



FSE RACING KIT 2020

Controller card KW-R25-CAN

2020-KW05-V2

AMK Arnold Müller Kirchheim

'Does not work, does not exist!'

said Arnold Müller (+2013) and founded 1963 **AMK in Kirchheim/Teck** (GmbH & Co. KG)



Development, production and sales for automation technology
in Kirchheim unter Teck, Donnstetten, Weida, Erfurt, Gabrovo (Bulgaria)...

Business:

Drive and control technology (servo motors, converters, controllers, software ...)
Automotive (air spring compressors, power steering drives, formula student drives ...)



AMK headquarters in Kirchheim unter Teck

Website:
www.amk-group.com

Trainer:



Training targets



- You get to know the components and functionality of the RACING KIT



- You can operate the commissioning software AIPEX PRO



- You can commission an inverter with FSE functionality



- You can control the inverter with your CAN controller


Agenda

Training first day

09:00 | Welcome

09:10 | Training Racing Kit 2020 Theory part 1 (Product overview, assembly, wiring, FSE functionality)



12:30 | Lunch break (until 13:30) 

14:30 | AMK Software AIPEX PRO and set up of inverters (practical work on the demo device)



16:30 | End



10:15 / 14:30




Training second day

09:00 | Training Racing Kit 2020 Theory part 2 (CAN communication, AIPEX PRO, diagnostics, commissioning)



10:00 | Connection to CAN controller and communication test (practical work on demo device)



12:30 | Lunch break (until 13:30) 

14:30 | Question and answer session with construction departments

15:15 | Open points, practical tests



16:30 | End

2020 05 V2



Content

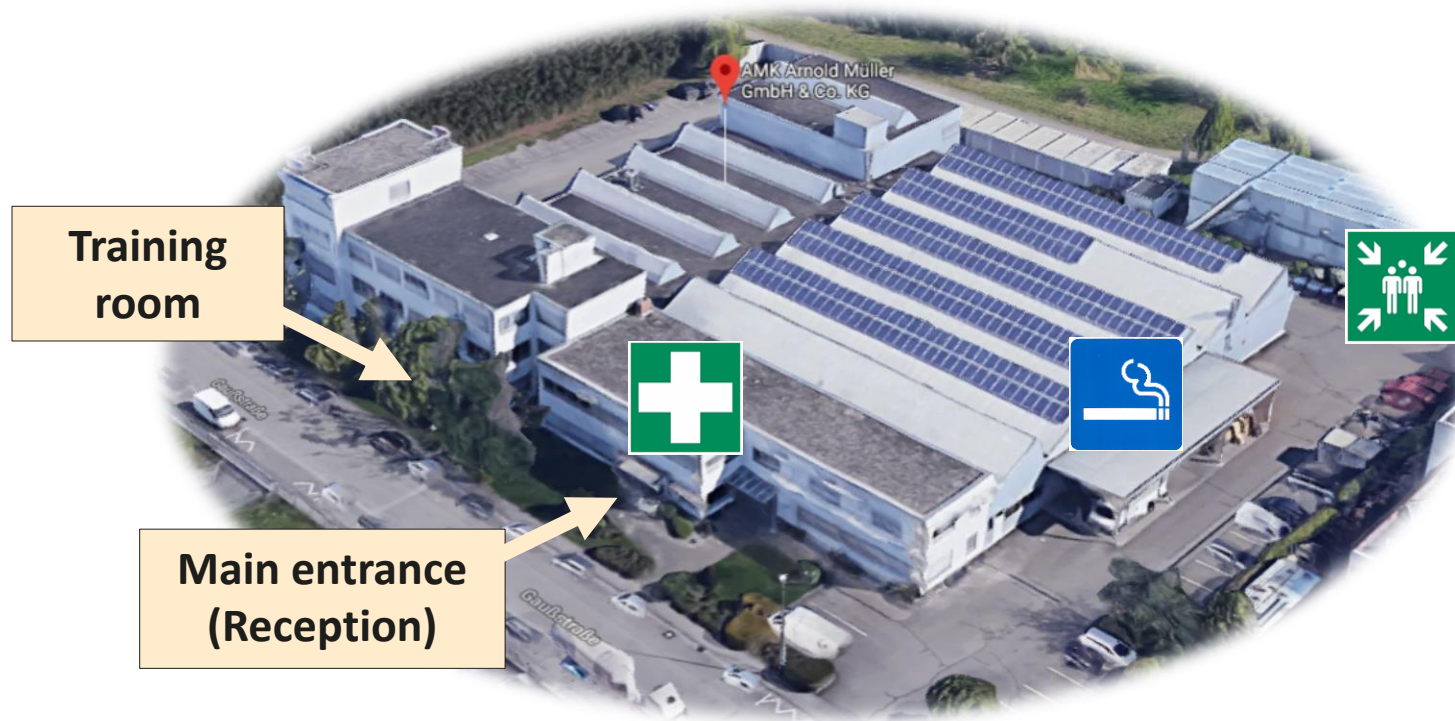
	Theme
	Information on work and visitor safety
	Product overview
	Assembly and liquid cooling, interfaces, status LED and wiring
	Functionality FSE, CAN communication
	AIPEX PRO, diagnosis, set up
	Safety



Information on work and visitor safety

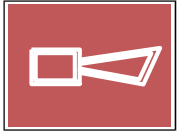


Object overview



-  First aid kit
-  Smoking area
-  Meeting point
-  Emergency call
external 112 / 0-112

Escape and rescue plan




Alarm tone for evacuation






 Location



 Fire extinguisher

 Escape and rescue route

Dangers in the training room

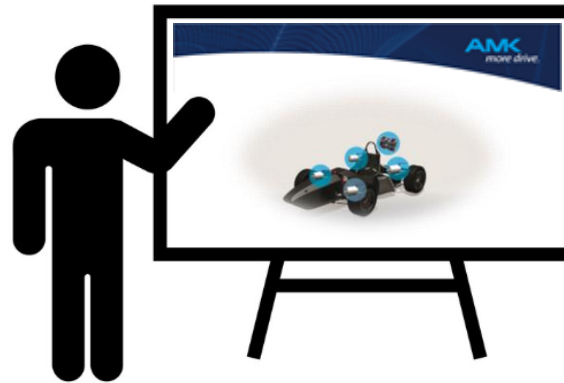


 DANGER		
 5 min		Danger to life when touching electrical connections due to electric shock! <ul style="list-style-type: none">• The demo devices are supplied with 3 x 400V or 230V.• The DC bus terminals (UZ, red and blue cables) carry life-threatening DC voltage, which continues up to 5 minutes after being switched off.• Touch or change wiring only by authorized personnel or at the instruction of the trainer.

WARNING		
		Hand injury (cutting and crushing) by rotating motor shaft



Product overview RACING KIT



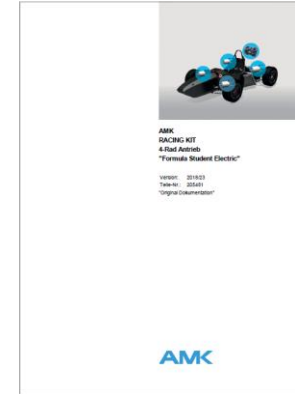
2020 05 V2

Product overview RACING KIT

AMK setup -
software AIPEX PRO



USB cable

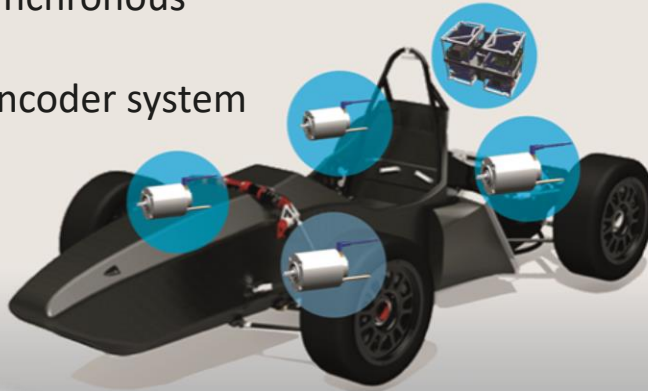


Documentation

<https://amk-group.com/amk-dokucd/dokucd/FSE/start.htm>

4 powerful synchronous
servo motors
with motor encoder system

Quad inverter with
AMK special software FSE,
(Formula Student Electric)



Training at AMK

+



10 h support
via telephone
und email

application@amk-group.com

2020 05 V2



FSE motor

Performance data

- Rated torque 9.8 Nm
- Maximum torque 21 Nm für 1.24 s
- Operation in field weakening up to 20000 rpm

Mechanical connection

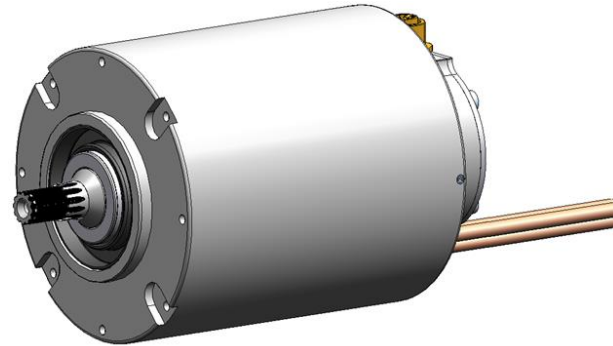
Motor shaft with
shaft seal and
spline according
to DIN 5480

Integrated motor encoder

Digital EnDat encoder (18 bit)

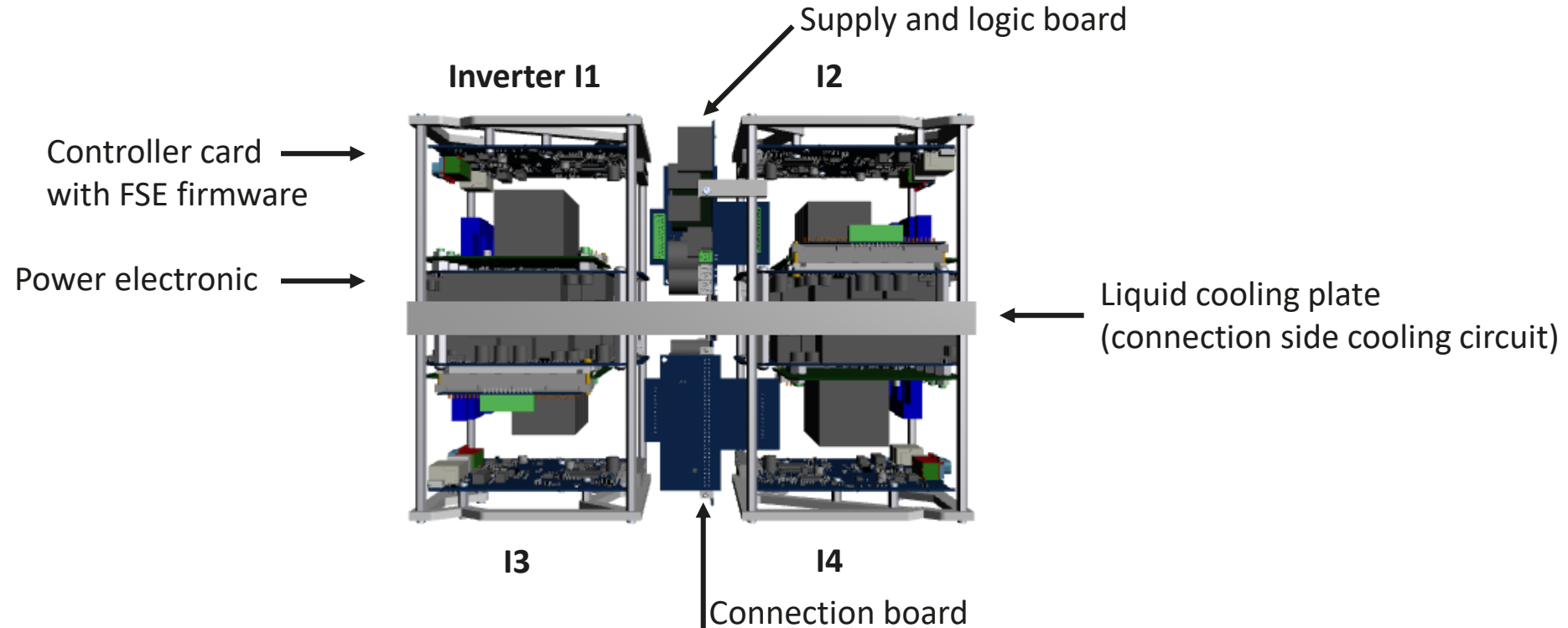
Winding protection

KTY84 temperature sensor

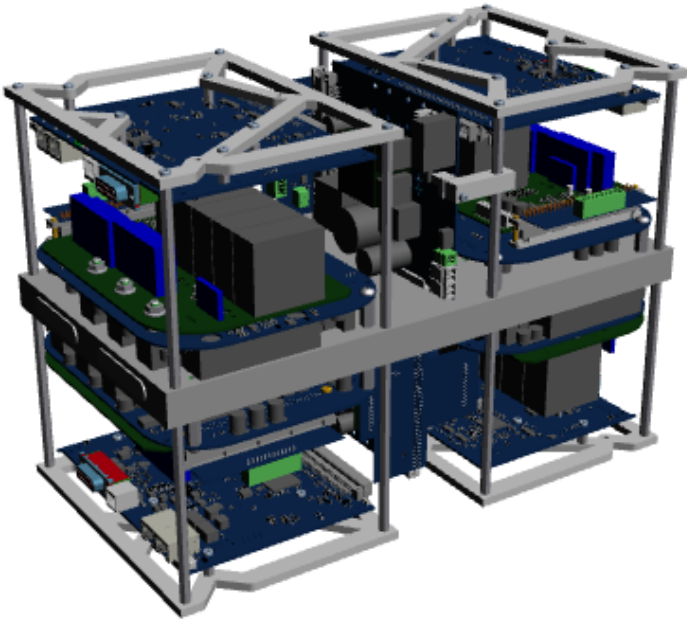


**10-pole synchronous servomotor
with permanent magnets**

FSE quad inverter



FSE quad inverter



Performance data quad inverter

Input (rated data)

540 VDC (possible area 250 VDC - 720 VDC)

4 x 48 A

Output (rated data)

350 VAC (190 VAC - 490 VAC)

4 x 26 kVA

4 x 43 A

Output (max.)

4 x 107 A ($f_{out} > 1 \text{ Hz}$ max. 10 s / $f_{out} < 1 \text{ Hz}$ max. 1 s)

Functions

Motor regulation

- Regulation of permanent-magnet synchronous servo motors
- Motor and recuperative operation
- Field weakening for higher speeds with simultaneously only slowly reducing motor torque

Operation modes

- Torque control
- Torque control through torque limitation (included speed controller)
- Torque control through torque limitation + dynamic speed limitation (included speed controller)

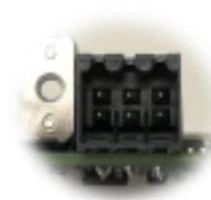
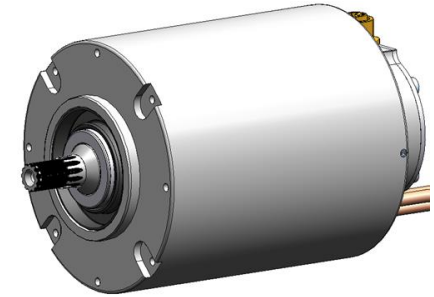
CAN Bus (Slave)

- Modus 'Fixed CAN message configuration'
- Modus 'Free CAN message configuration'

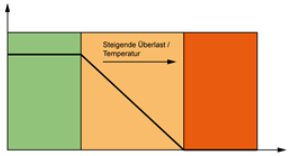
CAN

I/O interface

- Hardware release power output stage, motor control and motor torque
- Hardware signal 'Derating active'

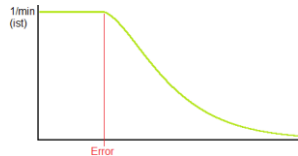


FSE firmware



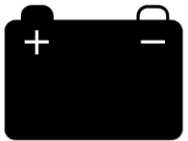
Torque limit

- Temperature (motor, power units, cooling plate)
- Overload (inverter, motor)



Motor coast down in case of error

Motor coast down instead of braking



Battery protection

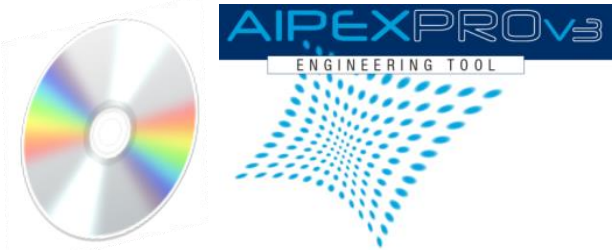
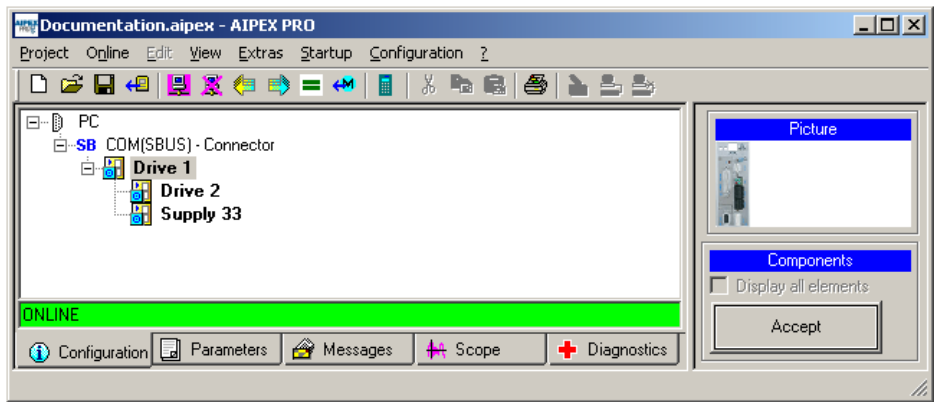
Basic battery protection, can prevent over and under voltage







Standard functions

Monitoring functions, diagnostic messages, scope function ...

AMK Software AIPEX PRO

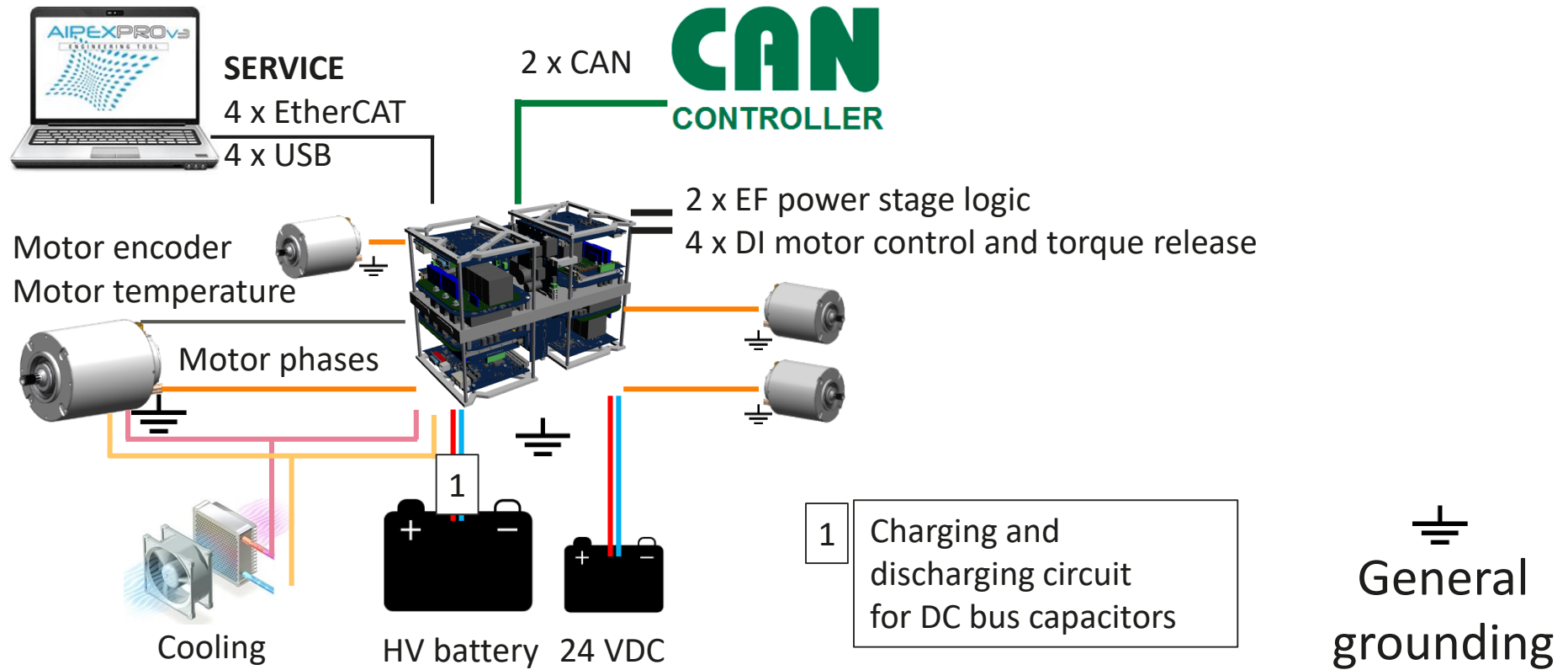


Communication connection to Inverter
EtherCAT (X85) or USB (X235)

 Configuration	Display and input possibility for device properties
 Parameters	Display and input possibility for parameter values
 Scope	Oscilloscope function to measure drive values
 Diagnostics	Diagnostic module

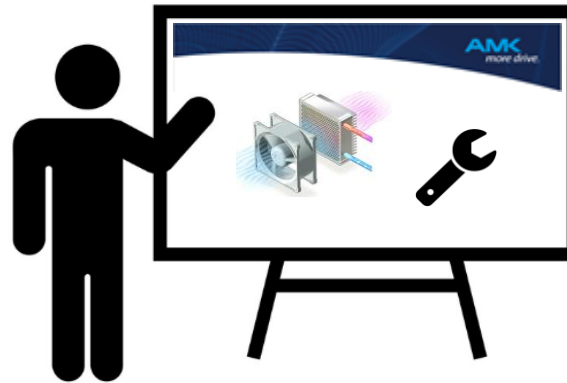


Complete system





Mounting and liquid cooling

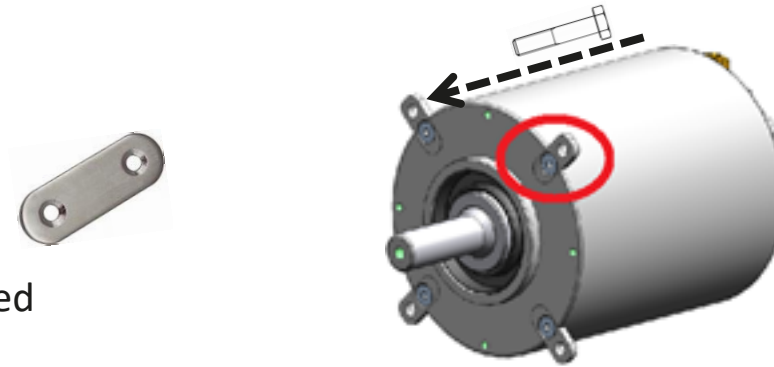


Mounting options

Front wall mounting with mounting plates

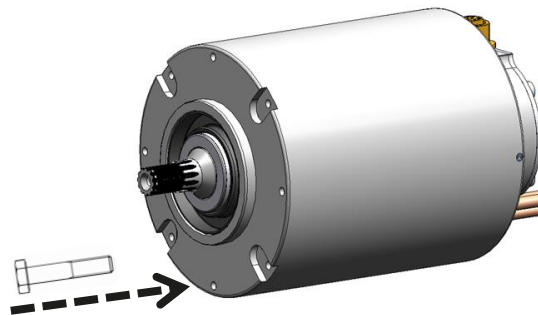


The mounting plates are not included and must be made by the user.



