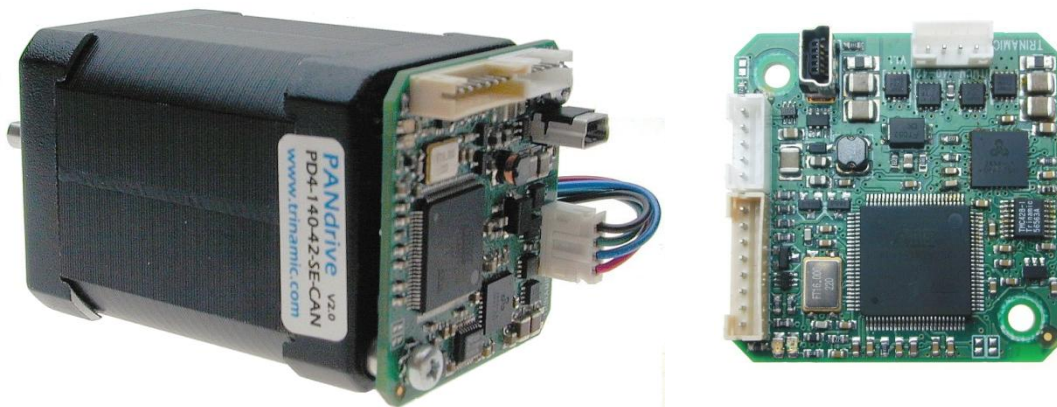


PDx-140-42-SE

TMCM-140-42-SE



Hardware Manual

Version: 1.05
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TRINAMIC

MOTION CONTROL

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1 Life support policy

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Specifications are subject to change without notice.

2 Features

The PDX-140-42-SE is a full mechatronic device consisting of a NEMA 17 (flange size 42mm) stepper motor, controller/driver electronics and integrated encoder. The electronics itself is also available without the motor as TCM-140-42-SE module.

Applications

- Very compact single-axis stepper motor solutions
- Encoder feedback for high reliability operation

Electrical data

- Supply voltage: +24V DC nominal (+7V... +28.5V DC)
- Motor current: up to 2.0A RMS (programmable)

Integrated motor (for PDX-140-42-SE only)

- Two phase bipolar stepper motor with 2A RMS nom. coil current
- Holding torque: 0.22Nm, 0.36Nm, 0.44Nm or 0.7Nm

Integrated encoder

Integrated sensOstep™ magnetic encoder (max. 4096 increments per rotation) e.g. for step-loss detection under all operating conditions and positioning

Integrated motion controller

- Motion profile calculation in real-time (TMC428 motion controller)
- On the fly alteration of motor parameters (e.g. position, velocity, acceleration)
- High performance ARM7 microcontroller for overall system control and serial communication protocol handling

Integrated bipolar stepper motor driver

- Up to 16 microsteps per full step
- High-efficient operation, low power dissipation (TMC249 stepper driver with external MOSFETs)
- Dynamic current control
- Integrated protection
- Integrated stallGuard™ for motor stall detection (e.g. elimination of end switches)
- Integrated chopSync™ for high velocity operation

Interfaces

- 2 inputs for reference switches, 2 general purpose inputs and 2 general purpose outputs
- USB and either RS232, RS485 or CAN (2.0B up-to 1Mbit/s) communication interfaces

Software

- Available with TMCL™ (all interface options) or CANopen (CAN interface option)
- TMCL™: stand-alone operation or remote controlled operation
- TMCL™: program memory (non volatile) for up-to 2048 TMCL™ commands
- TMCL™: PC-based application development software TMCL-IDE available for free
- CANopen: CiA 301 + CiA 402 (homing mode, profile position mode and velocity mode) supported
- Please see separate TMCL™ and CANopen firmware manuals for additional information

3 Order codes

The PDX-140-42-SE is currently available with four different stepper motors (between 0.22Nm and 0.70Nm holding torque), three interface options in addition to the standard on-board USB interface (RS232, RS485 or CAN) and two firmware versions (TMCL™ and CANopen):

Order code	Description	Dimensions [mm ³]
PD1-140-42-SE-option	PANdrive with 0.22Nm max./holding torque	42x42x72
PD2-140-42-SE-option	PANdrive with 0.36Nm max./holding torque	42x42x76,5
PD3-140-42-SE-option	PANdrive with 0.44Nm max./holding torque	42x42x85,5
PD4-140-42-SE-option	PANdrive with 0.70Nm max./holding torque	42x42x98,5

Table 3.1: Order codes (PDX-140-42-SE)

The electronic module TCM-140-42-SE itself is also available with three interface options in addition to the standard on-board USB interface (RS232, RS485 or CAN) and two firmware versions (TMCL™ and CANopen):

Order code	Description	Dimensions [mm ³]
TCM-140-42-SE-option	Single axis bipolar stepper motor controller / driver electronics with integrated encoder electronics	board size: 42x42

Table 3.2: Order codes (TCM-140-42-SE)

Both versions offer the following options:

Option	Communication interface + firmware
232	USB (mini USB connector) and RS232 interface, TMCL™ firmware
485	USB (mini USB connector) and RS485 interface, TMCL™ firmware
CAN	USB (mini USB connector) and CAN interface, TMCL™ firmware
CANopen	USB (mini USB connector) and CAN interface, CANopen firmware

Table 3.3: Options

For cost critical applications and applications with reduced requirements with regard to position feedback both versions - with and without motor - are also available without sensOstep™ encoder as PDX-140-42 and TCM-140-42 on request.

