# Motion Protocol CPR-CAN-V2
for
Closed Loop motor controller

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1 About this document

1.1 Contact

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1.2 Target group and qualification

This protocol documentation is aimed at technically trained professionals such as:

- Programmers
- Development Engineers

Experience with the following is required:

- Hardware-related programming e.g. with C++
- Knowledge of the CAN fieldbus
- ESD procedures when working with electronics

This documentation supplements the product documentation of the motor controllers. Knowledge of this documentation is assumed.

1.3 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.

2 Introduction

2.1 Brief description of the protocol

The CPR-CAN-V2 protocol is used for communication between a controller and the drive modules. The controller sends position setpoints or speeds to the motor controllers via the CAN field bus, and these respond with their current status.

The calculation of acceleration ramps and the interpolation between target points takes place in the controller, not in the motor controller. The controller sends the target position to the motor controller at short intervals of 10 to 50 ms.

The operation is thus comparable to the CANopen operation mode IPO or CSP. An operation mode like CANopen ProfilePosition is not supported.

In addition to transmitting the position or speed specifications, the controllers can be parameterized via the protocol.

2.2 Communication procedure

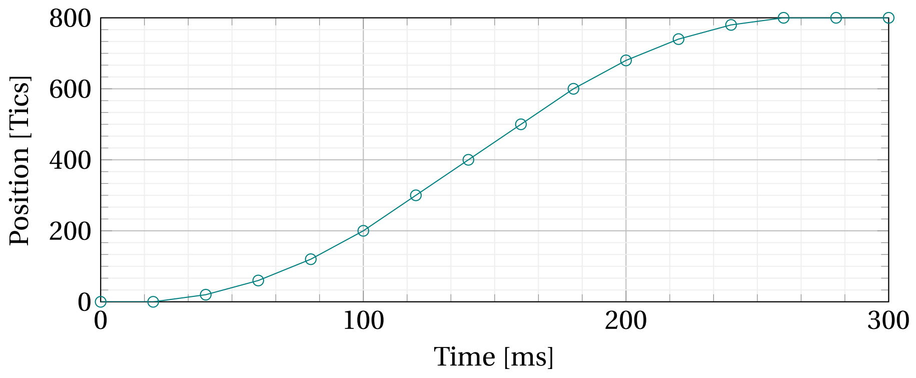
This example is intended to illustrate the communication sequence in positioning mode.

1. Starting the motor controller
2. Start of a cyclically called function which sends a position specification every 20 ms (chapter 3.1.1)
3. Aligning the positions of motorcontroller and master software. There are two options:

   Reset the current position to 0 (Chapter 3.3.2). Initialization of the setpoint position in the master software also with 0.
   This option is recommended for the first tests.

   Reading the current motor position from the CAN message answers (Chapter 3.2) and using this position as current setpoint position in the master software.
   This option is recommended for real applications.
4. Reset error on the axis. (Chapter 3.3.1)
5. Enable axis (chapter 3.3.3) so that error byte in response shows 0x00 (chapter 3.2).
6. Slowly change the target position in the cyclically sent position specification. The axis now follows the preset.

The following graphic shows the movement from 0 to 800 tics. The interpolation with acceleration and deceleration ramps takes place in the controller, which sends the target positions marked by points cyclically to the motor controller.



2.3 Communication parameters

CAN baud rate	500kBaud
Communication frequency	20 bis 100 hz

2.4 Configuration software ModuleCtrl

The ModuleControl configuration software is available to the user for simple control of all axis functions. This supports the bootloader and the parameter interface.

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

2.5 Demo software with sources

For a quick start in developing your own control, a sample program is available on GitHub:

```
https://github.com/CommonplaceRobotics/CANV2Prot
ocolDemoClient
```

Included is a VisualStudio2019 project in CSharp that connects to and drives a motor controller. All source files are included, these can be used as a starting point for your own development.
To run the code and test your own applications you need the following components:

1. Visual Studio 2019 or later
2. PCAN-USB CAN to USB Interface from PEAK-System Technik GmbH
3. Motor controller with motor
4. Connection cable depending on motor controller

3 CAN Messages

3.1 Motion commands

Motion commands fall into the category of cyclic commands. These commands must be sent repeatedly from the motion master to the motor controller in a fixed time. The basic cycle is 50ms. If the motion master does not keep to this time and exceeds a specified time, the motor controller goes into an error state. When changing between two motion commands, the axis interrupts the execution and stops the motion. Only after reset and enable a new movement in the new mode is possible.