Back wall mounting

Fixing via 8 x M4 thread.



M4
thread depth 5,5 mm



M4
thread depth 8,5 mm

Spline

NOTICE

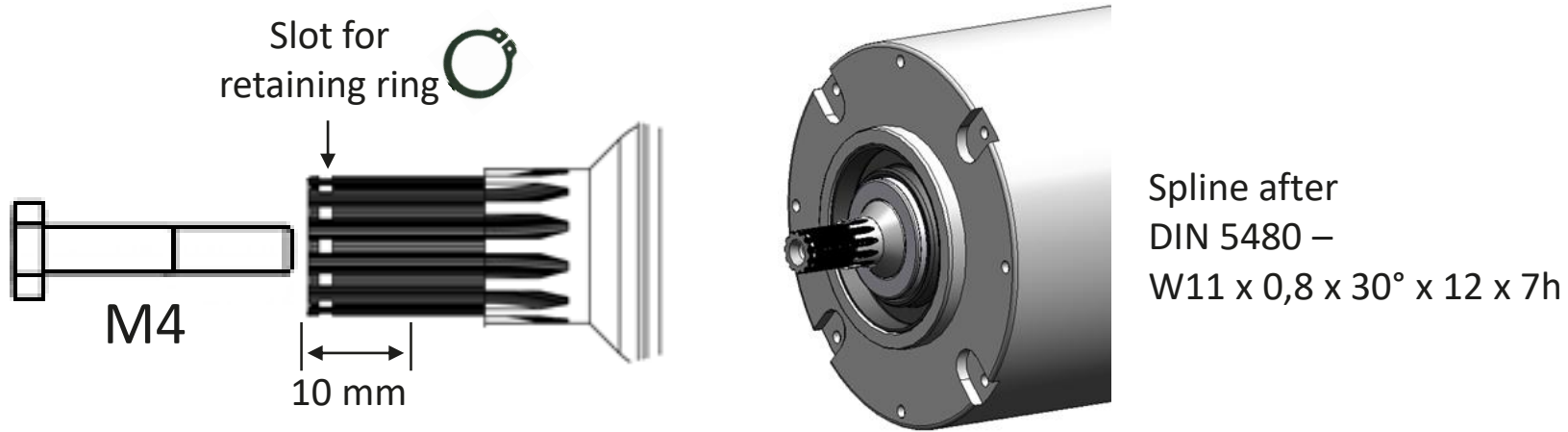
Material Damage!

Mechanical damage due to pressure on the motor shaft

Pressure on the motor shaft can damage the motor bearings or cause the motor shaft to move out of its fixing and into the motor casing.

Preventive measures:

Mounting parts such as toothed wheels or shafts must be attached without force (not pressed in) and must then be secured with a screw or a retaining ring.



B-bearing



NOTICE

Material Damage!

Mechanical damage due to pressure on the B-bearing shield

By pressing on the B-bearing shield the housing screws may break. The motor housing is damaged and the B-bearing shield is moving into the motor housing.

Preventive measures:

Support mechanically the motor housing
(picture pos. 1 + 2)
so that during assembly of attachments
e. g. the external liquid cooling no
pressure on the B-bearing shield is applied.



Liquid cooling

NOTICE	
Material Damage!	<p>Material damage due dew forms!</p> <p>When the surface temperature of the cooling plate or the cooled motors drops below the dew point, the water which bound in the air, condenses on the surface. The dew point depends on the ambient temperature and the humidity.</p> <p>Preventive measures:</p> <p>The flow temperature of the coolant must be designed based on the dew point table so that the surface temperatures of the cooling plate and the cooled motors do not fall below the dew point and there is therefore no condensation. (see dew point table)</p>

NOTICE	
Material Damage!	<p>Damage to the cooling plate/stator housing due to electrolysis</p> <p>The cooling plate is made of an aluminum alloy AlMgSi0.5, the stator housing made of AlZnMgCu1.5. If components such as supply line pipes and heat exchangers that are made of more precious materials (e.g. copper) are used.</p> <p>Steps to prevent:</p> <p>Only use components made of the same or a comparable aluminum alloy within the cooling circuit</p>

Liquid cooling

NOTICE

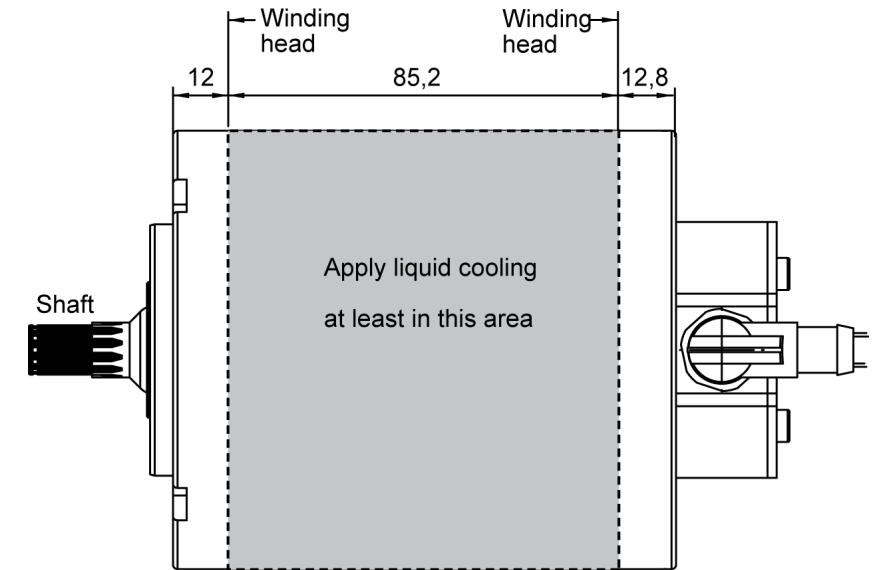
Material Damage!

Material damage due to overheating!

The drive system is intended solely for operation in a closed cooling circuit with a heat exchanger. Operation without the specified cooling system is not permitted. The engine overheats. The insulation in the motor is impaired or destroyed. Overheated permanent magnets are permanently weakened.

Preventive measures:

- Only operate the drive system with the specified cooling system
- Connect the PTC thermistor from the servo motor to the temperature monitoring equipment
- Activate the I²t monitoring of the servo motor in ID32773 'Service bits', bit 14



- Switch-off temperature monitoring 140 °C
- Insulation class F 155 °C
- Magnets max. continuous temperature <150 °C

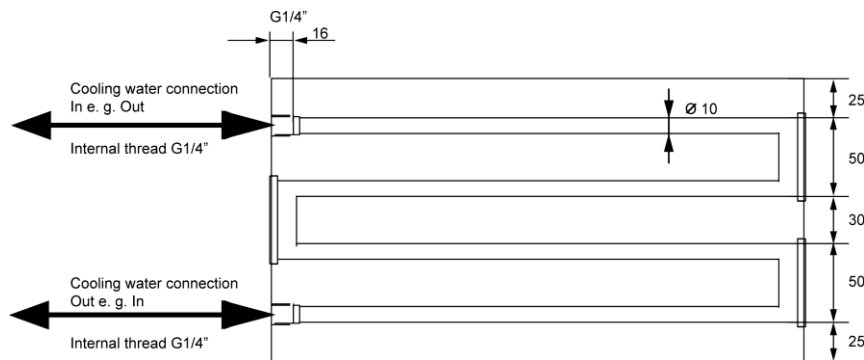
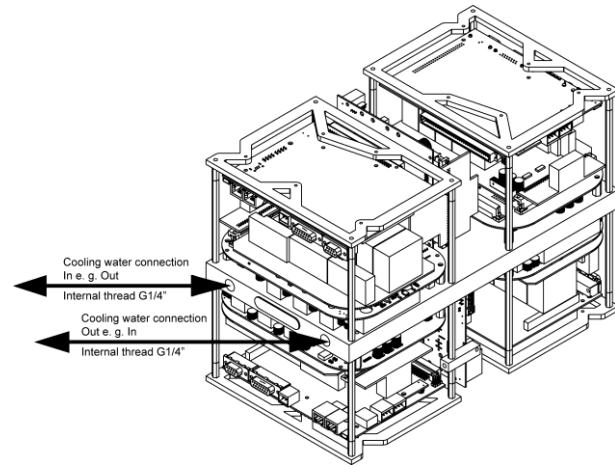


The cooling jacket must be designed and constructed by the user

Conditions for the specified rated power

- Max. inlet temperature of 40 °C (derating: from 40 °C to 60 °C 1% per 1K)
- Min. flow rate must be 4 l / min
- Max. temperature rise of the coolant < 5 K

Liquid cooling inverter



Conditions for the specified rated power

- Max. inlet temperature of $< 30\text{ }^{\circ}\text{C}$
- Flow rate approx. 1.5 bar / 10 l/min
- Max. permissible surface temperature $< 40\text{ }^{\circ}\text{C}$

- Switch-off temperature monitoring $65\text{ }^{\circ}\text{C}$



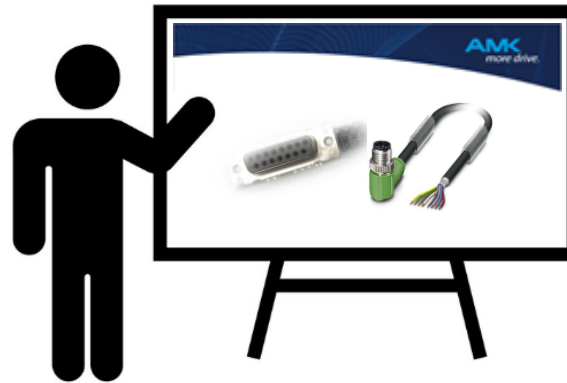
PE fittings

Do not damage the cooling channels during the pre-drilling.

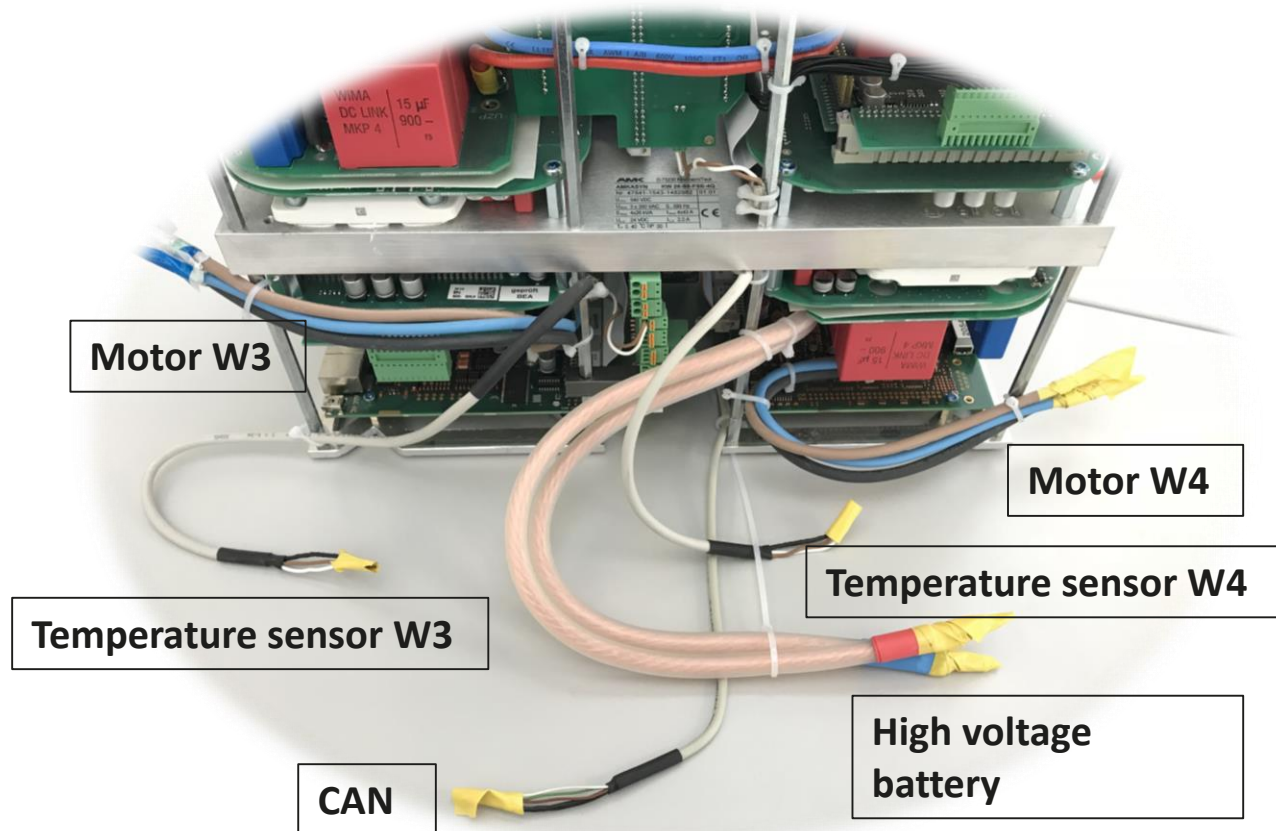
Tightening torque for G 1/4 ": max. 20 Nm



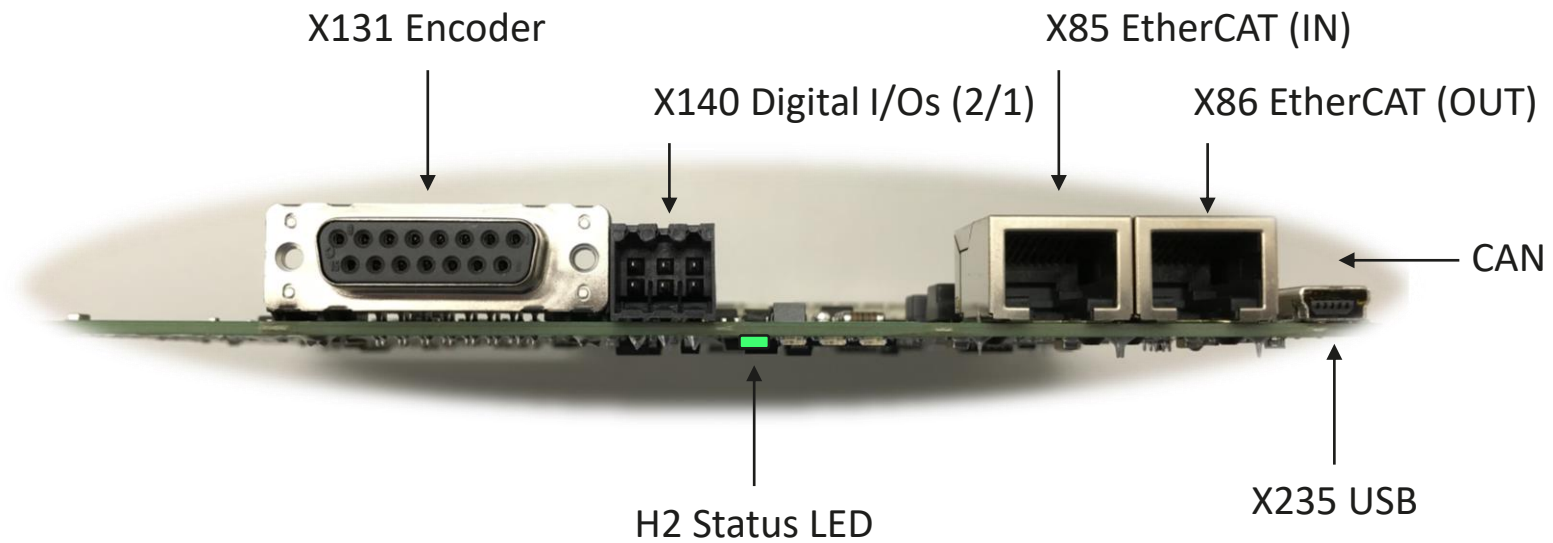
Interfaces and wiring



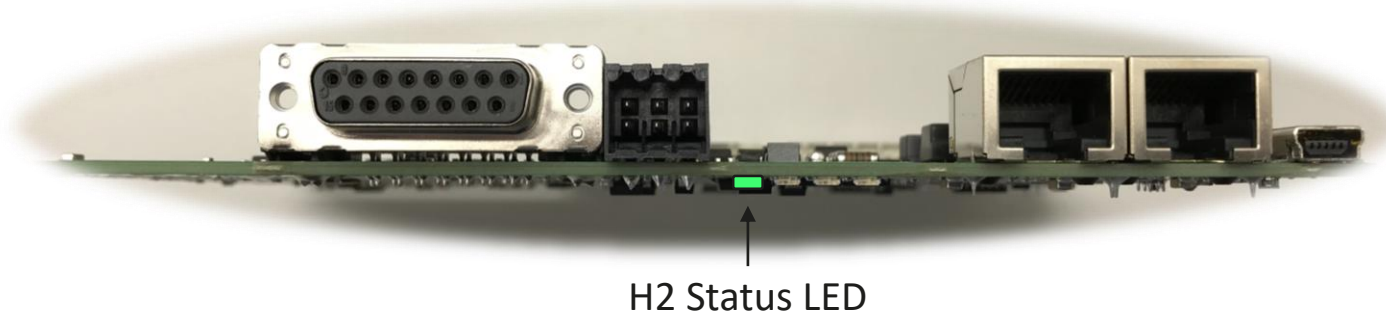
FSE quad inverter



Controller card

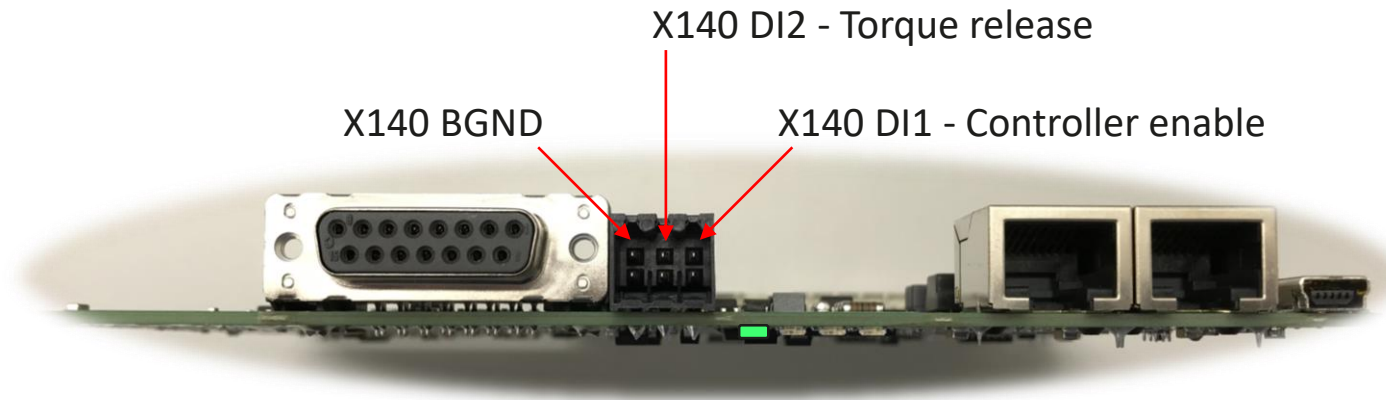


H2 Status LED



LED	Class	Status	Note
H2	Drive status	Green	System ready (SBM)
		Green flashing	Drive under control (SBM and QRF)
		Orange flashing	Warning occurs during active controller enable
		Red	Error with reaction depending on the error number

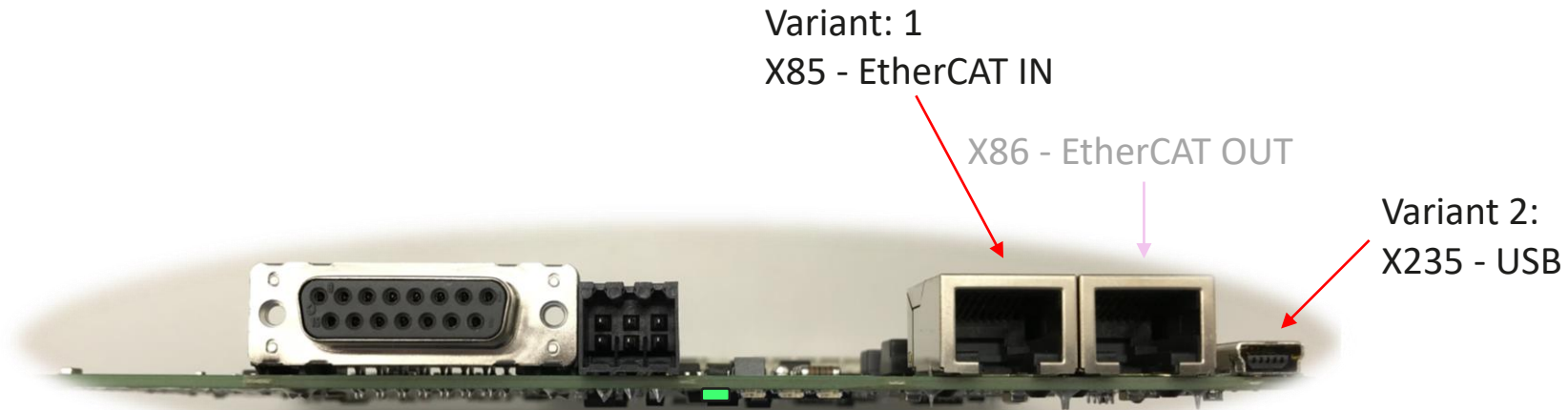
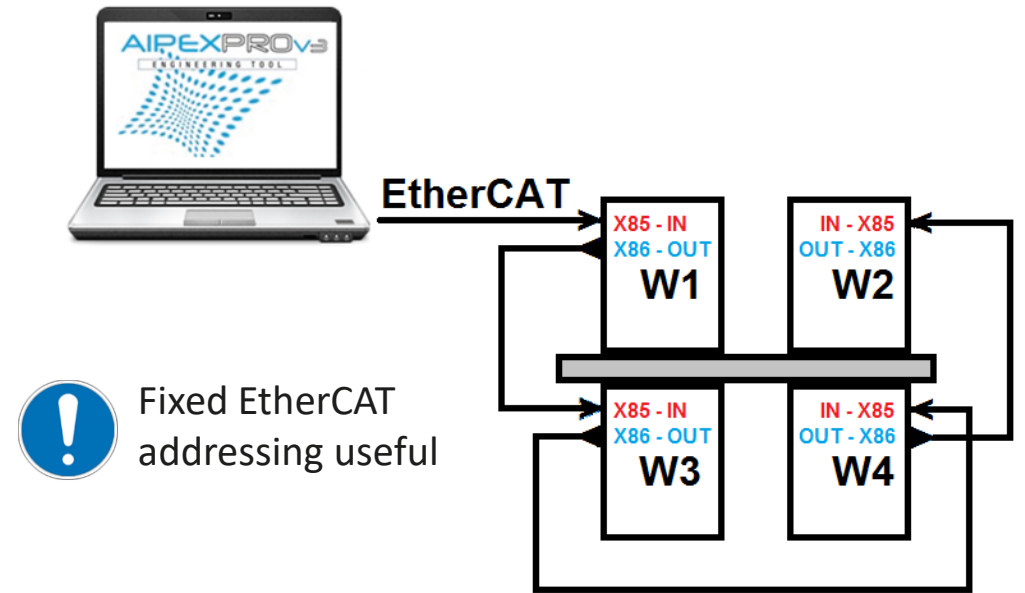
FSE functionality digital input



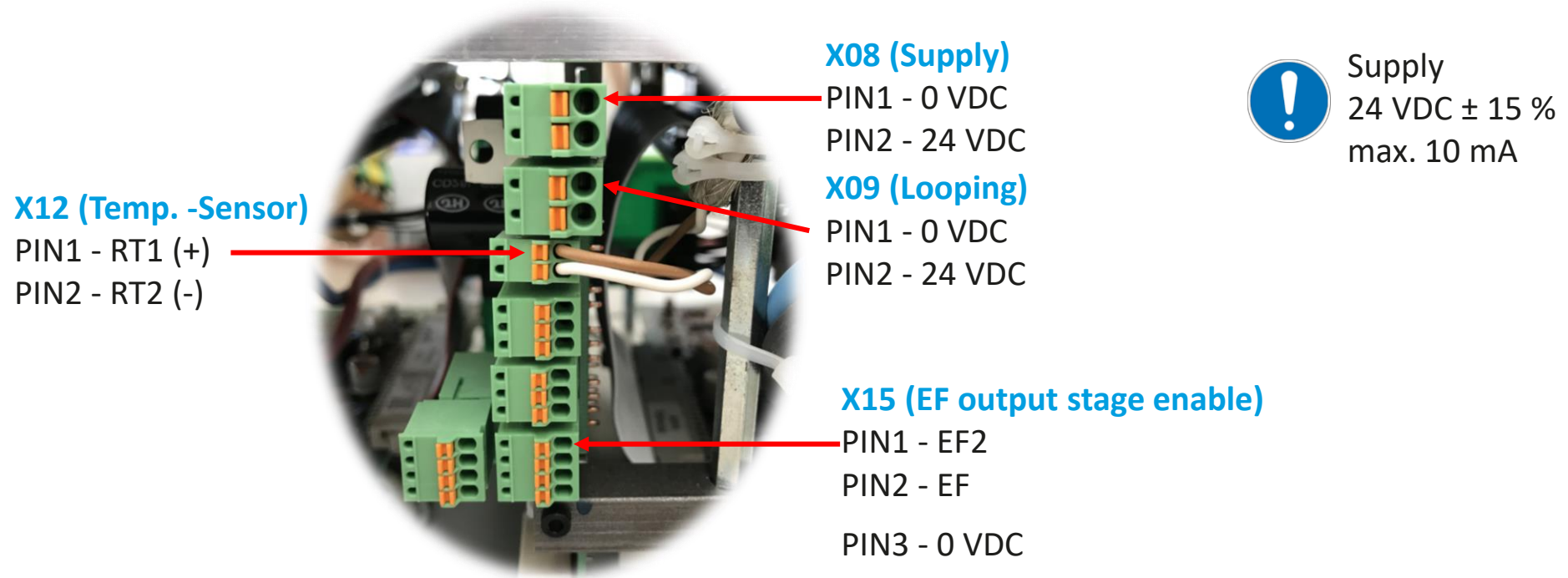
Supply DI
24 VDC \pm 15 %
max. 10 mA

DI1 = 1 : Controller enable RF possible DI1 = 0 : Controller enable RF locked	To activate the controller enable, the hardware input DI1 must be set in addition to the CAN signals ('AMK_DC_ON, AMK_bInverterOn' and 'AMK_bEnable').
DI2 = 1 : Torque limits active, setpoints via CAN possible DI2 = 0 : Torque limits deactivate, motor torque less	To activate the torque limits, you have to set digital input DI2.

