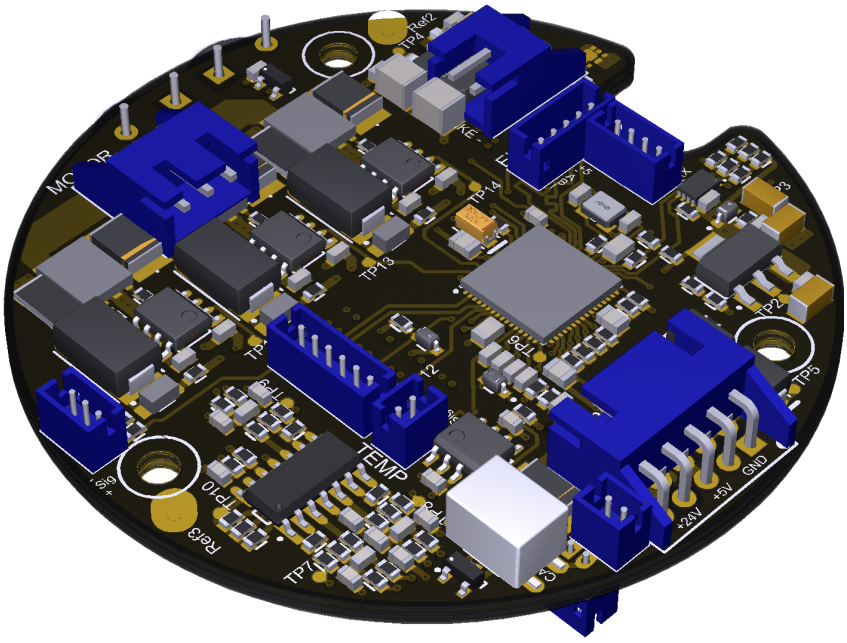
Instruction manual
igus® GmbH motor controller for integrated axes



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1 Introduction

1.1 Contact

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1.2 Intended Use

The intended use of the product is defined by the uses within the defined limits from the technical data. The permissible electrical parameters and the defined permissible ambient conditions must be observed in particular. These are specified in more detail later in this manual.
The intended use for this product can be found in the following section 3.

1.3 Target Group and Qualification

The product and this documentation are intended for technically trained professionals such as:

- development engineers
- plant designers
- assemblers/service personnel
- application engineers

Installation, commissioning, as well as operation is only allowed by qualified personnel. These are persons who meet all the following requirements.

- have appropriate training and experience in handling motors and their control.
- know and understand the contents of this technical manual.
- know the applicable regulations

1.4 Symbols Used

All notes in this document follow a consistent form and are structured according to the following classes.

The WARNING notice alerts the reader to possible dangerous situations.
Disregarding a warning can **possibly** result in moderate injury to the user.

- Within a warning, this describes ways to avoid hazards.

This note indicates possible incorrect operation of the product.
Failure to comply with this notice may **possibly** result in damage to this product or other products.

1.5 Product Safety

The following EU directives were observed:

- RoHS-Directive (2011/65/EU, 2015/863/EU)
- EMV-Directive (2014/30/EU)

1.6 Regulations

In addition to this technical manual, operation, commissioning is subject to the applicable local regulations, such as:

- Accident prevention regulations
- Local regulations for occupational safety

2 Safety

Damage to the controller due to wiring work.
Wiring work during operation can cause damage to the controller.
- Only carry out wiring work when the device is de-energized.

Danger of fatal injury from live parts!
Wiring work on the control cabinet or on assemblies can lead to electric shocks and life-threatening injuries.
- Wiring work must only be carried out when the device is de-energized.
- Work on electrical assemblies or elements must be carried out by trained electricians.

Damage to the controller due to improper handling of ESD-sensitive components.
The controllers contain parts and components that are sensitive to electrostatic discharge. Improper handling can damage the controller.
- Only carry out wiring work when the device is de-energized.

Damage to the controller due to reverse polarity.
Reverse polarity protection of the coponents is not provided. Reversing the polarity of the components leads to short circuits and destruction of the device.
- Install line protection devices in the supply line.