4 Mechanical and electrical interfacing

4.1 Size of PDx-140-42-SE

Currently, there is a choice between four 42mm bipolar stepper motors with different lengths and different holding torques.

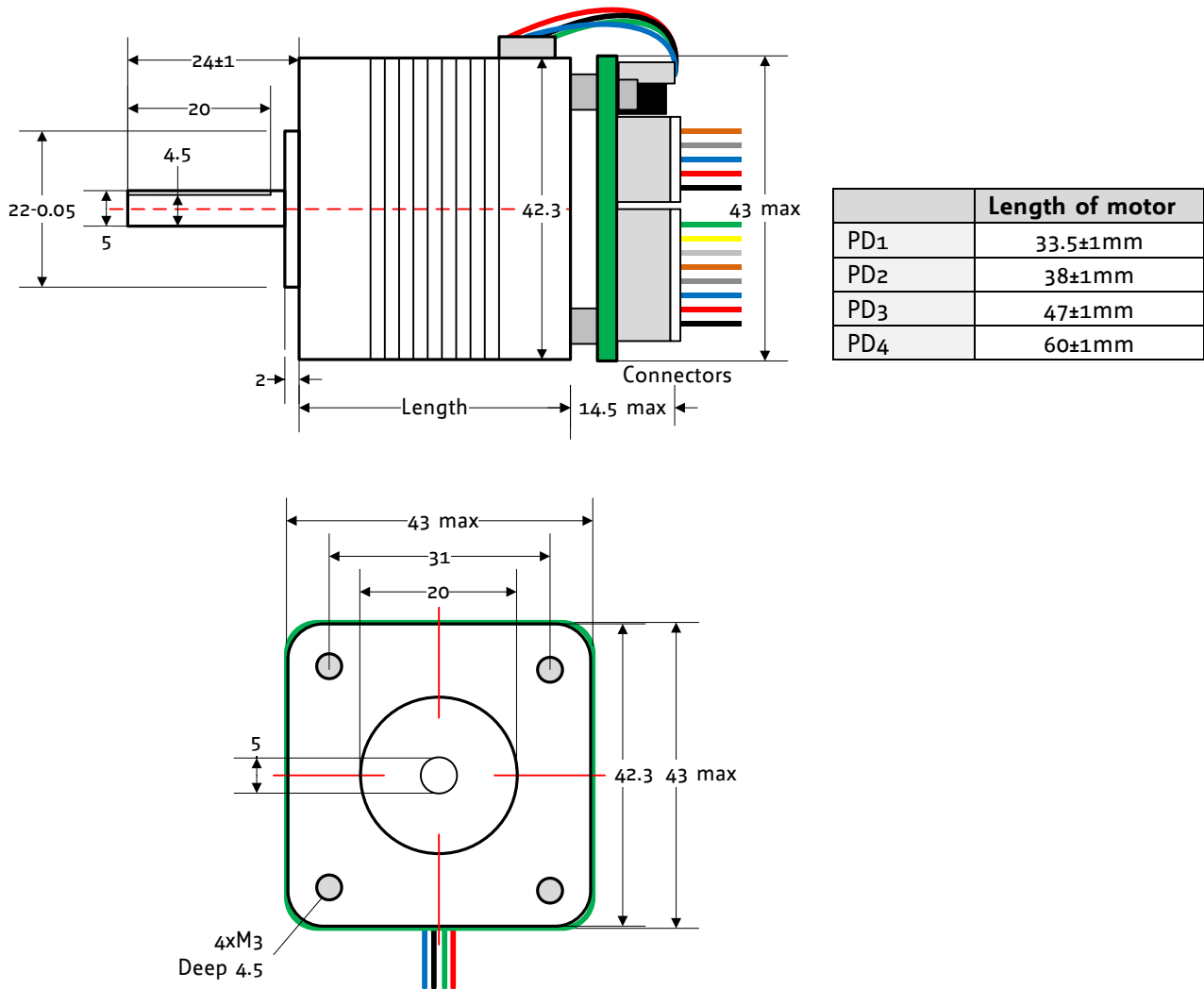


Figure 4.1: Dimensions PDx-140-42-SE (all values in mm)

4.2 Size of electronics (TCM-140-42-SE)

The electronic board has been designed in order to fit to a NEMA17 / 42mm size stepper motor with regard to board size and mounting holes. Board size is 42mm x 42mm and there are two mounting holes (size: 3.2mm) for M3 screws.

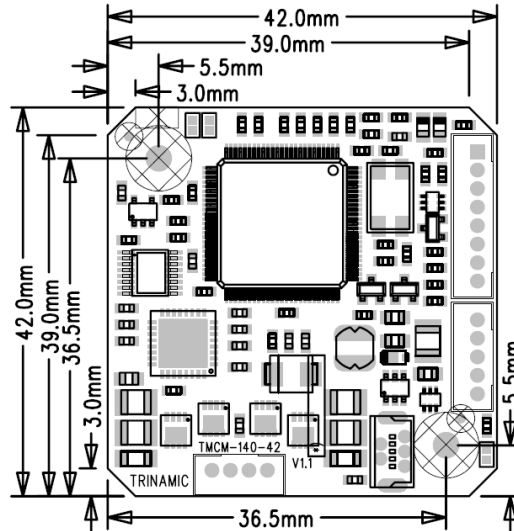


Figure 4.2: Dimensions TCM-140-42-SE (all values in mm)