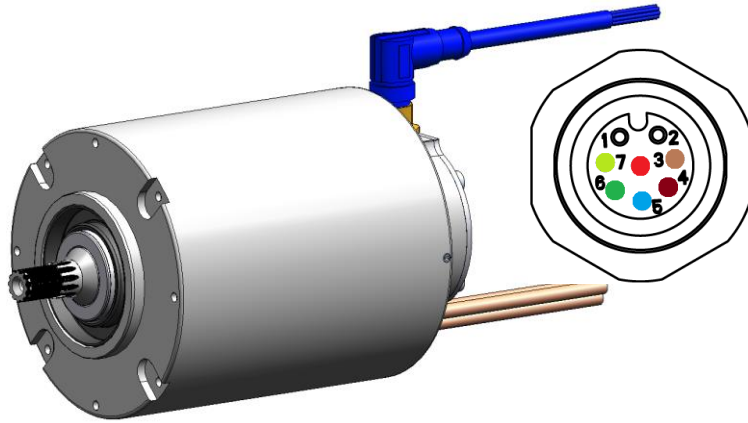
Communication interface AIPEX PRO



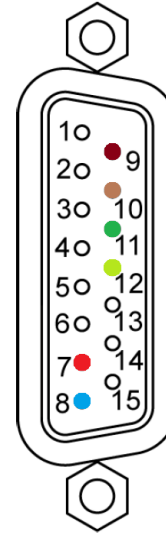
Supply and logic board




Encoder interface

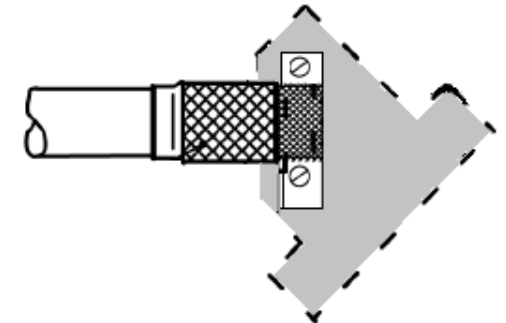


PIN Motor	Function	PIN inverter
1	KTY -	
2	KTY +	
3	Data +	10
4	Data -	9
5	GND	8
6	Clock -	11
7	Clock +	12
8	Up	7



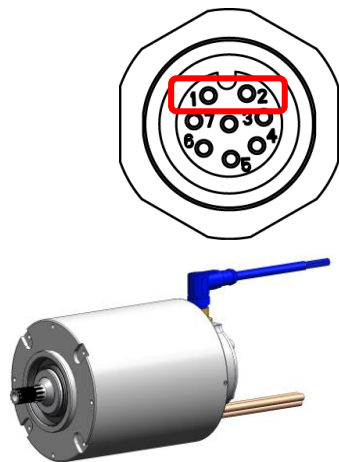
 Apply shield connection on both sides.

Metallized
D-SUB housing



Fix cable shield with
strain relief clamp

Temperature sensor



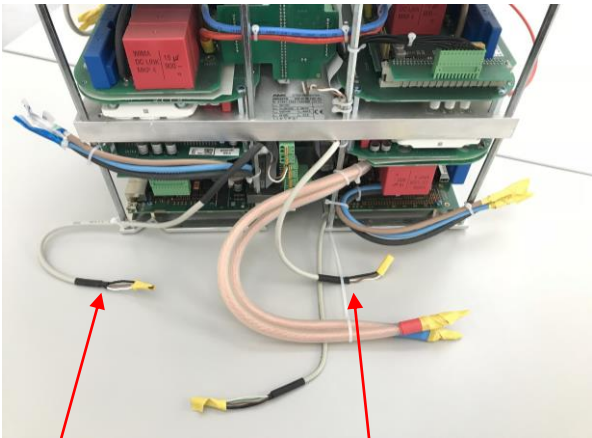
Inverter 2 and 4

Pin Motor	Function	Clamp inverter	Pin inverter	Cable
1	KTY -	X12_1	2	white
2	KTY +	X12_1	1	brown

Inverter 1 and 3

Pin Motor	Function	Clamp inverter	Pin inverter	Cable
1	KTY -	X12_2	2	white
2	KTY +	X12_2	1	brown

Black cable: cable shield

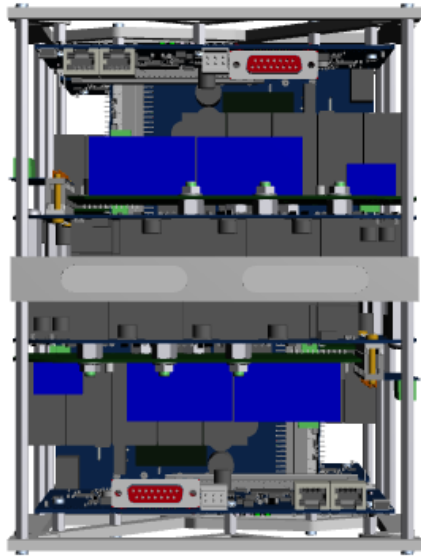



Temperature sensor W3

Temperature sensor W4



Motor interface



 Note pin assignment

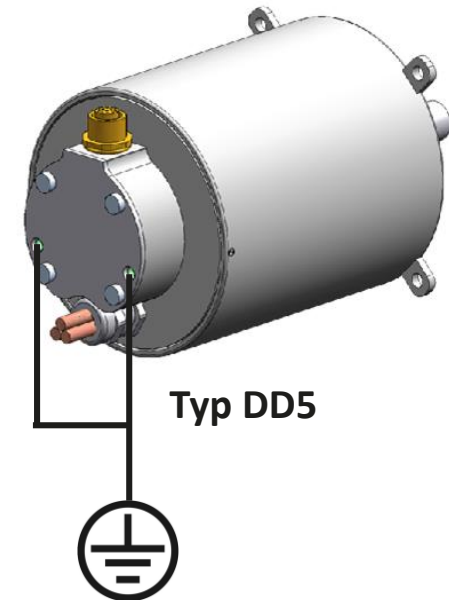
U (brown)
V (blue)
W (black)



U (black)
V (blue)
W (brown)



Generously overlap the cable shield
and connect on both sides



Motor interface



Phase rotator in a synchronous servomotor

Motor shaft stand still, high phase current

→ possibly diagnostic message 2334 'Overcurrent output terminal'

Motor shaft accelerates out of control

(positive torque and negative speed or negative torque and positive speed)

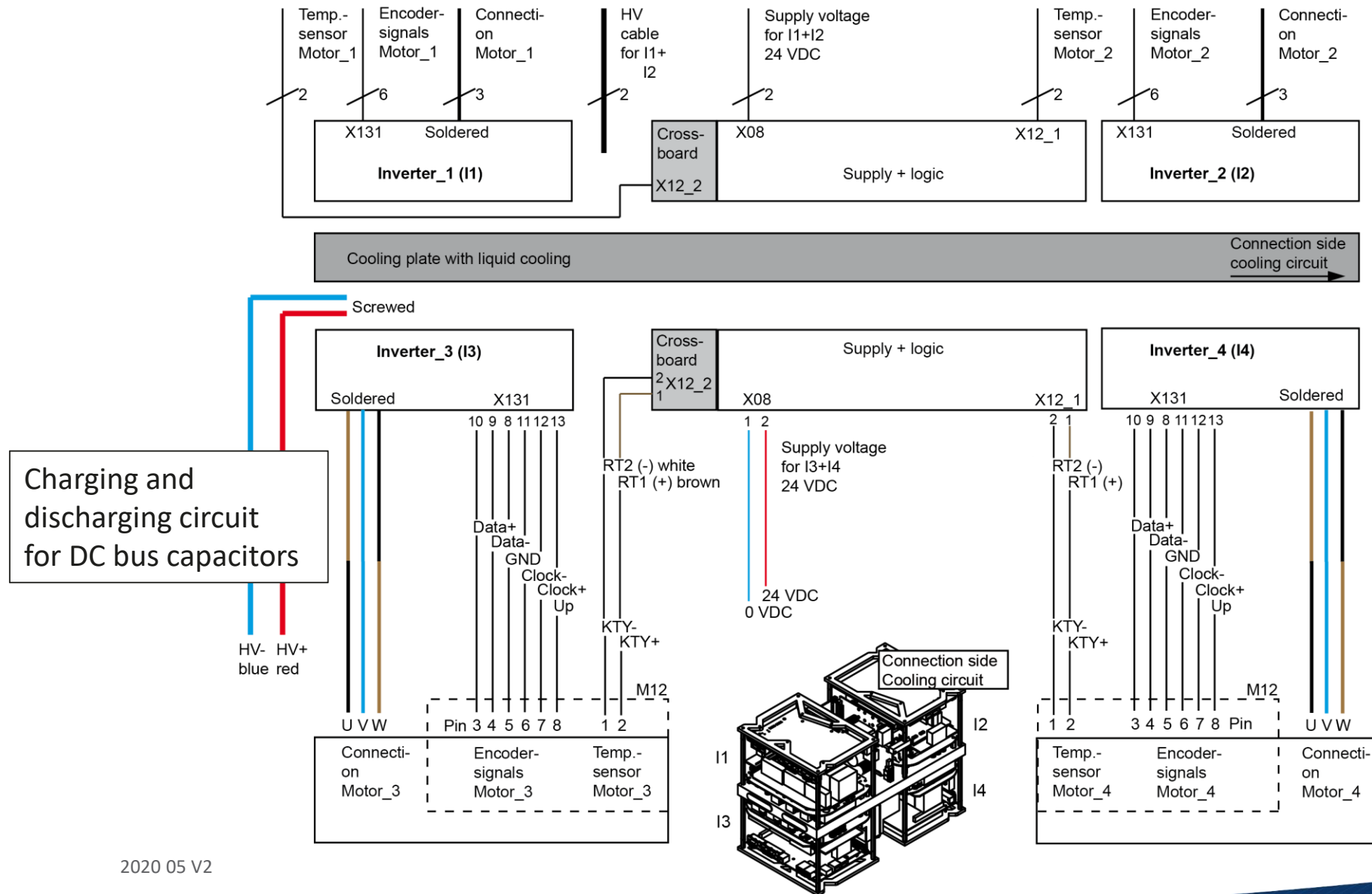
→ possibly diagnostic message 2319 'Actual speed greater than maximum speed' ($n > n_{max}$)

Reversal direction of rotation by phase rotator not possible!

Encoder signals do not match

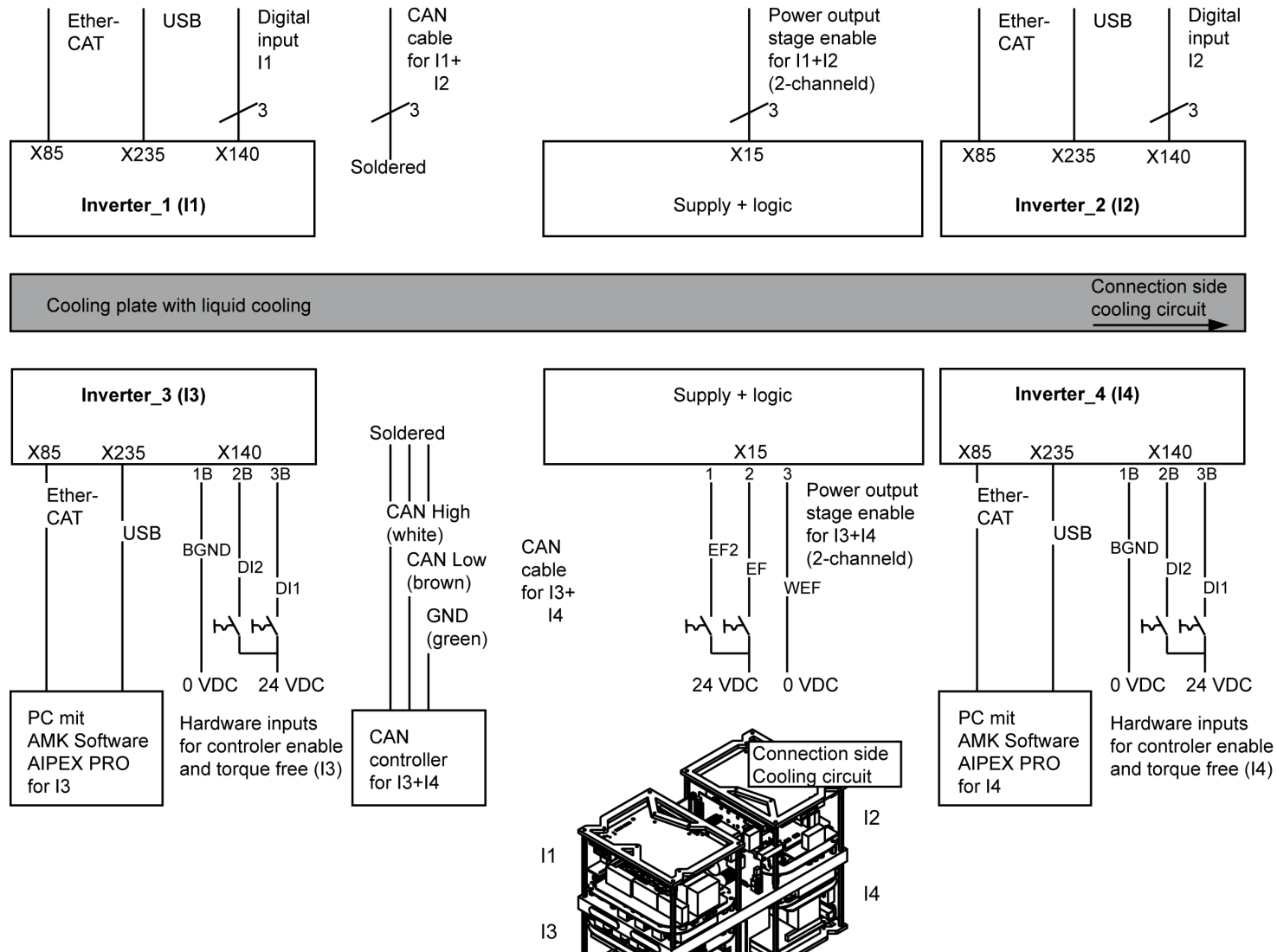
Solution: invert the direction of rotation: ID32773 Bit 16

Wiring motor and supply connections



2020 05 V2

Wiring interfaces and logic connections

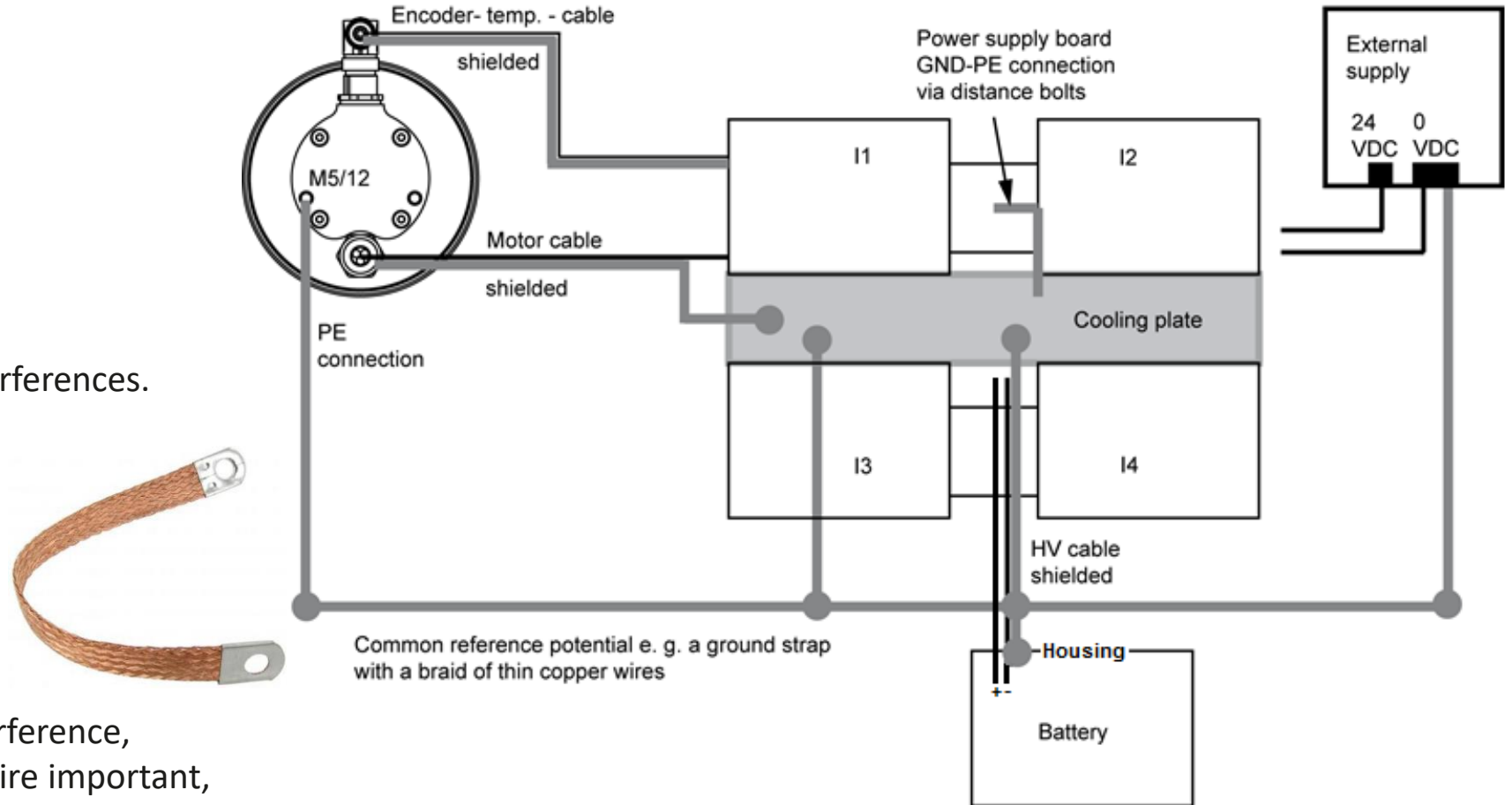


2020 05 V2

Ground terminal PE - Overview



The shield of the motor cable can prevent most of the electrical interferences.

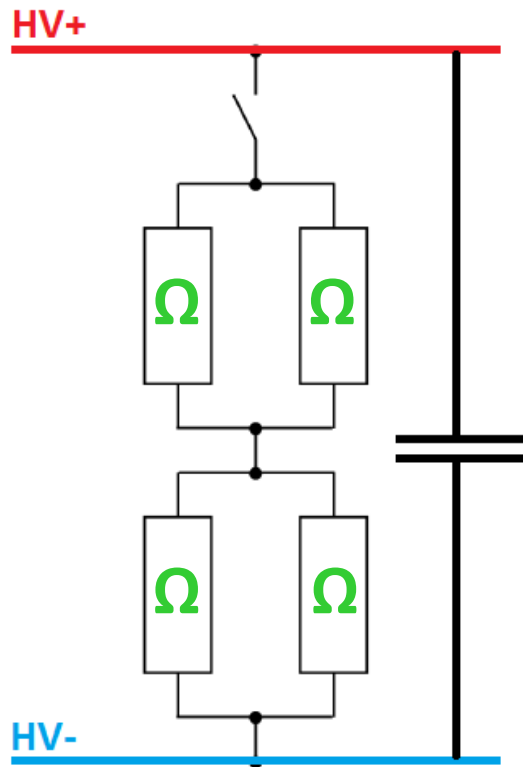


Ground strap advantage

In the case of high-frequency interference, it is not the cross-section of the wire important, but the surface (because of skin effect)



Charging / discharging the HV DC capacitors



Total DC bus capacity 300 μ F
(75 μ F per inverter)



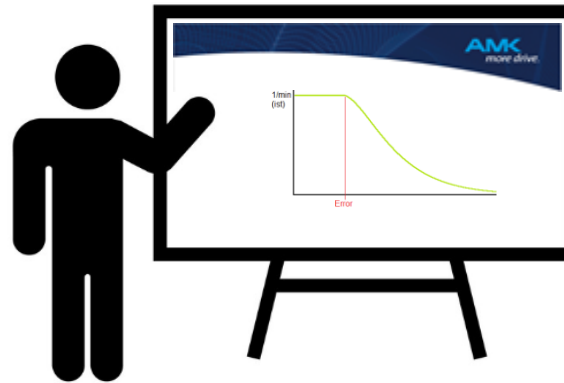
Maximum impulse load per capacitor: 240 A
RMS current per capacitor (at 10 kHz): 10,5 A



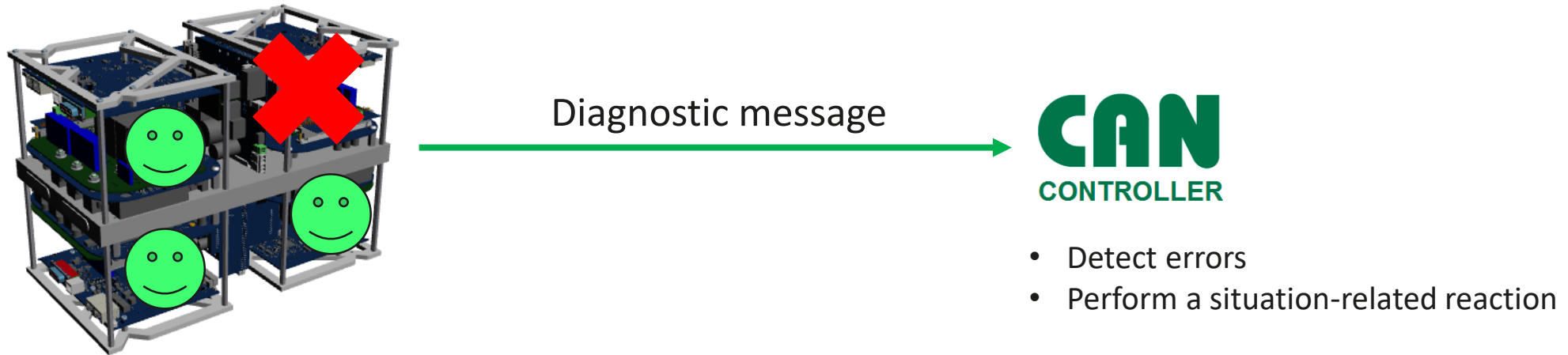
30 min without active discharge



FSE functionality



Drive behavior in case of error



Only the drive, which generate an error will set to torque free/power stage is locked, the other drives remain in control.

