deviation).
CORRIDOR	1…32 767	Load Corridor	Window around the target position.

7.1.4 Commands for configuring the fault pin and the digital inputs

Command	Argument	Function	Description
ERROUT	–	Error Output	Fault pin as error output.
ENCOUT	–	Encoder Output	Fault pin as pulse output (not for MCDC).
DIGOUT	–	Digital Output	Fault pin as digital output. The output is set to low level.
POSOUT	–	Position Output	Fault pin as digital output for display of the condition: "target position reached".
DIRIN	–	Direction Input	Fault pin as rotational direction input.
REFIN	–	Reference Input	Fault pin as reference or limit switch input.
DCE	0…65 535	Delayed Current Error	Delayed error output for ERROUT [1/100 s].
LPN	1…255 1…32 for MCBL AES	Load Pulse Number	Preset pulse number for ENCOUT.
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.
SETPLC	–	Set PLC-Threshold	Digital inputs PLC-compatible (24 V level).
SETTTL	–	Set TTL-Threshold	Digital inputs TTL-compatible (5 V level).

7.1.5 Commands for configuring the homing and the limit switches

Command	Argument	Function	Description
HP	Bitmask	Hard Polarity	Define valid edge and polarity of respective limit switches: ▪ 1: Rising edge and high level effective ▪ 0: Falling edge and low level effective
HB	Bitmask	Hard Blocking	Activate Hard Blocking function for relevant limit switch.
HD	Bitmask	Hard Direction	Presetting of direction of rotation that is blocked with HB of respective limit switch: ▪ 1: Clockwise direction blocked ▪ 0: Anticlockwise direction blocked
SHA	Bitmask	Set Home Arming for Homing Sequence	Homing behaviour (GOHOSEQ): Set position value to 0 at edge of respective limit switch.
SHL	Bitmask	Set Hard Limit for Homing Sequence	Homing behaviour (GOHOSEQ): Stop motor at edge of respective limit switch.
SHN	Bitmask	Set Hard Notify for Homing Sequence	Homing behaviour (GOHOSEQ): Send a character to RS232 at edge of respective limit switch.
HOSP	–30 000…30 000	Load Homing Speed	Load speed [min^{-1}] and direction of rotation for homing (GOHOSEQ, GOHIX, GOIX).
POHOSEQ	0…1	Power-On Homing Sequence	Start homing automatically after power-on: ▪ 0: No homing after power-on ▪ 1: Power-On Homing Sequence is activated
HA	Bitmask	Home Arming	Set position value to 0 and delete relevant HA bit at edge of respective limit switch. Setting is not saved.
HL	Bitmask	Hard Limit	Stop motor and delete relevant HL bit at edge of respective limit switch. Setting is not saved.
HN	Bitmask	Hard Notify	Send a character to RS232 and delete relevant HN bit at edge of respective limit switch. Setting is not saved.

Bit mask of the limit switches

The resulting decimal value must be transferred to the commands given here.

Bit:	0	1	2	3	4	5	6	7
Input:	Analogue input	Fault-Pin	3rd input	4th input (only MCDC)	5th input (only MCDC)	–	–	–

7.2 Query commands for basic setting

7.2.1 Operating modes and general parameters

Command	Argument	Function	Description
CST	–	Configuration Status	Set operating mode (see Tab. 4).
GMOD	–	Get Mode	Set mode (see Tab. 5).
GENCRES	–	Get Encoder Resolution	Set encode resolution (ENCRES).
GKN	–	Get Speed Constant	Motor speed constant K_N [min^{-1}/V].
GRM	–	Get Motor Resistance	Motor resistance R_M [mΩ].
GSTW	–	Get Step Width	Set step width (STW).
GSTN	–	Get Step Number	Set number of steps per revolution(STN).
GMV	–	Get Minimum Velocity	Set minimum velocity (MV) [min^{-1}].
GMAV	–	Get Minimum Analog Voltage	Set minimum start voltage value (MAV) [mV].
GPL	–	Get Positive Limit	Set positive limit position (LL).
GNL	–	Get Negative Limit	Set negative limit position (LL).
GSP	–	Get Maximum Speed	Set maximum speed (SP) [min^{-1}].
GAC	–	Get Acceleration	Set acceleration value (AC) [1/s^2].
GDEC	–	Get Deceleration	Set deceleration value (DEC) [1/s^2].
GSR	–	Get Sampling Rate	Set sampling rate (SR) of the speed controller as a multiple of the basic sampling time.
GPOR	–	Get Velocity Proportional Term	Set amplification value of the speed controller (POR).
GI	–	Get Velocity Integral Term	Set integral term of the speed controller (I).
GPP	–	Get Position Proportional Term	Set amplification value of the position controller (PP).
GPD	–	Get Position D-Term	Set D component of the position controller (PD).
GCI	–	Get Current Integral Term	Set integral term of the current controller (CI).
GPC	–	Get Peak Current	Set peak current (LPC) [mA].
GCC	–	Get Continuous Current	Set continuous current (LCC) [mA].
GDEV	–	Get Deviation	Set deviation value (DEV).
GCORRIDOR	–	Get Corridor	Set window around the target position (CORRIDOR).
GNODEADR	–	Get Node Address	Set node number (NODEADR).

