Module for Reference Design

MODULE

TMCM-1617-GRIP-REF HW & IOLINK FW Manual

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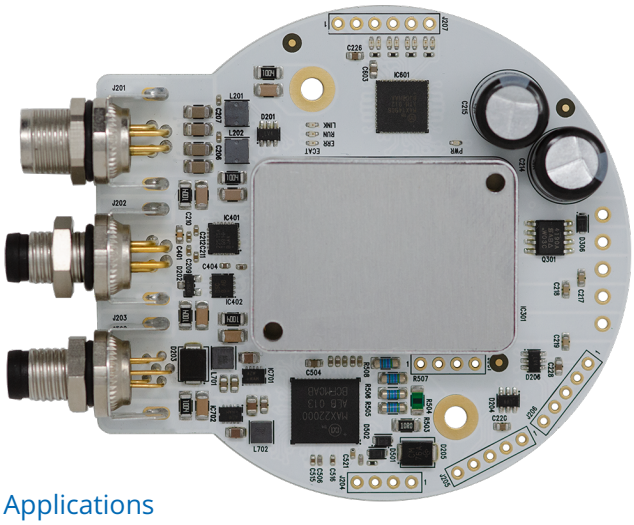
The TMCM-1617-GRIP-REF is an open source hardware reference design for the TMCM-1617 BLDC servo drive. To be used in robotic gripper applications, the board is designed in a standard gripper electronics form-factor. It is able to control a BLDC motor via EtherCAT®, IO-Link® or Trinamic's RS485 based TMCL protocol. In addition, the board features configurable analog output and input channels as well as configurable digital output and input channels using Maxim Integrated MAX22000 and MAX14906 industrial IO solutions.



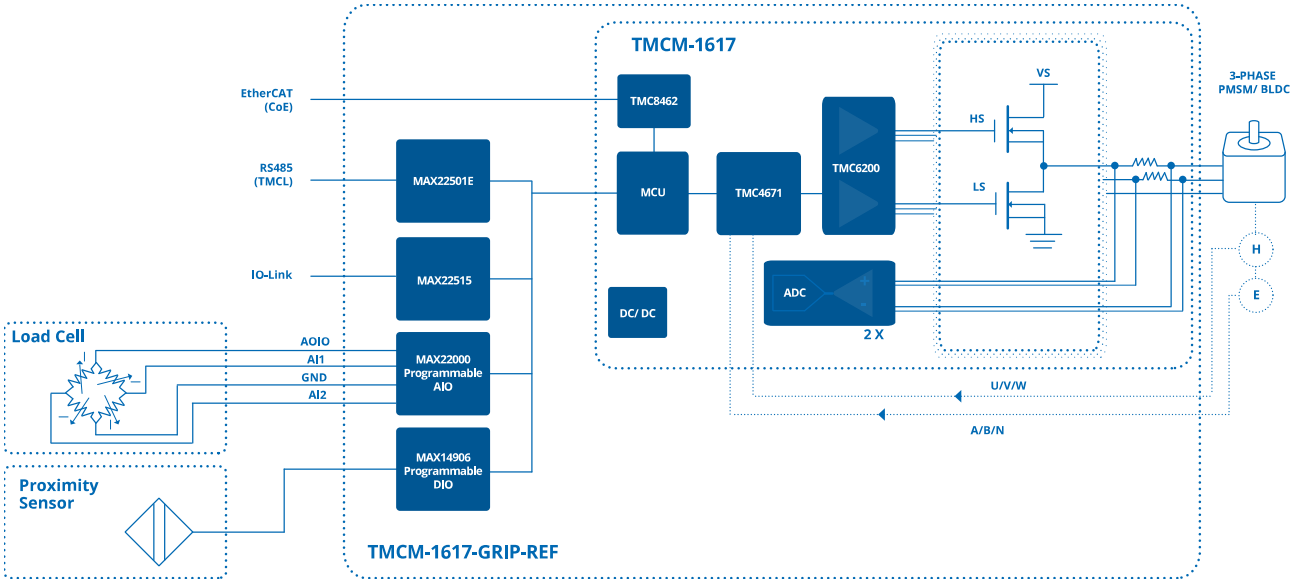
Applications

- Robotic Grippers

Features

- Single axis BLDC servo driver for up to 2.5 A RMS motor current
- +24 V Nominal Supply Voltage (+20 V to +28 V)
- Digital Hall sensor interface
- ABN encoder interface
- 4 Digital +24 V I/O (highside switch, push-pull driver, or a Type 1 and 3, or Type 2 digital input)
- 1 Analog output (±12.5 V output voltage range, or ±25 mA or ±2.5 mA output current range)
- 1 Differential analog input (±15 V, ±2.5 V, ±500 mV, ±250 mV, and ±125 mV input voltage ranges)

Simplified Block Diagram



Read entire documentation.

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Contents

1 Order Code

Order Code	Description
TMCM-1617-GRIP-REF	Robotic Gripper Reference Design.

Table 1: Order Code

2 Featured Parts

- TMCM-1617 - Low weight, miniaturized single axis servo drive for 3-phase BLDC motors
- MAX22000 - Industrial Software Configurable Analog I/O
- MAX14906 - Quad-Channel Industrial Digital Output, Digital Input
- MAX22515 - IO-Link Transceiver with Integrated Protection
- MAX17552 - 60V, 100mA, Ultra-Small, High-Efficiency, Synchronous Step-Down DC-DC Converter
- MAX22501 - 100Mbps Half-Duplex RS-485/RS-422 Transceivers

3 Mechanical Information

3.1 Module Size

The TMCM-1617-GRIP-REF is designed in a standard gripper electronics form-factor. The module has 2 mounting holes for M3 screws.

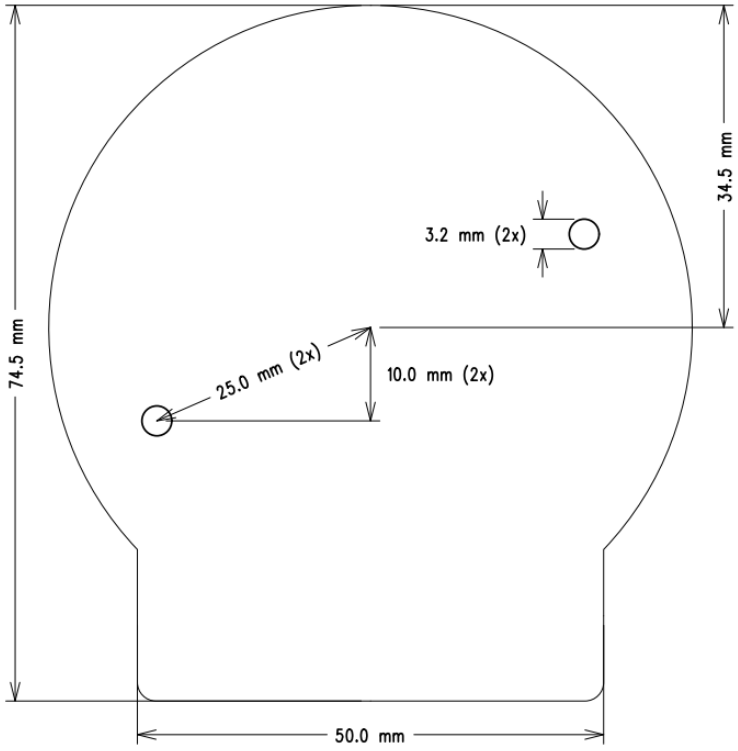


Figure 1: TMCM-1617-GRIP-REF Dimensions

3.2 Mounting a Heat Sink

The aluminum housing of TMCM-1617 has 2 mounting holes for M2.5 screws/bolts that allow mounting a heat sink. A thermal gap pad (electrically isolating) is recommended between the housing and the heat sink for proper heat transfer.