Drive behavior in case of error



Software functionality FSE

Reaction depending on the error:

Example 1: CAN error

Motor will be torque free instead of braking

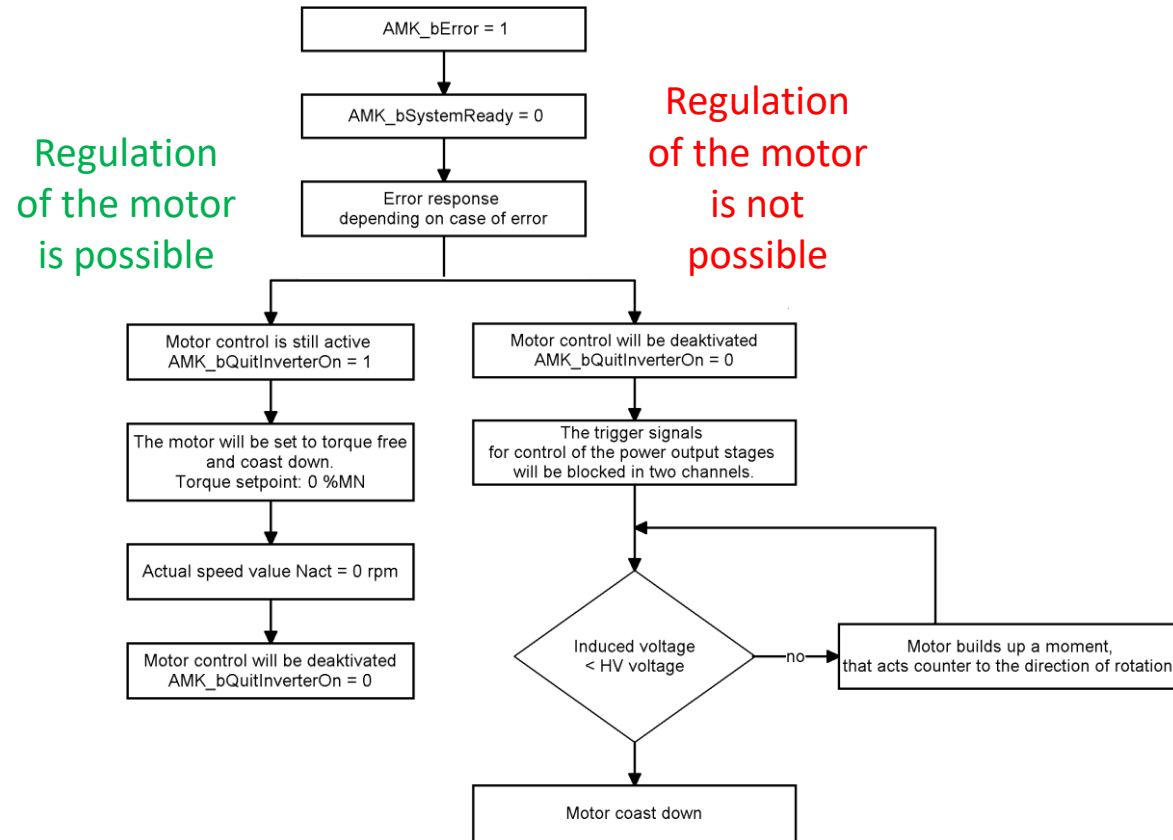
Power output stage remains active, torque setpoint 0% MN

Example 2: Encoder error

Motor coast down in case of error

Control of the power output stage is blocked

Drive behavior in case of error



Induced voltage > HV voltage

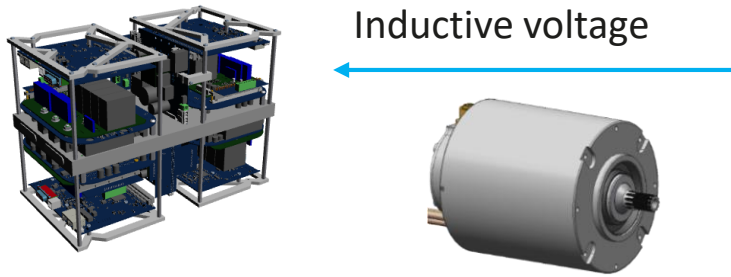
Via the freewheeling diodes in the inverter flows a current (because the induced voltage) into the DC bus
The DC bus voltage increases.

Maximum allowed HV voltage

Locked power stage in case of error



Maximum allowed HV voltage
800 VDC



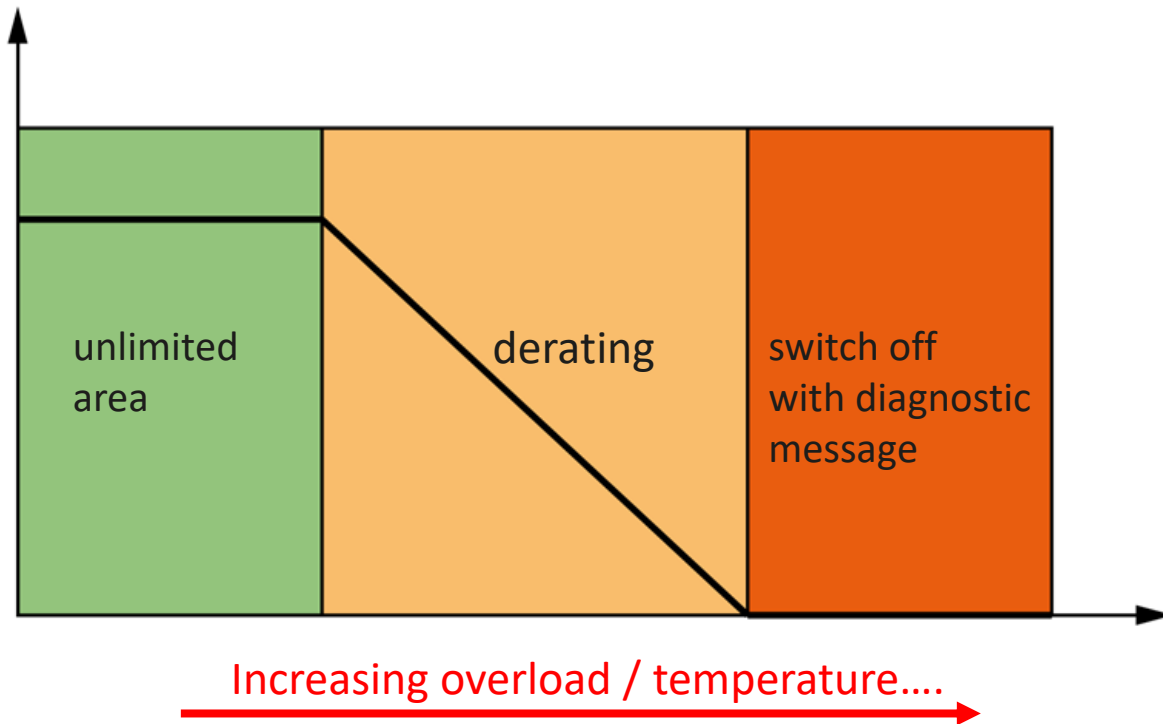
Motor data sheet DD5

Voltage constant "ke"
(ID 34234): 18,8 V/kU/min

$$U_{DC} = \frac{ID34234 \text{ Voltage constant } KE * Act. speed value * \sqrt{2}}{1000}$$
$$U_{DC} = \frac{18,8 \frac{V}{kU/min} * 20.000 * \sqrt{2}}{1000} = \mathbf{532 \text{ VDC}}$$



Torque limitation (derating) in the limit area



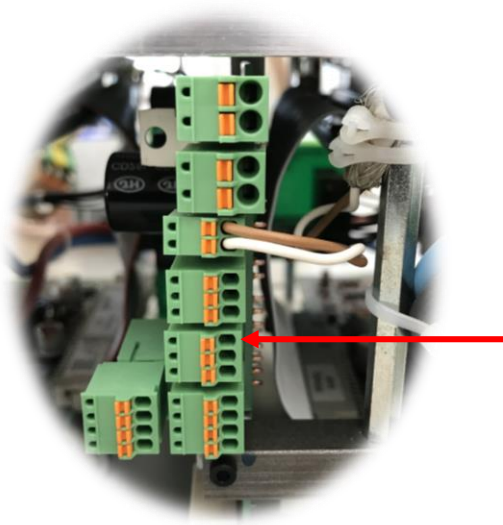
The derating is based on the following measured variables:

- Motor temperature
- Temperature of the inverter power elements (IGBT)
- Temperature of inverter cooling plate
- I^2t overload inverter
- I^2t overload motor
- Under / over-voltage in the HV circuit

Parameterization: ID32798 'User List 1'

CAN Status: AMK_bDerating

EF output stage



X15 (EF output stage enable)

PIN1 - EF2

PIN2 - EF

PIN3 - 0 VDC



Signal RF controller enable
→ Motor is energized

Functionality:

Protection against restart.

The control of the power output stage is interrupted in two channels, the motor is immediately in a torque less state.

EF + EF2 = 0 (0 VDC)

Control output stage (IGBT) interrupted

Motor can not be energized

EF + EF2 = 1 (24 VDC)

Control output stage (IGBT) possible




Motor can be energized with RF = 1 (controller enable)

EF output stage

Drive behavior

Responses of module to various switch statuses

(>> represents the signal change)

Input EF	Input EF2	n _{act} [rpm]	RF	Drive response	Response to errors
0	0	0	0 >> 1	Error message 2320 	Set RF 1 >> 0 Run command FL Clear error Wait for SBM
0	1	0	0 >> 1		
1	0	0	0 >> 1		
1	1	0	0 >> 1	The drive is supplied with power 	
1	1 >> 0	≠ 0	1	Power supply to motor is immediately cut. The motor runs down. Error message 2320 	Set RF 1 >> 0 Run command FL Clear error Wait for SBM
1 >> 0	1	≠ 0	1		
1 >> 0	1 >> 0	≠ 0	1		

Units

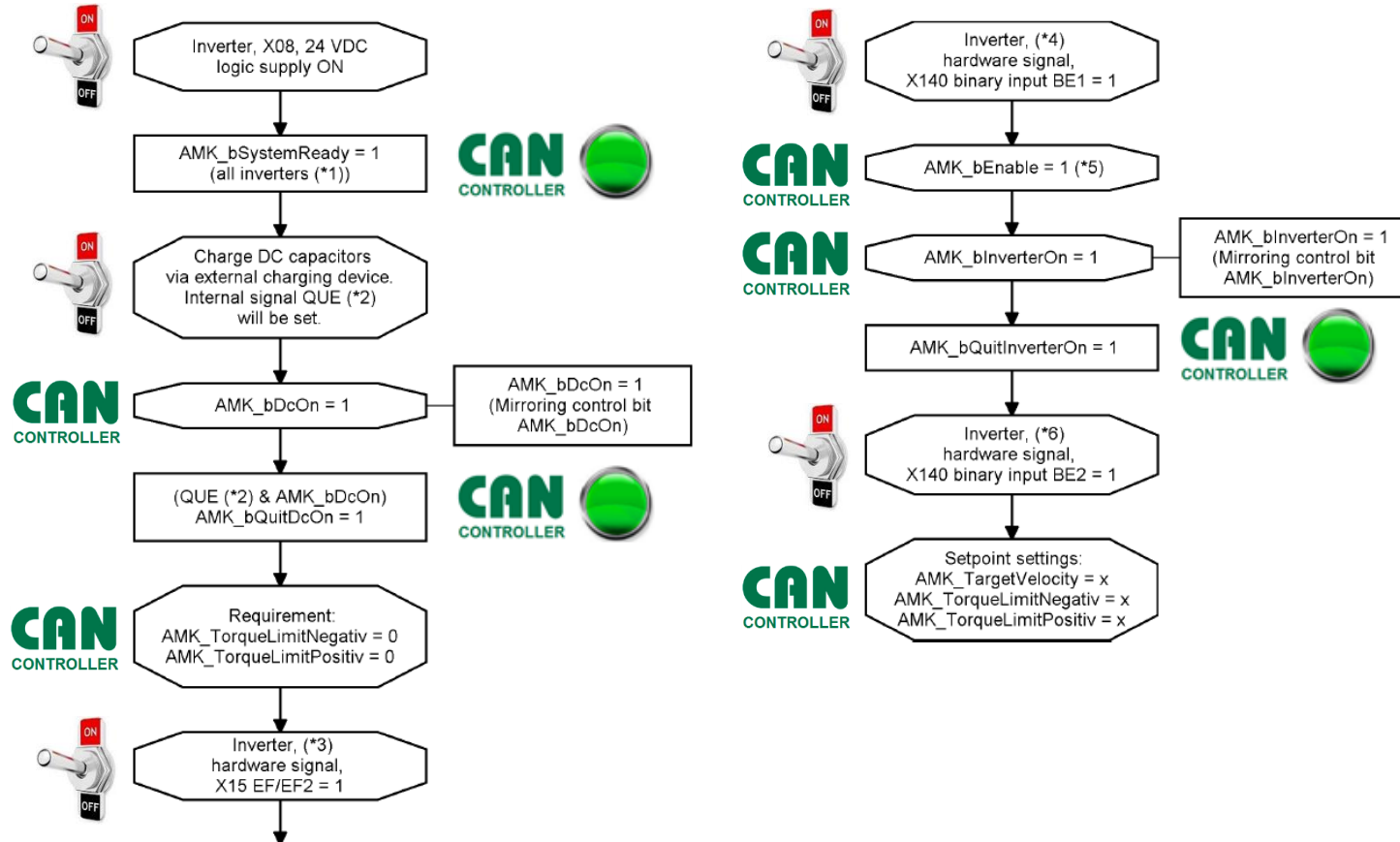
The following units and scaling apply to the FSE firmware (modus fixed CAN configuration)

Torque	All torque values of the system are related to the ID32771 'Nominal torque' and displayed in 0.1% of the value of MN.
Speed	All speed values are displayed in 1/min.
Temperature	All temperature values are displayed in 0.1 ° C.
Id and Iq	<p>The currents are related to the device-specific value in ID110 'Inverter peak current'. (107,2A) The actual current in A is calculated as follows:</p> $I_q = \frac{AMK_TorqueCurrent \times ID110}{16384} \quad I_d = \frac{AMK_MagnetizingCurrent \times ID110}{16384}$

AMK status messages and control signals

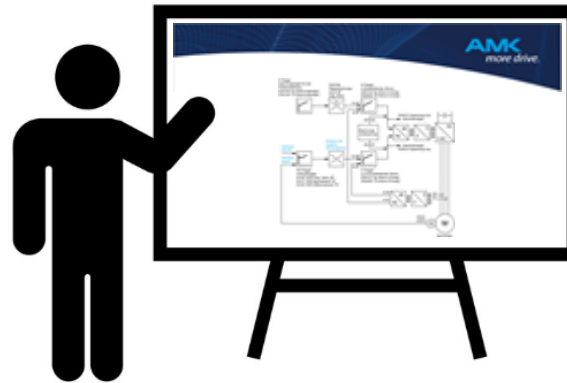
Status	SBM	System ready message	Shows that the device is error-free
Status	QUE	Acknowledgment DC bus on	Shows that DC bus is loaded
Signal	EF / EF2	Power output stage enable	0 = Power output stage locked
Signal	RF	Controller enable	Drive is energized
Status	QRF	Acknowledgment Controller enable	Drive is energized and will be controlled depending on the selected operation mode.

Switch on diagram



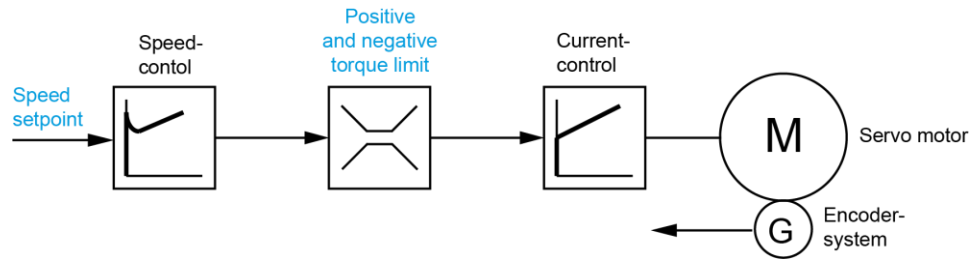


Motor operation



2020 05 V2

Operation modes



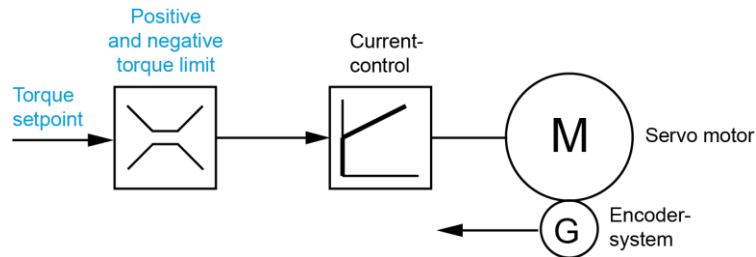
Modus 'Fixed CAN network configuration'

Variant 1: Torque control through torque limitation (included speed controller)

- Variable torque limitation setpoint
- Variable braking torque limitation setpoint (regenerative operation)
- Requirement: Speed setpoint = maximum value

Variant 2: Torque control through torque limitation + dynamic speed limitation (included speed controller)

- Variable torque limitation setpoint
- Variable braking torque limitation setpoint (regenerative operation)
- Variable speed setpoint



Modus 'Free CAN network configuration'

Variant 3: Torque control

- Variable torque setpoint
- Variable torque limitation setpoint
- Variable braking torque setpoint (regenerative operation)

Operation modes

Torque control through torque limitation (+ dynamic speed limitation) (incl. speed controller)

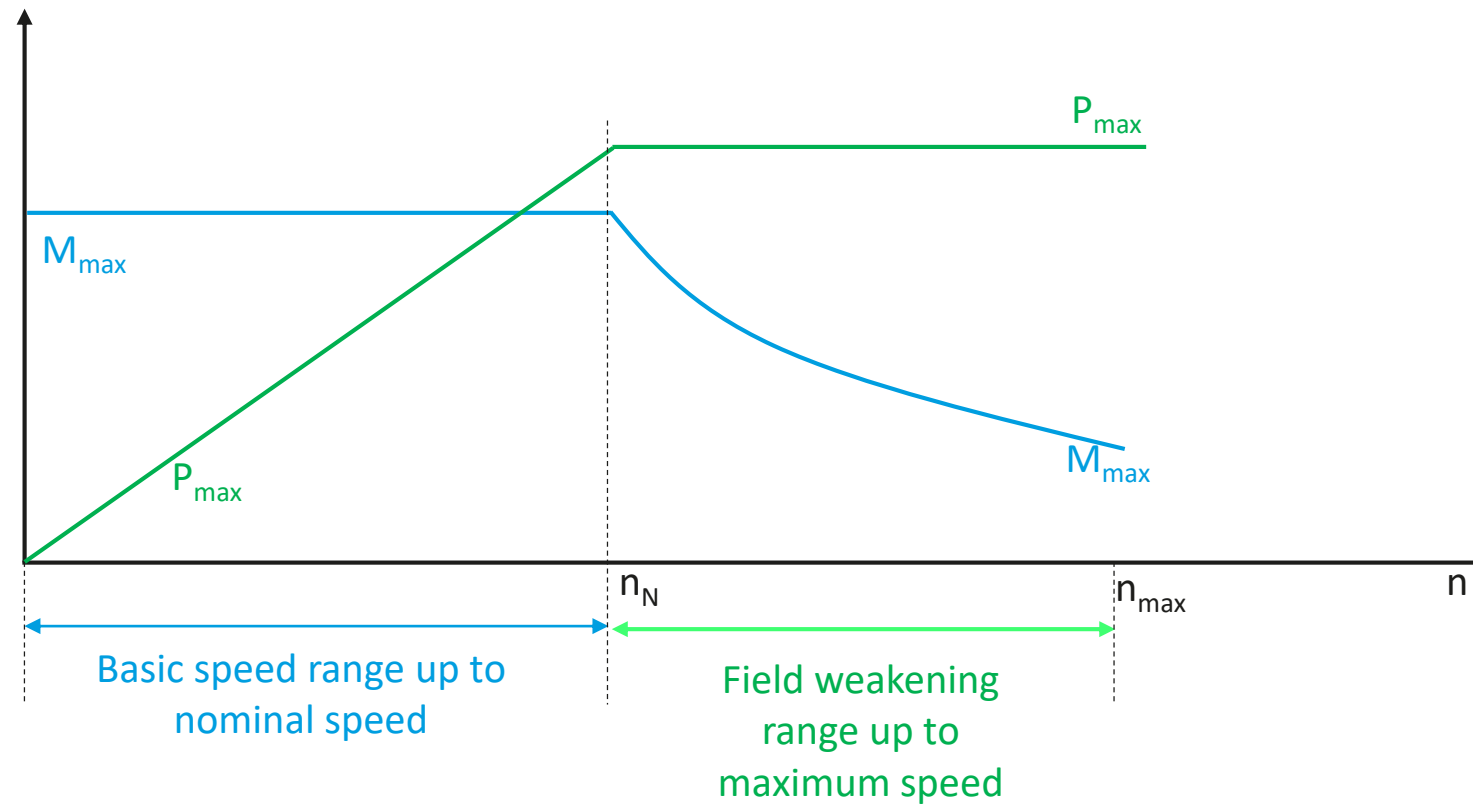
32800	AMK main op. mode	00480003	4	Hex
32801	ID32800 AMK main op. mode			
32802				
32803	Bit(s)	Description	Assignment	
32804	0 - 3	Operation mode	0011 - Speed control	
32805	4 - 5	Torque limitation	00 - ID82 and ID83 or ID92 active	
32806	6	Speed setpoint ramp	0 - Inactive	
	7	Speed fine interpolator	0 - (FIPO) inactive	
	8	Position controller type	0 - P controller	
	9	Following error compensation position control (setpoint values over ID47 and inter	0 - (SAK) inactive	
	10	Position fine interpolator	0 - (FIPO) inactive	
	13	Modulo value	0 - Active actual position source (see bit 14)	
	14	Actual position value source (valid for all main and s	0 - Motor encoder (ID32953, ID116)	
	16 - 23	Setpoint sources	0100 1000 FSE and internal AMK use (0x48)	
	24	Interpolation according to SERCOS	0 - Inactive	