Damage to the controller due to induced voltages.
Regenerative operation of connected motors with the controller switched off must be avoided. This generates voltages in the device which can lead to the destruction of the device or other devices.
- Do not move the motors when they are switched off.

3 Technical data

3.1 Environmental Conditions

Ambient conditions	Wert
Protection class	IP20
Ambient temperature (operating)	+10...+32°C
Ambient temperature (storage)	-10...+85°C
Humidity (non-condensing)	0...90%
Installation height above sea level (without power restriction)	1500m

Table 2: Ambient conditions

3.2 Installation dimensions

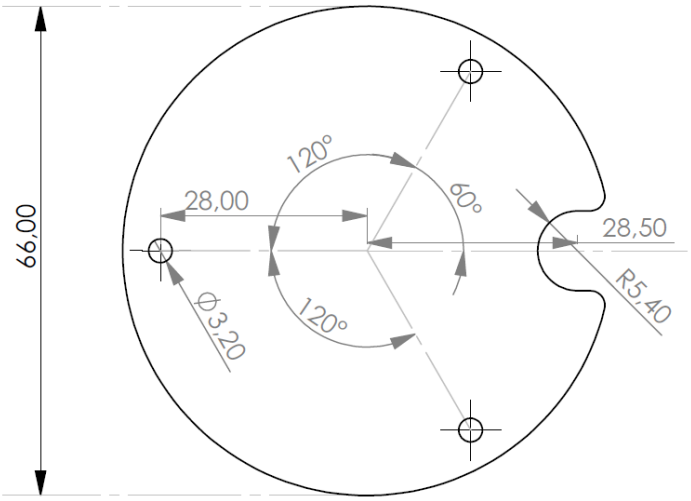


Figure 1: Installation dimensions

3.3 Electrical properties and data

Property	Description/value
Rated voltage	24VDC ±5%
Logic voltage	5VDC ±5%
Rated current	$3A_{eff}$
Peak current	$6A_{eff}$
Commutation	Closedloop with FOC
Setpoint specification	Single axis: Modulecontrol CL (min. V6) Multi-axis: CProg / IRC
Operating modes	Position control, speed control, torque control
Interfaces	CPR CAN V2 SPI (Rebelencoder) UART (internal use)

Table 3: Electrical properties

4 Pin assignment

4.1 K3/K4 Power Supply

Integration of a Current Limiter When operating with 2 or more Modules an Inrush Current Limiter must be used to avoid current spikes during switching on. This current limiter also has to work when an emergency stop on the DC side is released.

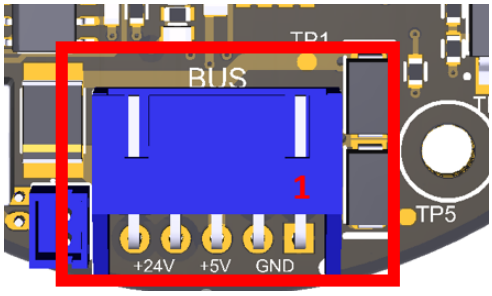


Figure 2: Pin assignment power supply

Connector type: JST XH 5-pole
Pin assignment:

1. GND
2. GND
3. +5V
4. +24VDC
5. +24VDC

Lines 1 and 2, as well as 4 and 5 are each connected to each other to allow higher currents with flexible double lines. For operation, only one pin needs to be connected at a time, e.g. in axes 4-6. The second bus connector for the power supply on the underside is identically assigned.

4.2 K5 Motor

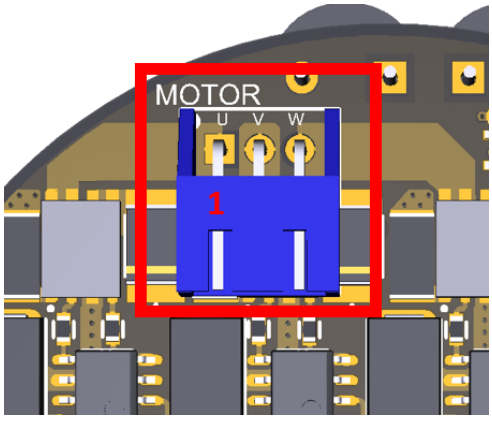


Figure 3: Pin assignment motor

Connector type: JST XH 3-pole
Pin assignment:

1. Motor U
2. Motor V
3. Motor W

4.3 K6 Temperature sensor motor

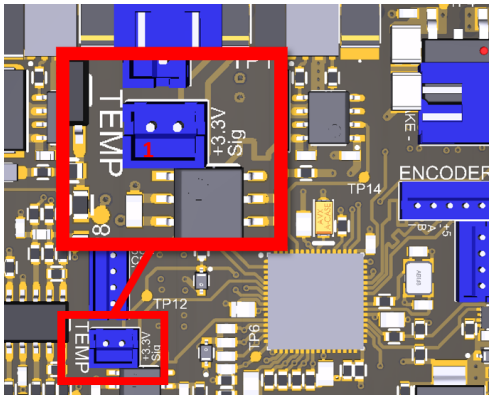


Figure 4: Pin assignment temperature sensor Motor

Connector type: JST ZH 2-pin
Pin assignment:

1. NTC Thermistor Pin 1
2. NTC Thermistor Pin 2

A thermistor for measuring the motor temperature can be connected to this two-pole terminal. The thermistor should be bonded in the stator. The measured values are transmitted to the controller via CAN.

4.4 K7 Brake

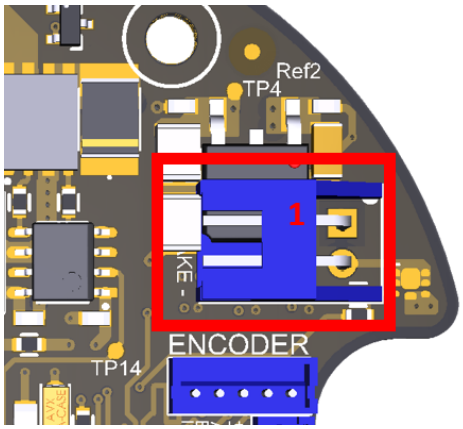


Figure 5: Pin assignment break

Connector type: JST XH 2-pin
Pin assignment:

1. 24VDC
2. GND

A holding brake can be integrated at this connection. The supported brake logic provides a release of the brakes for the movement. The 24VDC signal is always present as long as motor voltage is present. The board switches the GND signal. The voltage can be adjusted via PWM.

4.5 K8 Reference sensor

Different supply voltages (3.3VDC and 15VDC) are available for the reference sensor. The 15VDC are only available if motor voltage is also present. The selection is done via a solder bridge on the top side of the board.

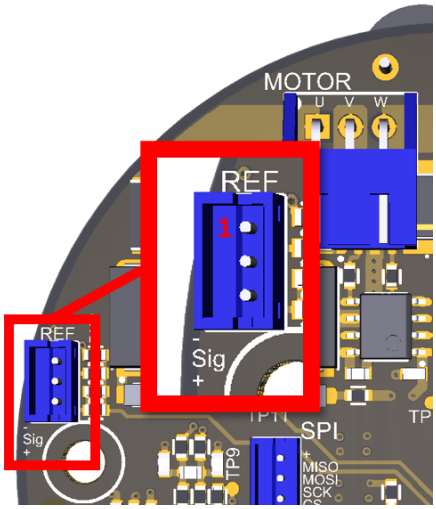


Figure 6: Pin assignment Reference sensor

Connector type: JST ZH 3-pol
Pin assignment:

1. GND
2. Signal
3. VCC

4.6 K9/10 CAN-Bus

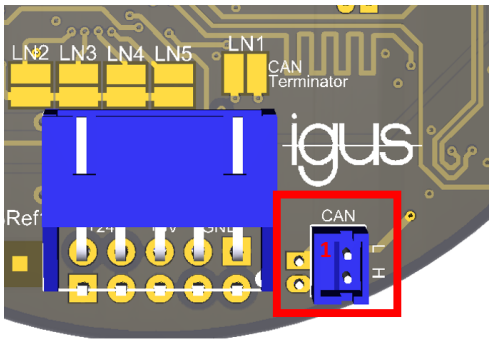


Figure 7: Pin assignment CAN-Bus

Connector type: JST ZH 2-pole
Pin assignment:

1. CAN L
2. CAN H

The second bus connector for CAN communication on the bottom side is identically assigned.