3.1.1 Position CMD 0x14

The Position CMD puts the axis into the positioning mode. This mode is comparable with the CANopen operating mode IPO or CSP. The specification of the position is done in Encodertics. The motor controller tries to reach the target position as fast as possible, no path with target speed and acceleration ramps is calculated. If the target position is too far away from the current position, this can lead to unexpected behavior or a shutdown.

1. Message to the motor controller

0	1	2	5	6	7
0x14	unused	Position		Timer	DOut

Position	32-bit position of the motor in [Tics]
Timer	Value for checking the correct order of messages
DOut	If the motor controller has outputs, they can be set here

2. Response from motor controller
   Standard response CANV2 (chapter 3.2)

3.1.2 Velocity CMD 16bit 0x25

This mode is comparable to the CANopen operating mode ProfileVelocity.

1. Message to the motor controller

0	1	2	3
0x25	Velocity		Timer

Velocity	Preset speed with 16bit in [RPM] as int16
Timer	Value for checking the correct order of messages

2. Response from motor controller
   Standard response CANV2 (chapter 3.2)

3.1.3 Torque CMD 0x16

This mode is comparable to the CANopen operating mode ProfileTorque.

1. Message to the motor controller

0	1	2	3
0x16	Torque		Timer

Torque	Specification of the Desired torque in engineering units between [-1024-1024]
Timer	Value for checking the correct order of messages

2. Response from motor controller
   Standard response CANV2 (chapter 3.2)

3.2 Response to motion commands

The motor controllers respond to all motion commands with a uniform response.
CAN-ID = BoardID + 1

0	1 4	5 6	7
errorCode	Position	Current	DIn + Flags

errorCode	Error byte see below for more information
Position	32-bit current axis position in [Tics].
Current	Current RMS current in [mA]
DIn + Flags	The inputs of the motor controllers, as well as the flags are explained below

The motor controller sends an error byte in every CANV2 response. This can define various error states.

7	6	5	4	3	2	1	0
DRV	OC	ENC	LAG	COM	MNE	ESTOP	TEMP

TEMP	Over temperature	The temperature of the motor controller or the motor is above the defined value in the parameters.
ESTOP	Emergency stop / no voltage	The voltage at the motor controller is below the set limit value. This may indicate a defective fuse or emergency stop.
MNE	Motor not activated	The movement of the motor is not enabled, it is not in control.
COM	Communication failure	The motor controller requires CAN messages at regular intervals. If the distance between the messages is too large or the messages do not arrive, the motor controller stops the movement.
LAG	Following error	The motor controller monitors the following error, if this is greater than the value set in the parameters, the motor controller stops the movement.
ENC	Encoder error	The motor controller has detected an encoder error. Errors can be triggered by both the motor or the output encoder.
OC	Over current	The RMS current in the motor controller was above the allowed value in the parameters.
DRV	Driver error	A driver error can have various causes. One possible cause is exceeding the maximum speed from the parameters. With the closedloop motor controllers, the error also occurs with problems with the initial rotor position.

The byte field for the inputs as well as the referencing flags of the motor controller is differentiated in the nibble. The low nibble contains the inputs, the high nibble the referencing flags.

7	6	5	4	3	0
Flag referenced	Flag aligned	unused	Flag axis ready	DIn	

Flag referenced	Axis is referenced
Flag aligned	Initial finding of the rotorfield orientation complete
Flag axis ready	Axis is ready for motion commands
DIn	State of the digital board inputs

3.3 Process CMD 0x01

This category includes control instructions which are not sent cyclically to the board.

3.3.1 Reset Error 0x06

This message resets all errors on the board.
Depending on the board version the board has irreversible errors, these cannot be reset. An example is an error in the motor wiring.

1. Motor controller message

0	1
0x01	0x06

2. Response from motor controller
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x0106		0x0001		0x0000	

3.3.2 Set position to 0 0x08

This message must be sent to the controller 2 times within 20 ms. This command sets the Current to 0. The controller then goes into an error state.