Torque control (without speed controller)

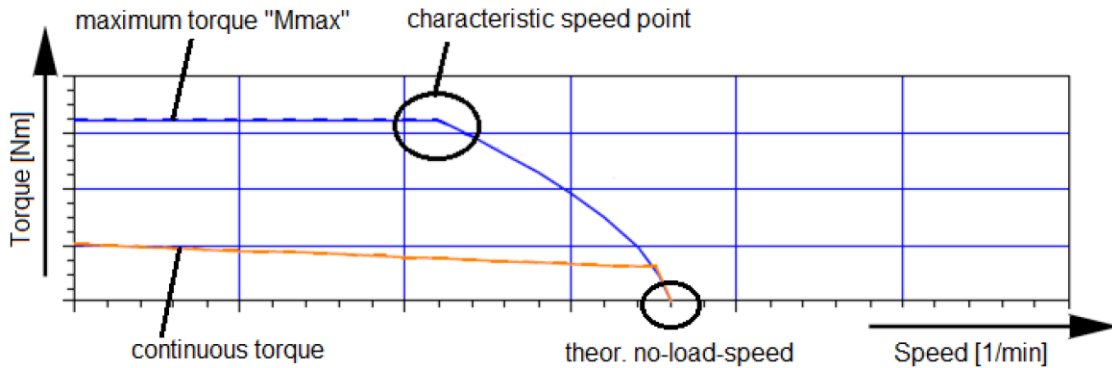
32800	AMK main op. mode	00480002	4	Hex
32801	ID32800 AMK main op. mode			
32802				
32803	Bit(s)	Description	Assignment	
32804	0 - 3	Operation mode	0010 - Torque control	
32805	4 - 5	Torque limitation	00 - ID82 and ID83 or ID92 active	
32806	6	Speed setpoint ramp	0 - Inactive	
	7	Speed fine interpolator	0 - (FIPO) inactive	
	8	Position controller type	0 - P controller	
	9	Following error compensation position control (setpoint values over ID47 and inter	0 - (SAK) inactive	
	10	Position fine interpolator	0 - (FIPO) inactive	
	13	Modulo value	0 - Active actual position source (see bit 14)	
	14	Actual position value source (valid for all main and s	0 - Motor encoder (ID32953, ID116)	
	16 - 23	Setpoint sources	0100 1000 FSE and internal AMK use (0x48)	
	24	Interpolation according to SERCOS	0 - Inactive	

Normal and field weakening operation



Normal operation

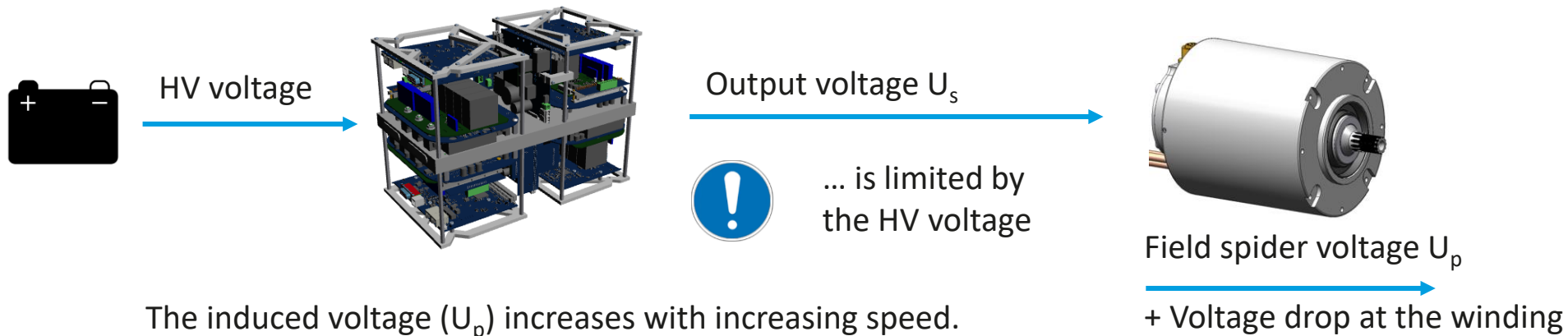
Normal operation (without field weakening)



After the 'characteristic speed point', the maximum motor torque decreases as the speed increases. When reaching the no-load-speed speed, the engine torque is 0 Nm.



At operating points at the 'characteristic speed point' the control reserve for the current controller is limited.



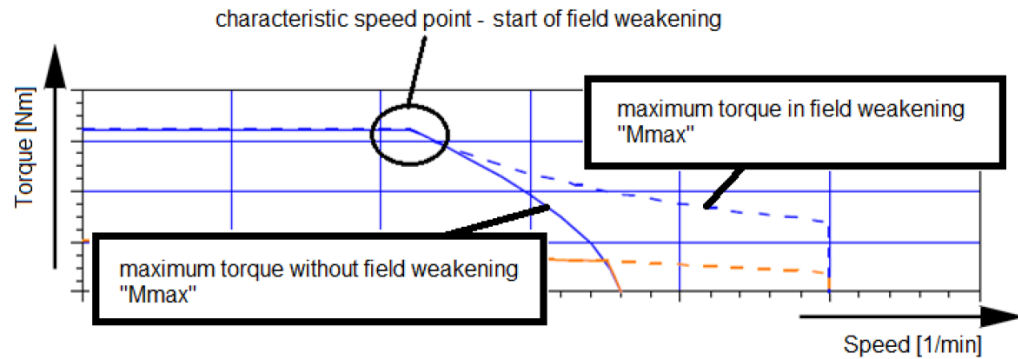
The induced voltage (U_p) increases with increasing speed.

If the induced voltage (back EMF) lies in the height of the maximum output voltage of the inverter, the current flow and thus the torque decreases.

Ohmic voltage drop is disregarded

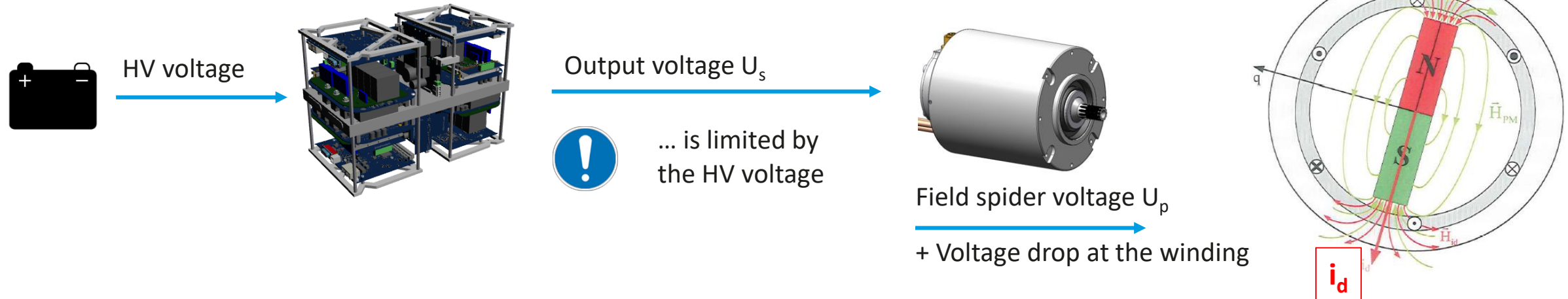
Field weakening operation

Operation with field weakening



A synchronous servo motor with field weakening can reach **higher speeds**, with simultaneously, **only slowly reducing motor torque**. In addition, **control reserves** in the area of the characteristic speed point are reached.

Field weakening operation



- During field weakening, a negative magnetizing current i_d is impressed.
- The field of the current i_d counteracts the field of the permanent magnet.
- The magnetic flux ψ is reduced, which also reduces the induced voltage (back EMF).
- If the output voltage of the inverter remains constant, the output frequency (speed) can be increased.

! Field weakening operation must be activated with ID32953

! **Disadvantage:**
Additional power losses due to the field weakening current 🌡️

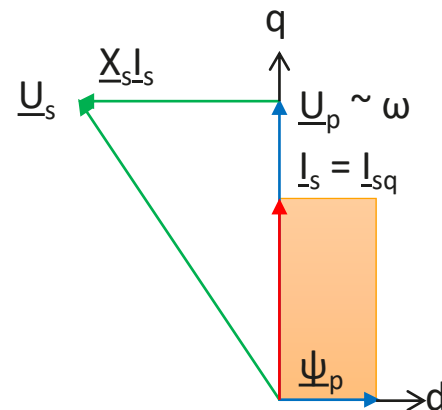
Vector diagram

Ohmic voltage drop neglected

Max. Output voltage inverter (stator voltage) $U_s = \text{constant}$

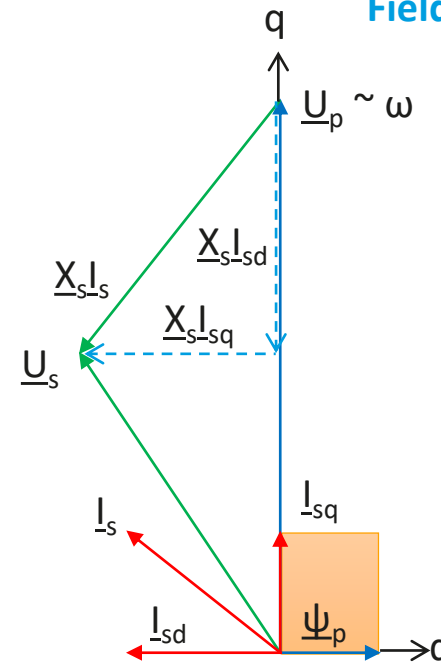
Normal operation

Power 100 %
Speed 100 %
Torque 100 %
 $I_s = I_q = 20 \text{ A}$
 $I_d = 0 \text{ A}$



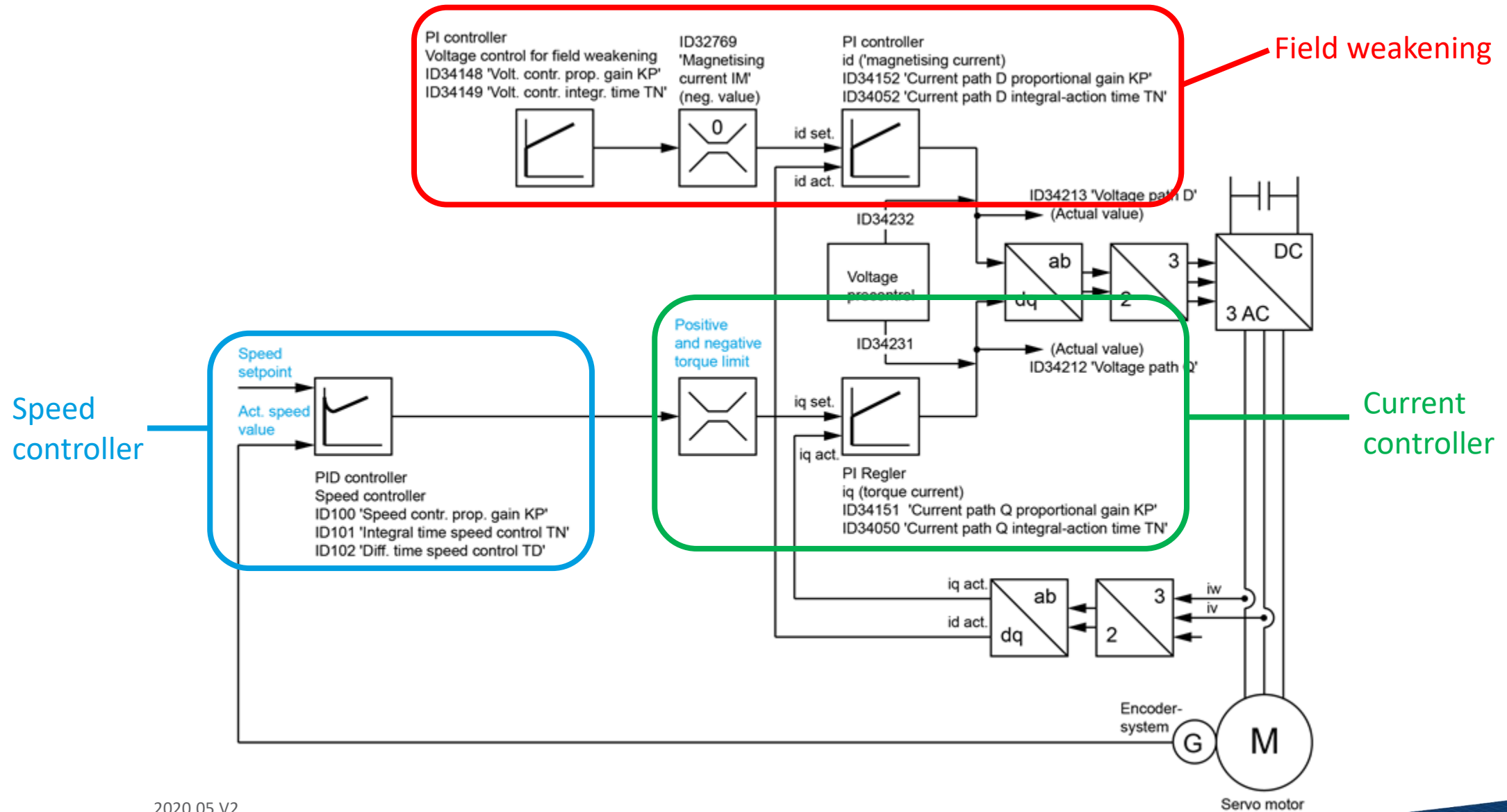
Field weakening operation

Power 100 %
Speed 185 %
Torque 60 %
 $I_s = 20 \text{ A}$
 $I_q = 12 \text{ A}$
 $I_d = 16 \text{ A}$



$$I_s = \sqrt{I_d^2 + I_q^2}$$

Over view control structure



2020 05 V2

Current controller

Motor-Datenblatt *motor data sheet*

Bezeichnung/name **DD5-14-10-POW** - 18600-B5
Teile-Nr./part number **A2370DD**

Reglereinstellungen *controller settings:*

~~Stromregler~~ *current controller:*

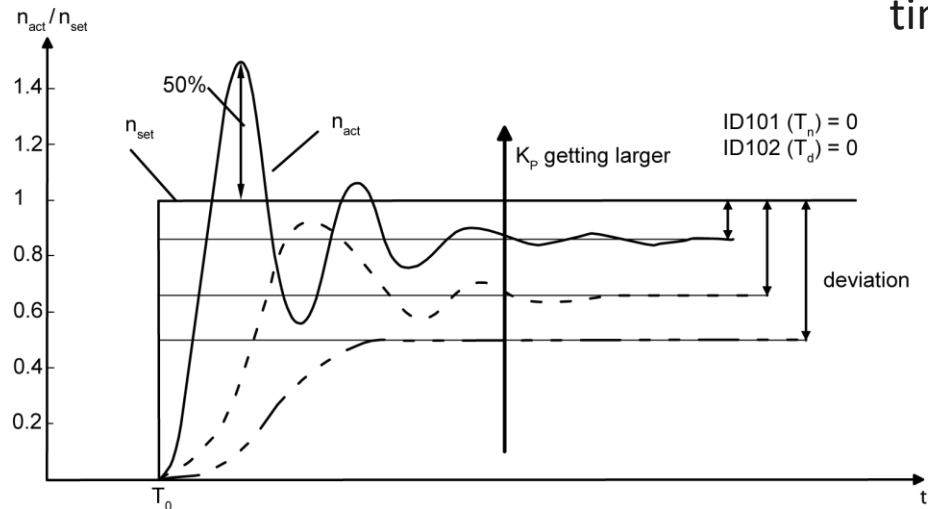
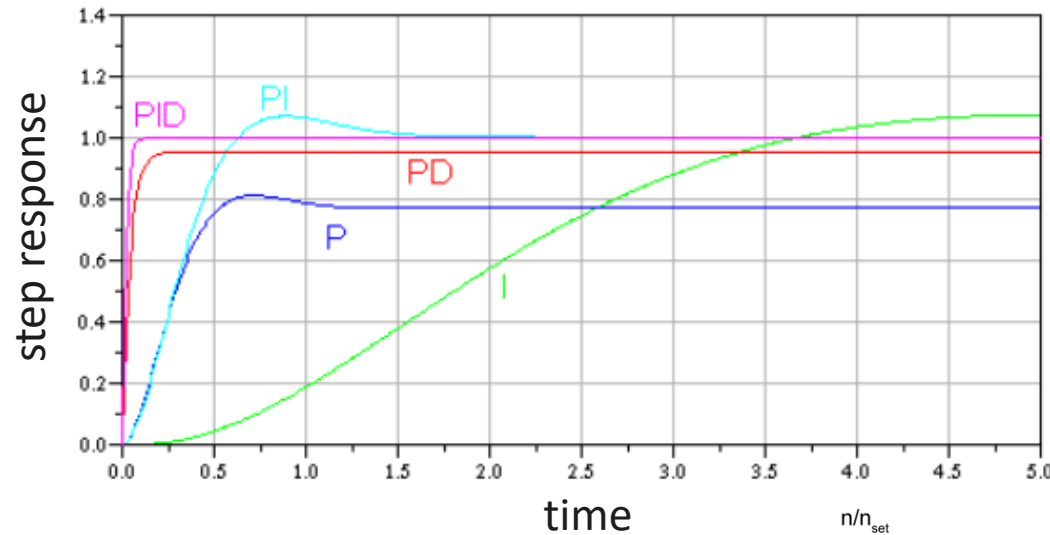
Verstärkung q-Achse/gain q-axis "Kpq" (ID34151):	0,64 V/A
Verstärkung d-Achse/gain d-axis "Kpd" (ID34152):	0,38 V/A
Nachstellzeitkonstante/time constant "Tnq" (ID34050):	1,2 ms
Nachstellzeitkonstante/time constant "Tnd" (ID34052):	1,2 ms
Adaption Verstärkung/adaption gain "Kpq2" (ID 34179)	20 %
Adaption Nachstellzeit/adaption time constant "Tnq2" (ID 34180)	400 %
Untere Anpaßschwelle/lower adaption limit "lua" (ID34177):	19 %
Obere Anpaßschwelle/upper adaption limit "loa" (ID34178):	68 %



Values determined by AMK

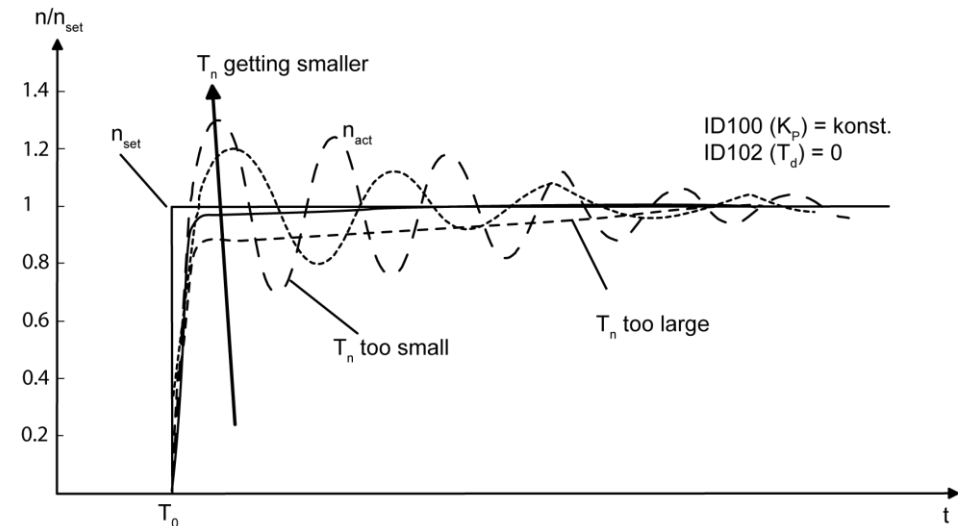


PID-Speed controller



Transfer function of the speed controller circuit,
effect ID100 'Speed control proportional gain KP' (KP)

2020 05 V2




Transfer function of the speed controller circuit,
effect ID101 'Integral-action time speed control TN' (T_n)



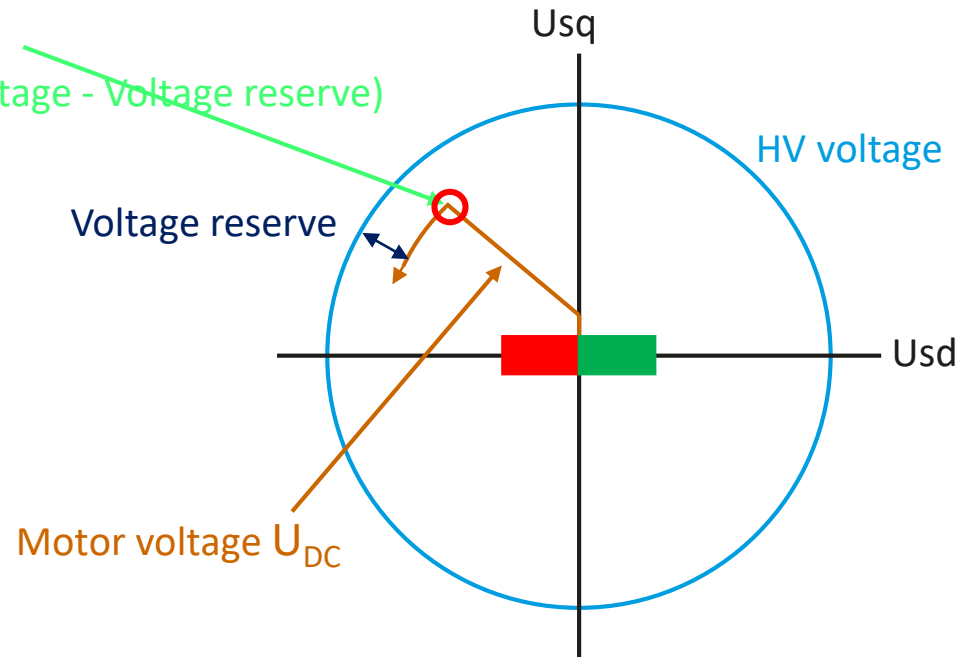
Acceleration and entry point into the field weakening



The entry point  into the field weakening is not fixed, it shifts through the variable HV voltage.

