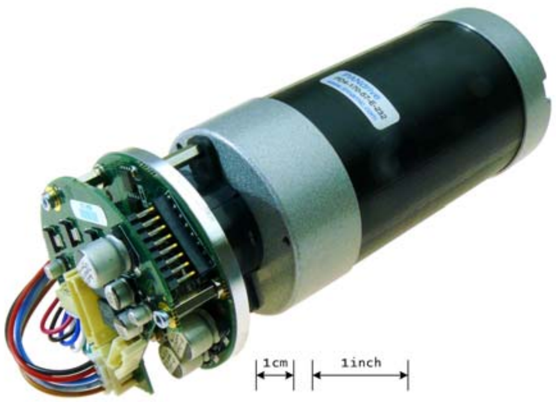
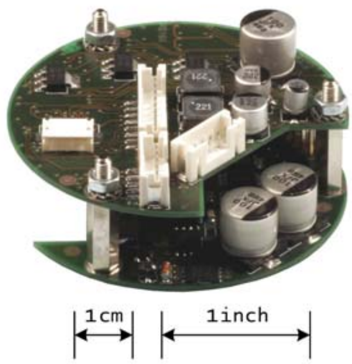
PANdrive PD-170-57
and
TMCM-170-57





Hardware Manual

57 mm BLDC servo motor and controller 10A/48V
with RS232 or RS485 and CAN interface

Trinamic Motion Control GmbH & Co. KG
Sternstraße 67
D – 20357 Hamburg, Germany
http://www.trinamic.com

Contents

1 Features

The PD-170-57 is a combination of an intelligent BLDC servo motor controller / driver, an optical encoder and a 57mm brushless DC motor. As controller / driver the TMCM-170 is used which has been designed for high performance servo drives based on brushless DC motors. It combines the high resolution known from stepper motors with the high dynamic, high velocity and high reliability of a BLDC drive. A build-in ramp generator allows parameterized smooth positioning. Its small form factor allows direct mounting on / into a motor-encoder assembly. The TMCM-170 supports BLDC motors with nearly any number of poles and incremental encoders with nearly any resolution.
The TMCM-170 integrates a position and a velocity regulator.
The module can be remote controlled via an RS232 or RS485 interface (ordering option) and an optional CAN interface.

Applications

- Replacement of servo drive by high reliability / low cost BLDC drive
- Fast and precise positioning
- Smooth very low to very high constant / variable velocity drives
- Very high velocity stability drives
- Extremely compact decentralized motor electronics

Motor / Encoder type

- Sine (or block) commutated BLDC motors with encoder and with / without additional hall sensors
- Hall sensor based motors can be operated without encoder
- Motor power from a few watts to 500W
- Motor velocity up to 100,000 RPM (electrical field)
- Incremental encoder (2 channel with option for N-channel) with resolution from 256 to 30000 / motor rotation (opt. per electrical field rotation)
- 12V to 48V nominal motor voltage
- Coil current up to 10A nominal (up to 14A current for short time)

PANdrive Motor and Encoder data

- Motor: Trinamic´s QBL 5704-94-04-032 or QBL 5704-116-04-042, rated torque 0.32 Nm or 0.42 Nm
- Encoder: HEDS-5640-A12 with resolution of 2000 per motor rotation
- Please refer to the datasheets for detailed motor and encoder information

Highlights

- High-efficiency operation, low power-dissipation
- CAN interface and RS232 or RS485 integrated
- Integrated Protection: Reverse polarity and overload / overtemperature / overvoltage
- TRINAMIC TMCL protocol and TMCL software environment for parameterizing and for update and for programming of stand alone mode
- 1024 entry 10 bit motor sine commutation table
- External (stop) switch or encoder N channel can be used for absolute position reference
- Different start up modes for automatic commutation calibration

Order code	Description	Dimensions [mm³]
PD4-170-57-E (-option)	PANdrive 0.32Nm	
PD5-170-57-E (-option)	PANdrive 0.42Nm	
TMCM-170 (-option)	BLDC servo module	
Option		
232	RS232 and CAN interface	
485	RS485 and CAN interface	

Table 1.1: Order codes

2 Life support policy

TRINAMIC Motion Control GmbH & Co. KG does not authorize or warrant any of its products for use in life support systems, without the specific written consent of TRINAMIC Motion Control GmbH & Co. KG.

Life support systems are equipment intended to support or sustain life, and whose failure to perform, when properly used in accordance with instructions provided, can be reasonably expected to result in personal injury or death.