1. 1. Motor controller message

0	1	2	3
0x01	0x08	0x00	0x00

2. 1. Response from motor controller CMD received
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x0108		0x0001		0x0000	

3. 2. Response from motor controller CMD ok
   Only sent if CMD is ok. CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x0208		0x0001		0x0000	

4. 2. Motor controller message

0	1	2	3
0x01	0x08	0x00	0x00

5. 3. Response from motor controller CMD received
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x0108		0x0001		0x0000	

6. 4. Response from motor controller CMD ok
   Only sent if CMD is ok. After this response, the motor controller has set the position to 0. CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x0208		0x0002		0x0000	

3.3.3 Enable Motor 0x09

Activates the motor. Only possible if no error is present.

1. Motor controller message

0	1
0x01	0x09

2. Response from motor controller
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x0109		0x0001		0x0000	

3.3.4 Disable Motor 0x0A

Deactivate motor. The power output stage switches off the current to the motor.

No Safe Stop!
This function does not represent a safe stop. It is possible that the motor continues to be supplied with voltage.

1. Motor controller message

0	1
0x01	0x0A

2. Response from motor controller
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x010A		0x0001		0x0000	

3.3.5 Referencing 0x0B

Request for referencing. The message must be sent to the motor controller several times.

1. 1. Motor controller message

0	1
0x01	0x0B

2. 1. Response from motor controller
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x020B		0x0001		0x0000	

3. 2. Motor controller message

0	1
0x01	0x0B

4. 2. Response from motor controller
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x020B		0x0002		0x0000	

5. Error from motor controller Referencing active. Referencing of the axis is already active.
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x07	0x00	0x020B		0x0098		0x0000	

3.3.6 Rotor alignment 0x0C

For the operation of closed loop motor controllers it is necessary that they know the initial rotor orientation. This can be recalibrated by the following command. This command must also be sent twice.

1. 1. Motor controller message

0	1
0x01	0x0C

2. 1. Response from motor controller
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x020C		0x0001		0x0000	

3. 2. Motor controller message

0	1
0x01	0x0C

4. 2. Response from motor controller
   CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0x06	0x00	0x020C		0x0002		0x0000	

3.3.7 Ping 0xCC

The controller responds to this message with the startup message.

1. Motor controller message

0	1
0x01	0xCC

2. Response from motor controller
   The CAN message sent corresponds to the startup message. (chapter 3.5.1)

3.3.8 EEPROM write enable 0xCD

Before parameters can be stored on the motor controller, the EEPROM must be enabled with this message. The motor controller does not respond to this message.

0	1
0x01	0xCD

3.4 Parameter V2 0x94 & 0x96

The following parameter interface is available for the closed loop motor controller. This uses a structure consisting of index and subindex.
The description of the corresponding parameters with index and subindex can be found in the product documentation of the motor controllers.

3.4.1 Save parameters 0x94

1. Enabling the EEPROM (chapter 3.3.8)
2. Message to motor controller

0	1	2	3				6
0x94	Index	SubIndex	Data				

Index	category of the parameter
SubIndex	parameter in the category
Data	32bit value of the data

3. Message from motor controller: Transmission ok
   CAN-ID = BoardID + 2

0	1		3	4	5	6	7
0x06	0x00	0x0068		Adress		0x0000	

Address	Calculated EEPROM Address

4. Error from motor controller: EEPROM not enabled
   The EEPROM was not enabled before, see chapter 3.3.8
   CAN-ID = BoardID + 2

0	1		3	4	5	6	7
0x07	0x00	0x00AA		Index		SubIndex	

Index	category of the parameter
SubIndex	parameter in the category

5. Error from motor controller: Not stored
   The data could not be stored in the EEPROM.
   CAN-ID = BoardID + 2

0	1		3	4	5	6	7
0x07	0x00	0x0068		Index	SubIndex	EEPROM Address	

Index	category of the parameter
SubIndex	parameter in the category
EEPROM Address	EEPROM Address to be written

3.4.2 Read parameters 0x96

Interruption of the cyclic messages
For transmitting the parameters the cyclic CAN messages must be interrupted. The response for reading the parameters and the standard response (chapter 3.2) share the response ID BoardID + 1.