Entry into the field weakening
at motor voltage $U_{DC} > (\text{HV voltage} - \text{Voltage reserve})$

ID34212 'Voltage U_{sq} '
ID34213 'Voltage U_{sd} '
ID32836 'DC bus voltage' (HV voltage)
ID34266 'Voltage reserve'



Entry point into the field weakening

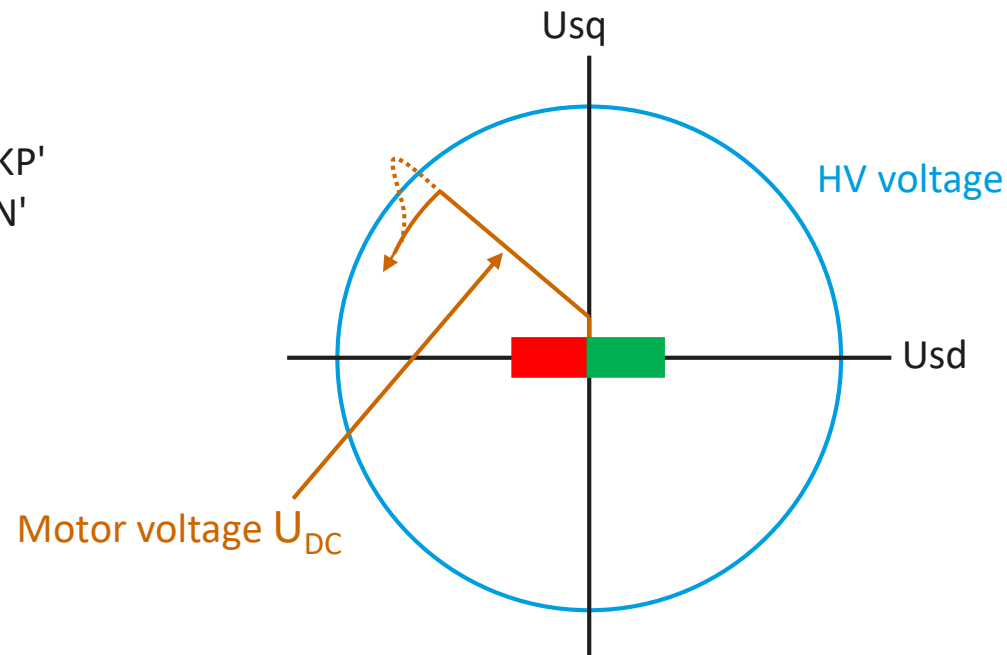
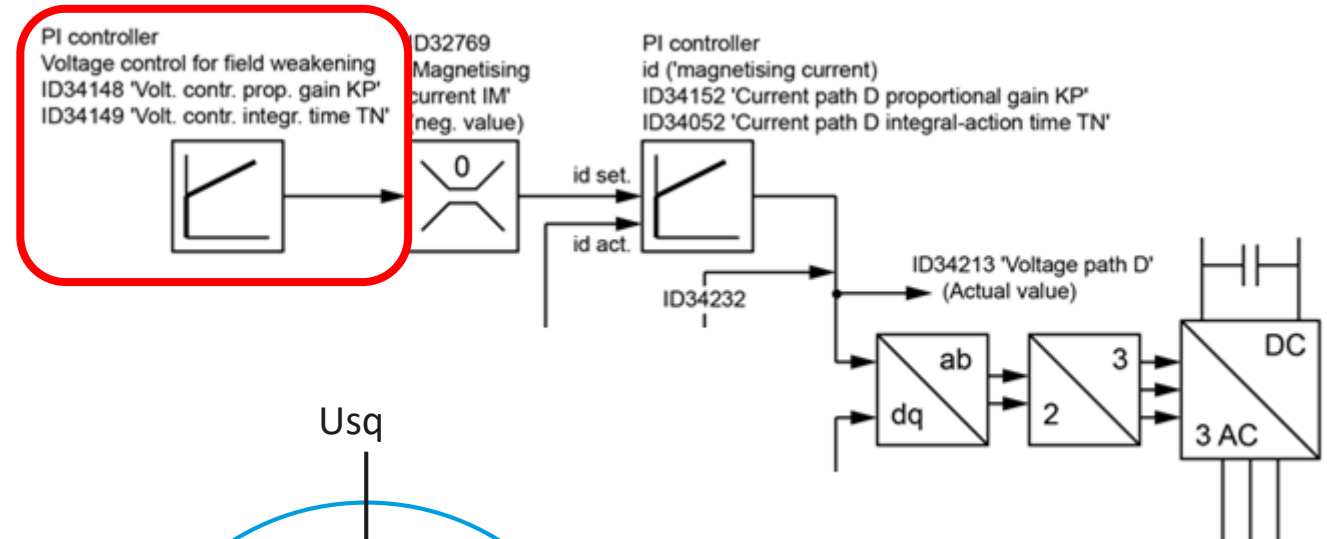


An optimized entry into the field weakening improves the performance of the engine.

The voltage control defines the settling properties of the field weakening current.

ID34148 'Voltage control proportional gain KP'

ID34149 'Voltage control integrating time TN'

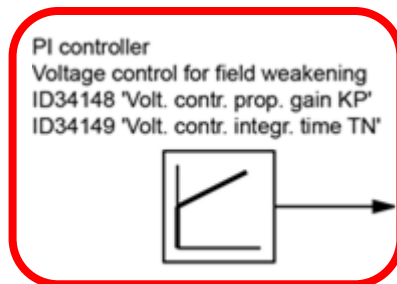


Entry point into the field weakening

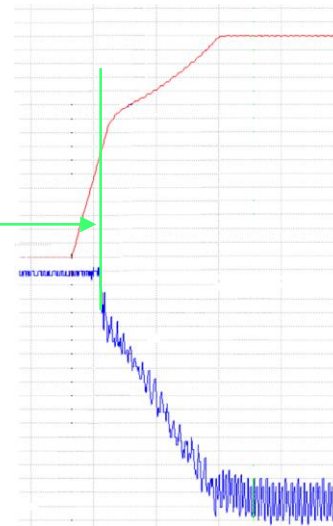
(Kink) Entry into the field weakening

Objective:

Minimization of the kink in the actual speed value when entering the field weakening, As small overshoot of the field weakening current.

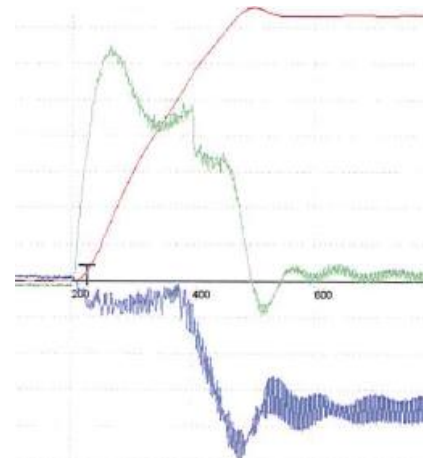


ID34148 'Voltage control proportional gain KP'
ID34149 'Voltage control integrating time TN'



ID40 'Actual speed value'

ID33185 'Actual magnetizing current value'



ID40 'Actual speed value'

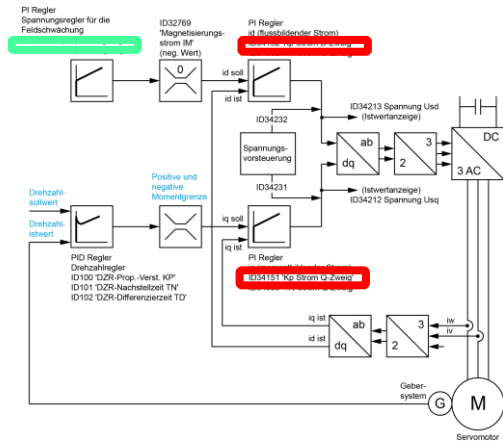
ID33186 'Actual torque current value'

ID33185 'Actual magnetizing current value'

Optimization of voltage controller for field weakening

PID controller-
speed controller
ID101 'Speed Integral Time TN'

e. g. 20 ms



PI controller-
voltage controller for field weakening
ID34149 'Voltage Integral Time TN'

Start value
between speed und current controller
e. g. 10 ms



Oscillation
TN voltage controller at least
factor 2 to current controller

PI controller-
id (field weakening current)

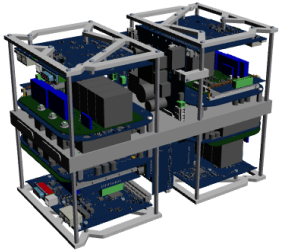
ID34052 'Integral Time D'

iq (torque current)
ID34050 'Integral Time Q'

e. g. 1 ms

Total currents with field weakening

Inverter



$I_{max} = 105 \text{ A}$

$f_{out} > 1 \text{ Hz}$ max. 10 s

$f_{out} < 1 \text{ Hz}$ max. 1 s

The inverter limits the output current in field weakening to I_{max}

$$I_{max} = \sqrt{I_d^2 + I_q^2}$$

Motor



$$I_s = \sqrt{I_d^2 + I_q^2}$$

The total current I_s is not automatically limited. The total current I_s may exceed the maximum current motor in some situations.

The setpoint torque value must be adjusted.

If i²t monitoring motor is active, I_d and I_q are taken into account. The FSE firmware limits the target torque.



Without i²t monitoring an inadmissible heating of the motor is possible.

ID32773 'Service bits', bit 14.

Setpoint torque value in field weakening

WARNING



Risk of unstable controller behavior

The torque setpoint may not be higher than the maximum torque that can be made available from the motor at the current operating point.

Possible consequences:

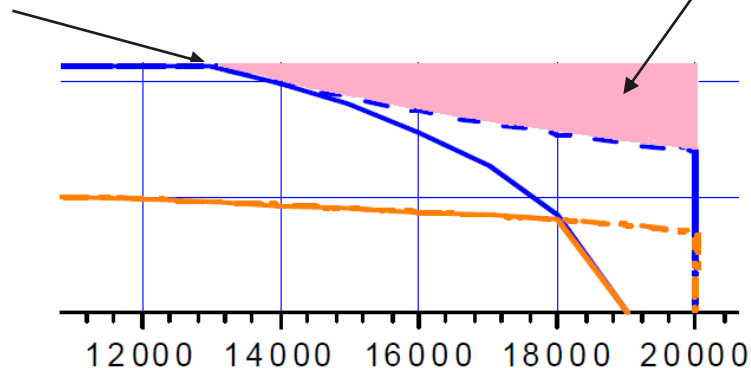
- Output terminal overcurrent (diagnoses-no. 2334), drive runs down
- Drive runs down (induced voltage > HV voltage = DC braking)

Steps to prevent:

Calculate maximum nominal torque specification and limit online

Entry point field weakening, setpoint torque input must be reduced

Target torque specifications in the pink range are not allowed.



The maximum motor torque in the field weakening depends on the HV voltage. Change in the HV voltage, especially when accelerating must be taken into account by the user.

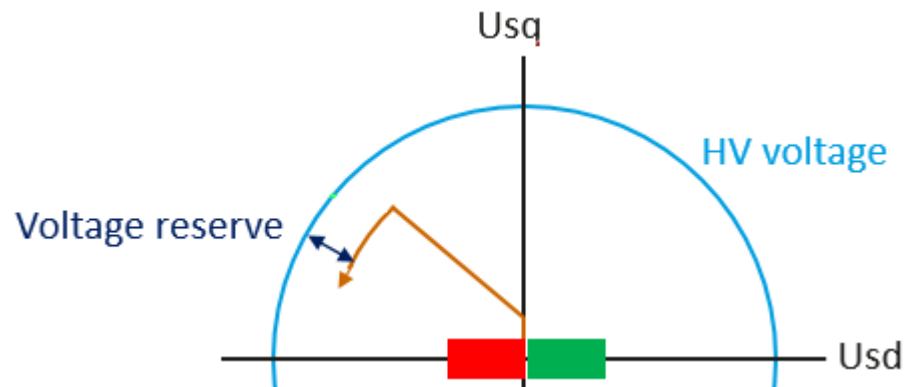
Parameterization field weakening

32953	Encoder type	003C	2
ID32953 Encoder type			
Nibble	Description	Assignment	
0	Motor encoder type	C - P - or Q- encoder	
1	Motor model	3 - Field-weakening synchronous motor	
2	Speed encoder	0 - Like motor encoder	
3	Position encoder	0 - Like motor encoder	

34266	Voltage reserve	30.0	V	2	Dec
-------	-----------------	------	---	---	-----

ID34266 'Voltage reserve'

The voltage reserve defines the reserve for the current controller.
Field weakening area starts at:
Motor voltage $U_{DC} > (U_{DC-Bus} - ID34266)$



2020 05 V2



Motor-Datenblatt *motor data sheet*

Bezeichnung/name **DD5-14-10-POW** - 18600-B5

Teile-Nr./part number **A2370DD**

Spannungsregler voltage controller:

Spannungsregler/voltage controller "Kp" (ID34148):

Spannungsregler/voltage controller "Tn" (ID34149):

0,08 A/V

6 ms



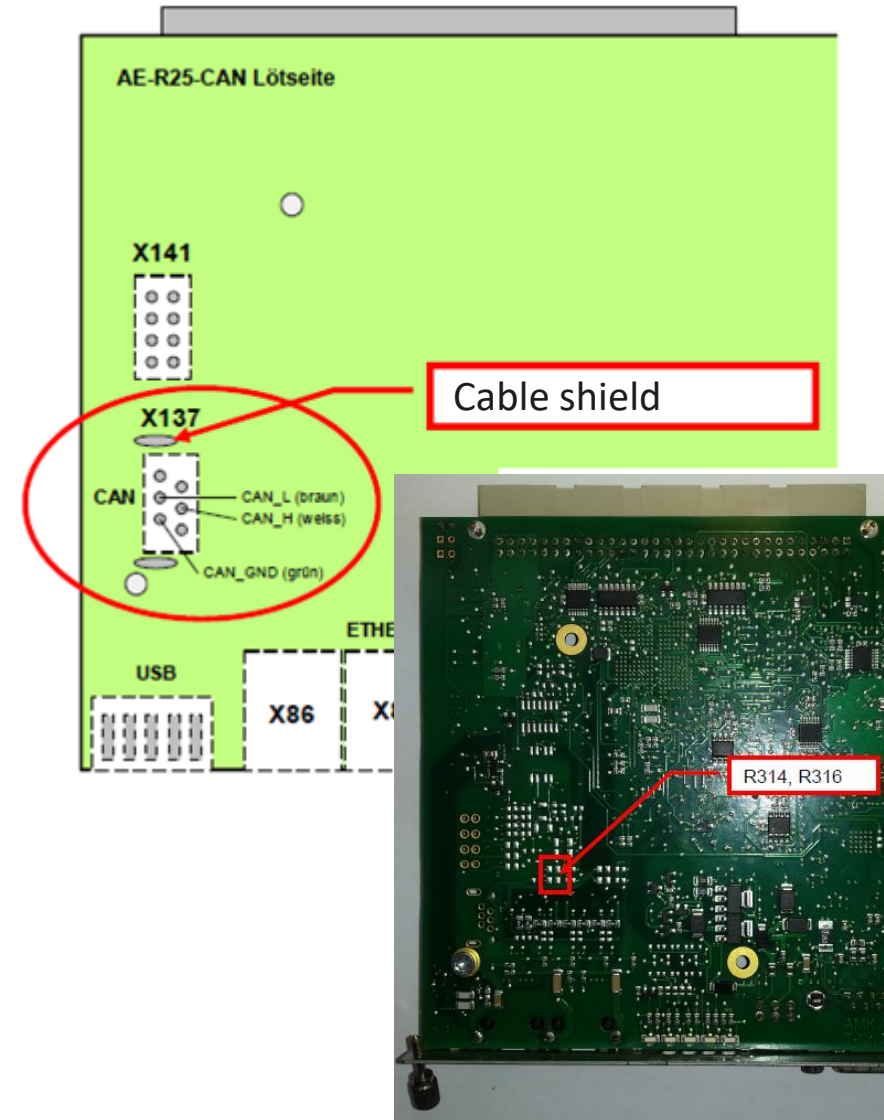
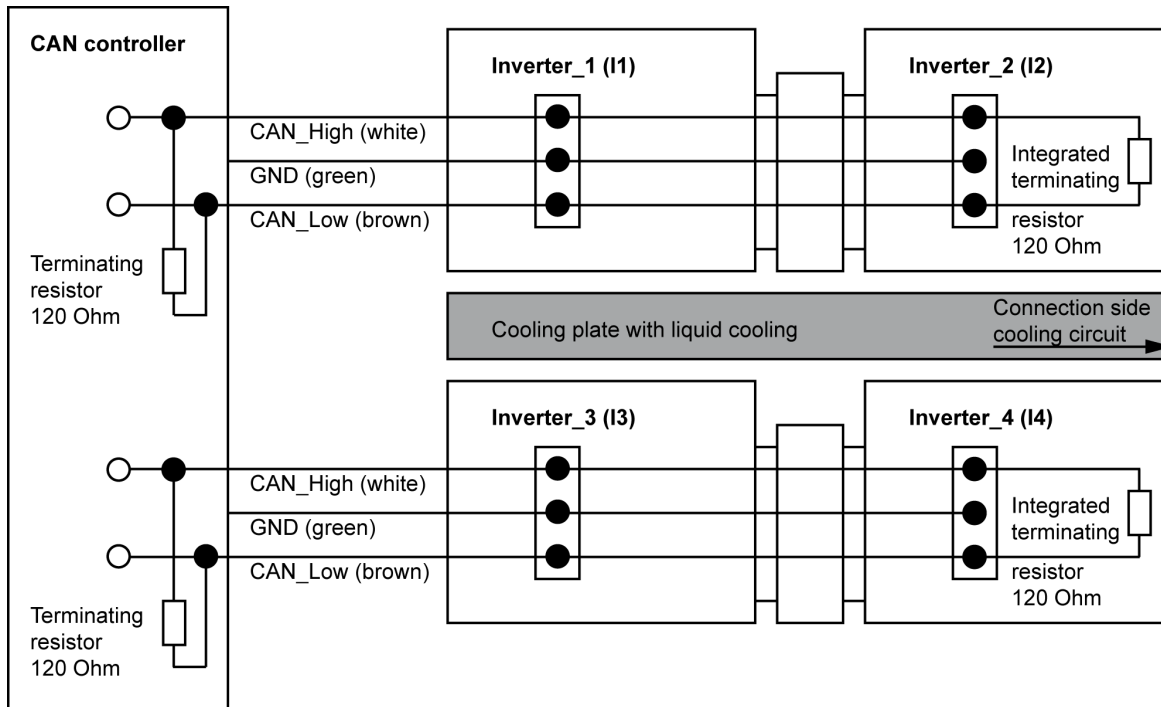


CAN communication



Wiring

It is planned that in each case one inverter pair (W1 + W2, or W3 + W4) is operated on a common CAN.



Termination resistor

Data exchange

Variant 1

Mode 'Fixed CAN message configuration'

Clearly defined CAN messages
are implemented for exchanging data.

AMK Actual Values 1

AMK Actual Values 2

AMK Setpoints 1

fixed

Variant 2

Mode 'Free CAN message configuration'

The data exchange between inverter and CAN controller can be
configured by the user.

SERCOS parameter (see documentation)

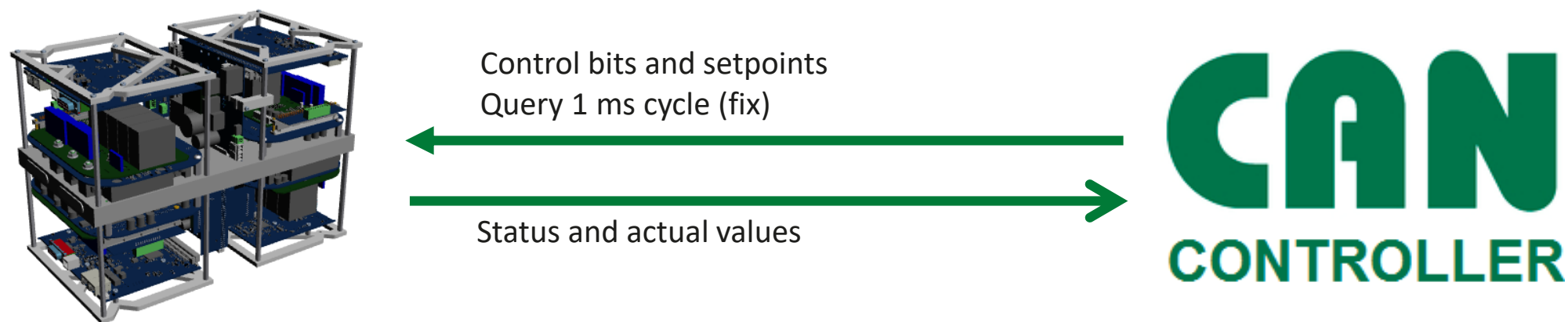
Special signals (see documentation)

free

Data messages

fixed

The data messages are 8 bytes long and are transmitted in Intel format.



Telegram failure monitoring (Fixed configuration):

Enable: Automatic with first received data telegram

Error message when telegram failure > 50 ms

Reaction: Coast (setpoint torque 0 %MN)

Mode 'Fixed CAN message configuration'

Description of the data telegrams

Control bits and setpoints (CAN controller → Inverter)	
AMK Setpoints 1 (0x183)	<ul style="list-style-type: none">Control word (Controller enable, HV enable, drive enable, clear error)Speed setpointTorque limitation positiveTorque limitation negative

fixed

Status bits and actual values (Inverter → CAN controller)	
AMK Actual Values 1 (0x282)	<ul style="list-style-type: none">Status word (System ready, error, warning, feedback and mirror HV enable and controller enable, derating active)Actual speedActual torque current (Iq)Actual magnetic current (Id)
AMK Actual Values 2 (0x284)	<ul style="list-style-type: none">Motor temperatureColdplate temperatureDiagnosis numberIGBT temperature

Mode 'Fixed CAN message configuration'

fixed

Name	Basic address	Node address	CAN Identifier
AMK Actual Values 1	0x282	X	0x282 + x
AMK Actual Values 2	0x284	X	0x284 + x
AMK Setpoints 1	0x183	X	0x183 + x

Example:

Node address	ID34091 'Anwenderliste 3'	CAN Identifier	Name
1	0x0104	0x283 0x285 0x184	AMK Actual Values 1 AMK Actual Values 2 AMK Setpoints 1
2	0x0204	0x284 0x286 0x185	AMK Actual Values 1 AMK Actual Values 2 AMK Setpoints 1

Mode 'Fixed CAN message configuration'

fixed

AIPEX configuration example with default values

ID	Name	Wert	Länge	Typ
34091	User list 3	3	*2	Hex
34091-1	[maximum]	[1024]		
34091-2	Node address and mode	0104	2	Hex
34091-3	Transmission rate in kBit/s	0000	2	Hex
34091-4	Output rate in ms	0000	2	Hex

High byte) node address = 0x01

(Low Byte) Fixed configuration = 0x04

Transfer rate in kBit / s = 0 = default value 500 kBit / s

Output rate in ms = 0 = default value 5 ms

AIPEX configuration example with variable transmission and output rate

ID	Name	Value	Length	Type
34091	User list 3	3	*2	Hex
34091-1	[maximum]	[1024]		
34091-2	Node address and mode	0104	2	Hex
34091-3	Transmission rate in kBit/s	1000	2	Dec
34091-4	Output rate in ms	1	2	Dec

(High byte) node address = 0x01

(Low Byte) Fixed configuration = 0x04

Transmission rate in kBit / s = 1000

Output rate in ms = 1

Mode 'Free CAN message configuration'

Characteristics:

- CAN 2.0 A bus supports the 11-bit identifier format ('base frame format')
- Any CAN identifier
- Transmission in Intel format
- Up to 10 send messages which can contain up to 10 signals
- Up to 10 receive messages each containing up to 10 signals
- Transmission of SPECIAL signals
- Transmission of SERCOS parameters
- Limitation data range of a signal
- Cyclic transmission, variable output rates in 1 ms steps
- Event-controlled transmission, variable delay time in 1 ms steps
- Variable transfer rate
- Inverted control signal for the plausibility check of setpoints and actual values
- Telegram failure monitoring
- Message counter
- Checksum



Mode 'Free CAN message configuration'

free

Structure

ID34091 'User List 3':

Selection mode

Total of send messages
(max. 10 send messages)

Head send message 1

Total of signals
(max. 10 signals)

Signal 1
Signal 2

...

Head send message 2

...

Total of receive messages
(max. 10 receive messages)

Head receive message 1

Total of signals
(max. 10 signals)

Signal 1
Signal 2

...

Head receive message 2

...

Transmission rate

The end



Maximum data length of 8 bytes
Transmission rate for the selected
transmission cycles must be sufficient.