3 Electrical and Mechanical Description

3.1 Pinning

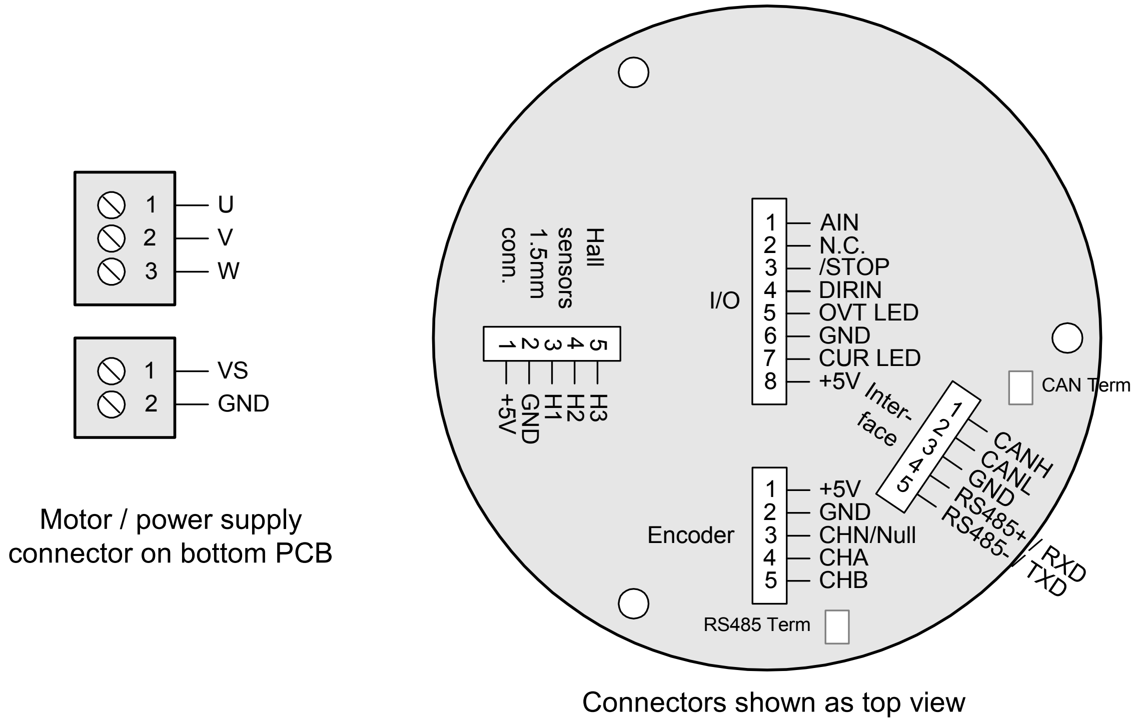
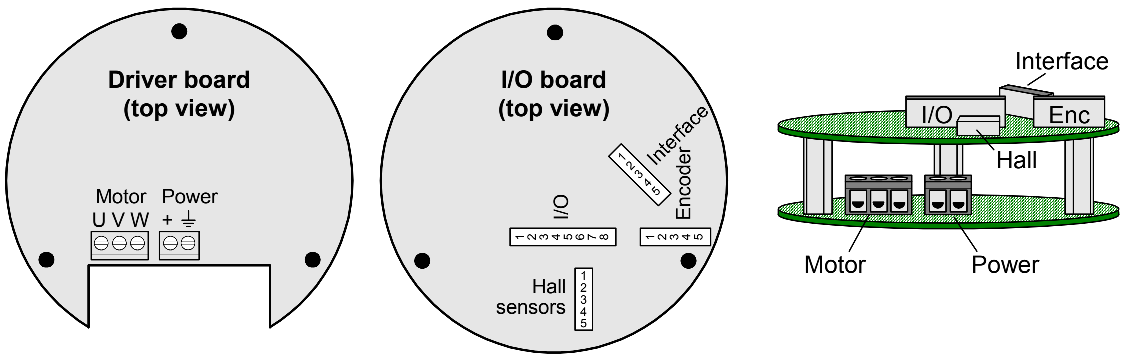


Figure 3.1:Pinning

Pin	Function
AIN	Analog input: Can measure 0 - 10V signal.
DIRIN	5V TTL input. Not used in current firmware releases
/STOP	Reference Switch / Emergency stop. Tie this pin to GND to stop the motor or to clear the position counter. Function / polarity depends on Software setting. (5V TTL input with integrated 10K pull-up resistor to 5V)
OVT LED	5V TTL output: Toggling with 3Hz when temperature pre-warning threshold is exceeded, high when module shut down due to overtemperature.
CUR LED	5V TTL output: High, when module goes into current limiting mode or into overvoltage switch off. Toggling with 3Hz on undervoltage condition.
+5V	5V supply for motor hall sensors and as reference for external purpose
GND	Power GND / GND reference GND is also connected to the mounting holes on the bottom PCB
RXD / RS485+	RXD signal of module for RS232 communication (RS232 version) Non-inverting RS485 signal (RS485 version)
TXD / RS485-	TXD signal of module for RS232 communication (RS232 version) Inverting RS485 signal (RS485 version)
CANH / CANL	CAN interface signals
U, V, W	BLDC motor coil outputs
CHN	Encoder null channel (optional use) (5V TTL input with integrated pull-up resistor to 5V)