4.3 Motor

Main characteristics of the four different motors available as part of the PDx-140-42-SE:

Specifications	Parameter	Units	QSH4218			
			-34-20-022	-38-20-036	-47-20-044	-60-20-070
Step angle		°	1.8	1.8	1.8	1.8
Step angle accuracy		%	+/-5	+/-5	+/-5	+/-5
Ambient temperature		°C	-20 ... +50	-20 ... +50	-20 ... +50	-20 ... +50
Max. motor temperature		°C	80	80	80	80
Shaft radial play (450g load)		mm	0.02	0.02	0.02	0.02
Shaft axial play (450g load)		mm	0.08	0.08	0.08	0.08
Max radial force (20mm from front flange)		N	28	28	28	28
Max axial force		N	10	10	10	10
Rated voltage	V_{RATED}	V	2.0	2.4	2.4	4.4
Rated phase current	$I_{RMS RATED}$	A	2.0	2.0	2.0	2.0
Phase resistance at 20°C	R_{COIL}	Ω	1.0	1.2	1.4	2.3
Phase inductance (typ.)		mH	1.6	2.2	2.1	6.0
Holding torque		Nm	0.22	0.36	0.44	0.70
Insulation class			B	B	B	B
Rotor inertia		g cm ²	35	57	68	102
Weight		kg	0.22	0.24	0.35	0.5

Table 4.1: Technical motor data

4.4 Connectors

The PDx-140-42-SE / TCM-140-42-SE offers four connectors, a 5-pin power and serial communication interface connector, an 8-pin input/output connector, a 4-pin motor connector (with PDx-140-42-SE already connected to the attached motor) and a 5-pin mini-USB connector.

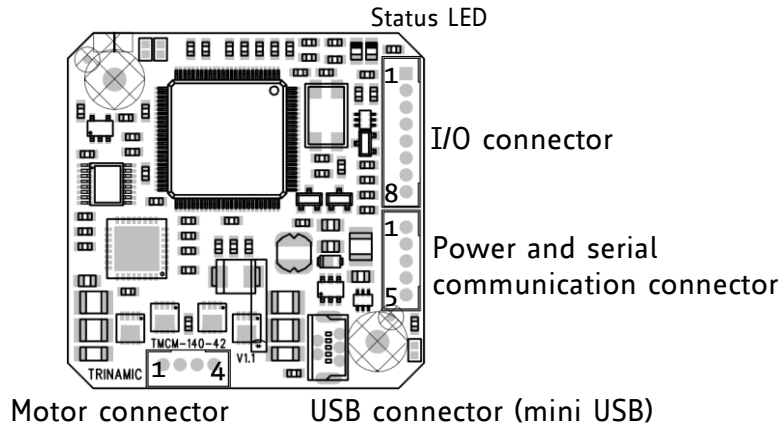


Figure 4.3: PDx-140-42-SE Connectors

4.4.1 Power and serial communication connector

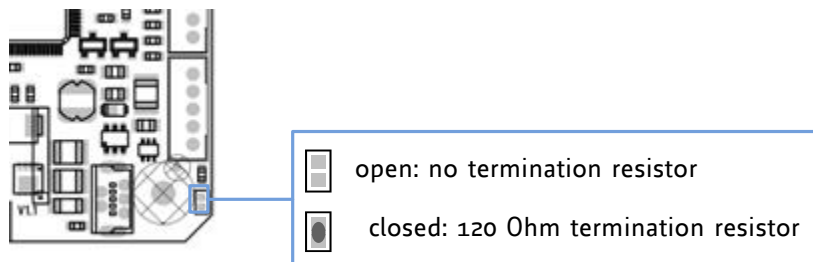
A 5-pin JST PH series connector is used for power supply and serial communication. Three different communication interface standards are available with this unit (as options): RS232, RS485 and CAN.

	Pin	RS232	RS485	CAN	Description
	1	GND	GND	GND	Power and signal ground
	2	VDD	VDD	VDD	Supply voltage (+24V DC nom.)
	3	GND	GND	GND	Power and signal ground
	4	RS232_TxD	RS485A	CAN_L	
	5	RS232_RxD	RS485B	CAN_H	

Table 4.2: Connector for power and communication

Mating connector from JST: PHR-5 (housing) and SPH-002T-P0.5S (crimp contact for AWG #30 to 24 / 0.05mm² to 0.22mm² wires).

For RS485 and CAN interface option the module contains a 120Ohm termination resistor:



For early versions of the unit a zero Ohm resistor is already assembled in order to activate the 120 Ohm line termination on-board. This has to be removed in case the unit is not connected as last / first node in a network or there is already proper bus termination installed!

4.4.1.1 Reset the module to factory defaults

Interface	Description
RS232	Short RxD and TxD for resetting the module.
RS485	<ul style="list-style-type: none"> - Demount the board from the motor. - Short the two pins which are marked on the figure below. The pins are on the back of the board. - Turn power ON and wait. The LED flashes quickly now. - Turn power OFF. The module is reset to factory defaults now.
CAN	<ul style="list-style-type: none"> - Demount the board from the motor. - Short the two pins which are marked on the figure below. The pins are on the back of the board. - Turn power ON and wait. The LED flashes quickly now. - Turn power OFF. The module is reset to factory defaults now.