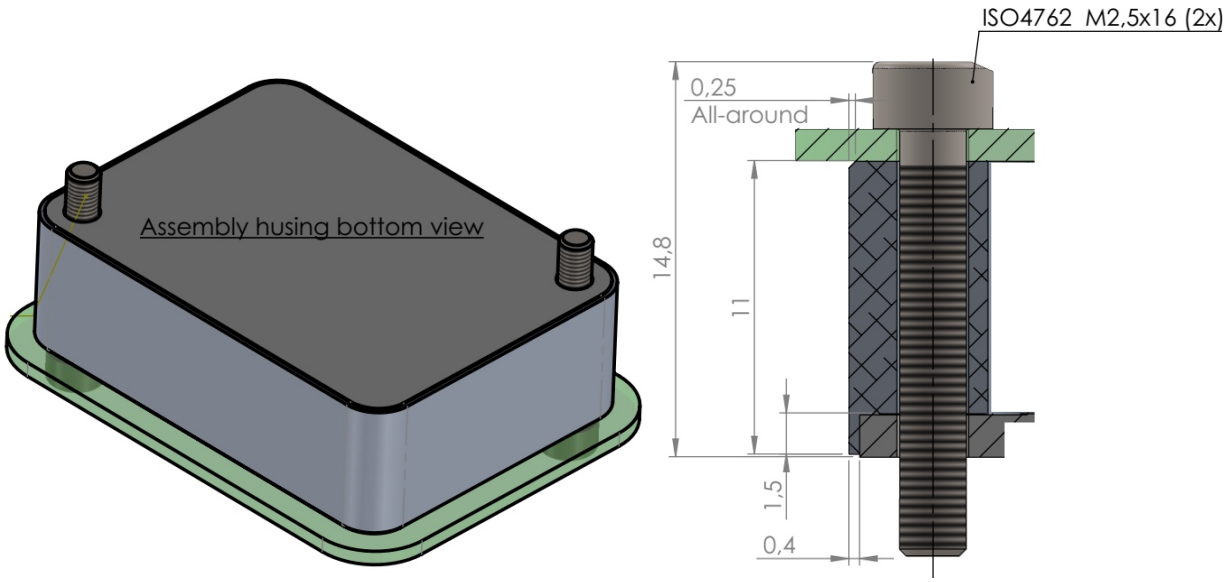


Figure 2: Heat Sink Mounting

4 Connectors and LEDs

The TMCM-1617-GRIP-REF comes with 3 connectors:

- EtherCAT® (in)
- IO-Link
- Supply and RS485

The connectors for other interfaces are not mounted to allow the user to choose between mounting standard 2.54/3.81 mm headers or connecting wires directly to the board:

- Motor
- Brake output
- Hall sensor
- Encoder
- Analog I/O
- Digital I/O
- Programming

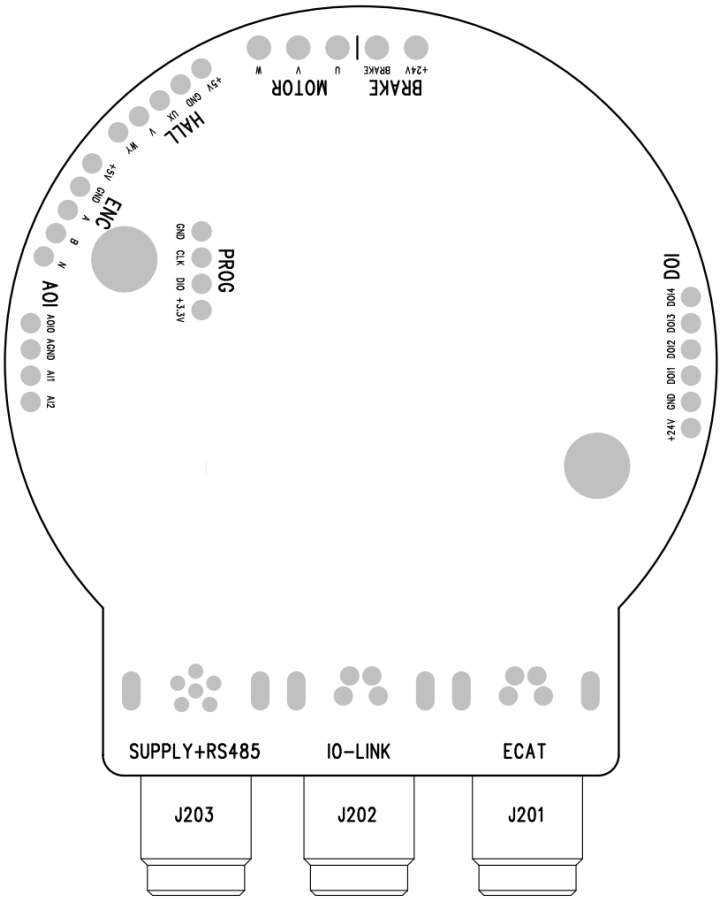
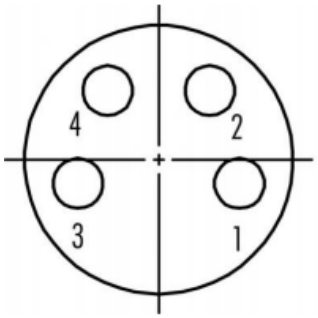


Figure 3: TMCM-1617-GRIP-REF Connectors (bottom view)

4.1 EtherCAT® Connector and LEDs

Connector: 4-pin female M8 (Binder 86 6618 1121 00004).



Pin	Signal	Description
1	TP	Transmit line (non-inverting)
2	RP	Receive line (non-inverting)
3	RN	Receive line (inverting)
4	TN	Transmit line (inverting)

Figure 4: EtherCAT® Connector (J201)

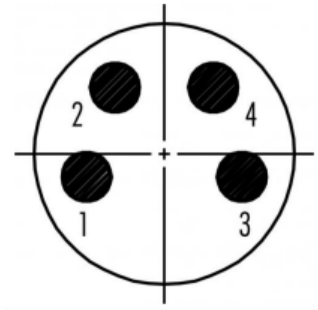
The EtherCAT® interface includes 3 status LEDs.

Label	Description
RUN	EtherCAT® status LED, green
ERR	EtherCAT® error LED, red
IN	EtherCAT® in LED, green

Table 2: EtherCAT® LEDs (D303-D305)

4.2 IO-Link Connector

Connector: 4-pin male M8 (Binder 86 6319 1121 00004).

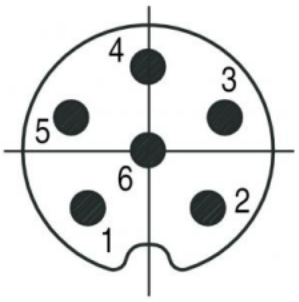


Pin	Signal	Description
1	V24	Supply input
2	DI	Not in use
3	GND	Supply and signal ground
4	C/Q	IO-Link transceiver input/output

Figure 5: IO-Link Connector (J202)

4.3 Supply and RS485 Connector and PWR LED

Connector: 6-pin male M8 (Binder 86 6319 1121 00006).