Pin	Function
CHA, CHB	Incremental encoder channel A / channel B (5V TTL input with integrated pull-up resistor to 5V)
H1, H2, H3	Hall sensor signals (5V TTL input with integrated pull-up resistor to 5V)
VS	Positive power supply voltage (reverse polarity protected)
All other pins	Leave all other pins unconnected!

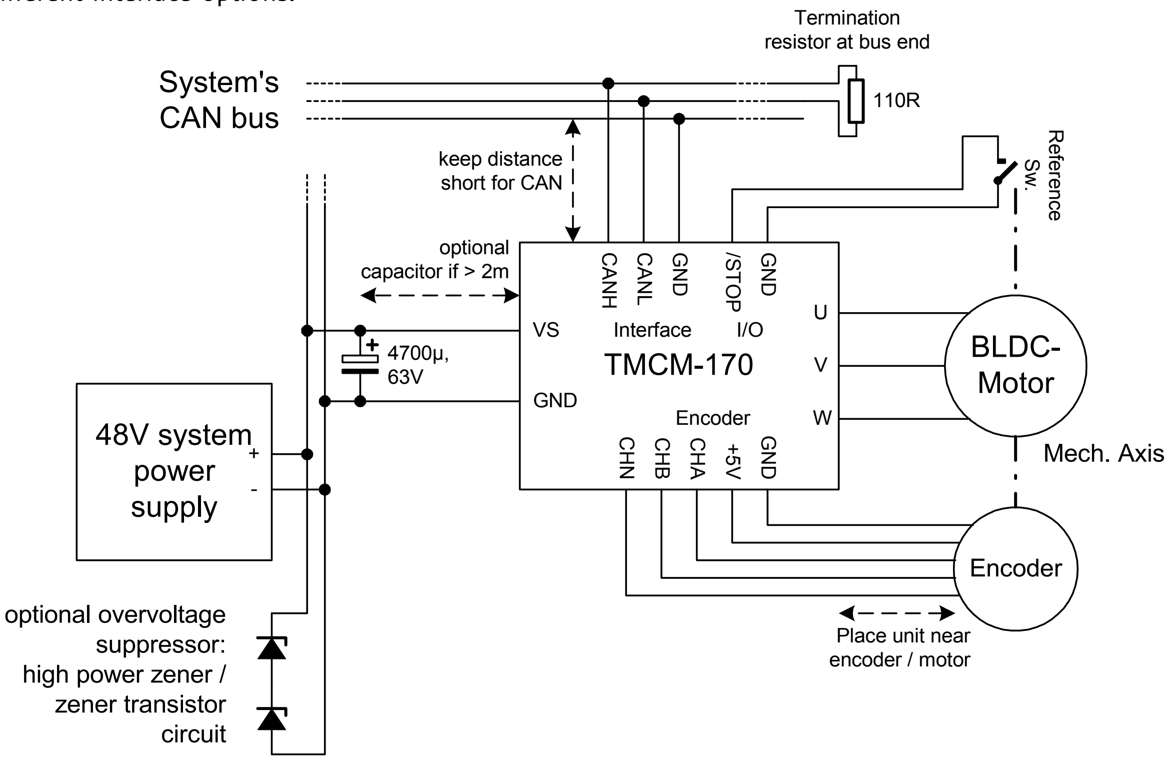
Table 3.1: Pinning



Important note: For the PANdrives PD-170, the motor coils, hall sensor signals and encoder signals are already connected. Nevertheless, in order to connect power supply the upper interface board has to be removed. Never connect or disconnect the boards while power is switched on!

3.2 Application circuit

The schematic shows a typical application circuit using CAN bus interface. Optionally the unit allows connection of motor hall sensors and encoder N-channel as well as further digital / analog pins and different interface options.