Table 4.3: Reset the module to factory defaults

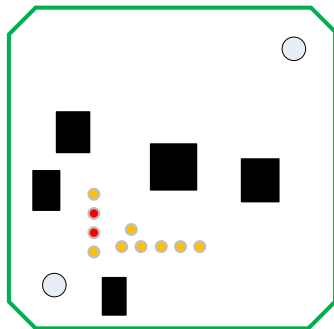


Figure 4.4: Pins for resetting the module

4.4.2 I/O connector

An 8-pin JST PH series connector is used for input/output signals.

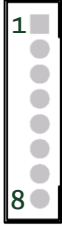
	Pin	Label	Direction	Description
	1	STOP_L	Input	Left stop switch input (+5V compatible)
	2	STOP_R	Input	Right stop switch input (+5V compatible)
	3	GND	Power (GND)	Power and signal ground
	4	VDD	Power	Supply voltage +24V DC nom.
	5	OUT_o	Output	General purpose output (open collector)
	6	OUT_1	Output	General purpose output (open collector)
	7	IN_o	Input	General purpose input (+5V and +24V compatible)
	8	IN_1	Input	General purpose input (+5V and +24V compatible)

Table 4.4: Connector for power and I/O

Mating connector from JST: PHR-8 (housing) and SPH-002T-Po.5S (crimp contact for AWG #30 to 24 / 0.05mm² to 0.22mm² wires).

4.4.3 Motor connector

A 4-pin JST PH series connector is used for connecting the motor.

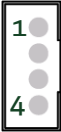
	Pin	Label	Direction	Description
	1	OA1	Output	2-phase stepper motor phase A
	2	OA2	Output	2-phase stepper motor phase A
	3	OB1	Output	2-phase stepper motor phase B
	4	OB2	Output	2-phase stepper motor phase B

Table 4.5: Connector for motor

Mating connector from JST: PHR-4 (housing) and SPH-002T-Po.5S (crimp contact for AWG #30 to 24 / 0.05mm² to 0.22mm² wires).

4.4.4 USB connector

A 5-pin mini-USB connector is available on board.

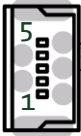
	Pin	Label	Description
	1	VBUS	+5V power
	2	D-	Data -
	3	D+	Data +
	4	ID	Not connected
	5	GND	Ground

Table 4.6: Connector for USB

4.5 Input/output circuits

The module offers 2 stop switch inputs, 2 general purpose inputs and 2 general purpose outputs. The stop switch inputs STOP_L and STOP_R are +5V tolerant and include 1k pull-up resistors to +5V. The general purpose inputs IN_0 and IN_1 accept digital (e.g. 5V or 24V compatible) signals or analog signals (0..10V) and include pull-down resistors.

The general purpose outputs are open-collector outputs with integrated freewheeling diodes. Max. sink current per output is 100mA and max. voltage at output when output is inactive / output transistor is switched off is limited to module supply voltage due to the integrated freewheeling diode.

4.5.1 Reference switch inputs

There are 2 reference/stop switch inputs (STOP_L / STOP_R). Both inputs offer an internal pull-up resistor (1k) and accept voltages between 0 and +5V.

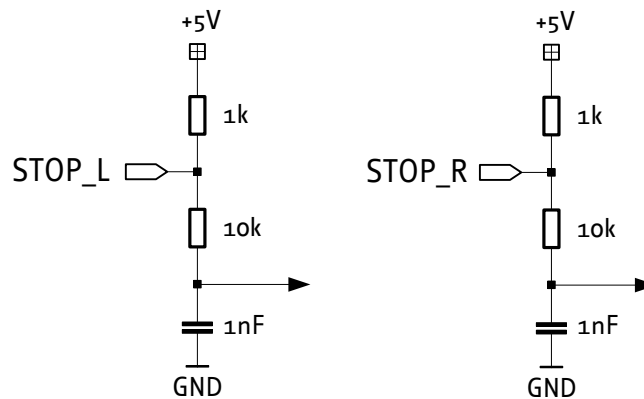


Figure 4.5: Reference/stop switch inputs STOP_L, STOP_R

4.5.2 General purpose inputs

There are 2 general purpose inputs (IN_0 / IN_1). Both inputs offer internal voltage divider and voltage limiter and accept input voltages between 0 and +24V as digital inputs and between 0 and +10V as analog inputs (depending on software settings). The voltage divider resistors act as pull-down resistors, also.

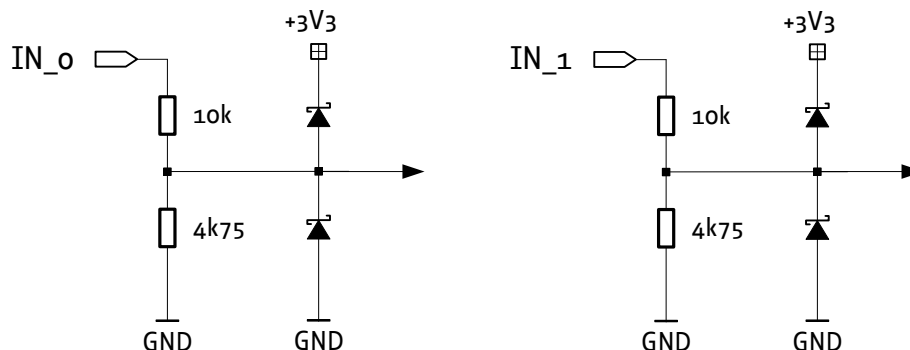


Figure 4.6: General purpose inputs IN_0, IN_1

Early version of module (with pcb version 1.0 and 1.1) contained 1k resistor instead of 4k75 resistor as low side resistor in voltage divider. For these modules full scale analog input range is +36V instead of +10V.