Pin	Signal	Description
1	RS485 B	RS485 interface (inverting)
2	RS485 A	RS485 interface (non-inverting)
3	+24V	Supply input
4	+24V	Supply input
5	GND	Supply ground
6	GND	Supply ground

Figure 6: Supply and RS485 Connector (J203)

There is a blue status LED on the board indicating that the board is powered.

4.4 Motor Connector

Connector: 3-pin 3.81mm standard header.

Connector	Signal	Description
1	U	Motor phase U
2	V	Motor phase V
3	W	Motor phase W

Table 3: Motor connector (PTH203-PTH205)

4.5 Brake Output Connector

Connector: 2-pin 3.81mm standard header.

Connector	Signal	Description
1	+24V	Supply output
2	Brake	PWM controlled low-side output

Table 4: Brake Output Connector (PTH206-PTH207)

4.6 Hall Sensor Connector

Connector: 5-pin 2.54mm standard header.

Pin	Signal	Description
1	+5V	Supply output for external sensor
2	GND	Signal and supply ground
3	U	Digital Hall sensor input, U channel, internal 4.7k Ω pull-up to +5V
4	V	Digital Hall sensor input, V channel, internal 4.7k Ω pull-up to +5V
5	W	Digital Hall sensor input, W channel, internal 4.7k Ω pull-up to +5V

Table 5: Hall Sensor Connector (J206)

4.7 Encoder Connector

Connector: 5-pin 2.54mm standard header.

Pin	Signal	Description
1	+5V	Supply output for external sensor
2	GND	Signal and supply ground
3	A	Digital quadrature/incremental encoder, A channel, internal 4.7k Ω pull-up to +5V
4	B	Digital quadrature/incremental encoder, B channel, internal 4.7k Ω pull-up to +5V
5	N	Digital quadrature/incremental encoder, N channel, internal 4.7k Ω pull-up to +5V

Table 6: ABN Encoder Connector (J205)

4.8 Analog I/O Connector

Connector: 4-pin 2.54mm standard header.

Pin	Signal	Description
1	AOI0	Analog input/output
2	AGND	Analog ground
3	AI1	Analog input
4	AI2	Analog input

Table 7: Analog I/O Connector (J204)

The table below describes the different I/O modes and available connections.

Mode	Connection
Analog Output Voltage Mode (AOVM)	AOI0 to AGND
Analog Output Current Mode (AOCM)	AOI0 to AGND
Analog Input Voltage Mode (AIVM)	AI1 or AI2 to GND for single-ended AI1 to AI2 for differential
Analog Input Current Mode (AICM)	AI1 to AI2

Table 8: Analog I/O Modes

4.9 Digital I/O Connector and LEDs

Connector: 6-pin 2.54mm standard header.

Pin	Signal	Description
1	+24V	Supply output
2	GND	Signal and supply ground
3	DOI1	Digital input/output
4	DOI2	Digital input/output
5	DOI3	Digital input/output
6	DOI4	Digital input/output

Table 9: Digital I/O Connector (J207)

The digital I/O interface includes 8 status LEDs (1 green status LED and 1 red error LED per channel).

4.10 Programming Connector

Connector: 4-pin 2.54mm standard header.

Pin	Signal	Description
1	+3.3V	Supply output
2	SWDIO	SWD data input/output
3	SWCLK	SWD clock input
4	GND	Signal and supply ground

Table 10: Programming Connector (J301)

5 Operational Ratings and Characteristics

5.1 Absolute Maximum Ratings

Parameter	Min	Max	Unit
Supply voltage	+20	+28	V
Motor phase current RMS		2.5	A
Ambient temperature	-30	+60	° C
Max load on +5V supply outputs		100	mA
Max load on +3.3V supply output		50	mA

Table 11: Absolute Maximum Ratings

NOTICE

Never Exceed the absolute maximum ratings! Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

5.2 Electrical Characteristics (Ambient Temperature 25° C)

The basic electrical characteristics of the IO-Link interface are given in the table below. For complete information refer to Maxim Integrated MAX22515 IO-Link transceiver datasheet.

Parameter	Symbol	Min	Typ	Max	Unit
Supply voltage	$V24$	8	24	36	V
C/Q and DI input voltage range	V_{IN}	V_{V24} - 36		36	V
C/Q and DI input threshold high	V_{TH}	10.8		12.5	V
C/Q and DI input threshold low	V_{TL}	8.8		10.5	V
C/Q and DI input hysteresis	V_{HYS}		2		V
C/Q driver current limit	I_{CL}	210	240	270	mA

Table 12: IO-Link Electrical Characteristics

The basic electrical characteristics of the RS485 interface are given in the table below. For complete information refer to Maxim Integrated MAX22501E RS485 transceiver datasheet.

Parameter	Symbol	Min	Typ	Max	Unit
Driver common-mode output voltage	V_{OC}		2.5	3	V

Driver differential output voltage	V_{OD}	1.5			V
Receiver common-mode voltage range	V_{CM}	-15		15	V
Receiver differential input threshold high	V_{TH_H}	50		200	mV
Receiver differential input threshold low	V_{TH_L}	-200		-50	mV
Receiver differential input hysteresis	V_{HYS}		250		mV

Table 13: RS485 Electrical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit
Input threshold high	V_{TH}		1.9		V
Input threshold low	V_{TL}		1.1		V
Input hysteresis	V_{HYS}		0.8		V
Input bandwidth	f_U		34		kHz

Table 14: Hall Sensor Electrical Characteristics

Parameter	Symbol	Min	Typ	Max	Unit
Input threshold high	V_{TH}		1.9		V
Input threshold low	V_{TL}		1.1		V
Input hysteresis	V_{HYS}		0.8		V
Input bandwidth	f_U		3.4		MHz

Table 15: Encoder Electrical Characteristics

The basic electrical characteristics of the analog I/O interface are given in the table below. For complete information refer to Maxim Integrated MAX22200 datasheet.

Parameter	Symbol	Min	Typ	Max	Unit
Input voltage range	V_{IN}		±12.5		V
Input voltage linear range	V_{IN}	-10.5		10.5	V
Output current range	I_{OUT}		±25		mA
Output current linear range	I_{OUT}	-21		21	mA

Table 16: Analog I/O Electrical Characteristics

The basic electrical characteristics of the digital I/O interface are given in the table below. For complete information refer to Maxim Integrated MAX14906 datasheet.

Parameter	Symbol	Min	Typ	Max	Unit
Input threshold high	V_{TH}	6.7		8.0	V
Input hysteresis	V_{HYS}		1.2		V
Output high-side on-resistance	R_{ON_HS}		120	240	m Ω
Output low-side on-resistance	R_{ON_LS}		1	3	Ω

Table 17: Digital I/O Electrical Characteristics

6 Introduction

IO-Link® is a 3-wire industrial communication standard designed for linking sensors and actuators into control networks.

The TMCM-1617-GRIP-REF operates at an IO-Link COM3 bitrate (230.4 kbit/s), and with a minimum cycle time of 4 ms. The IODD-file which is standardized by the IO-Link community, contains all required information to interface with the TMCM-1617-GRIP-REF in a machine readable format. It can be downloaded from the Trinamic website [2].

For further information on IO-Link in general, please have a look at Maxim's IO-Link Handbook [1].