3.3 Dimensions

Diameter 61mm, TMCM-170 height 28mm (16mm + highest part), mounting holes diameter is 2.8mm

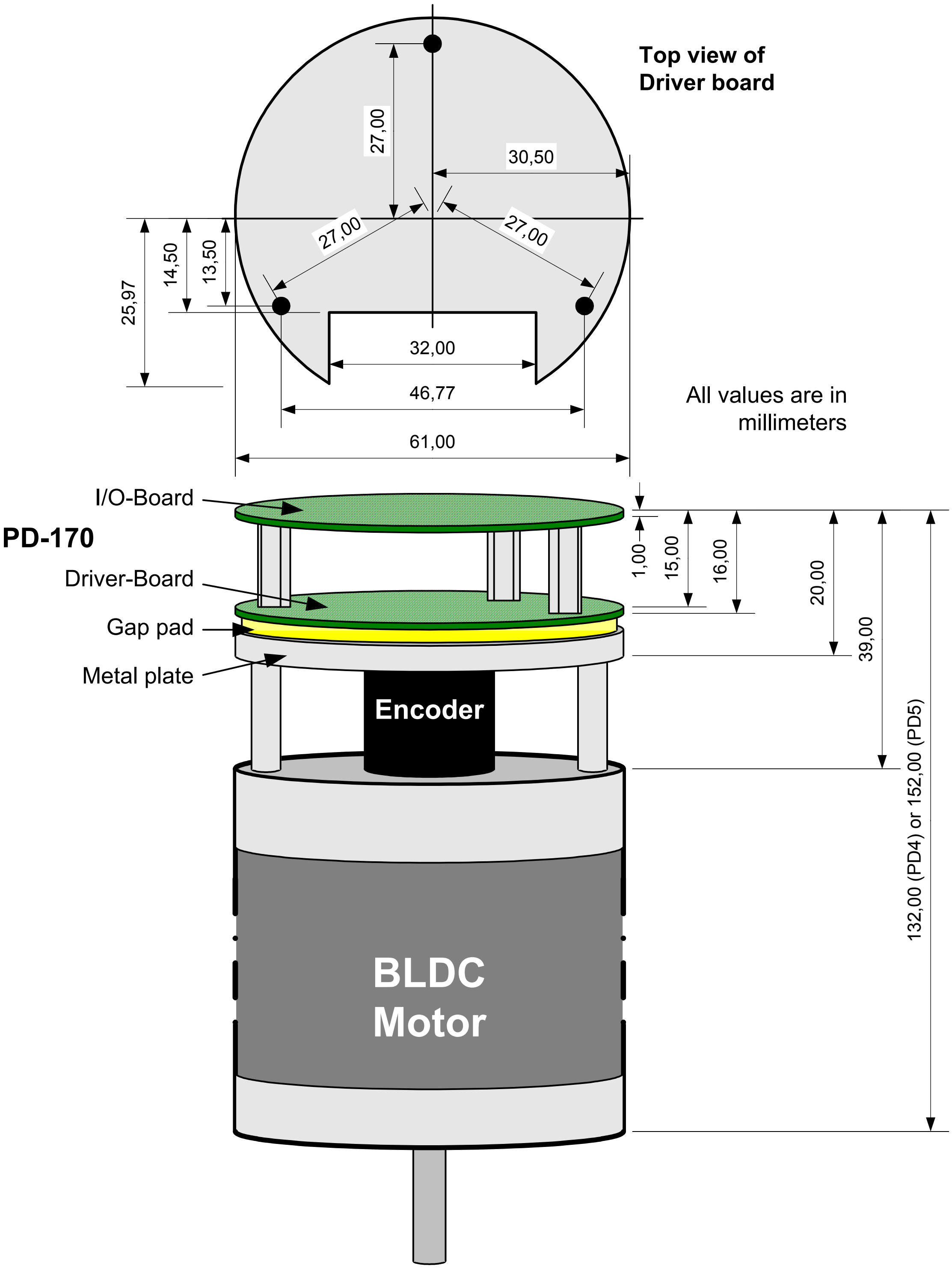


Figure 3.2: Dimensions of TMCM-170 and PD-170

3.4 Connectors

Hall sensor: JST1.5mm type: S5B-ZR-SM2-TF
Other interfaces: JST-PHR – 8 and JST PHR – 5 2.00 mm

3.5 PANdrive Specifications

This chapter describes the additional components of the PD-170.