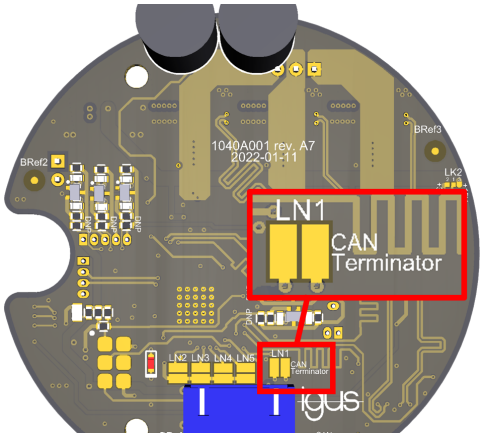
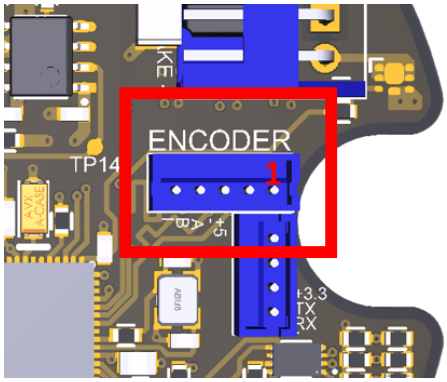


Figure 8: Pin assignment jumper for terminating resistor CAN

According to the definition of the CAN bus, two terminating resistors are required in the entire bus system. These should be located at the first and at the last bus participant. For this purpose there is a jumper on the board.

Termination resistor
For the function of the boards, two terminating resistors are required in the CAN bus according to ISO 11898-1. See CiA 303-1 or chapter 4.6.

4.7 K11 Encoder



Connector type: JST ZH 5-pol
Pin assignment:

1. 5VDC
2. GND
3. A
4. B
5. I

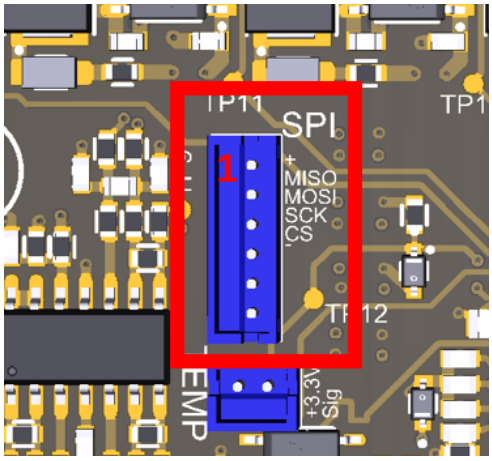
Figure 9: Pin assignment encoder

The motor position is necessary for control and is read in via an incremental ABI encoder at TTL level.

4.8 K12 UART

The UART interface is currently only available for internal purposes.

4.9 K13 SPI / Free

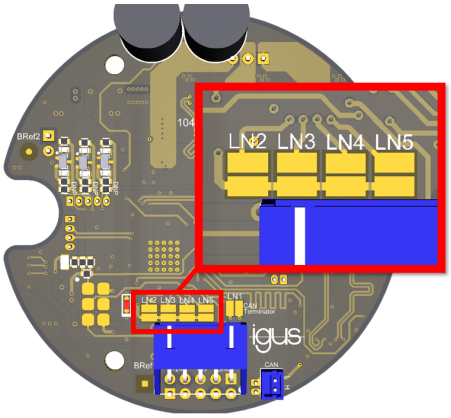


1. VCC
2. MISO
3. MOSI
4. SCK
5. CS
6. GND

Figure 10: SPI Connector

For using the Rebel absolute encoder the SPI interface is available. The interface is implemented as a master.

4.10 CAN-Adress Jumper



1. Value LN2: 0x08
2. Value LN3: 0x10
3. Value LN4: 0x20
4. Value LN5: 0x40

Figure 11: Pin assignment CAN-Adresslink

The CAN ID under which the module communicates can be set via solder bridges. The base address without solder bridge is 0x10. This can be increased binary by 0x08 each via four solder bridges. Possible addresses are therefore 0x10, 0x18, 0x20, 0x28, . . . , 0x88.