7 Process Data

7.1 Output Process Data

The output process data is used to control the motor and to set the value for the analog and digital outputs.
Note: in the following tables, data types are given according to international standard IEC 61131.

7.1.1 Frame Structure

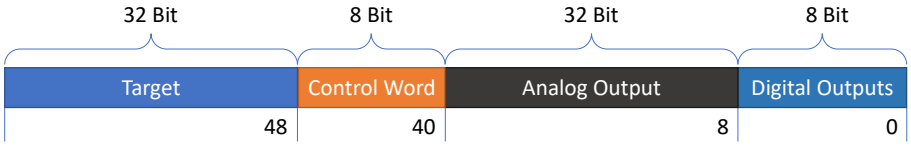


Figure 7: TMCM-1617-GRIP-REF Output Process Data Bit Sizes and Bit Positions

7.1.2 Field Description

Target (DINT)	Depending on the mode of operation configured in the Control Word, the value written into this field sets the target torque, velocity, or position.
Control Word (DWORD)	Set the mode of operation.

Value	Operation
0	No Control
1	Torque Control
2	Velocity Control
3	Position Control

Analog Output (DINT)	Set the DAC value for the analog output.
Digital Output (BYTE)	Set the logic level for DOI pin 1-4.

Bit	
0	DOI1 level
1	DOI2 level
2	DOI3 level
3	DOI4 level
4-6	reserved
7	output enable

7.2 Input Process Data

The input process data can be used to get feedback from the servo drive and to read the analog and digital inputs.

7.2.1 Frame Structure

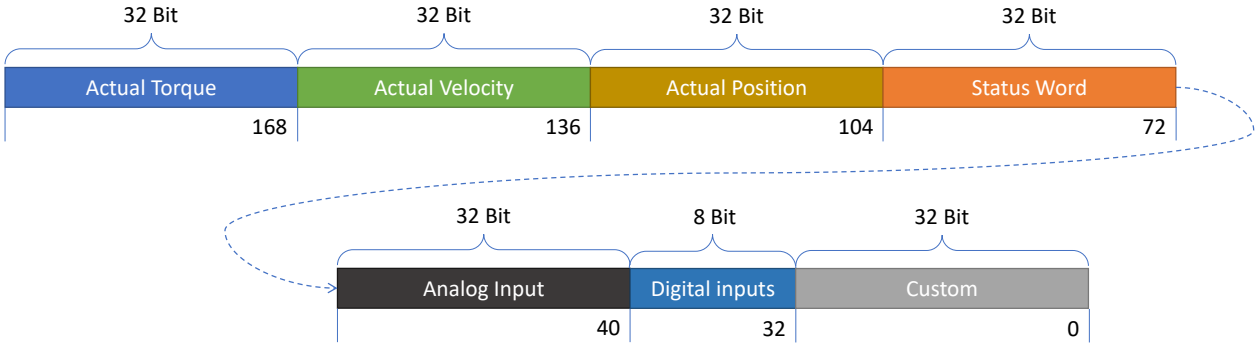


Figure 8: TMCM-1617-GRIP-REF Input Process Data Bit Sizes and Bit Positions

7.2.2 Field Description

Actual Torque (DINT)	Reflects the torque of the motor.
Actual Velocity (DINT)	Reflects the velocity of the motor.
Actual Position (DINT)	Reflects the position of the motor.
Analog Input (DINT)	Reflects the ADC value of the analog input.
Digital Input (BYTE)	Reflects the digital input states of DOI pin 1-4.

Bit pos	IO
0	DOI1 state
1	DOI2 state
2	DOI3 state
3	DOI4 state

Custom (DINT)	Value of one of the monitoring parameters selected by parameter Custom Process Data Select

Status Word (DWORD) A bit field used to check for positioning status, actual control mode and errors.

Bit pos	Flag	Description
3	Over Temperature	Signals a driver over-temperature error.
8	Stop Mode	Signals that the motor is not controlled in any way.
9	Velocity Control	Signals that the “Velocity Control” mode is active.
10	Position Control	Signals that the “Position Control” mode is active.
11	Torque Control	Signals that the “Torque Control” mode is active.
14	Position Reached	In Position control mode this bit signals, that the target position is reached. The bit is cleared if a new target position is given.
15	Module Initialized	Signals that the configured motor is initialized.

8 ISDU Parameter

8.1 Parameter List

Index	Parameter Name
	General Configuration
0x40	Enable Drive
0x41	Motor Type
0x42	Motor Pole Pairs
0x43	Motor Direction
0x44	Motor Commutation Mode
0x45	Motor PWM Frequency
0x46	Max Current
0x47	Max Velocity
0x48	Acceleration
0x49	Enable Velocity Ramp
0x4A	Custom Process Data Select
	Open Loop
0x50	Open Loop Current
0x51	Open Loop Commutation Angle
	Digital Hall
0x60	Digital Hall Commutation angle
0x61	Digital Hall Polarity
0x62	Digital Hall Direction
0x63	Digital Hall Interpolation
0x64	Digital Hall phi_e Offset
	Encoder
0x70	Encoder Commutation Angle
0x71	Encoder Steps
0x72	Encoder Direction
0x73	Encoder Init Mode
0x74	Encoder Init State
0x75	Encoder Init Delay
0x76	Encoder Init Velocity
0x77	Encoder Offset
0x78	Clear on Null

Index	Parameter Name
0x79	Clear once
	Torque Mode
0x81	Actual Flux
	Velocity Mode
0x84	Ramp Velocity
	Position Mode
0x88	Ramp Position
0x89	Position reached Distance
0x8A	Position reached Velocity
0x8B	Position Scaler
0x8C	Set Actual Position
	PI Controller Settings
0x90	Torque P
0x91	Torque I
0x96	Velocity P
0x97	Velocity I
0x9A	Position P
	Feedback ADC
0xA0	adc_I0_offset
0xA1	adc_I1_offset
0xA2	adc_I0_raw
0xA3	adc_I1_raw
0xA4	adc_I0
0xA5	adc_I1
0xA6	adc_I2
	Brake Chopper
0xAA	Enable Brake Chopper
0xAB	Brake Chopper Voltage Limit
0xAC	Brake Chopper Hysteresis
	Monitoring
0xB0	Supply Voltage
0xB1	Driver Temperature
	Analog IO
0xD0	AOI0 Mode

Index	Parameter Name
0xD1	DAC Calibration Gain
0xD2	DAC Calibration Offset
0xD8	AI1/AI2 Mode
0xD9	ADC Ch1 Calibration Gain
0xDA	ADC Ch1 Calibration Offset
0xDB	ADC Ch2 Calibration Gain
0xDC	ADC Ch2 Calibration Offset
	Digital IO
0xE0	DI Mode
0xE1	Pin Mode DOI1
0xE2	Pin Mode DOI2
0xE3	Pin Mode DOI3
0xE4	Pin Mode DOI4
0xE5	DO Mode DOI1
0xE6	DO Mode DOI2
0xE7	DO Mode DOI3
0xE8	DO Mode DOI4

Table 19: Parameter List

8.2 Parameter Details

Note: in the following tables, data types are given according to international standard IEC 61131. The column with the heading NV tells if the parameter is stored in non-volatile memory immediately on change. And the column with the heading DS tells if the parameter is included in the IO-Link data storage.

8.2.1 Enable Drive

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x40	BOOL	rw	0	1	1	-	yes	yes

Enables the motor driver.