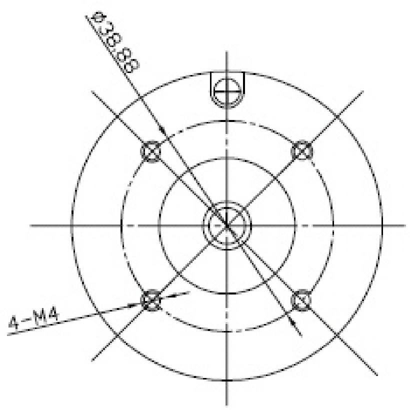
3.5.1 PANdrive Motor

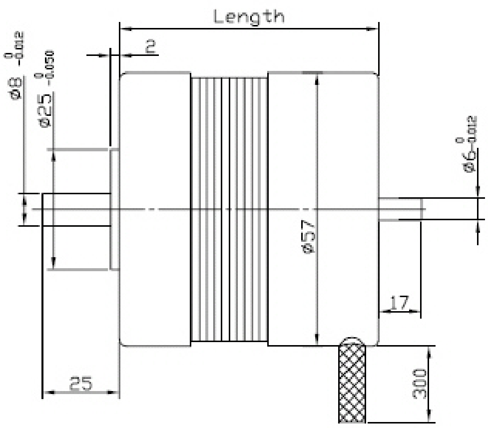
The PD-170 comes either with the QBL 5704-94-04-032 or QBL 5704-116-04-042 motor (ordering option). For further information refer to the QBL 5704 motor manual, also.

Main characteristics:
Hall Effect Angle: 120° electric angle
Shaft run out: 0,025 mm
Insulation Class: B
Radial Play: 0,02 mm 450G load
Max Radial Force: 75N (10mm from flange)
Max Axial Force: 15N
Dielectric Strength: 500 VDC For One Minute
Insulation Resistance: 100M Ohm min. 500VDC
Recommended Ambient Temp.: -20 to +40°C
Bearing: Brushless motors fitted with ball bearings

Specifications		QBL 5704	
		-94-04-032	-116-04-042
No. of Pole		4	4
No. of Phase		3	3
Rated Voltage	V	36	36
Rated Phase Current	A	5.08	6.67
Rated Speed	RPM	4000	4000
Rated Torque	Nm	0.32	0.42
Max Peak Torque	Nm	0.98	1.3
Torque Constant	Nm/A	0.063	0.063
Line to Line Resistance	Ohm	0.45	0.35
Line to Line Inductance	mH	1.4	1
Max Peak Current	A	16.5	20.5
Lenth (L_{MAX})	mm	94	116
Rotor Inertia	kgm² x 10^{-6}	17,3	23
Mass	kg	1	1,25
Related Trinamic PANdrive		PD4-170-57	PD5-170-57

Table 3.2: Motor technical data





In opposite to the QBL 5704-94-04-032 the Reverse Hall sensor polarity has to be switched on and Reverse Encoder Direction off for the QBL 5704-116-04-042 in the basic control and diagnostics software.

4 Operational / Limiting Ratings

The operational ratings show the intended / the characteristic range for the values and should be used as design values. An operation within the limiting values is possible, but shall not be used for extended periods, because the unit life time may be shortened. In no case shall the limiting values be exceeded.

Symbol	Parameter	Min	Typ	Max	Unit
V_S	Power supply voltage for operation	12.5	14 - 48	52	V
V_{SMAX}	Maximum power supply voltage (for surge)			60	V
V_{SLOOFF}	Under voltage switch off trip point	9.5	10	10.5	V
V_{SON}	Under voltage switch on trip point	10.5	12	12.5	V
V_{SOFF}	Over voltage switch off trip point (Feature can be switched off, then V_{SMAX} limit applies)	52	55	58	V
V_{SD}	Power supply voltage for module operation with motor disabled	7	8	9.5	V
I_S	Power supply current	0.04	(P_{Motor} +3..10W) / V_S	I_{MOT}	A
P_{ID}	Module idle power consumption without encoder / hall sensor		2.4		W
V_5	5 Volt (+-4%) output external load (encoder plus hall sensors plus other load)	0		200	mA
I_{MC}	Continuous Motor RMS current (module surface at maximum 85°C)			10	A
I_{MP}	Short time Motor current in acceleration periods It is not recommended to set motor current above 12A!			14	A
I_{MPP}	Peak coil output current for 100ms			40	A
f_{CHOP}	Chopper frequency		20		kHz
T_{SL}	Motor output slope (U, V, W)		100		ns
V_I	Logic input voltage on digital inputs, encoder and hall sensor inputs	-0.3		V_{CC}+ 0.3	V
I_I	Pull-up resistor current for hall and encoder inputs	50	250	400	µA
V_O	Logic output current on digital outputs (5V CMOS output)			10	mA
V_{IA}	Analog input voltage	-24	0 – 10	24	V
E_V	Exactness of voltage measurement	-5		+5	%
E_C	Exactness of current measurement (the measured coil current value might not correspond to the RMS current, but is repeatable within the given exactness)	-10		+10	%
f_{ENC}	Encoder count rate (signals 50% duty cycle)			13.3	MHz
T_O	Environment temperature operating	-25		+85	°C
T_{board}	Temperature of the bottom (driver) PCB, as measured by the integrated sensor.		<105	115	°C

4.1 Power supply requirements

The power supply should be designed in a way, that it supplies the nominal motor voltage at the desired maximum motor power. In no case shall the supply value exceed the upper / lower voltage limit. The BLDC motor unit uses a chopper principle, i.e. the power supply to the motor is pulsed at a frequency of 20kHz. To ensure reliable operation of the unit, the power supply has to have a sufficient output capacitor and the supply cables should have a low resistance, so that the chopper operation does not lead to an increased power supply ripple directly at the unit. Power supply ripple due to the chopper operation should be kept at a maximum of a few 100mV.