1. Message to motor controller

0	1	2
0x96	Index	SubIndex

Index	category of the parameter
SubIndex	parameter in the category

2. Message from motor controller: Transmission ok
   CAN-ID = BoardID + 1

0	1	2	3			6
0x96	Index	SubIndex	Data			

Index	category of the parameter
SubIndex	parameter in the category
Data	32bit value of the data

3. Error from motor controller: Error while reading
   CAN-ID = BoardId + 2

0	1	2	3	4	5	6	7
0x07	0x00	0x0067		Index		SubIndex	

Index	category of the parameter
SubIndex	parameter in the category

3.5 Special CAN messages

This section contains the description of special CAN messages, e.g. the motor controllers send various status information cyclically without request.

3.5.1 Startup message

When the motor controllers are started, they send a defined message. This message helps to identify the motor controller.
CAN-ID = BoardID + 2

0	4	5	6	7
0x01020304	Restart cause	HW-Ident	Version	

HW-Ident	Board identification
Version	Major and minor version of the firmware

The following values are implemented for the identification of the board:

DIN-RAIL CL BLDC	0x50	Closed Loop BLDC motor controller for DIN rail mounting with CPR backplane bus
DIN-RAIL CL STEPPER	0x51	Closed Loop stepper motor controller for DIN rail mounting with CPR backplane bus
ON-AXIS CL BLDC	0x52	Closed Loop integrated motor controller for on axis mounting
DIN-RAIL CL DC	0x53	Closed Loop DC motor controller for DIN rail mounting with CPR backplane bus
dsPIC33EP128GM Boot loader	0x89	Boot loader for motor controller dsPIC33
dsPIC33EP256GM Boot loader	0x8A	Boot loader for motor controller dsPIC33
dsPIC33EP128MC Boot loader	0x8B	Boot loader for motor controller dsPIC33
dsPIC33EP256MC Boot loader	0x8C	Boot loader for motor controller dsPIC33

3.5.2 Environmental parameters 0x12

The motor controller sends a message once per second with the current voltage, as well as the motor and board temperature.
CAN-ID = BoardID + 3

0	1	2	3	4	5	6	7
0x1200		Voltage		Temp Motor		Temp Board	

Voltage	Current voltage at motor controller [mV]
Temp Motor	Motor Temperature [m°C]
Temp Board	Temperature Motor Controller [m°C]

3.5.3 Extended error messages

The motor controller sends a message with the detailed status information once per second. For an evaluation of the individual bytes please use the configuration software ModuleControl.
CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0xE0	Motor Error	ADC Error	Enc V2 Error	Control Error	Enc V3 Gear	Enc V3 Motor	reserved

Motor Error	byte with errors of the motor
ADC Error	byte with errors of the AD converter
Rebel Error	byte with rebel encoder errors
Controll Error	byte with control errors
Enc V3 Gear	byte with Rebel V3 output side encoder errors
Enc V3 Motor	byte with Rebel V3 drive side encoder errors

The Rebel Base also sends a message with detailed error information once per second. For evaluation of these bytes please use the configuration software ModuleControl.

CAN-ID = 2

0	1	2	3				7
0xE1	Power Error	Voltage Error	reserved				

Power Error	byte with errors of the power delivery system of the Rebel Base
Voltage Error	byte with errors where the measured subsysteme voltage deviated to much from the expected range

3.5.3.1 Motor Error

The motor controller monitors various parameters of the motor. Important for monitoring the currents are two different values, the RMS-value according to the parameters and the hard coded value for the single phases. In the standard messages both errors show up as OC.

7 3	2	1	0
reserved	OC RMS	OC Phase	Motor n.c.

Motor n.c.	motor not connected, currently not in use
OC Phase	overcurrent of a single phase
OC RMS	overcurrent according to the rms measurement

3.5.3.2 ADC Error

The correct offset is instrumental for the operation of the motor controller, which is why it is checked for a defect beforehand.

7 1	0
reserved	ADC Offset

ADC Offset	ínvalid offset in the current measurement

3.5.3.3 Control Error

The different control methods of the closed loop motor controllers can also be a source of errors. These cause a driver error in the higher-level controller and are explained more thoroughly in this byte.