Available signals:

SERCOS parameters

SPECIAL signals

See documentation



Mode 'Free CAN message configuration'

free

34091	User list 3	56		*2	Hex	
34091-1	[maximum]	[1024]				
34091-2	Selection mode	01		1	Hex	Mode: Free CAN message configuration
34091-3	Total of send messages	2		1	Dec	
34091-4	CAN Identifier send messages 1	0283		2	Hex	Start Sending message 1
34091-5	Cycle in ms	5		2	Dec	Cycle 5 ms
34091-6	Data length in byte	8		1	Dec	
34091-7	Attribute	00		1	Hex	Send cyclically
34091-8	Total of signals	4		1	Dec	
34091-9	Signal type	2		1	Dec	Signal 1
34091-10	Subindex	0		1	Dec	
34091-11	Index	3		2	Dec	Status word
34091-12	Length in bits	16		1	Dec	
34091-13	Shift in bits	0		1	Dec	
34091-14	Attribute signal	00		1	Hex	
34091-15	Signal type	2		1	Dec	Signal 2
34091-16	Subindex	0		1	Dec	
34091-17	Index	5		2	Dec	Actual speed
34091-18	Length in bits	16		1	Dec	
34091-19	Shift in bits	16		1	Dec	
34091-20	Attribute signal	02		1	Hex	Signal is signed
34091-21	Signal type	2		1	Dec	Signal 3
34091-22	Subindex	0		1	Dec	
34091-23	Index	25		2	Dec	Actual current value



Little-Endian / Intel-Format

When transmitting data, the low-order value is listed first. Example for positive and negative values:

1.	Setpoint value <Torque limitation positive>	30 %MN
2.	The torque scaling is 0.1 %MN	300 (dec)
3.	Conversion into hex (Big-Endian / Motorola-Format)	<u>01</u> <u>2C</u> (hex)
4.	Switch to Little-Endian / Intel-Format	<u>2C</u> <u>01</u> (hex)

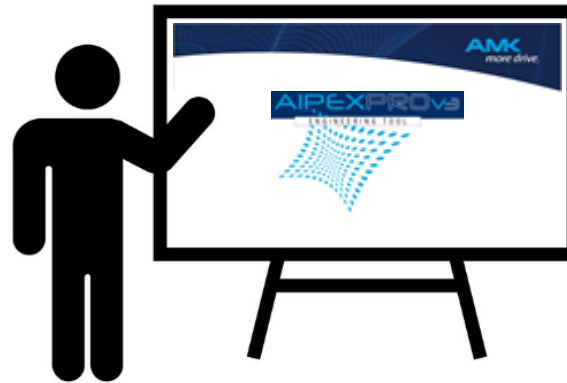
1.	Setpoint value <Torque limitation negative>	-30 %MN
2.	The torque scaling is 0.1 %MN	-300 (dec)
3.	Conversion into hex (2 BYTE = 1 WORD!) (Big-Endian / Motorola-Format)	<u>FE</u> <u>D4</u> (hex)
4.	Switch to Little-Endian / Intel-Format	<u>D4</u> <u>FE</u> (hex)



Set calculator
to 'WORD' format



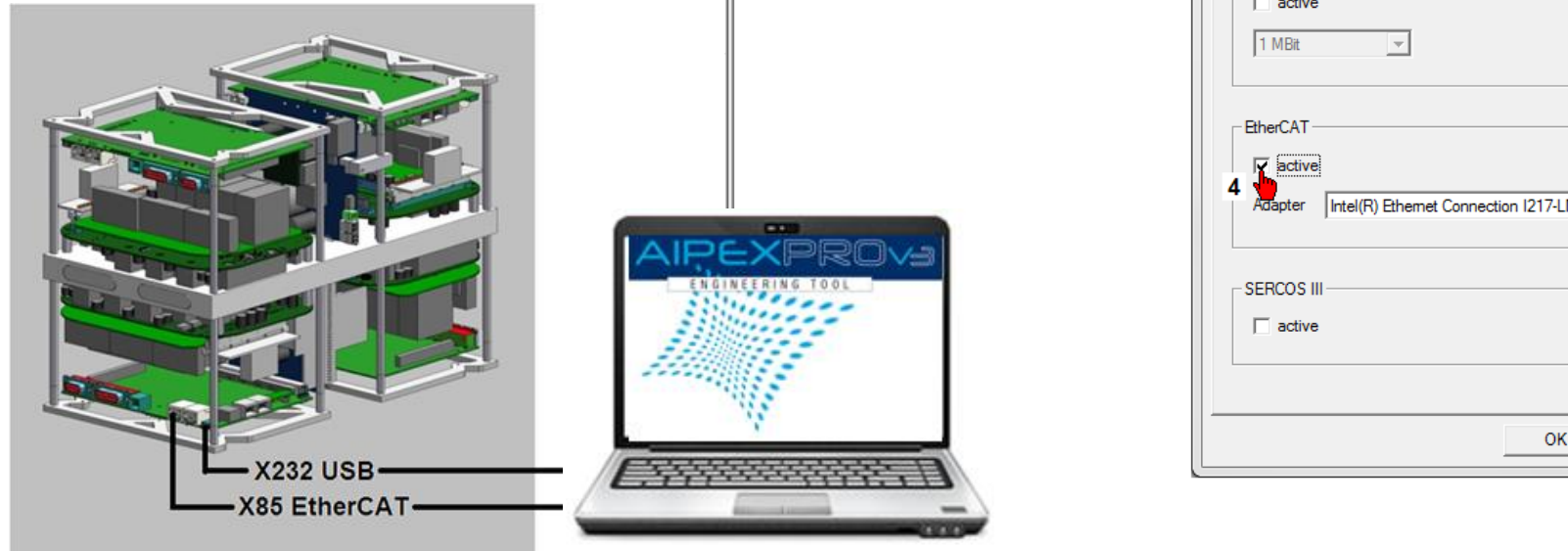
AIPEX PRO



2020 05 V2

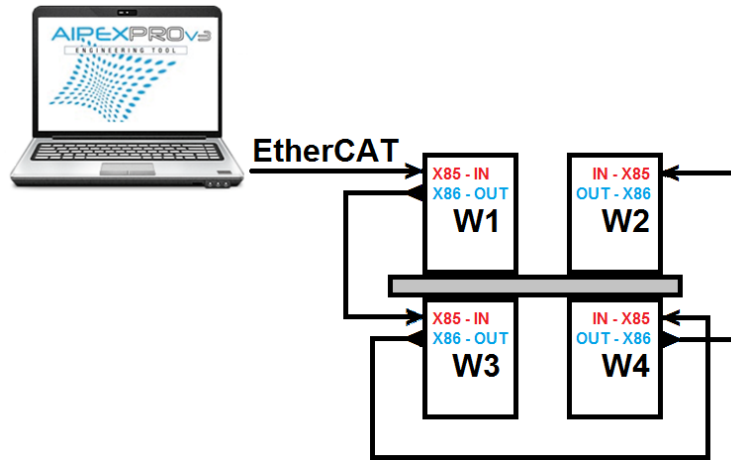


EtherCAT communication settings (EtherCAT)



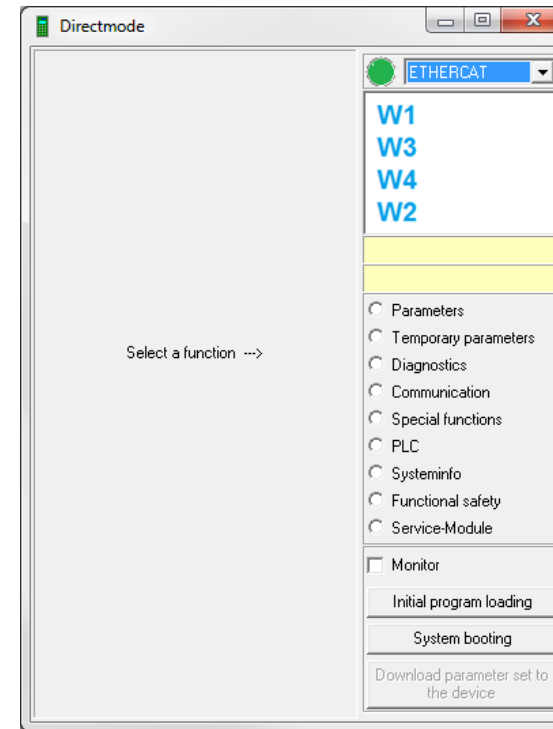
The USB interface is always active,
no settings required!

Network connection (EtherCAT)

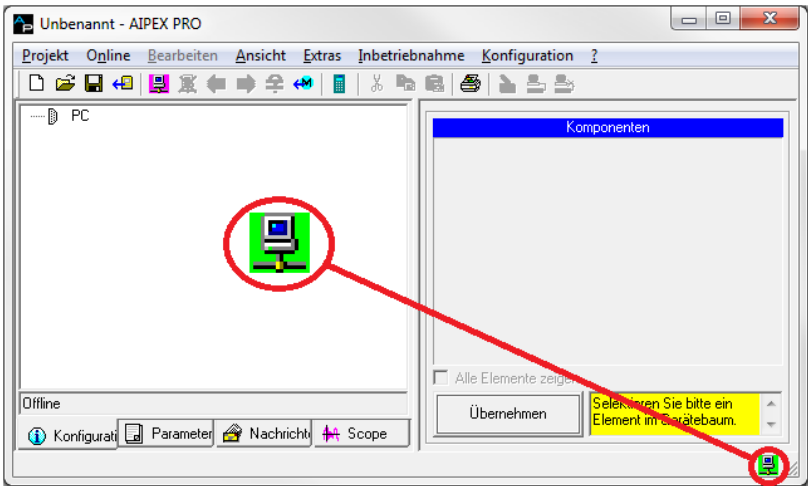


Fixed EtherCAT
addressing useful

Example Direct mode



Communication test



**Logic supply
24 VDC ON**

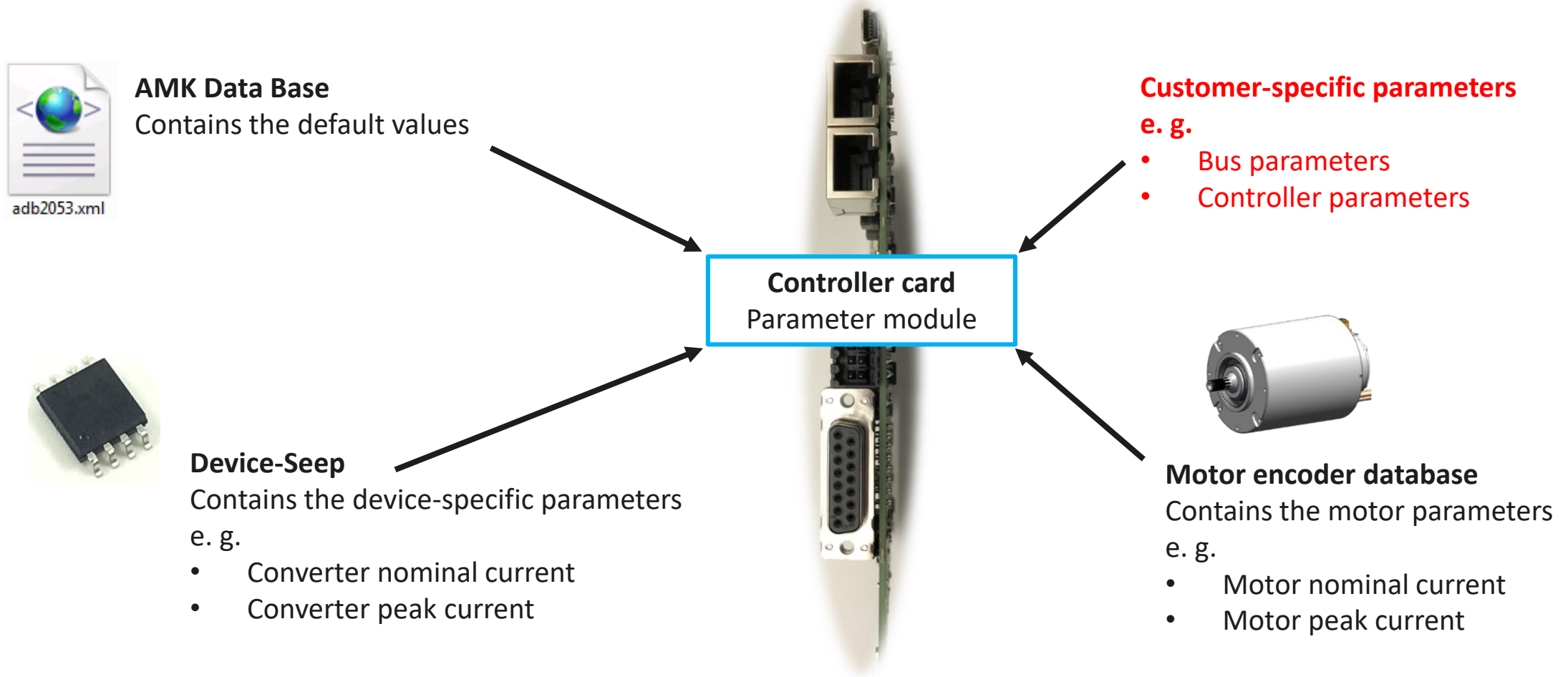
green symbol	Activated connection between the AIPEX PRO PC and the AMK device.
no or red symbol	No connection established, no interface defined, AIPEX PRO window not at full screen.
two-colored symbol (green / red)	Multiple communication interfaces activated in AIPEX PRO.



First plug in the adapter, then install AIPEX PRO

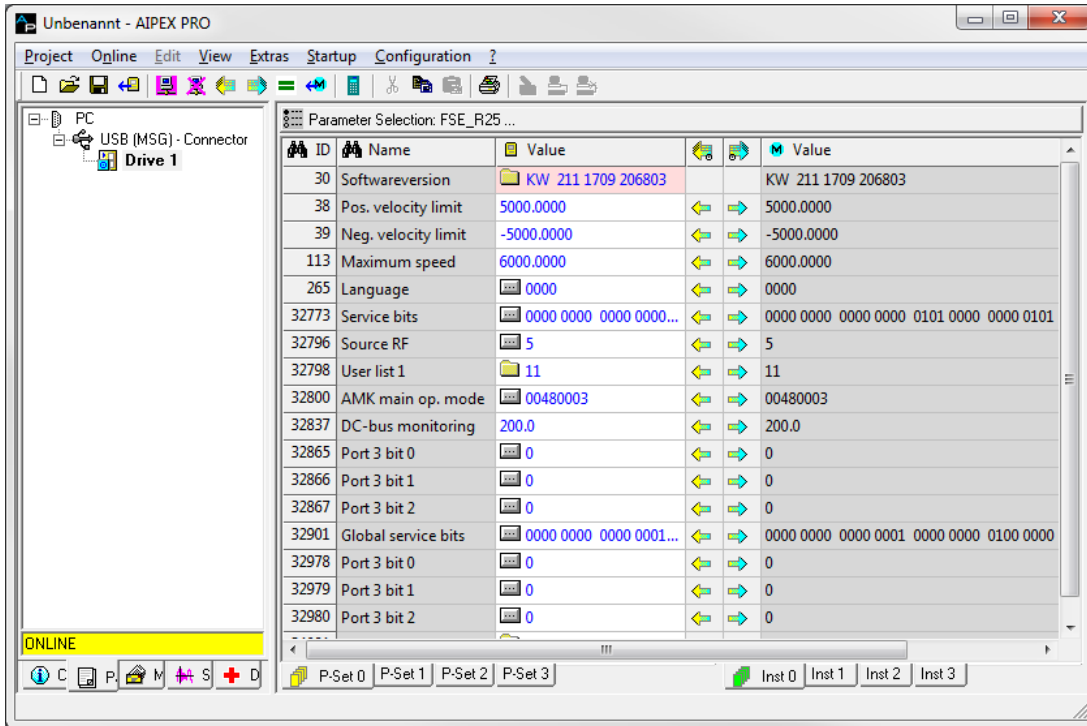


Parameter module

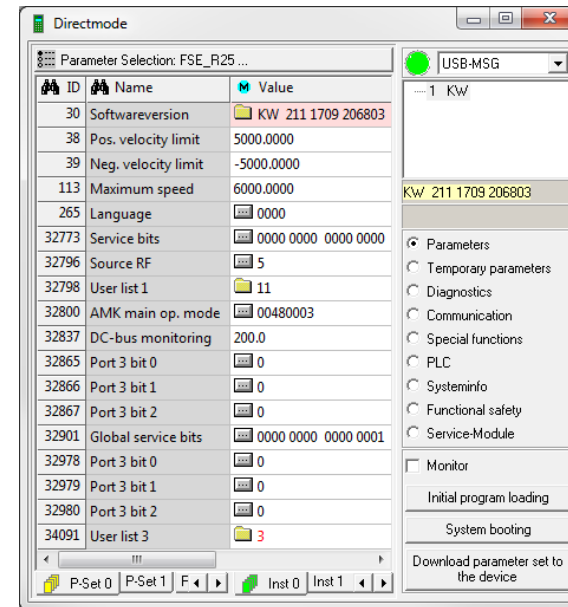


Parameter access

Variant: AIPEX PRO project



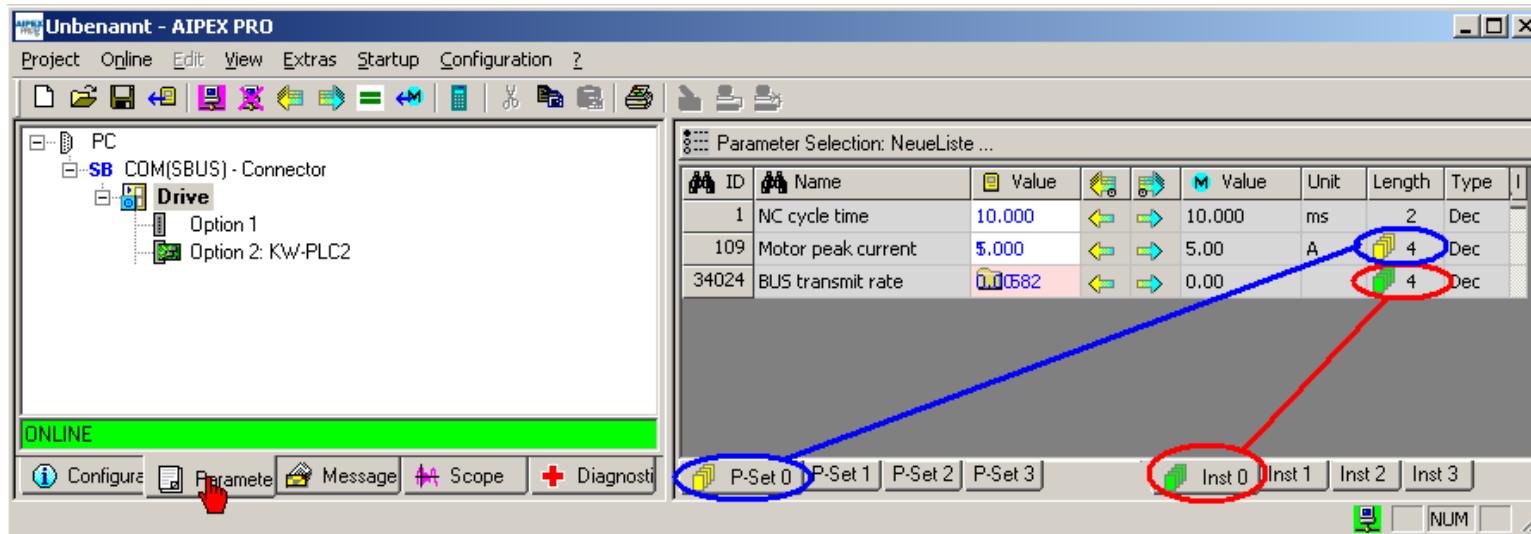
Variant: Direct mode



2020 05 V2



Parameter display AIPEX PRO



 Wert Offline value (PC)

 Wert Online value (AMK device)



 P-Satz 0 Relevant parameter set

 Inst 0 CAN Bus

Activate parameter change

Remanent parameters

Ways to activate parameters	24 VDC OFF/ON	RF (OFF)/ON	System booting 1)	System reset
Global parameter e. g. ID265 Language	✓	✗	✓	✓
Instance parameter e. g. ID34025 Bus mode	✓	✗	✓	✓
Drive-specific parameter e. g. ID32800 Main operating mode	✓	✓	✓	✓

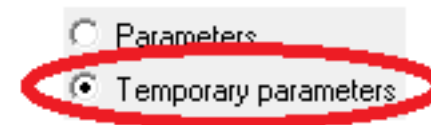
1) Does not work with ID2 and ID34023

ID33730 System booting or function in AIPEX PRO available

ID33732 System reset

Temporary parameters

Changes are effective immediately



Parameterization with AIPEX PRO

Parameter Selection: FSE_R25 ...

ID	Name	Value
30	Softwareversion	KW 211 709 206803
38	Pos. velocity limit	5000.0000
39	Neg. velocity limit	-5000.0000
113	Maximum speed	6000.0000
265	Language	0000
32773	Service bits	0000 0000 0000 0000
32796	Source RF	5
32798	User list 1	11
32800	AMK main op. mode	00480003
32837	DC-bus monitoring	200.0
32865	Port 3 bit 0	0
32866	Port 3 bit 1	0
32867	Port 3 bit 2	0
32901	Global service bits	0000 0000 0000 0000
32978	Port 3 bit 0	0
32979	Port 3 bit 1	0
32980	Port 3 bit 2	0
34041	User list 3	3

Parameter Selection

☐ All parameters
☐ Single group
☒ Own list

System internal parameters
☒ display

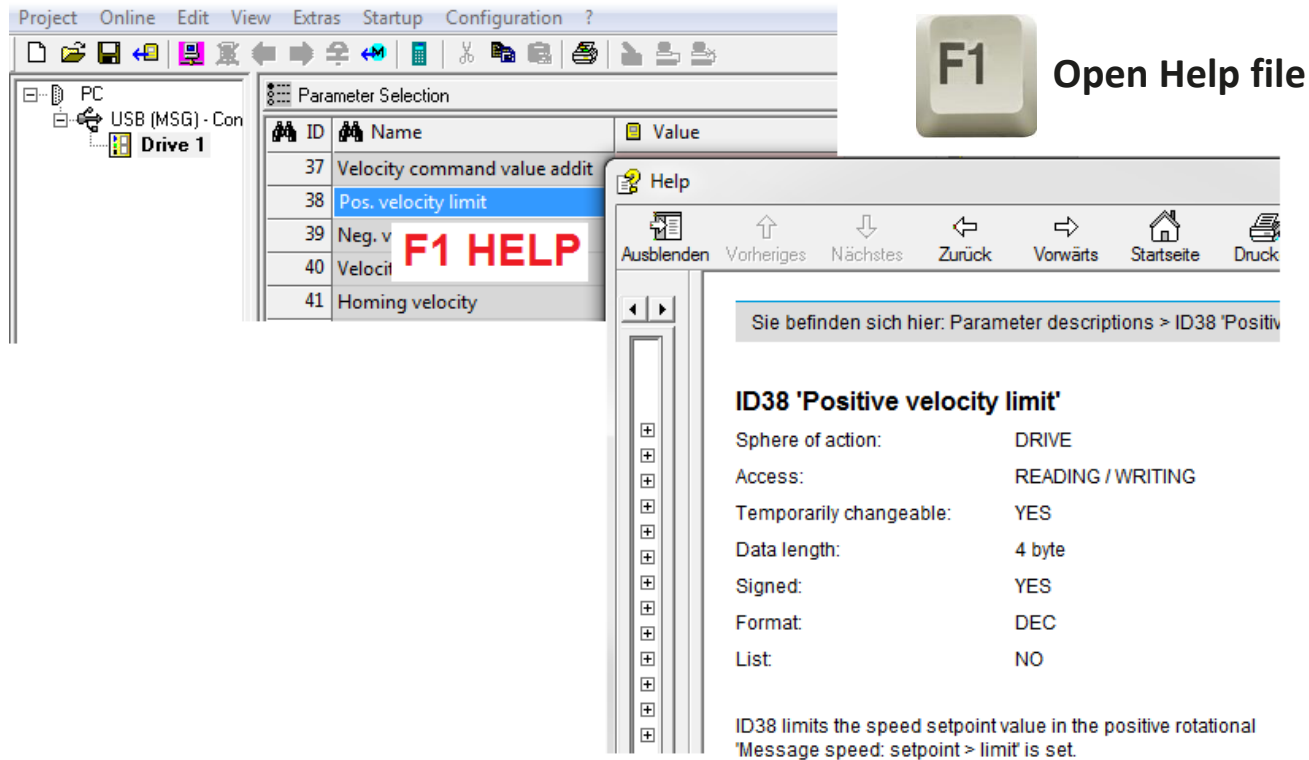
Admit changes (password) 500591

FSE_R25,30,38,39,113,265,32773,32;



The 'Own list' must be entered manually

Parameter help file



The screenshot shows the AMK software interface. On the left, a tree view shows 'PC' and 'USB (MSG) - Con'. Below it, 'Drive 1' is selected. The 'Parameter Selection' table is open, showing a list of parameters. The 'Pos. velocity limit' parameter (ID38) is highlighted. A red 'F1 HELP' text is overlaid on the table. To the right, a 'Help' window is open, displaying the details for ID38 'Positive velocity limit'. The window includes a navigation bar with buttons like 'Ausblenden', 'Vorheriges', 'Nächstes', 'Zurück', 'Vorwärts', 'Startseite', and 'Druck'. The main content area shows the parameter details and a description.