Therefore we recommend to

a) keep power supply cables as short as possible
b) use large diameter for power supply cables
c) if the distance to the power supply is large (i.e. more than 2-3m), use a robust 4700µF or larger additional filtering capacitor located near to the motor driver unit.

An effect the power supply has to cope with, is, that the motor can feed back substantial current into the power supply whenever it is actively braked! While this generally is a positive effect (because it saves energy), precautions have to be taken, to limit the supply voltage to within the operational limits. The TMCM-170 contains an overvoltage protection circuit, which disables braking whenever the upper supply voltage limit is exceeded. This automatic function may lead to an unwanted behavior, i.e. overshooting the target position, and thus can be disabled. Disabling the overvoltage protection should only be done, provided that the user takes additional precautions to limit the voltage:

It is recommended to use

a) a large capacitor on the power supply lines able to store substantial part of feed back energy
b) a zener / suppressor diode circuitry, limiting the power supply voltage to a maximum of 52-60V

4.2 Bus Interface

The TMCM-170 supports an optional CAN interface. It can be operated via CAN or RS232 / RS485 in the same way. CAN bus and RS485 require a termination resistor at both ends of the cable (but not at every unit). This resistor is integrated and can be activated on the TMCM-170 by shorting a soldering bridge (dotted line in the connector drawing), but for most purposes it is more elegant to provide this resistor external to the unit.

4.2.1 Terminating the RS485 network

For RS485 in addition to the termination resistor a termination network is required, which forces an "inactive" level to the line, when no driver is on. Typically, use a 1K resistor to + 5V for RS485+ line and a 1K resistor to GND for the RS485- line at some point of the network.

5 Functional description

5.1 Setting the basic values for operation (using the demonstration application)

The TMCM-170 can use nearly any BLDC motor and encoder type. However, care has to be taken to correctly set the motor pole count (default: 8) and encoder resolution (default: 4096) and direction (default: Encoder gives same direction as motor) before trying to operate the motor! If a hall sensor is used, please check if the hall sensor polarity is to be reversed (try operating the motor in block commutation mode, first). Also choose a fitting initialization mode (2 is most universal) and set the corresponding parameters (please see chapter on start up).
The motor behavior afterwards may still give unsatisfactory results: The next step is to tune the PID parameters.
For these basic settings, the Windows based demonstration application can be used. It requires connection to the RS232 interface or via an RS485 converter to the RS485 interface. For RS485, as a first step use the TMCL-IDE to set the parameter "Telegram pause time" to a value of about 20. Further basic settings are required for motor start up (see next chapter).

Hint: *To avoid motor operation or damage, before the unit is completely parameterized, use a supply voltage of only 8V! This disables the motor.*

5.2 Start up for encoder based commutation

The TMCM-170 uses an incremental encoder for motor commutation. Incremental means, that the encoder does not give an absolute position reference. Thus, the unit needs an internal start up procedure, which determines the encoder position with respect to the actual pole motor orientation.

The TMCM-170 provides basically two modes for encoder initialization:

Mode 0 uses additional motor hall sensors for the start up phase. Therefore, the motor can not do a precise positioning until it has done at least one electrical rotation. This can be perceived by a somehow rough behavior on the first positioning run.
We recommend using this mode, when the motor has hall sensors and mode 1 does not give reliable results.
However, the motor hall sensors typically are not as precise, as this would be desired for sine commutation. To accomplish with the hall sensor error and hysteresis, you can set the corresponding parameters "Init Sine Block Offset CW" and CCW.

Mode 1 drives the motor field into a known position and then evaluates the encoder position. While this is a very precise scheme, it is susceptible to external force applied to the rotor: The rotor is not to be blocked in any direction. Additionally external mechanical torque applied to the axis should be kept low. To use this mode, it is important to set the "Sine Initialization Current A" as high as possible (within the 14A limit). Default value is 11A. You can set Sine Initialization Current B to a somewhat lower value (at least ½ of Current A) to give optimum results. The best setting has do be determined for a given motor. To allow for minimum motor movement upon initialization, this mode also checks the hall sensor positions.