4.5.3 General purpose outputs

There are 2 general purpose outputs (OUT_o / OUT_1). Both outputs are open collector outputs and can drive loads up-to 100mA. Especially for inductive loads a freewheeling diode to supply voltage (VDD) has been included. This is also the reason why the external voltage at the general purpose outputs - when the outputs are switched off - should not be higher than the supply voltage of the module + approx. 0.5V.

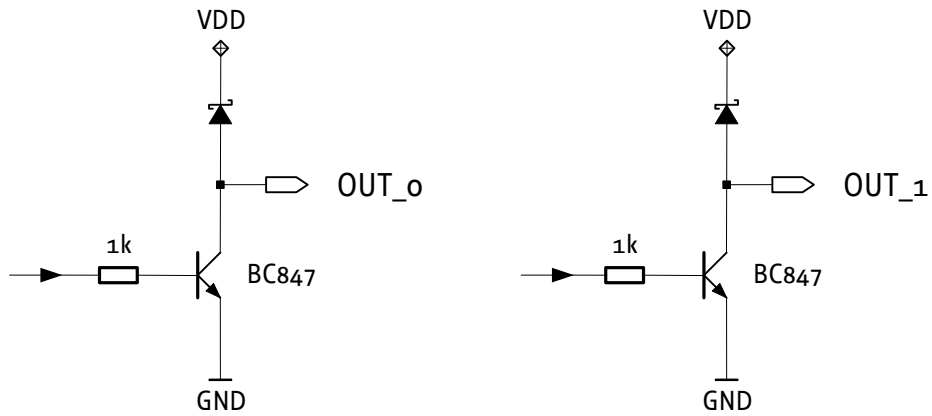


Figure 4.7: General purpose outputs OUT_o, OUT_1

5 Functional Description

The PANdrive PD-140-42-SE is a mechatronic solution including a 42 mm flange motor, a controller board and a sensOstep™ encoder. It offers four motor torque options and can be controlled via CAN, RS232, RS485 or USB interface. Power supply, interface and general purpose I/Os can be connected with high density JST connectors. The chopSync™ feature allows high speed movement avoiding resonances. The PD-140-42-SE comes with the PC based software development environment TMCL-IDE for the Trinamic Motion Control Language (TMCL™). Using predefined TMCL™ high level commands like „move to position” or „constant rotation” a rapid and fast development of motion control applications is guaranteed. Communication traffic is kept very low since all time critical operations, e.g. ramp calculation are performed on board. The TMCL™ program can be stored in the onboard EEPROM for stand-alone operation. In addition to TMCL™ CANopen is available as firmware option, also.

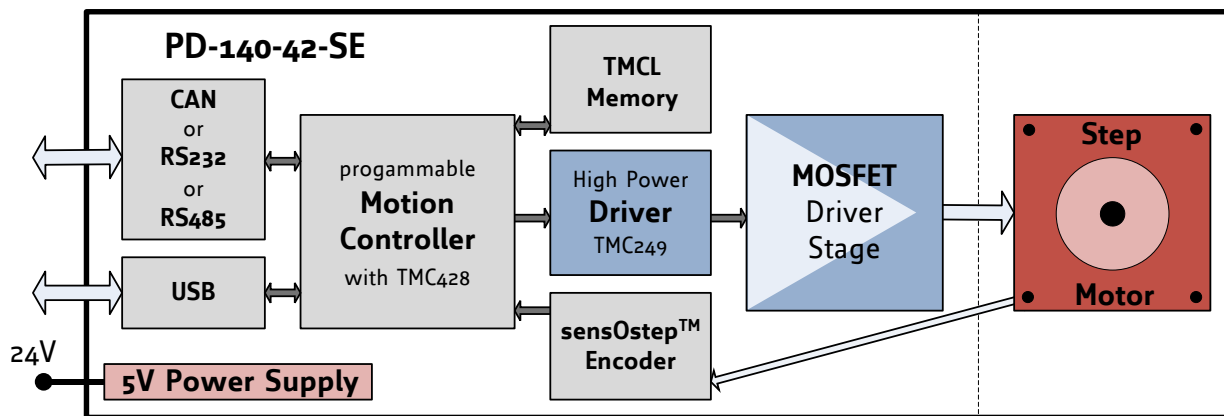


Figure 5.1: Main parts of the PDx-140-42-SE

6 Firmware

Currently, there are two different firmware versions available for this unit – TMCL™ and CANopen. TMCL™ is available for all interface options and is supplied as default firmware. Please refer to the TMCL™ firmware manual for this unit for more details [TMCL].

With the CAN interface option also CANopen is available as firmware. This firmware supports the CiA 301 and CiA 402 profiles with support for homing mode, profile position mode and velocity mode. For more details please refer to the CANopen manual [CANopen].