Value	Explanation
0	driver disabled
1	driver enabled (default)

8.2.2 Motor Type

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x41	USINT	rw	0	3	0	-	yes	yes

Sets the type of the motor that is connected to the TMCM-1617-GRIP-REF.

Value	Explanation
0	No motor
1	Single phase DC motor
3	Three phase BLDC motor

8.2.3 Motor Pole Pairs

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x42	INT	rw	1	255	4	-	yes	yes

Sets the number of pole pairs of the motor that is connected to the TMCM-1617-GRIP-REF.

8.2.4 Motor Direction

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x43	BOOL	rw	0	1	0	-	yes	yes

Also known as shaft bit, this parameter can be used to invert the motor direction. On change, the actual position value is inverted accordingly.

Value	Explanation
0	Motor direction not inverted
1	Motor direction inverted

8.2.5 Motor Commutation Mode

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x44	USINT	rw	0	3	0	-	yes	yes

Sets the commutation mode.

Value	Explanation
0	Disabled
1	Open loop
2	Digital hall
3	Encoder

8.2.6 Motor PWM Frequency

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x45	DINT	rw	25000	100000	25000	-	yes	yes

Sets the frequency of the servo controllers PWM engine.

8.2.7 Max Current

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x46	INT	rw	0	3000	2500	mA	yes	yes

Maximum allowed absolute motor current. (This value can be temporarily exceeded marginal due to the operation of the current regulator.)

8.2.8 Max Velocity

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x47	DINT	rw	0	200000	4000	-	yes	yes

Maximum absolute velocity in velocity and positioning control mode.

8.2.9 Acceleration

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x48	DINT	rw	0	100000	2000	-	yes	yes

Acceleration in velocity and positioning control mode.

8.2.10 Enable Velocity Ramp

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x49	BOOL	rw	0	1	1	-	yes	yes

An activated ramp allows a defined acceleration for velocity and position mode.

Value	Explanation
0	Deactivate velocity ramp generator.
1	Activate velocity ramp generator. (default)

8.2.11 Custom Process Data Select

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x4A	USINT	rw	0	7	0	-	yes	yes

Maps one of the monitoring parameters to the custom input process data field.

Value	Parameter that is mapped to the custom process data field
0	Actual Flux
1	Ramp Velocity
2	Ramp Position
3	Open Loop Commutation Angle
4	Digital Hall Commutation angle
5	Encoder Commutation Angle
6	Supply Voltage
7	Driver Temperature
8	adc_I0
9	adc_I1
10	adc_I2

8.2.12 Open Loop Current

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x50	INT	rw	0	3000	800	mA	yes	yes

Motor current used in open loop commutation mode.

8.2.13 Open Loop Commutation Angle

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x51	INT	r	-32768	32767	-	-	no	no

Actual open loop angle value.

8.2.14 Digital Hall Commutation angle

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x60	INT	r	-32768	32767	-	-	no	no

Actual digital hall angle value.

8.2.15 Digital Hall Polarity

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x61	BOOL	rw	0	1	0	-	yes	yes

Hall sensor polarity.

Value	Explanation
0	Standard
1	Inverted

8.2.16 Digital Hall Direction

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x62	BOOL	rw	0	1	0	-	yes	yes

Hall sensor direction.

Value	Explanation
0	Standard
1	Inverted

8.2.17 Digital Hall Interpolation

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x63	BOOL	rw	0	1	0	-	yes	yes

Hall sensor interpolation.

Value	Explanation
0	Off
1	On

8.2.18 Digital Hall phi_e Offset

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x64	INT	rw	-32768	32767	0	-	yes	yes

Offset for electrical angle hall_phi_e of hall sensor.

8.2.19 Encoder Commutation Angle

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x70	INT	r	-32768	32767	-	-	no	no

Actual encoder angle value.

8.2.20 Encoder Steps

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x71	DINT	rw	0	16777215	4096	-	yes	yes

Encoder steps per full motor rotation.

8.2.21 Encoder Direction

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x72	BOOL	rw	0	1	0	-	yes	yes

Use this parameter to invert the encoder direction in cases where the encoder direction is physically inverted.

Value	Explanation
0	Standard
1	Inverted

8.2.22 Encoder Init Mode

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x73	USINT	rw	0	2	0	-	yes	yes

Select an encoder initialization mode that fits best to your motor's sensors.

Value	Explanation
0	Estimate offset
2	Use hall

8.2.23 Encoder Init State

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x74	USINT	r	0	3	0	-	no	no

Actual state of encoder initialization.

Value	Explanation
0	nothing to do
1	start init
2	wait init time
3	estimate offset

8.2.24 Encoder Init Delay

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x75	INT	rw	0	10000	1000	ms	yes	yes

Duration for encoder initialization sequence. This parameter should be set in a way, that the motor has stopped mechanical oscillations after the specified time.

8.2.25 Encoder Init Velocity

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x76	DINT	rw	-200000	200000	100	rpm	yes	yes

Velocity for encoder initialization with encoder N-channel.

8.2.26 Encoder Offset

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x77	DINT	rw	0	65535	0	-	yes	yes

This value represents the internal commutation offset (0...max. encoder steps per rotation).

8.2.27 Clear on Null

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x78	BOOL	rw	0	1	0	-	no	no

Clear the position counter on encoder N-channel.

Value	Explanation
0	do not clear position counter on the next N-channel event
1	set position counter to zero at next N-channel event

8.2.28 Clear once

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x79	BOOL	rw	0	1	0	-	no	no

Set this parameter to 1 if you like the “Clear on Null” to clear the position counter only on the very next occurrence of a N-channel event.

Value	Explanation
0	The position counter is always cleared at every N-channel event.
1	The position counter is set to zero only at the next N-channel event.

8.2.29 Actual Flux

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x81	DINT	r	-2147483640	2147483647	-	mA	no	no

The actual motor flux.

8.2.30 Ramp Velocity

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x84	DINT	r	-200000	200000	-	-	no	no

The actual velocity of the velocity ramp used for positioning and velocity mode.

8.2.31 Ramp Position

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x88	DINT	r	-2147483640	2147483647	-	-	no	no

The actual position of the position ramp used for positioning mode.

8.2.32 Position reached Distance

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x89	DINT	rw	0	100000	5	-	yes	yes

Maximum distance at which the position end flag is set.

8.2.33 Position reached Velocity

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x8A	DINT	rw	0	200000	500	-	yes	yes

Maximum velocity at which position reached flag can be set. Prevents issuing of position reached flag (in the status word) when the target is passed at high velocity.

8.2.34 Position Scaler

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x8B	DINT	rw	6	2147483647	65536	-	yes	yes

Scale the external position (external_position = (internal_position * scaler) / 65536.

8.2.35 Set Actual Position

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x8C	DINT	w	-2147483648	2147483647	-	-	no	no

With this parameter the actual position can be set to zero or any other value. This is helpful in the context of homing. Please make sure not to set a new position during an ongoing position move.

8.2.36 Torque P

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x90	UINT	rw	0	32767	300	-	yes	yes

P parameter for current PID regulator.

8.2.37 Torque I

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x91	UINT	rw	0	32767	300	-	yes	yes

I parameter for current PID regulator.

8.2.38 Velocity P

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x96	UINT	rw	0	32767	300	-	yes	yes

P parameter for velocity PID regulator.

8.2.39 Velocity I

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x97	UINT	rw	0	32767	100	-	yes	yes

I parameter for velocity PID regulator.