7 4	3	2	1	0
reserved	No free Rotation	Low Align	Parameter fault	VEL High

VEL High	velocity higher than allowed
Parameter fault	failure to read all controller parameters
Low Allign	alignment current could not be reached
No free Rotation	the axis could not be moved after alignment

3.5.3.4 Rebel Base Power Error

This byte contains the power delivery errors of the the differrent Rebel Subsystems. Error according to this message often point to a short circuit or electrical problem of the Rebel.

7 4	3	2	1	0
reserved	Logic Bus Fault	Motor Bus Fault	System Bus Fault	VIN Fault

VIN Fault	Input voltage fault
System Bus Fault	24V supply for fan and dio channels faulty

Motor Bus Fault	24V supply for motors faulty
Logic Bus Fault	5V supply for motor controller and higher-level controller faulty

3.5.3.5 Rebel Base Low Voltage Error

This byte is dedicated to the measured voltages of the Rebel Base Subsystems. If a voltage deviates from an expected range it is marked as faulty. Error according to this message often point to a short circuit or electrical problem of the Rebel.

7 4	3	2	1	0
reserved	Logic Voltage	Motor Voltage	System Voltage	VIN Voltage

VIN Voltage	input voltage not within expected range(21,1V-26,0V)
System Voltage	24V supply for fan and dio channels not within expected range (22,0V-24,0V)
Motor Voltage	24V supply for motors not within expected range (23,0V-26,0V)
Logic Voltage	5V supply not within expected range (4,7V-5,6V)

3.5.3.6 Rebel V3 Encoder Error

This byte is dedicated to the errors of the absolute encoder of the Rebel V3. Error in this message point to a defect of the encoder hardware or a faulty calibration. The drive side and output side encoder have their own dedicated error byte. The output side error is located at byte five and the drive side error at byte six of the extended error message of the motor controller.

7	6	5	4	3	2	1	0
Other	Not Calibrated	Position Error	Checksum Error	I2C Error	Master Analog	Nonius Analog	$\overline{\text{COM Error}}$

$\overline{\text{COM Error}}$	communication with encoder not possible or faulty (inverted)
Nonius Analog	Analog error of the nonius track
Master Analog	Analog error of the master track
I2C Error	communication with the EEPROM not possible or faulty
Checksum Error	Checksum not consistent with EEPROM value
Position Error	Absolut position not consistent with counted position
Not Calibrated	calibration if the axis was deleted or still has to be done
Other	Absolut position during referencing inconsistent or abnormal error registers was set

3.5.4 Encoder Rebel V3 Position

The Igus Rebel V3 is equipped with On-Axis motor controllers. These axes contain a drive side and output side absolut encoder. If these encoderes are parameterized the motor controller sends their position once per second.

CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0xEF	Encoder Identifier	reserved		Encoder Position			

Encoder Identifier	Identifier of the drive side and output side encoder (one for drive side and two for output side)
Encoder Position	Position of the encoder in $\frac{Grad}{100}$

3.5.4.1 Rebel V2 output side encoder error

This byte is dedicated to the errors of the absolute encoder of the Rebel V2. Error in this message point to a defect of the encoder hardware or a faulty calibration.

7	6	5	4	3	2	1	0
Contact B	Contact A	reserved		Calib. corrupt	Calib. logic	Out of Range	COM Error

COM Error	checksum not received
Out of Range	measured value not inside expected range $[-180° - 180°]$
Calib. logic	encoder detected error in the calibration
Calib. corrupt	encoder detected missing values in the calibration
Contact A	Sliding contact Track A lifted
Contact B	Sliding contact Track B lifted

3.5.5 Output side encoder Rebel V2 position

THe Igus Rebel V2 is equipped wit an On-Axis motor controller. The axis contains a output side absolut encoder. Is the output side encoder parameterized the motor controller sends the output side position once per second.
CAN-ID = BoardID + 2

0	1	2	3	4	5	6	7
0xEF	0x0000		0x7E	Encoder Position			

0x7E	Identifier of the Hatron made encoder
Encoder Position	position of the output side in $\frac{Grad}{100}$