7 Torque curves

The following torque curves have been measured using the PANdrive PDx-140-42-SE with all four stepper motors available as part of this unit. The four different stepper motors all offer the same max. coil current but, differ with respect to holding torque, motor length, coil resistance and inductivity – to name a few. As rule of thumb, more holding torque means more copper, longer motor, more coil resistance and higher inductivity which limits the max. reachable velocity at the same supply voltage. All measurements were taken at +24V driver supply voltage and max. motor current.

The figures below include torque curves for microstep operation and full step operation. With full step mode it is possible to reach higher velocities whereas resonances normally prevent any smooth operation at lower speeds (see torque curves below). Therefore, TMCL™ firmware offers programmable automatic switch over between microstep operation at lower speeds and full-step operation at higher speed in order to take advantage of both modes (please see TMCL™ firmware manual, axis parameter 211).

7.1 PD1-140-42-SE

The PD1-140-42-SE is the most compact version of this PANdrive series with the shortest stepper motor.

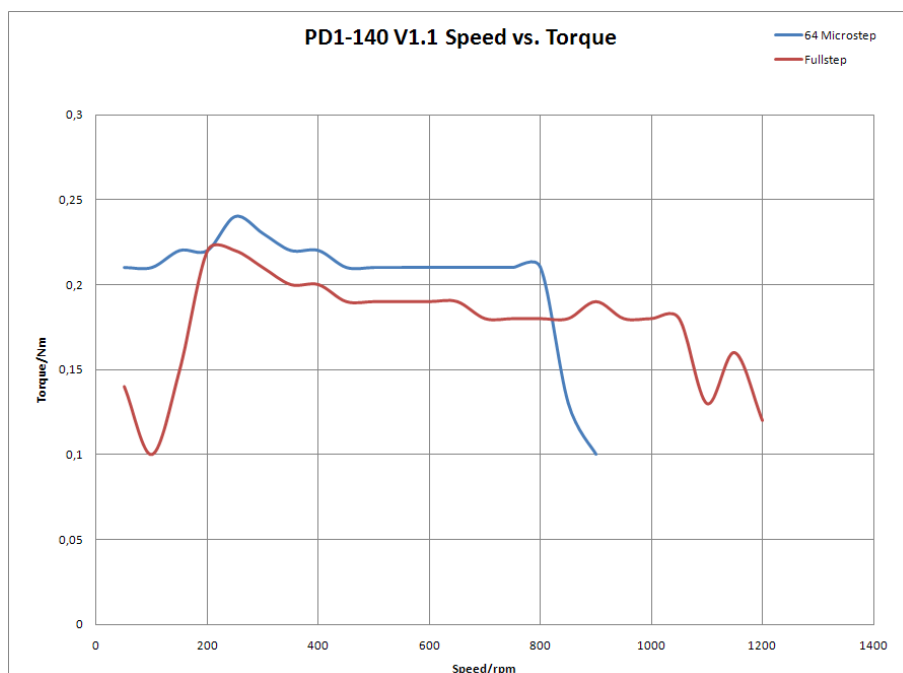


Figure 7.1: PD1-140-42-SE torque curve

7.2 PD2-140-42-SE

For applications where more torque is required than available with the PD1-140-42-SE, the PD2-140-42-SE might be an option.

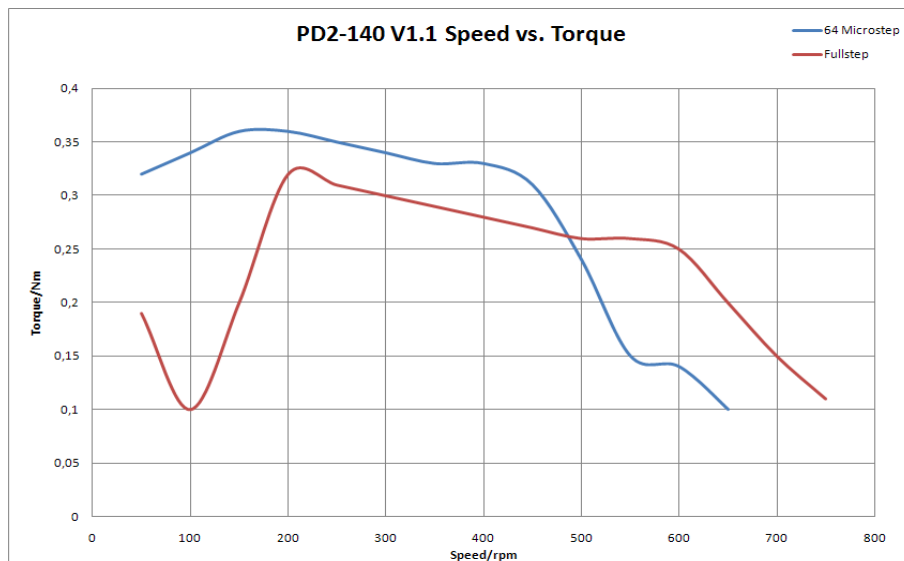


Figure 7.2: PD2-140-42-SE torque curve

7.3 PD3-140-42-SE

For applications where more torque is required than available with the PD2-140-42-SE, the PD3-140-42-SE might be an option.