5 CAN interface

The motor controller is addressed via the CAN bus, a simple protocol is used. This protocol is not compatible to CANopen.
A description of the interface can be found here:

`https://wiki.cpr-robots.com/index.php/CAN_Protocol`

Example projects including source code in C and C# help with the first implementation. These can also be found at the link above.
Both examples use the PCAN-USB adapter from Peak Systems to establish the connection from USB to CAN bus. Other adapters can be used accordingly.

6 Parameterization

6.1 Parameters

This chapter describes the parameter interface for motor controllers from CPR.

Danger to life!
Changes to the parameter sets may only be carried out by trained personnel. Changing the parameters can override safety interrogations and lead to danger for persons and equipment! High currents can cause fires!.

The motor controllers use the CPR parameter interface in the 2nd version. The parameters are addressed via an index (8bit) [0-255] and a subindex (8bit) [0-255]. The index carries information about the assignment of the parameters to individual system modules. The index contains the following modules:

Index	Beschreibung
0	Board parameters
1	Motor parameters
2	Axis parameters
3	Control parameters
4	Communication parameters

Table 4: Parameter groups

Index 0 board parameters

Idx	SIdx	Name	Unit	Default value
0	**0**	**Serial no.**		
Beschreibung:		Serial number of the product. Used to identify the date of manufacture.		
0	**1**	**Firmwareversion**		
Beschreibung:		Firmware version number to identify the current software version.		
0	**2**	**Hardwareno.**		
Beschreibung:		Hardware version number to identify the hardware configuration used.		
0	**3**	**min. supply Voltage**	**V**	$V_{cc} - 2V$
Beschreibung:		Minimum permissible supply voltage. The minimum supply voltage should be approx. 2V below the nominal voltage. If the supply voltage falls below this limit, the board issues an error message.		
0	**4**	**max. Boardtemp.**	**m°C**	**70000**
Beschreibung:		Maximum permissible board temperature		

Table 5: Board parameters

Index 1 motor parameters

Idx	SIdx	Name	Unit	Default value
1	**0**	**Encoder Tics**	**1/Rev**	**4096**
Beschreibung:		Number of encoder pulses per revolution according to data sheet.		
1	**1**	**No. of Polepairs**		**7**
Beschreibung:		Number of pole pairs in the motor according to the data sheet.		
1	**2**	**Reserved**		
Beschreibung:		Reserved for future use.		
1	**3**	**Reserved**		
Beschreibung:		Reserved for future use.		
1	**4**	**max. RPM**	**RPM**	**0**
Beschreibung:		Maximum rotational speed of the motor. Setting is made according to the data sheet of the motor or on the basis of subsequent components. The value 0 cancels the limitation.		
1	**5**	**max. Motortemp.**	**m°C**	**0**
Beschreibung:		Maximum temperature in the motor. The measurement is performed via an optional sensor. The value 0 deactivates the query.		
1	**6**	**max. Current**	**mA**	**6000**
Beschreibung:		Maximum motor current according to data sheet.		
1	**7**	**StartUpMethod**		**1**
Beschreibung:		Method used to set up the motor when starting the controller. with the Autostart options, the motor starts IPO afterwards. 0. Openloop 1. Closedloop with rotor alignment 2. Closedloop with index search 10. Closedloop with rotor alignment and autostart		
1	**8**	**Reserved**		
Beschreibung:		Reserved for future use.		
1	**9**	**EncoderInverted**	**boolean**	**0**
Beschreibung:		Setting for the direction of rotation of the encoder. The direction of rotation of the signals at the input of the controller must be clockwise according to DIN EN 60034-8. After a change, the controller must be restarted. 0. Encoder not inverted 1. Encoder inverted		
1	**10**	**MotorInverted**	**boolean**	**0**
Beschreibung:		The direction of rotation of the motor must be clockwise according to DIN EN 60034-8. If the setting is incorrect, the motor does not rotate. Only the motor current increases. 0. Motor not inverted 1. Motor inverted		
1	**11**	**OpenLoopCurrent**	**mA**	**2000**