8.2.40 Position P

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0x9A	UINT	rw	0	32767	200	-	yes	yes

P parameter for position PID regulator.

8.2.41 adc_I0_offset

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xA0	UINT	rw	0	65535	33500	-	yes	no

Manually set/get the dual-shunt phase_A offset.

8.2.42 adc_I1_offset

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xA1	UINT	rw	0	65535	33500	-	yes	no

Manually set/get the dual-shunt phase_B offset.

8.2.43 adc_I0_raw

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xA2	UINT	r	0	65535	-	-	no	no

Raw adc measurement of the phase_A shunt.

8.2.44 adc_I1_raw

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xA3	UINT	r	0	65535	-	-	no	no

Raw adc measurement of the phase_B shunt.

8.2.45 adc_I0

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xA4	INT	r	-32768	32767	-	-	no	no

Calculated current measurement for phase_A shunt and used offset.

8.2.46 adc_I1

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xA5	INT	r	-32768	32767	-	-	no	no

Calculated current measurement for phase_B shunt and used offset.

8.2.47 adc_I2

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xA6	INT	r	-32768	32767	-	-	no	no

Calculated current of phase_C from the phase_A and phase_B measurements.

8.2.48 Enable Brake Chopper

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xAA	USINT	rw	0	1	0	-	yes	yes

Enable brake chopper functionality.

8.2.49 Brake Chopper Voltage Limit

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xAB	UINT	rw	60	300	300	0.1 V	yes	yes

If the brake chopper is enabled and supply voltage exceeds this value, the brake chopper output will be activated.

8.2.50 Brake Chopper Hysteresis

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xAC	USINT	rw	0	50	5	0.1 V	yes	yes

An activated brake chopper will be disabled if the actual supply voltage falls below Brake Chopper Voltage Limit minus this hysteresis value.

8.2.51 Supply Voltage

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xB0	INT	r	0	1000	-	0.1 V	no	no

The actual supply voltage.

8.2.52 Driver Temperature

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xB1	INT	r	-20	150	-	1.0°C	no	no

The actual temperature of the motor driver.

8.2.53 AOI0 Mode

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xD0	USINT	rw	0	7	0	-	yes	yes

Analog output mode.

Value	Explanation
0	High Impedance
1	Do not use!
2	Analog output voltage mode, ±12.5V setting
3	Analog output current mode, ±25mA setting
4	Analog output current mode, ±2.5mA setting

8.2.54 DAC Calibration Gain

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xD1	DINT	rw	0	262143	256250	-	yes	no

Use this parameter to adjust the analog output gain.

8.2.55 DAC Calibration Offset

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xD2	DINT	rw	-131072	131071	0	-	yes	no

Use this parameter to adjust the analog output offset.

8.2.56 AI1/AI2 Mode

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xD8	USINT	rw	0	7	0	-	yes	yes

Sets the mode for the ADC at pins AI1/AI2.

Value	Explanation
0	Power Down
1	Analog input differential ±25V* (Channel 1)
2	Analog input differential ±2.5V (Channel 2)
3	Analog input differential ±500mV (Channel 2)
4	Analog input differential ±250mV (Channel 2)
5	Analog input differential ±125mV (Channel 2)

*only ±15V can be measured effectively

8.2.57 ADC Ch1 Calibration Gain

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xD9	DINT	rw	0	16777215	0	-	yes	no

Gain calibration of the ADC channel 1.

8.2.58 ADC Ch1 Calibration Offset

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xDA	DINT	rw	-8388608	8388607	12582912	-	yes	no

Offset calibration of the ADC channel 1.

8.2.59 ADC Ch2 Calibration Gain

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xDB	DINT	rw	0	16777215	12582912	-	yes	no

Gain calibration of the ADC channel 2.

8.2.60 ADC Ch2 Calibration Offset

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xDC	DINT	rw	-8388608	8388607	0	-	yes	no

Offset calibration of the ADC channel 2.

8.2.61 DI Mode

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE0	USINT	rw	0	1	0	-	yes	yes

Digital input mode for all DIOs configured as digital input.

Value	Explanation
0	Type 1 and 3
1	Type 2

8.2.62 Pin Mode DOI1

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE1	USINT	rw	0	2	0	-	yes	yes

Pin mode for digital IO pin DOI1

Value	Explanation
0	Digital Output (DO)
1	Digital Input (DI)
2	Low-leakage, High-impedance

8.2.63 Pin Mode DOI2

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE2	USINT	rw	0	2	0	-	yes	yes

Pin mode for digital IO pin DOI2

Value	Explanation
0	Digital Output (DO)
1	Digital Input (DI)
2	Low-leakage, High-impedance

8.2.64 Pin Mode DOI3

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE3	USINT	rw	0	2	0	-	yes	yes

Pin mode for digital IO pin DOI3

Value	Explanation
0	Digital Output (DO)
1	Digital Input (DI)
2	Low-leakage, High-impedance

8.2.65 Pin Mode DOI4

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE4	USINT	rw	0	2	0	-	yes	yes

Pin mode for digital IO pin DOI4

Value	Explanation
0	Digital Output (DO)
1	Digital Input (DI)
2	Low-leakage, High-impedance

8.2.66 DO Mode DOI1

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE5	USINT	rw	0	3	0	-	yes	yes

If pin DOI1 is configured as output the output mode can be configured.

Value	Explanation
0	High-side
1	High-side with 2x inrush current for t_INRUSH time
2	Active clamp push-pull
3	Simple push-pull

8.2.67 DO Mode DOI2

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE6	USINT	rw	0	3	0	-	yes	yes

If pin DOI2 is configured as output the output mode can be configured.

Value	Explanation
0	High-side
1	High-side with 2x inrush current for t_INRUSH time
2	Active clamp push-pull
3	Simple push-pull

8.2.68 DO Mode DOI3

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE7	USINT	rw	0	3	0	-	yes	yes

If pin DOI3 is configured as output the output mode can be configured.

Value	Explanation
0	High-side
1	High-side with 2x inrush current for t_INRUSH time
2	Active clamp push-pull
3	Simple push-pull

8.2.69 DO Mode DOI4

Index	Data Type	Access	Min	Max	Default Value	Unit	NV	DS
0xE8	USINT	rw	0	3	0	-	yes	yes

If pin DOI4 is configured as output the output mode can be configured.

Value	Explanation
0	High-side
1	High-side with 2x inrush current for t_INRUSH time
2	Active clamp push-pull
3	Simple push-pull

9 Getting Started

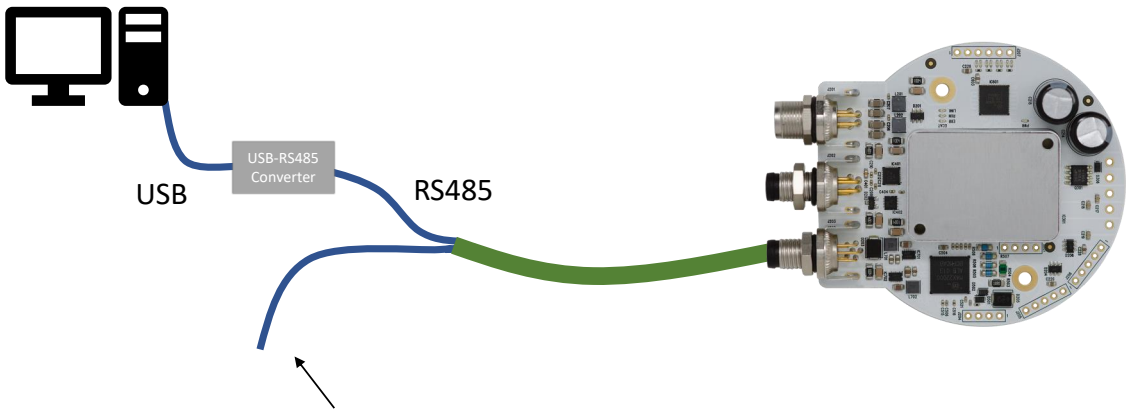
9.1 Upload the IO-Link Firmware

The TMCL firmware that is pre-programmed into the TMCM-1617-GRIP-REF is not able to communicate via IO-Link, so the IO-Link firmware needs to be uploaded via RS485 first. This is done using the TMCL-IDE [3] and an USB-to-RS485 converter.