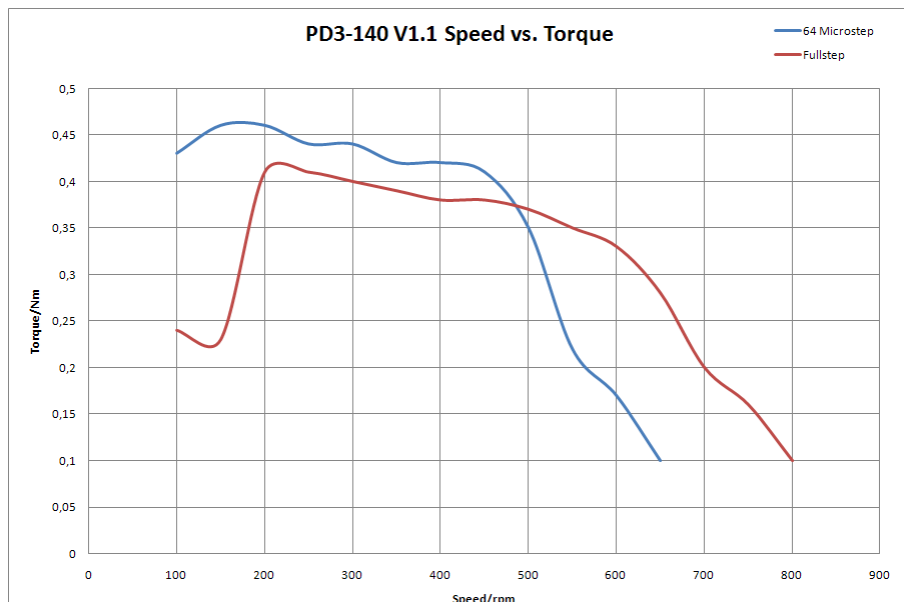


Figure 7.3: PD3-140-42-SE torque curve

7.4 PD4-140-42-SE

For applications where more torque is required than available with the PD3-140-42-SE, the PD4-140-42-SE might be an option. The PD4-140-42-SE is the version with highest holding torque and the longest stepper motor available for this PANdrive series.

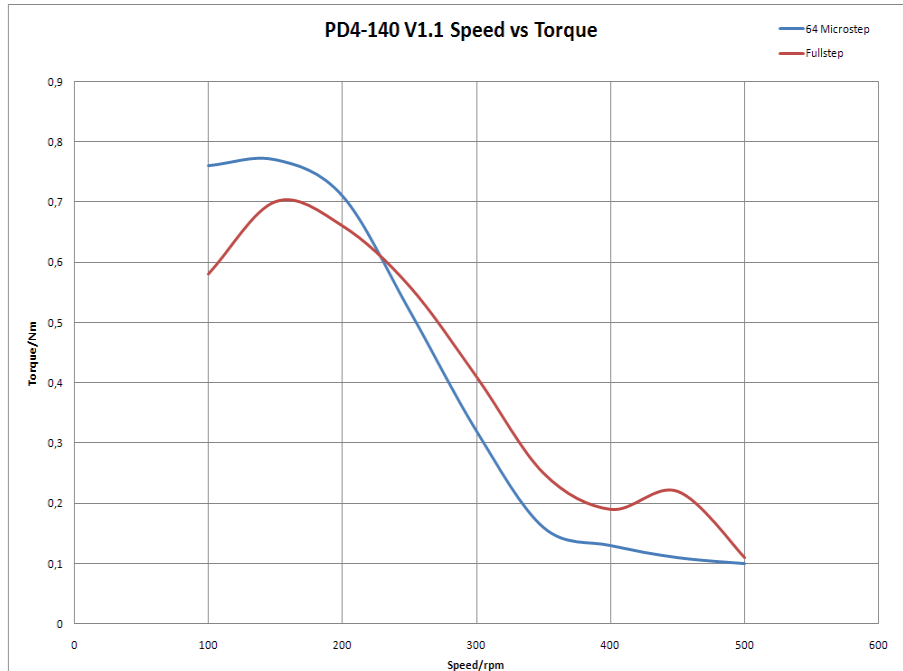


Figure 7.4: PD4-140-42-SE torque curve

8 Operational ratings

The operational ratings shown below should be used as design values. In no case should the maximum values been exceeded during operation.

Symbol	Parameter	Min	Typ	Max	Unit
Vcc	+24 DC input	7	24	28.5	V
I _{COIL_peak}	Motor coil current for sine wave peak (chopper regulated, adjustable via software)	0		2.8 *)	A
I _{COIL_RMS}	Continuous motor current (RMS)	0		2 *)	A
I _{SUPPLY}	Power supply current		<< I _{COIL}	1.4 * I _{COIL}	A
T _{ENV}	Environment temperature at max. current, 100% duty cycle (no forced cooling required)			+40 **)	°C

Table 8.1: General operational ratings of the module

*) Please note: only PDx-140-42-SE and TCM-140-42-SE with pcb version 1.1 or newer support specified max. current over full temperature range. Older / pre-series versions may be limited with regard to temperature range and / or max. motor current.

***) Test set-up / procedure: PANdrive PD4-140-42-SE mounted to a metal base plate in order to keep stepper motor temperature within limits for the motor during test (table 4.1) / test inside climate chamber with approx. 53l volume / no forced air convection during test / test duration at least 30min.

Please note: motor temperature should always be kept below upper limit for the motor - that is, motor / PANdrive should be mounted to an appropriate metal / cooling plate or frame. Especially, the longest available stepper motor which is part of the PD4-140-42-SE may easily reach 100°C or above when operated at full current over long time without being mounted to any heat-conducting structure or forced air convection. In case the TCM-140-42-SE electronic module is mounted close to the motor as with the PANdrives, the motor might substantially heat up the electronics and limit the maximum environmental temperature during operation. The unit may be operated at higher environmental temperatures than specified when the duty cycle of the motor and / or the motor current is reduced or in case the TCM-140-42-SE electronic module is mounted separately from the motor.