Mode 2 is the same as mode 1, but does not check if the motor has hall sensors.

Mode 3 is the most precise and reliable initialization mode: It uses the encoder N-channel for initialization. To first find the N-channel reference position, the motor is turned by up to one rotation, until the N-channel is found positive. The velocity and direction can be specified using the parameter "Sine Init Velocity". After finding the reference position, the "Actual Commutation Offset" gives the angular relationship between motor and encoder.

Therefore this parameter has to be stored correctly in EEPROM before power on! Do not enable this mode, before the parameter has been set correctly. Mode 4 helps for the very first initialization of this mode.

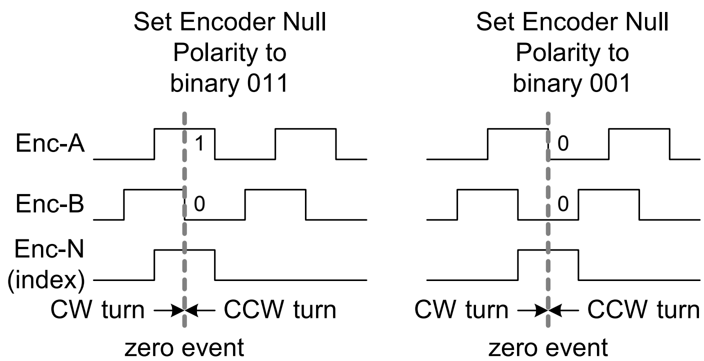
Mode 4 helps to do a first initialization and tuning of mode 3. It searches for the N-channel reference point first, and then does a *mode 2* initialization to determine the correct setting for the "Actual Commutation Offset". The encoder N-channel polarity has to be high active for this mode (the actual setting of the encoder null polarity has no influence in this mode), and, additionally, you have to specify the polarity of the encoder A- and B-channel upon N-channel activity using the setting "Encoder Null Polarity", bits 1 and 2. The correct setting of this depends on the encoder. If the N-channel referencing fails, the motor does two full rotations and then stops. Try again with reversing the "Encoder Null Polarity". After successfully initializing the "Actual Commutation Offset", you can try moving the motor and tune the offset, if desired. Then store the offset and switch to *mode 3*. If any encoder errors are flagged during operation of the motor, retry with a modified setting for A- and B-channel polarity.

Attention: *Initialization modes 1 to 4 apply a high current to the motor for a few seconds. Be sure to parameterize the initialization current correctly (i.e. not more than 2* the maximum rated motor current) before first powering on the unit.*

The quality of the initialization phase result can be checked by rotating the motor left and right at the maximum velocity (use a velocity setting slightly higher than the motor can follow). Maximum velocity for left and right direction shall not differ by more than a few percent. Also make some checks if results are reproducible.
Whenever changing one of these parameters, re-power the unit to restart initialization phase!

5.3 Encoder setting

The N-channel (index channel) of the encoder is not required for motor operation, but it is very good for motor initialization, because it gives an absolute and exact reference point. So, the motor initialization modes 3 and 4 use the N-channel for motor initialization. Behavior of the N-channel signal is very dependent on the encoder type and has to be taken into account for the setting of the TMCM170 encoder interface. Please refer to the following figure for correct setting of the Encoder Null Polarity flag.
A wrong setting may either hinder the module from initializing the sine mode, or might lead to the Encoder Error flag being set, in spite of correct encoder function.



5.4 Hall sensor only operation w/o encoder

The module can be used without an encoder. In this case, set the encoder resolution parameter (SGP 250) to the hall sensor resolution, i.e. 3 times the number of motor poles. Example: For a 4 pole motor set the encoder resolution to 12. To avoid oscillations in positioning mode, the algorithm in this mode stops regulation, as soon as the target distance is below the setting as determined by "MVP target reached distance". Adapt this setting to your needs. Switch the module to hall sensor based commutation permanently in order to skip encoder initialization procedure in this configuration. Please be aware, that the hall sensor resolution is very low, when compared to an encoder, and thus, the PID regulator parameterization values have to be set much higher than the default setting. Without encoder, the velocity measurement is not available. You may want to set a lower value than the default for the "PWM Hysteresis" setting to get a softer response upon target reaching.

5.5 Stop switch

For positioning applications, typically some kind of global initialization is required. This can either be done via a central unit operating the motor via its bus interface, or a reference switch can be connected to the stop input (pull down to 0V at reference point). The position counter can be automatically cleared when this point is reached. Be careful not to apply a voltage different from GND to this digital input!