ID	Name	Value
37	Velocity command value addit	
38	Pos. velocity limit	
39	Neg. v	
40	Velocit	
41	Homing velocity	

Help

Sie befinden sich hier: Parameter descriptions > ID38 'Positiv

ID38 'Positive velocity limit'

Sphere of action:	DRIVE
Access:	READING / WRITING
Temporarily changeable:	YES
Data length:	4 byte
Signed:	YES
Format:	DEC
List:	NO

ID38 limits the speed setpoint value in the positive rotational 'Message speed: setpoint > limit' is set.

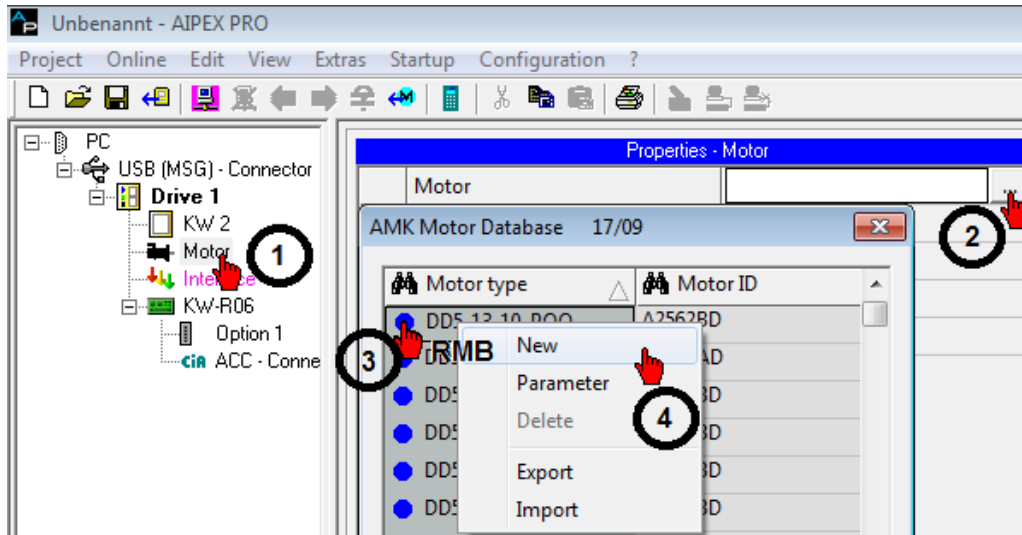


Open Help file



Most parameters
have no influence on the FSE functionality.

Motor parameter



Motor-Datenblatt motor data sheet

Bezeichnung/name **DD5-14-10-POW** - 18600-B5

Teile-Nr./part number **A2370DD**

Motorbeschreibung motor description:

Motorprinzip/motor principle: synchron
Kühlart/cooling type: Flüssigkeit
Bauform/mounting type: IMB5
Schutzart/degree of protection: IP 65
Isolierklasse/insulation class: F

Leistungsdaten performance data:

Betriebsart/duty type: S1 dT=80K
Dauerstillstandsmoment/continuous Stall Torque "Mo": 13,8 Nm
Maximales Moment/maximum torque "Mmax": 21 Nm
Bemessungsmoment/rated torque "Mn" (ID32771): 9,8 Nm
Bemessungsleistung/rated power "Pn": 12,3 kW
Bemessungsdrehzahl/rated speed "Nn" (ID32772): 12000 rpm
Theo. Leerlaufdrehzahl/theor. no-load-speed "No": 18617 rpm

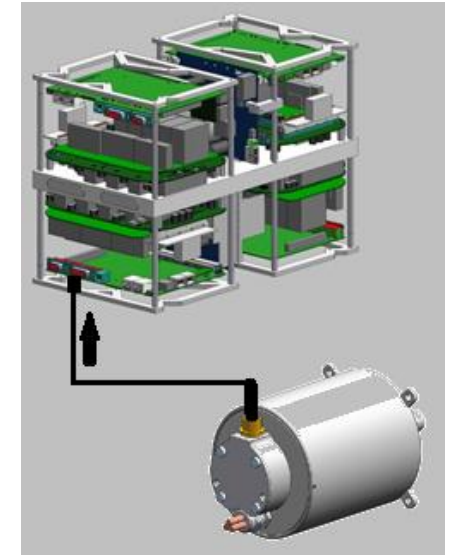
Encoder with memory

The motor parameter will automatically upload into a initial load device

NOTICE

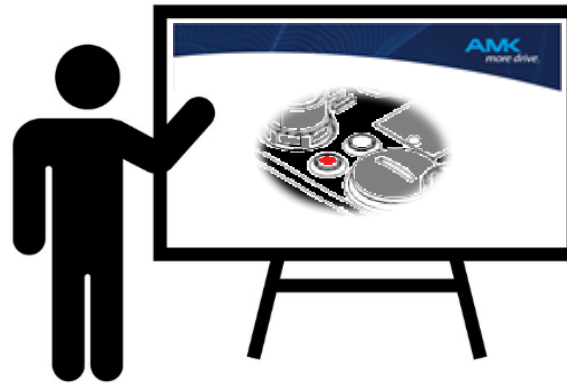
The I²t monitoring motor must be activate manually.

32773 Bit 14 = 1

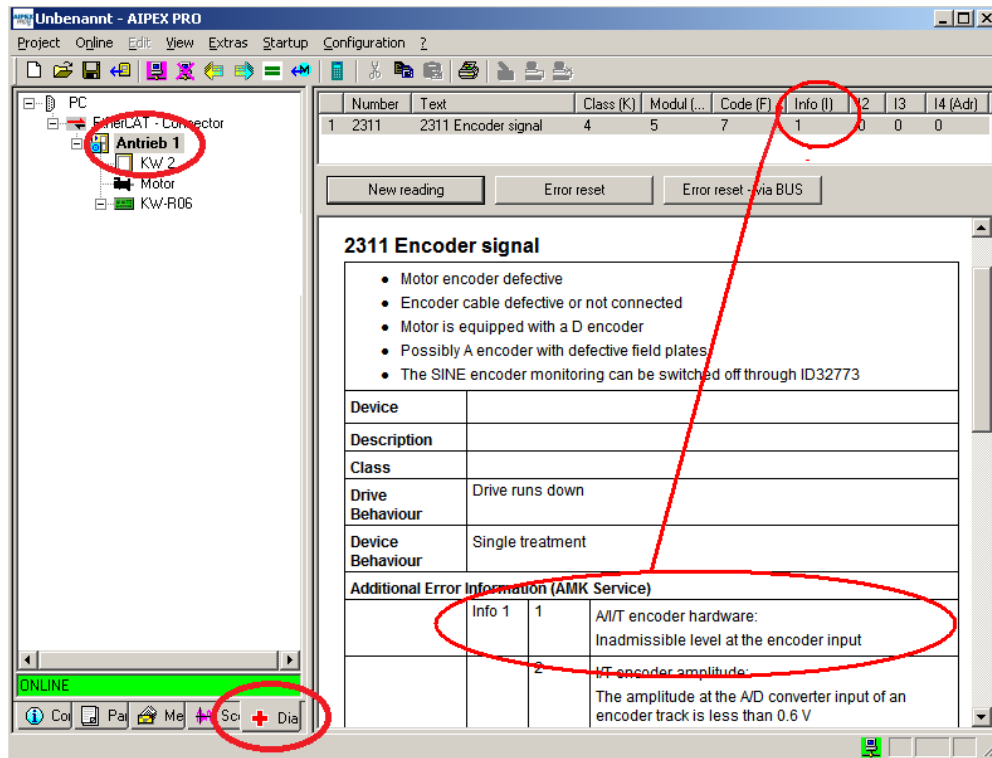




Diagnose

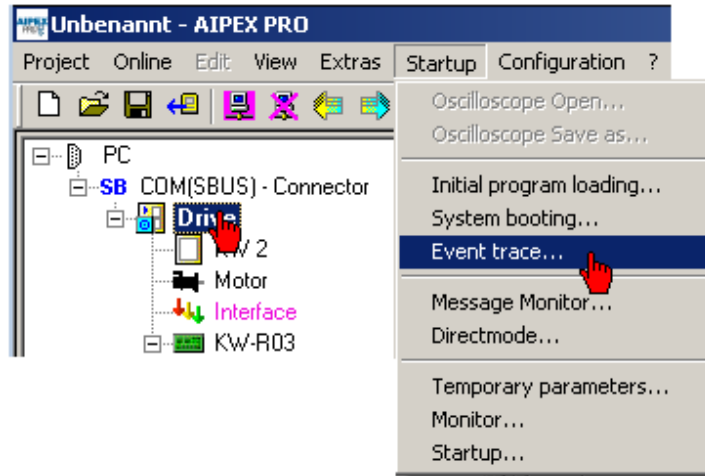


Diagnostic with AIPLEX PRO



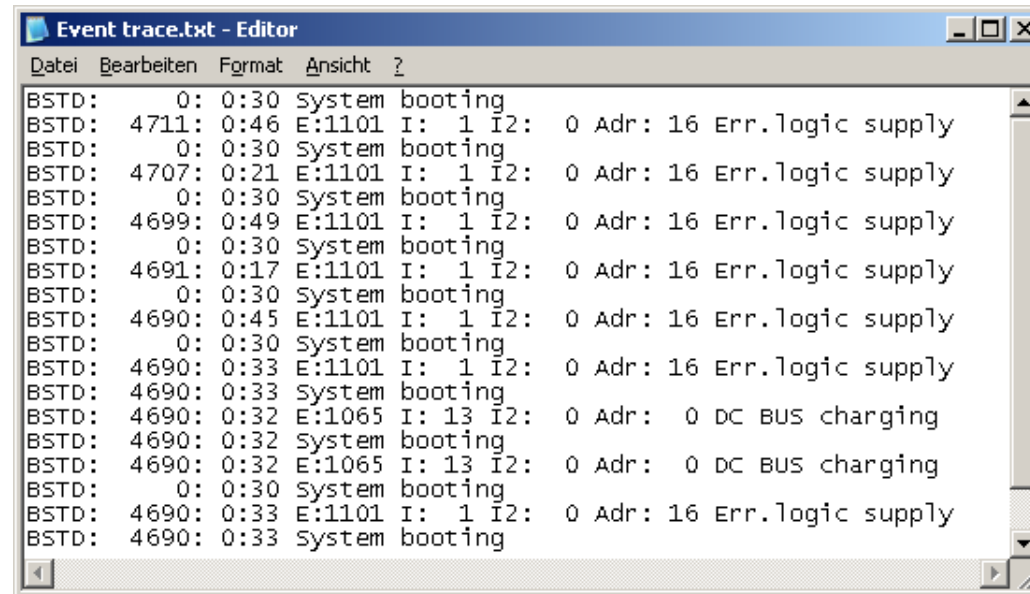
Pay attention to the additional information

Event trace

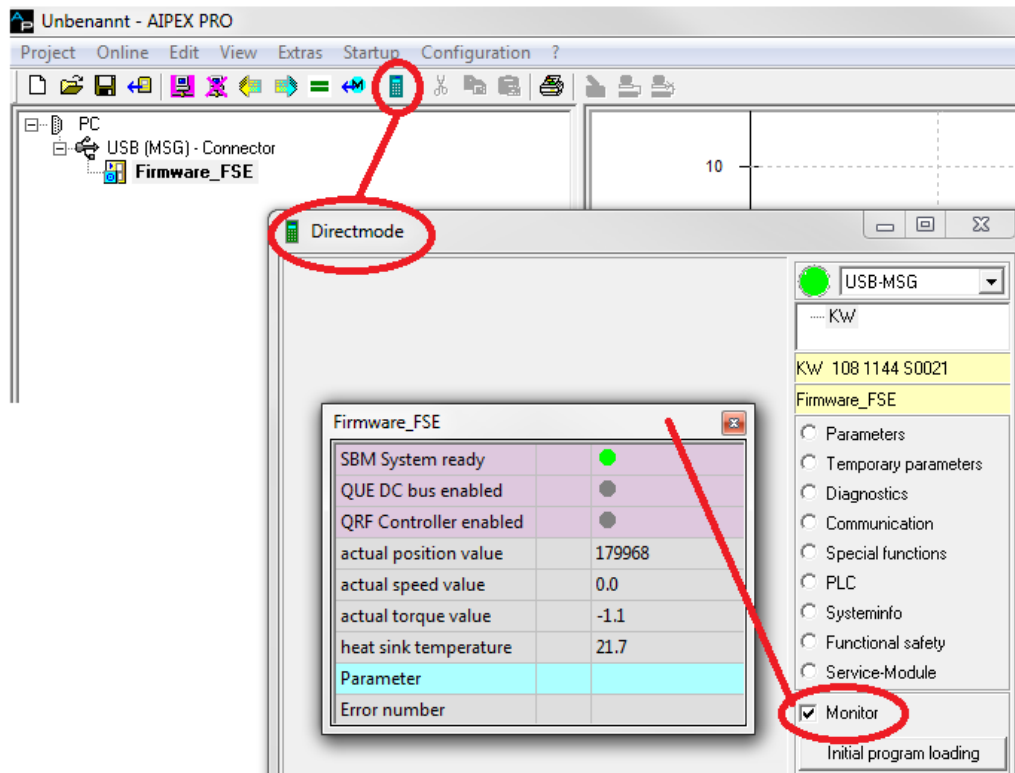


Parameter
ID34088 Event trace

Fifo memory



Direktmode AIPEX PRO



Direct mode

Online access to Parameter, Temporary Parameters, Diagnose, Communication

...

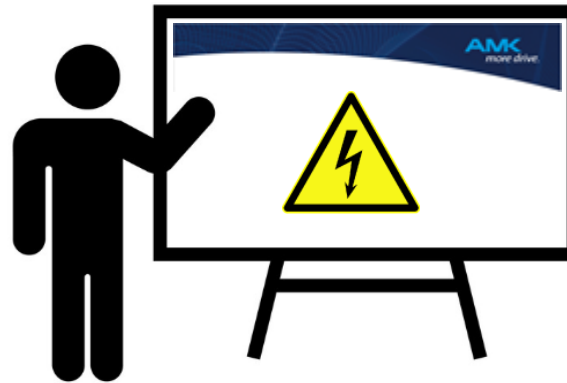
Monitor function

Displays cyclic actual values.

Displayed values are configurable.



For your Safety



2020 05 V2

For your safety

Safety Rules

In particular on drive systems, the instructions pertaining to safety and the following five safety rules have to be kept in the specified sequence:

1. Switch off electrical circuits (also electronic and auxiliary circuits).
2. Secure against being switched on again.
3. Determine that there is no voltage.
4. Earth and short circuit.
5. Cover or close off neighbouring parts that are under voltage.

Reverse the measures taken in reverse order after completing the work.



For your safety

DANGER



30 min *

Lethal electrical hazard when touching electrical connections!

Electrical terminals and connectors carry voltages that may cause death or serious injury upon contact. In OFF state, the LED indicators on the device front panels do not indicate the voltage status of the terminals.

Steps to prevent:

Wait at least 30 minutes for components to discharge.

At each work at the units the five safety rules have to be keeping in.

Measure the voltage at the clamps. They must be free of voltage.

Connection or disconnection of terminals is only allowed if they are free of voltage.

* without active discharge



For your safety

DANGER



Lethal electrical hazard when touching electrical connections!

The permanent magnets of the rotor of a synchronous machine induce dangerous direct current at the motor connections when the axis rotates.

Steps to prevent:

- Make sure that the motor shaft does not rotate.
- Prior to any work on the device: Observe the 5 safety rules.



For your safety

WARNING



Risk of burns when touching hot surfaces!

The casing temperature, for example of the line filter, the choke or the braking resistance, can be more than 60 degrees Celsius during and even after operation. Contact causes burns.

Steps to prevent:

- Make sure that the surfaces have cooled down.
- Wear protective clothing such as gloves if hot parts need to be touched.
- Fit a warning shield with warning hot surface.



For your safety

NOTICE

Material Damage!

Material damage from excessive DC bus voltage!

If the PWM is blocked in the case of an error with synchronous motors that are operated in field weakening, the still rotating motor induces a voltage that is higher than that of the supplying DC bus. Due to the induced voltage, a current flows into the DC bus via the free-wheeling diodes in the inverter so that the voltage in the DC bus may rise above the permissible value and can therefore destroy the power supply.

Steps to prevent:

- Ensure that the current regeneration of the power supply is active.
- Use an appropriately sized brake resistor at the feed-in.



For your safety

NOTICE

Material Damage!

Electronic components could be destroyed through static discharge!

Therefore touching of the electrical connections (e.g. signal and power supply cable or option and controller cards) must be avoided.

Steps to prevent:

- Avoid touching electrical connections and contacts during handling the electronic component
discharge yourself by touching PE
- Pay attention to the ESD-notes (electrostatic discharge)





Demo



2020 05 V2



Test at the AMK Demo

DC BUS Voltage

At power on > Torque values must be 0

☐ AMK_bSystemReady

☐ AMK_bWarn

☐ AMK_bError

Derating

AMK_ErrorInfo: %d

AMK_bErrorReset

AMK_bEnable

☐ AMK_bDcOn

☐ AMK_bQuitDcOn

☐ AMK_bInverterOn

☐ AMK_bQuitInverterOn

AMK_ActualVelocity: %d 1/min

AMK_TempInverter: %d C°

AMK_TorqueCurrent: %d

AMK_MagnetizingCurrent: %d

AMK_TempMotor: not supported

AMK_TempIGBT: not supported

Accelerate - AMK_TorqueLimitPositiv - Setpoint 0.1 %%NM: %d

◀

▶

Decelerate - AMK_TorqueLimitNegativ - Setpoint - 0.1 %%NM: %d

◀

▶

TargetVelocity Setpoint 1/min: %d

▲

▼

Energize the engine
Set RF controller
enable:

Requirement:
QUE = 1 (DC ON)

Hardware
signals

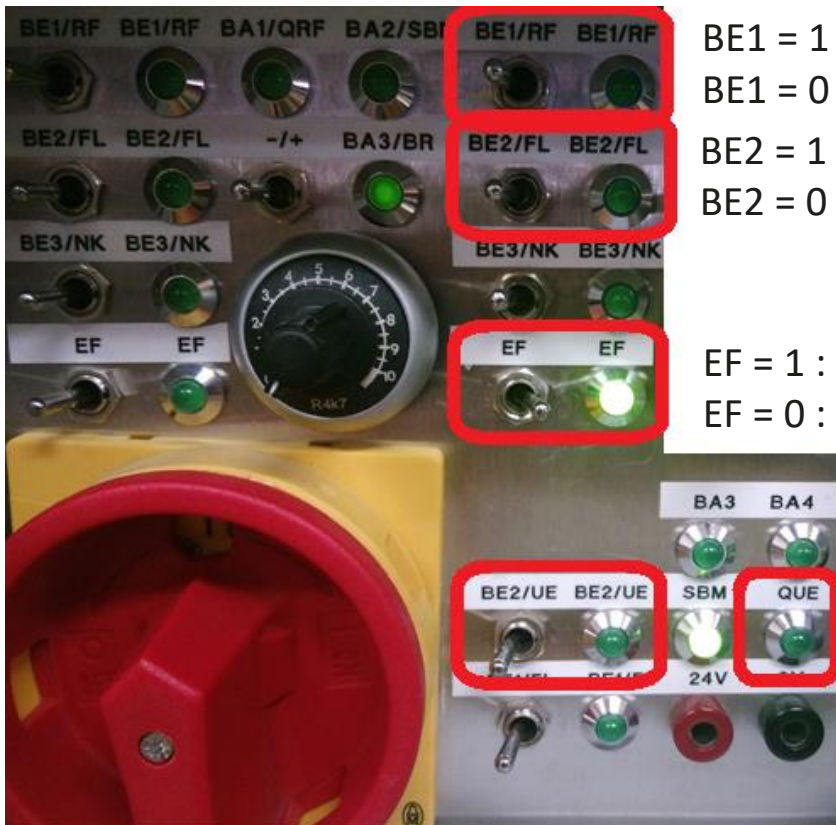
Switch EF
Switch BE1 / RF

Software signals

AMK_bEnable
AMK_bDCOn
AMK_bInverterOn



AMK Demo



BE1 = 1 : RF Controller enable possible

BE1 = 0 : RF Controller enable locked

BE2 = 1 : Torque limits active

BE2 = 0 : Torque limits deactivate, Motor torque less

EF = 1 : Motor can be energized

EF = 0 : Motor can not be energized

BE2 = 1 : HV (DC Bus) charge

BE2 = 0 : HV (DC Bus) discharge

QUE = 1 : HV (DC Bus) active

QUE = 0 : HV (DC Bus) deactivate



Positive edge
required

2020 05 V2



*THANK YOU FOR YOUR
ATTENTION*

Combined expertise of a strong group

AMK Holding GmbH & Co. KG

Gaußstraße 37-39
73230 Kirchheim/Teck
Germany

Phone: +49 7021 5005 0

info@amk-group.com

**AMK Arnold Müller
GmbH & Co. KG**

Gaußstraße 37-39
73230 Kirchheim/Teck
Germany

Phone: +49 7021 5005 0

info@amk-group.com

**AMK Automotive GmbH
& Co. KG**

Gaußstraße 37-39
73230 Kirchheim/Teck
Germany

Phone: +49 7021 5005 0

info@amk-group.com

**AMK Elektroanlagen und
Gerätebau GmbH & Co. KG**

Aumatalweg 3
07570 Weida
Germany

Phone: +49 7021 5005 9100

weida@amk-group.com

**AMK Automatisierungstechnik
GmbH & Co. KG**

Wilhelm-Wolff-Straße 17
99099 Erfurt
Germany

Phone: +49 7021 5005 8100

erfurt@amk-group.com

AMK Drives and Controls

Gen. Nikolov Str. 1
OPB 163
5300 Gabrovo
Bulgaria

Phone: +359 66 819100

info@amk-group.com

AMK Automation Corp.

5631 South Laburnum Avenue
Henrico, Virginia 23231
USA

Phone: +1 804 3482125

info@amk-group.com

AMK Automation Corp.

256 S Washington St, Suite 1
Carpentersville, IL 60110
USA

Phone: +1 847 5652652

info@amk-group.com

**Drive Right Holdings Ltd.
An AMK Company**

Unit 626 Kilshane Avenue
North West Business Park
Ballycoolin, Dublin 15
Ireland

Phone: +353 18612 632

info@driveriteair.com
www.driveriteair.com

**AMK (Anhui) Automotive
E-drive Co., Ltd.**

Intersection of Qingyi River Avenue
and Baocheng Road, Xuanchen,
Economic and Technological
Development Zone
Anhui Province, 242300
China

Phone: +86 56 32165890

info@amk-group.com