Tab. 4: Binary encoded return values of the operating mode (CST)

Bit	Description
0 (LSB)	Reserved
1…2	Automatic responses: ▪ 0: ANSW0 (no automatic responses) ▪ 1: ANSW1 (asynchronous responses) ▪ 2: ANSW2 (additional command acknowledgements) ▪ 3: ANSW3 (Debug)
3…5	Velocity presetting: ▪ 0: SOR0 (RS232 interface) ▪ 1: SOR1 (Analogue voltage) ▪ 2: SOR2 (PWM signal) ▪ 3: SOR3 (current limitation value) ▪ 4: SOR4 (current limitation value with presetting of rotational direction via input polarity)
6	Reserved
7…9	FAULHABER mode: ▪ 0: CONTMOD ▪ 1: STEPMOD ▪ 2: APCMOD ▪ 3: ENCMOD / HALLSPEED ▪ 4: ENCMOD / ENCSPEED ▪ 5: GEARMOD ▪ 6: VOLTMOD ▪ 7: IXRMOD
10	Power amplifier: ▪ 0: Disabled (DI) ▪ 1: Enabled (EN)
11	Position controller: ▪ 0: Switched off ▪ 1: Switched on
12	Analogue direction of rotation: ▪ 0: ADL ▪ 1: ADR
13	Position Limits APL: ▪ 0: Deactivated ▪ 1: Activated
14	Sinus commutation SIN: ▪ 0: Allow block commutation ▪ 1: Do not allow block commutation
15	Bit 15, Network operation: ▪ 0: NET0 (Single device on an RS232) ▪ 1: NET1 (Multiplex mode activated)

Tab. 5: Return values of the modes (GMOD)

Set FAULHABER mode	MCDC	MCBL
CONTMOD	D	c
STEPMOD	S	s
APCMOD	A	a
ENCMOD	–	h
ENCSPEED	–	e
GEARMOD	G	g
VOLTMOD	V	v
IXRMOD	I	–

7.2.2 Query commands for configuring the fault pin and the digital inputs

Command	Argument	Function	Description
IOC	–	I/O Configuration	Set input/output configuration (see Tab. 6).
GDCE	–	Get Delayed Current Error	Set value of the error output delay (DCE).
GPN	–	Get Pulse Number	Set pulse number (LPN).

Tab. 6: Binary encoded return values of the input/output configuration (IOC)

Bit	Description
0…7 (0 = LSB)	Hard Blocking: ▪ 0…31: Function active for input 1…5
8…15	Hard Polarity: ▪ 0…31: Rising edge at input 1…5
16…23	Hard Direction: ▪ 0…31: Clockwise movement blocked at input 1…5
24	State of digital output: ▪ 0: Low ▪ 1: High
25	Level of digital inputs: ▪ 0: TTL level (5 V) ▪ 1: PLC level (24 V)
26…28	Function of fault pin: ▪ 0: ERROUT ▪ 1: ENCOUT ▪ 2: DIGOUT ▪ 3: DIRIN ▪ 4: REFIN

7.2.3 Query commands for configuring homing

Command	Argument	Function	Description
HOC	–	Homing Configuration	Set homing configuration (see Tab. 7).
GHOSP	–	Get Homing Speed	Set homing speed (HOSP).