5.6 General Functions (explore using the Windows based demo software)

The TMCM-170 module can either be remote controlled via the PC demonstration software or a user specific program. The function of the stand alone mode can be modified by the user by writing initialization values to the on-board EEPROM, e.g. a maximum rotation velocity, motor current limit and rotation direction. **For more detailed software information refer to the TMCM-170 Module – Reference and Programming Manual (see 7: References).**

5.7 Temperature, Current and Voltage monitoring functions

LED / Output	Action	Meaning
Current Limit	Blink	The current limit LED blinks upon under voltage switch off
Current Limit	On / Flicker	Motor PWM is reduced due to exceeding the set motor current limit or overvoltage threshold is exceeded
Temperature Warning	Blink	The power stage on the module has exceeded a critical temperature of 85°C. (Pre-warning)
Temperature Warning	On	The power stage on the module has exceeded a critical temperature of 115°C. The motor becomes switched off, until temperature falls below 105°C. The measurement is correct to about +/-10°C

5.8 Programmable motor current limit

The motor current limiting function is meant as a function for torque limiting, and for protection of motor, power supply and mechanical load.

Whenever the pre-programmed motor current is exceeded in a chopper cycle, the TMCM-170 calculates a reduced PWM value for the next chopper cycle. New values are calculated 1000 times a second. The response time of the current regulation can be set using the parameter "current regulation loop delay":

A value of zero means, that in every 1kHz period, the current correction calculation is directly executed and the resulting PWM value is taken. A higher current loop delay acts like a filter for the current. The higher the delay value, the slower the current loop response time. A value of 10 (default) leads to a current regulation response time of about 10 ms for an 1/e response. On the mechanical side, a higher value simulates a higher dynamic mass of the motor.

The actual current regulation time may differ, depending on the PID settings.

Attention: *Please be careful, when programming a high value into the current regulation loop delay register: The motor current could reach a very high peak value upon mechanical blocking of the motor. The same goes for the motor current limit value: do not set higher than 12A if you are not sure about this.*
If the short time motor coil current is not limited to a maximum of about 40A, this could destroy the unit.

There is a number of aspects when using the current limiting function:

- The current measurement is done at a point of the chopper cycle, where just one coil is switched on. When using sine commutation, the effective coil current is about 88% of the measured current respectively of the current limit setting.
- The current measurement can not detect currents below about 200-300mA. If the current limit is set to a too low value, the motor may operate spuriously or become continuously switched off.
- The current limiting function is not meant as a protection against a hard short circuit.
- The performance of the current limiting depends on the motor and on the commutation mode. Especially in sine commutation mode, the measured current and thus current limiting may be quite instable. The current limit should be programmed to a value high enough, in order to achieve good positioning and acceleration performance.
- Operation of the current limiter and the PID regulator may result in instable behavior, if the motor gets into a resonance area. Try adapting the current regulation loop delay parameter.
- If the motor is blocked and the ramp generator is not stopped, the motor will speed up and try to catch up with the ramp generator position after removal of the blocking. To control this effect, you can set the parameter "Clear Target Distance" in order to stop the ramp generator, when the deviation between the positions become to large. The effect of this may look somehow weird if the user does not expect it.

6 Revision History

6.1 Documentation Revision

Version	Comment	Author	Description
1.00	2005 – 2007	Dw	Initial Versions
1.05	05-09-2007	HC	Added Documentation Revision and PANdrive information
1.06	10-09-2007	GE	Update of dimensions and pictures
1.07	30-10-2007	HC	Encoder graphics added (chapter 5.3)
1.08	21-11-2007	HC	PanDrive Encoder resolution info corrected to 2000 per rotation

6.2 Firmware Revision

Version	Comment	Description
0.90	Initial Version	Attention: Use Documentation V0.90 or later for connector pinning!!!
0.92	First release	Added encoder N-channel initialization
0.93		Added encoder N-channel for automatic correction and encoder error flag
0.94		Allows specifying of CHA and CHB polarity for nulling of encoder – uses higher bits of Encoder Null Polarity
1.00	Release 1.0	Added operation mode with hall sensors only.
1.01		Corrected RS485 behavior
1.02		Added stand alone mode feature
1.03		Fixed RS485 delay problem (master had to wait for timeout time before sending new command), when multiple units share a bus
1.07	TMCL	Added TMCL stand alone program capability, extended command set for TMCL. Up to 64 commands can be stored in EEPROM.

7 References

[TMCL] TMCL Manual, www.trinamic.com
TMCM –170 Software Reference and Programming Manual, www.trinamic.com
QBL5704 Manual QBL5704 BLDC servo motor manual, www.trinamic.com
HEDS-5640#A12 info HEDS-5640#A12 encoder information http://www.avagotech.com