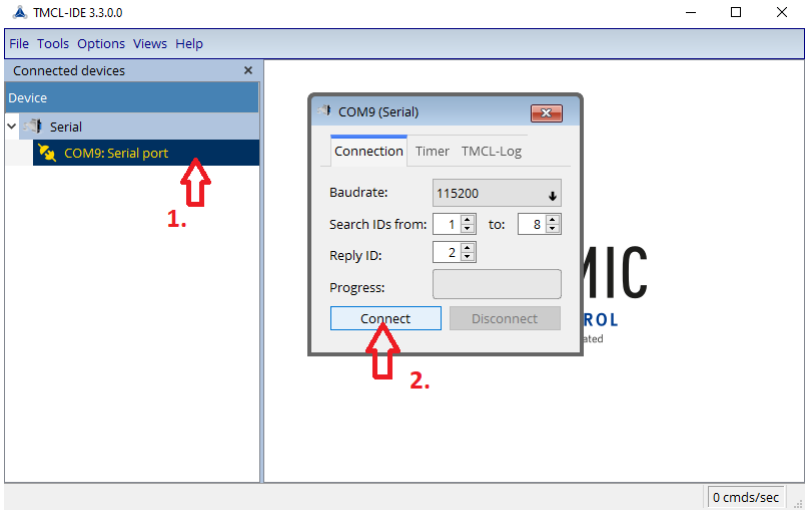
NOTICE Beware that it is best to use the TMCL-IDE prior to uploading the IO-Link firmware to find suitable setting for your system.

The following procedure describe how to upload the IO-Link firmware onto the TMCM-1617-GRIP-REF.

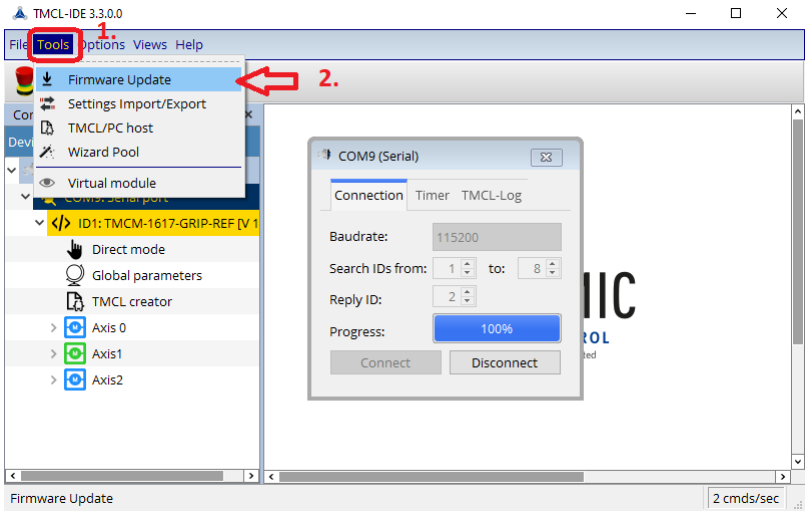
- Connect the RS485 lines that are available alongside the power lines to the USB-to-RS485 converter.



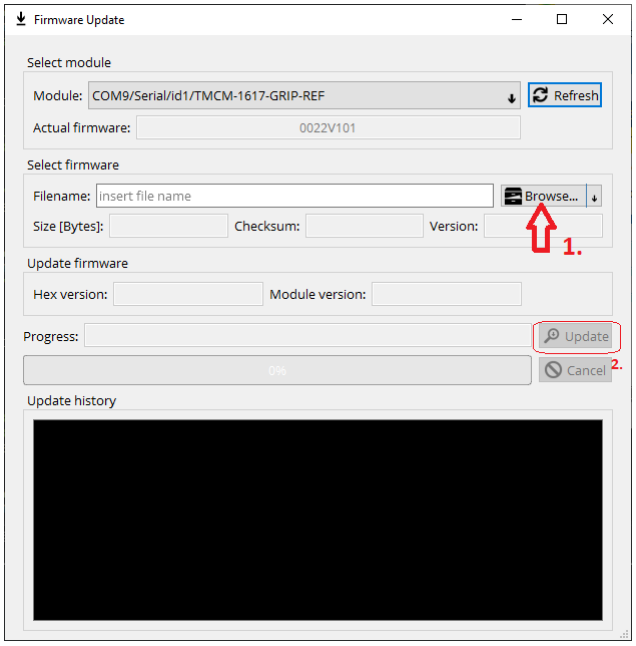
- Download and install the TMCL-IDE [3].
- Download and unpack the IO-Link firmware zip file from the TMCM-1617-GRIP-REF's product site [2]. (Make sure you download the latest version.)
- After you have the TMCL-IDE running, connect to the TMCM-1617-GRIP-REF:



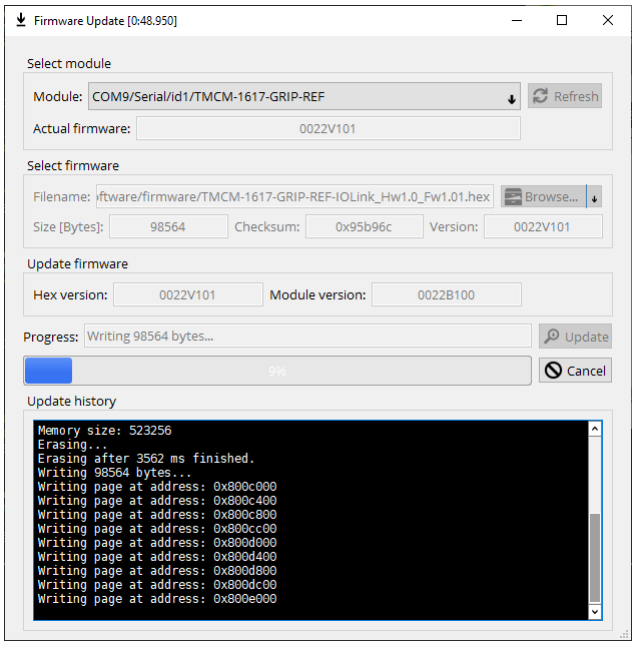
- The connected module should now show up in the device tree and the firmware update dialog can now be started.



- In the firmware update dialog browse to the firmware hex file that was inside the downloaded zip file, and then click the “Update” button.



- The firmware will now be uploaded, what will take several minutes.



- Once the download finished the TMCL-IDE tries to reconnect with the TMCM-1617-GRIP-REF, but the IO-Link firmware that is now running does not support RS485 TMCL protocol. You can now close the firmware upload dialog and the TMCL-IDE and connect to the TMCM-1617-GRIP-REF using IO-Link.