Tab. 7: Binary encoded return values of the homing configuration (HOC)

Bit	Description
0…7 (0 = LSB)	SHA setting
8…15	SHN setting
16…23	SHL setting
24	Power-On Homing Sequence: ▪ 0: deactivated ▪ 1: activated (homing after power-on)

7.3 Miscellaneous commands

Command	Argument	Function	Description
NE	0…1	Notify Error	Notification in the event of errors: ▪ 1: An “r” is returned if an error occurs ▪ 0: No error notification
SAVE EEPSAV	–	Save Parameters	Save current parameters and configuration setting to Flash memory. The drive will also start with these settings when next switched on. **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	–	Reset	Restart drive node.
RN	–	Reset Node	Set application parameters to original values (ROM values) (current, acceleration, controller parameters, maximum speed, limit positions…). Communication parameters, operating mode and hardware configuration are retained.
FCONFIG	–	Factory Configuration	All configurations and values are reset to the standard delivery status. After this command the drive performs a reset. **Attention: Customer-specific factory settings are also lost, programmed sequence programs are retained.** **The command can be executed a maximum 10 000 times.**

7.4 Motion control commands

Command	Argument	Function	Description
DI	–	Disable Drive	Deactivate drive.
EN	–	Enable Drive	Activate drive.
M	–	Initiate Motion	Activate position control and start positioning.
LA	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Load Absolute Position	Load new absolute target position.
LR	$-2{,}14 \cdot 10^9 \ldots 2{,}14 \cdot 10^9$	Load Relative Position	Load new relative target position, in relation to last started target position. The resulting absolute target position must lie between the values given as argument.
NP	–	Notify Position	▪ Without argument: A "p" is returned when the target position is attained. ▪ With argument: A "p" is returned if the specified position is over-travelled.
NPOFF	–	Notify Position Off	Notify Position command that has not yet been triggered is deactivated again.
V	–30 000…30 000	Select Velocity Mode	Activate velocity mode and set specified value as target velocity (velocity control) [min^{-1}].
NV	–30 000…30 000	Notify Velocity	A "v" is returned when the nominal speed is reached or passed through.
NVOFF	–	Notify Velocity Off	Velocity command that has not yet been triggered is deactivated again.
U	–32 767…32 767	Set Output Voltage	Output motor voltage (corresponds to $-U_B \ldots +U_B$) for SOR0 only in VOLTMOD.
GOHOSEQ	–	Go Homing Sequence	Execute FAULHABER homing sequence. A homing sequence is executed (if programmed) irrespective of the current mode..
FHIX	–	Find Hall Index	For BL 4-pol motors only (not for MCDC): Move BL 4-pole motor to Hall zero point (Hall index) and set action position value to 0. In the case of 4-pol motors, two Hall zero points, each opposite, are present within a revolution. The respective nearest index is approached.
GOHIX	–	Go Hall Index	For BL 2-pol motors only (not for MCDC): Move BL 2-pol motor to Hall zero point (Hall index) and set actual position value to 0.
GOIX	–	Go Encoder Index	Move to the encoder index at the Fault pin and set actual position value to 0.
HO	$-1{,}8 \cdot 10^9 \ldots 1{,}8 \cdot 10^9$	Define Home Position	▪ Without argument: Set actual position to 0. ▪ With argument: Set actual position to specified value.

7.5 General query commands

Command	Argument	Function	Description
GTYP	–	Get Controller Type	Designation (name) of the controller.
GSER	–	Get Serial Number	Serial number.
VER	–	Get Version	Current software version.
POS	–	Get Actual Position	Current actual position.
TPOS	–	Get Target Position	Target position.
GV	–	Get Velocity	Current target velocity [min^{-1}]
GN	–	Get N	Current actual velocity [min^{-1}]
GU	–	Get PWM Voltage	Set PWM value in VOLTMOD.
GRU	–	Get Real PWM Voltage	Current controller output value.
GCL	–	Get Current Limit	Current limitation current [mA].
GRC	–	Get Real Current	Current actual current [mA].
TEM	–	Get Temperature	Current housing temperature [°C].
GADV	▪ Input 1: –10 000…10 000 ▪ Inputs 3, 4, 5: 0…10 000	Get Analog Voltage	Read out the voltage applied at the given input (value): ▪ 1: Voltage at AnIn ▪ 3: Voltage at 3. In ▪ 4: Voltage at 4. In (MCDC only) ▪ 5: Voltage at 5. In (MCDC only) Scaling: 1 000 digits = 1 V
OST	–	Operation Status	Current operating status (see Tab. 8).
SWS	–	Switch Status	Temporary limit switch settings (see Tab. 9).