Symbol	Parameter	Min	Typ	Max	Unit
V_{STOP_L/R_L}	Low level input voltage for STOP_L/R switch inputs			0.9	V
V_{STOP_L/R_H}	High level input voltage for STOP_L/R switch inputs	1.9		5	V
$V_{IN_1/2_L}$	Low level input voltage for general purpose inputs IN_1/2 (when configured as digital inputs)			1.6	V
$V_{IN_1/2_H}$	High level input voltage for general purpose inputs IN_1/2 (when configured as digital inputs)	4.0		24	V
$V_{IN_1/2_ANA}$	Analog voltage full scale input range for general purpose inputs IN_1/2 (when configured as analog inputs)	0		10 [*])	V
$V_{OUT_1/2}$	Maximum voltage at general purpose outputs (open collector output switched off)			VDD + 0.5 ^{**)}	V
$I_{OUT_1/2}$	Maximum output sink current for general purpose outputs (open collector)		10	100	mA

Table 8.2: Operational ratings of input and output signals

^{*}) Analog voltage full scale input range is +36V for early version of module

^{**)} limited to module supply voltage + 0.5V due to integrated freewheeling diode between general purpose output and module supply voltage

9 PD-140 operational description

9.1 Calculation: Velocity and acceleration vs. microstep and fullstep frequency

The values of the parameters sent to the TMC428 do not have typical motor values like rotations per second as velocity. But these values can be calculated from the TMC428-parameters as shown in this document.

The parameters for the TMC428 are:

Signal	Description	Range
f _{CLK}	clock-frequency	0... 16 MHz
velocity	-	0... 2047
a_max	maximum acceleration	0... 2047
pulse_div	divider for the velocity. The higher the value is, the less is the maximum velocity default value = 0	0... 13
ramp_div	divider for the acceleration. The higher the value is, the less is the maximum acceleration default value = 0	0... 13
Usrs	microstep-resolution (microsteps per fullstep = 2 ^{usrs})	0... 7 (a value of 7 is internally mapped to 6 by the TMC428)

Table 9.1: TMC428 velocity parameters

The **microstep-frequency** of the stepper motor is calculated with

$$usf[Hz] = \frac{f_{CLK}[Hz] \cdot velocity}{2^{pulse_div} \cdot 2048 \cdot 32} \quad \text{with usf: microstep-frequency}$$

To calculate the **fullstep-frequency** from the microstep-frequency, the microstep-frequency must be divided by the number of microsteps per fullstep.

$$fsf[Hz] = \frac{usf[Hz]}{2^{usrs}} \quad \text{with fsf: fullstep-frequency}$$

The change in the pulse rate per time unit (pulse frequency change per second – the **acceleration a**) is given by

$$a = \frac{f_{CLK}^2 \cdot a_{max}}{2^{pulse_div+ramp_div+29}}$$

This results in acceleration in fullsteps of:

$$af = \frac{a}{2^{usrs}} \quad \text{with af: acceleration in fullsteps}$$

Example:

Signal	value
f_CLK	16 MHz
velocity	1000
a_max	1000
pulse_div	1
ramp_div	1
usrs	6

$$msf = \frac{16\text{MHz} \cdot 1000}{2^1 \cdot 2048 \cdot 32} = \underline{\underline{122070.31\text{Hz}}}$$

$$fsf[\text{Hz}] = \frac{122070.31}{2^6} = \underline{\underline{1907.34\text{Hz}}}$$

$$a = \frac{(16\text{Mhz})^2 \cdot 1000}{2^{1+1+29}} = \underline{\underline{119.21 \frac{\text{MHz}}{\text{s}}}}$$

$$af = \frac{119.21 \frac{\text{MHz}}{\text{s}}}{2^6} = \underline{\underline{1.863 \frac{\text{MHz}}{\text{s}}}}$$

Calculation of the number of rotations:

A stepper motor has e.g. 72 fullsteps per rotation.

$$\text{RPS} = \frac{fsf}{\text{fullsteps per rotation}} = \frac{1907.34}{72} = 26.49$$

$$\text{RPM} = \frac{fsf \cdot 60}{\text{fullsteps per rotation}} = \frac{1907.34 \cdot 60}{72} = 1589.46$$

10 Revision history

10.1 Document revision

Version	Date	Author	Description
1.00	2008-07-23	GE	Initial version
1.01	2008-09-01	GE	Ordering codes added
1.02	2008-10-28	GE	CAN connector pin assignment corrected
1.03	2008-12-17	SD	Size of the unit and functional description added
1.04	2009-10-21	GE	New hardware version + torque curves added
1.05	2010-09-29	SD	Paragraph <i>Reset the module to factory defaults</i> added.

Table 10.1: Document revision

10.2 Hardware revision

Version	Date	Description
1.00	2008-04-27	First version, reduced motor current
1.10	2009-06-29	Second version, full production (series) version
1.20	2009-12-09	Several minor improvements

Table 10.2: Hardware revision

11 References

[TMCL] PD-140 TMCL™ Firmware Manual (see <http://www.trinamic.com>)
[CANopen] CANopen Manual (see <http://www.trinamic.com>)

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