NOTICE

Notice that the parameter of the TMCL firmware and the IO-Link firmware are not stored in the same non-volatile memory region, both firmware variants store the settings in individual memory locations. That means that settings you found and stored using the TMCL-IDE, you need to apply again once you uploaded the IO-Link firmware.

9.2 Motor, Hall and Encoder settings

To be able to initially spin a motor, there are some important parameters that most likely need to be changed:

- Motor Type,
- Motor Pole Pairs and
- Motor Commutation Mode.

In case you use a digital hall sensor also:

- Digital Hall Direction and
- Digital Hall phi_e Offset.

In case you use an encoder also:

- Encoder Direction and
- Encoder Steps.

In addition for small motors the ADC offset values adc_I0_offset, and adc_I1_offset are crucial for the motor phase current measurement, and thus for the current regulation.

9.3 Moving a motor in position mode

If the parameters for your system are set correctly, moving a motor in position mode is as easy as:

- setting the Control Word to “Position Control” and
- writing the desired target position into the Target field.

9.4 Rotating a motor in velocity mode

Rotating a motor is done very much the same way

- set the Control Word to “Velocity Control” and
- write the desired target velocity into the Target field.

With negative target values the motor will rotate in the opposite direction.

9.5 Firmware Update

Even though the IO-Link firmware was uploaded, the TMCL/RS485 based bootloader is kept in the TMCM-1617-GRIP-REF MCUs flash memory. To upload a newer IO-Link firmware version, or to upload the TMCM-1617-GRIP-REF’s TMCL or CoE firmware variant, follow these instructions:

- Connect to the board via IO-Link.
- Write the keyword `J2emjH5QLrkSUF33` into the “Application-specific Tag” standard ISDU parameter.
- The IO-Link connection will be interrupted immediately. As long as you don’t powercycle the TMCM-1617-GRIP-REF you can now connect via RS485 and use the TMCL-IDE to upload any other firmware like described in section 9.1.

9.6 Example Setup

Here we show how to use the TMCM-1617-GRIP-REF in combination with Trinamics QBL4208-61-04-013-1k [4] Qmot BLDC motor with a 1024 lines (4096 counts) optical incremental encoder.

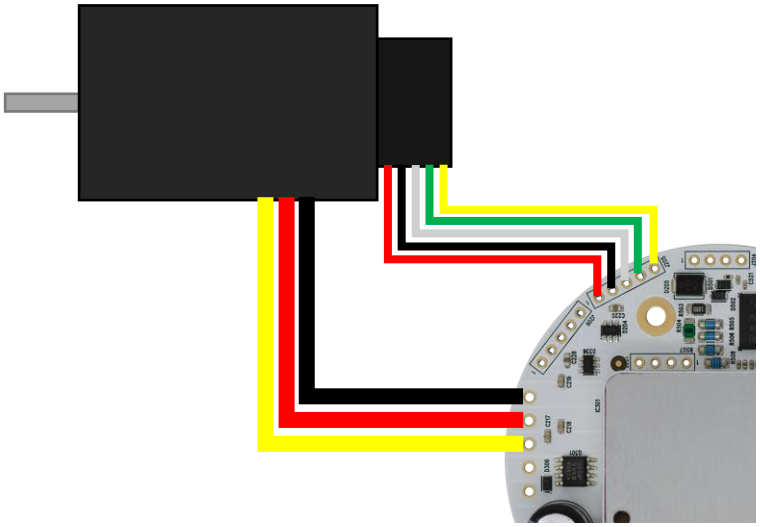


Figure 9: TMCM-1617-GRIP-REF attached to a QBL4208-61-04-013-1k

To use this motor/encoder combination you need to:

- reset all parameters to there default values with the “Restore Factory Settings” system command,
- invert the Encoder Direction,
- set the Motor Type to “Threee phase BLDC motor” and
- set the Motor Commutation Mode to “Encoder”.

Now you are able to move the motor in position or velocity mode (checkout section 9.3/9.4). Note that the Encoder Steps and Motor Pole Pairs can be kept as they are, because the default values are already suitable.

9.7 Using the Analog Output

The 18-bit analog output can ether be used in voltage- or current output mode. Select the desired mode and range, with the parameter AOI0 Mode. Once selected the Analog Output process data is used to update output voltage- or current.

Analog Output Value	Output Voltage ±12.5V mode	Output Current ±25mA mode	Output Current ±2.5mA mode
-131072	-12.5 V	-25 mA	-2.5 mA
0	0 V	0 mA	0 mA
131071	12.4999 V	24.9998 mA	2.49998 mA

Table 20: AOI0 Mode

NOTICE The analog output dose not come factory-calibrated. You can use DAC Calibration Gain and DAC Calibration Offset for a 2-point calibration. The gain and offset correction is done by the MAX22000 in hardware.

9.8 Using the Analog Input

The analog input has a 24-bit resolution. Select the desired range, with the parameter AI1/AI2 Mode. Once selected the Analog Input process data is used to get the converted voltage.

Analog Input Value	Input Voltage ±25V mode*	Input Voltage ±2.5V mode	Input Voltage ±500mV mode	Input Voltage ±250mV mode	Input Voltage ±125mV mode
-8388608	-25 V	-2.5 V	-500 mV	-250 mV	-125 mV
0	0 V	0 V	0 mV	0 mV	0 mV
8388607	25 V	2.5V	500 mV	250 mV	125 mV

Table 21: AI1/AI2 Mode

*only ±15V can be measured effectively

NOTICE

The analog input dose not come factory-calibrated. You can use ADC Ch1 Calibration Gain and ADC Ch1 Calibration Offset for a 2-point calibration of the ±25V mode, or ADC Ch2 Calibration Gain and ADC Ch2 Calibration Offset for 2-point calibration of the other modes. The gain and offset correction is done by the MAX22000 in hardware.

10 References

[1] Maxim Integrated. IO-Link Handbook. https://www.maximintegrated.com/an6454

[2] Trinamic. Product website - TMCM-1617-GRIP-REF. https://www.trinamic.com/support/eval-kits/details/tmcm-1617-grip-ref

[3] Trinamic. TMCL-IDE. https://www.trinamic.com/support/software/tmcl-ide

[4] Trinamic. QBL4208-x-1k. https://www.trinamic.com/products/drives/bldc-motors-details/qbl4208-x-1k/

11 Figures Index

12 Tables Index

13 Supplemental Directives

13.1 Producer Information

13.2 Copyright

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13.7 Collateral Documents & Tools

This product documentation is related and/or associated with additional tool kits, firmware and other items, as provided on the product page at: www.trinamic.com.

14 Revision History

14.1 Hardware Revision

Version	Date	Author	Description
1.0	12.02.2021	MM	

Table 22: Hardware Revision

14.2 Firmware Revision

Version	Date	Author	Description
1.01	21.05.2021	BP	Launch release.
1.02	03.06.2021	BP	Ability to restart the TMCL bootloader.
1.03	08.07.2021	BP	IO-Link compliance update.

Table 23: Firmware Revision

14.3 Document Revision

Version	Date	Author	Description
1.01	07.05.2021	MM/BP	Launch release.
1.02	04.06.2021	BP/ED	Adds section 9.
1.03	08.07.2021	BP	Firmware revision update - no change in content.

Table 24: Document Revision