Tab. 8: Binary encoded return values of the operating status (OST)

Bit	Description
0 (LSB)	Homing running
1	Program sequence running
2	Program sequence stopped because of DELAY command
3	Program sequence stopped because of NOTIFY command
4	Current limitation active
5	Deviation error
6	Overvoltage
7	Overtemperature
8	Status input 1
9	Status input 2
10	Status input 3
11	Status input 4
12	Status input 5
13…15	Reserved for further inputs

Bit	Description
16	Position attained
17	Limitation to continuous current

Tab. 9: Binary encoded return values of the temporary limit switch settings (SWS)

Bit	Description
0…7	HA setting
8…15	HN setting
16…23	HL setting
24…31	Information which limit switch has already switched (is reset on resetting the respective input)

7.6 Commands for sequence programs

Commands for generating and executing sequence programs

Command	Argument	Function	Description
PROGSEQ […] END	–	Program Sequence	Defines the start and end of the sequence program. All commands sent to PROGSEQ are not executed, but transferred to the sequence program memory. An END marks the end of the sequence program. All commands after END are directly executed again. There is no SAVE command necessary for saving the program sequence. Command must not be executed more than 10 000 times, as otherwise the function of the Flash memory can no longer be guaranteed. These commands do not have to be entered in the FAULHABER Motion Manager, as they are automatically attached by the "Transfer program file…" function. **Note:** The Xon/Xoff protocol must be used to transfer lengthy program sequences.
GPROGSEQ	1	Get Program Sequence	Reads out and sends back the stored program sequence. Each program line is output in lower case letters, ending with a CR character. At the end of the program, the "end:" line is sent with details of the program length in bytes followed by a CR and LF character. GPROGSEQ1: Reads out the program sequence and indicates at which program line the program counter is currently located („PC--").
ENPROG	–	Enable Program	Execution of the program is released, i.e. the sequence is started. This status can be permanently stored with SAVE/EEPSAV, so that the drive starts up with the stored program sequence immediately after power-on.
DIPROG	–	Disable Program	Deactivate program execution.
RESUME	–	Resume	Continue program sequence after DIPROG at the point at which it was interrupted.
MEM	–	Memory	Return available program memory in Word.

Additional commands for use within sequence programs

Command	Argument	Function	Description
DELAY	0…65 535	Delay	Stop sequence for a defined time [1/100 s].
TIMEOUT	0…65 535	Timeout	With Notify commands, only wait for the specified time and then continue the sequence again. Can also be used via RS232: Send an "o" if Notify condition has not been fulfilled.
JMP	0…255	Jump	Jump to the given address (can also be used via RS232).
JMPGx	0…255	Jump if greater than x	Jump to the specified address if result of last query command is greater than variable x (A, B, C).
JMPLx	0…255	Jump if less than x	Jump to the specified address if result of last query command is less than variable x (A, B, C).
JMPEx	0…255	Jump if equal x	Jump to specified address if result of last query command is equal to variable x (A, B, C).
JPH	0…255	Jump if Hard-Input activated	Jump to the specified address if the analogue input is active (HP determines the polarity).
JPF	0…255	Jump if Fault-Input activated	Jump to the specified address if the Fault Pin input is active (HP determines the polarity). Fault Pin must be configured as input (REFIN).
JPT	0…255	Jump if 3. Input activated	Jump to the specified address if the 3rd input is active (HP determines the polarity).
JPD (MCDC only)	0…255	Jump if 4. Input activated	Jump to the specified address if the 4th input is active (HP determines the polarity).
JPE (MCDC only)	0…255	Jump if 5. Input activated	Jump to the specified address if the 5th input is active (HP determines the polarity).
SETx	–2 147 483 648… 2 147 483 647 (Int32)	Set Variable x	▪ Without argument: Result of last query command is loaded into the variable. ▪ Set variable x (A, B, C) to the specified value.
GETx	–	Get Variable x	Query content of variable x (A, B, C).
ADDx	–2 147 483 648… 2 147 483 647 (Int32)	Add to Variable x	Add or subtract variable x (A, B, C) with given value.
SETARGx	–	Set argument	Set value of variable x (A, B, C) as argument for the next command (if no argument is given there).
DxJNZ	0…255	Decrement x, Jump if not Zero	Decrease the value of variable x (A, B, C) by one and jump to specified address if the value is not 0.
ERI	0…255	Error Interrupt	An error interrupt is activated from execution of this command. This means that if an error subsequently occurs (overvoltage, current limitation, …), then the sequence branches to the specified address. The error handling mode is ended if a JMP or RETI command is executed.
RETI	–	Return Error Interrupt	Return from an error handling routine. **Important:** the interrupted command is not continued, even if it was not completed at the time of interruption.

Parameter description

Command	Argument	Function	Description
DIERI	–	Disable Error Interrupt	The ERI command is deactivated, i.e. in the event of an error the program does not jump to the error handling routine.
CALL	0…255	Call Subroutine	Call a subroutine at specified address.
RET	–	Return from Subroutine	Return from a subroutine. **Important:** only one subroutine level is possible, i.e. no subroutines can be called within subrou-tines.
A	0…255	Define Address	Definition of current position as entry address for jump commands.

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