Idx	SIdx	Name	Unit	Default value
Beschreibung:		Setpoint current for the openloop control of the motor		
1	**12**	**OpenLoopCurrentStandstill**	**mA**	**1000**
Beschreibung:		Setpoint current for the openloop control at standstill.		
1	**13**	**Calibration Current**	**mA**	**1000**
Beschreibung:		Set current for rotor alignment.		
1	**14**	**Calibration Time**	**ms**	**10**
Beschreibung:		Duration for the alignment of the rotor		
1	**15**	**Reserved**		
Beschreibung:		Reserviert für zukünftige Verwendung.		
1	**16**	**ThirdHarmonicActive**	**boolean**	**0**
Beschreibung:		Selection for inserting the 3rd harmonic oscillation in the BLDC FOC. Here the effective output voltage can be increased by approx. 30%.		

Table 6: Motor parameters

Index 2 Axis parameters

Idx	SIdx	Name	Unit	Default value
2	**0**	**Reserved**		
Beschreibung:	Reserved for future use.			
2	**1**	**ReferencingType**		**1**
Beschreibung:	Selection for the referencing type. 0. no referencing current position = 0 1. Linear motion 2. Sinusoidal movement (Sinusoidal search for the sensor.) 3. Half disks (referencing method for axes equipped with a half disk, e.g. Robolink DP)			
2	**2**	**ReferencingOffset**	**Tics**	**0**
Beschreibung:	Offset for the axis position after referencing.			
2	**3**	**ReferencingSpeed**	**RPM**	**10**
Beschreibung:	Speed for approaching the sensor. If the axis is referenced in the wrong direction, this parameter can be set to negative.			
2	**4**	**ReferencingSpeedSlow**	**RPM**	**2**
Beschreibung:	Speed for fine positioning of the axis during homing. If the axis is referenced in the wrong direction, this parameter can be set to negative.			
2	**5**	**ReferencingSwitchType**		**0**
Beschreibung:	Type of the reference sensor. 0. n.C. 1. n.O.			
2	**6**	**max. Positionlag**	**Tics**	**10000**
Beschreibung:	Permissible position error of the axis. With fast movements, the axis runs after the position setpoint. If the limit value is exceeded, the axis stops and an error message appears. If the value is set to 0, there is no monitoring.			
2	**7**	**Break Type**	[0 – 2]	**0**
Beschreibung:	Parameter for activating a brake on the robot axis. If the robot has a holding brake, which should be controlled by the motor controller, this value must be set. The brakes are released when the axes are activated. 0. no brake 1. friction brake 2. blocking brake In the blocking brake mode, a free-positioning movement occurs. A blocking brake means a pin or similar, which blocks the rotor. A friction brake describes a disc brake.			
2	**8**	**Break PWM High**	**% V_{cc}**	**100**

Idx	SIdx	Name	Unit	Default value
Beschreibung:		If a brake is configured on the axis, this parameter specifies the PWM value for releasing the brake.		
2	**9**	**Break PWM Low**	**% V_{cc}**	**50**
Beschreibung:		Voltage to hold the brake after releasing the brake, the motor controller lowers the output voltage to the specified value.		
2	**10**	**IPO Position**	**Tics**	**200000**
Beschreibung:		Positive position value for the IPO. In standalone mode, the IPO moves this value symmetrically around the zero point. Thus from -IPO position to IPO position.		
2	**11**	**IPO Velocity**	**Tics/10ms**	**200**
Beschreibung:		Speed for IPO mode in standalone operation,		

Table 7: Axis parameters

Index 3 Control parameters

Idx	SIdx	Name	Unit	Default value
3	**0**	**Position P**	1/100	
Beschreibung:		P component for position control.		
3	**1**	**Position I**	1/100	**0**
Beschreibung:		I component for position control.		
3	**2**	**Position D**	1/100	
Beschreibung:		D component for position control.		
3	**3**	**Position AntiWindUp**	1/100	
Beschreibung:		AntiWindUp for position control.		
3	**4**	**Position min.**	**RPM**	
Beschreibung:		minimum limitation for the output of the position control.		
3	**5**	**Position max.**	**RPM**	
Beschreibung:		maximum limitation for the output of the position control.		
3	**6**	**Reserved**		
Beschreibung:		Reserved for future use.		
3	**7**	**Velocity P**	1/100	
Beschreibung:		P component for speed control.		
3	**8**	**Velocity I**	1/100	
Beschreibung:		I portion for speed control.		
3	**9**	**Velocity D**	1/100	
Beschreibung:		D component for speed control.		
3	**10**	**Velocity AntiWindUp**	1/100	
Beschreibung:		AntiWindUp for speed control.		
3	**11**	**Velocity min.**		**-1024**
Beschreibung:		minimum limitation for the output of the speed control.		
3	**12**	**Velocity max.**		**1024**
Beschreibung:		maximum limitation for the output of the speed control.		
3	**13**	**Reserved**		
Beschreibung:		Reserved for future use.		
3	**14**	**DQ-P**	1/100	
Beschreibung:		P component for DQ control		
3	**15**	**DQ-I**	1/100	
Beschreibung:		I component for DQ control		
3	**16**	**DQ-D**	1/100	
Beschreibung:		D component for DQ control		
3	**17**	**DQ-AntiWindUp**	1/100	
Beschreibung:		AntiWindUp for DQ control		
3	**18**	**DQ-min.**		**-1024**
Beschreibung:		minimum limitation for the output of the DQ control		
3	**19**	**DQ-max.**		**1024**
Beschreibung:		maximum limitation for the output of the DQ control		
3	**20**	**Openloop P**	1/100	

Idx	SIdx	Name	Unit	Default value
Beschreibung:		P component for Openloop current control.		
3	**21**	**Openloop I**	1/100	
Beschreibung:		I component for Openloop current control.		
3	**22**	**Openloop D**	1/100	
Beschreibung:		D component for Openloop current control.		
3	**23**	**Openloop AntiWindUp**	1/100	
Beschreibung:		AntiWindUp for Openloop current control		
3	**24**	**Openloop min.**		
Beschreibung:		minimum limitation for the output of the Openloop current control.		
3	**25**	**Openloop max.**		
Beschreibung:		maximum limitation for the output of the Openloop current control.		

Table 8: Control parameters

Index 4 Communication parameters

Idx	SIdx	Name	Unit	Default value
4	**0**	**CAN max. missed Coms**		**100**
Beschreibung:		maximum number of failed communication attempts on the CAN bus. Exceeding the value leads to the motor controller being switched off.		
4	**1**	**CAN ID Source**		**1**
Beschreibung:		Source for the CAN ID: 1. hardware jumper 2. parameter set		
4	**2**	**CAN ID**		**16**
Beschreibung:		CAN ID for the controller		
4	**3**	**SPI Active**	**boolean**	**0**
Beschreibung:		Enable SPI communication		

Table 9: Communication parameters

6.2 Parameterization with different softwares

The previously presented parameters can be changed via two possible programs. As a prerequisite, a connection to the robot via CAN is necessary.

6.2.1 Module Control

Module Control is a special software for setup, parameterization and error analysis of individual axes. Module Control provides more detailed error messages than iRC. Module Control also visualizes detailed status information. The software, as well as further information can be found under the following link:

`https://wiki.cpr-robots.com/index.php/Config_Software_ModuleCtrl`

6.2.2 CProg / IRC

The modules are used with the CPR-CANV2 protocol, which allows operation with current CProg / IRC and TinyCtrl versions (see the following link for more information).

`https://www.igus.de/info/roboter-software`

7 Operation

7.1 Boot behavior

Starting the board is done in several steps. Before the motor controller starts, the bootloader starts. This allows a firmware update to be imported during later operation. The bootloader is active for about 6s, during this time the LED is on for 1s and off for 2s, this sequence is repeated. Subsequently, the motor controller starts. The rotor is aligned according to the parameter settings. Before the rotor alignment the LED flashes. To avoid current peaks, the waiting time depends on the CAN-ID of the board. If the rotor alignment is done, the LEDs start blinking with high frequency. In the next step the board goes into error state. (Chapter 7.3)

7.2 Behavior in operation

After the successful boot process, communication can be established via CAN. The board responds to successful communication by flashing the LED.

7.3 Error codes

In the event of an error, the LED on the board lights up continuously. Furthermore the board sends a message with the cause to the used control software.