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PD42-1070 Hardware Manual

Hardware Version V1.00 | Document Revision V1.00 • 2016-Aug-04

PD42-1070 is an easy to use PANdrive™ smart stepper motor. The module is controlled via a step and direction interface. One configuration pin selects the current control mode between stealth-Chop™ for absolute silent motor control and spreadCycle™ for high speed. A TTL UART interface allows for more advanced configuration, for example of the stallGuard2™ and coolStep™ features, and permanent parameter storage via TMCL™-IDE.
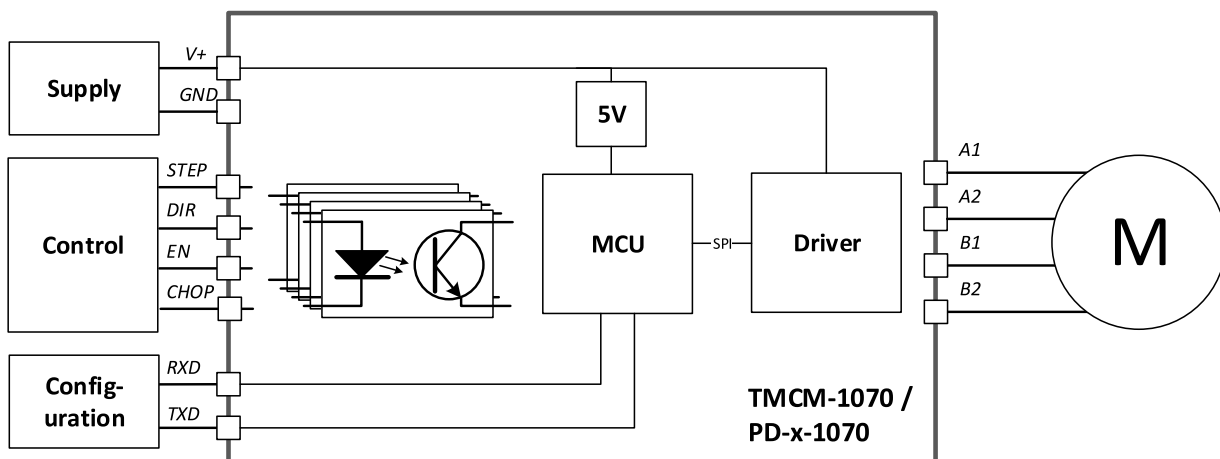
Features

- Supply Voltage +9 to +24V DC
- Step and Direction Interface
- **microPlyer™** to 256µ-steps
- **stealthChop™** silent PWM mode
- **spreadCycle™** smart mixed decay
- **stallGuard2™** load detection
- **coolStep™** autom. current scaling
- UART configuration interface

Applications

- Lab-Automation
- Manufacturing
- Robotics
- Factory Automation
- CNC
- Laboratory Automation

Simplified Block Diagram

Read entire documentation;
Especially the supplemental directives on page 23.

TRINAMIC
MOTION CONTROL

Contents

1 Features

The PANdrive™ PD42-1070 is a full mechatronic solution with state of the art feature set. It is highly integrated and offers a convenient handling.
The PD42-1070 includes a stepper motor and driver electronics. It can be used in many decentralized applications and has been designed for 0.20...0.47 Nm max. holding torque and 24V DC nominal supply voltage. With stealthChop™, the PD42-1070 offers absolutely silent and smooth motor operation for lower and medium velocities. With spreadCycle™, the PD42-1070 offers a high performance current controlled chopper mode for highest velocities with perfect zero crossing performance. With stallGuard2™, a sensorless load detection feature is provided, which is required for using the automatic current scaling feature coolStep™. The PD42-1070 can be used with a simple step and direction interface and can be configured using a TTL UART interface.
stallGuard2 and coolStep must be configured via TTL UART interface and are disabled by default.

1.1 General Features

Main Characteristics

- Supply Voltage +9V to +24V DC

- 1.0A RMS phase current (ca. 1.4A peak phase current)

- Highest micro step resolution, up to 256 micro steps per full step

- microPlyer™ microstep interpolator for obtaining increased smoothness of microstepping over a low frequency STEP/DIR interface

- With housing and motor mounted

- Permanent onboard parameter storage

- Simple step & direction mode

- Noiseless stealthChop™ chopper mode for slow to medium velocities

- High performance spreadCycle™ chopper mode

- High-precision sensorless load measurement with stallGuard2™

- Automatic current scaling algorithm coolStep™ to save energy and keep your drive cool

Optically Isolated Inputs

- Step & direction interface with up to 45kHz input frequency

- Enable input to power-on/-off driver H-bridges

- Mode select input to switch between the two chopper modes

TTL UART Interface

- TTL-level UART interface for parameter configuration

- Interface speed 9600-115200 bps (default 9600 bps)

- TMCL-based protocol for online configuration and permanent parameter settings

- Bootloader for firmware updates

1.2   TRINAMIC's Unique Features

1.2.1   stealthChop™

stealthChop is an extremely quiet mode of operation for low and medium velocities. It is based on a voltage mode PWM. During standstill and at low velocities, the motor is absolutely noiseless. Thus, stealthChop operated stepper motor applications are very suitable for indoor or home use. The motor operates absolutely free of vibration at low velocities. With stealthChop, the motor current is applied by driving a certain effective voltage into the coil, using a voltage mode PWM. There are no more configurations required except for the regulation of the PWM voltage to yield the motor target current.
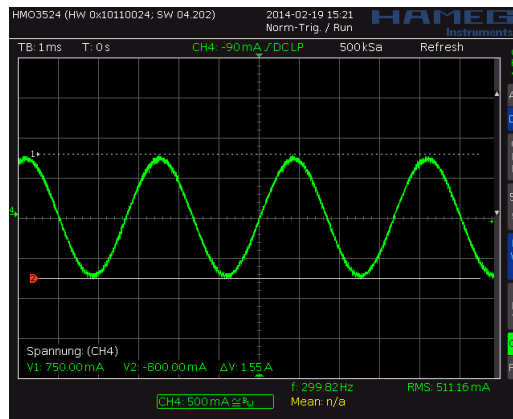
Figure 1: Motor coil sine wave current using stealthChop (measured with current probe)

1.2.2   spreadCycle™

The spreadCycle chopper is a high-precision, hysteresis-based, and simple to use chopper mode, which automatically determines the optimum length for the fast-decay phase. Several parameters are available to optimize the chopper to the application. spreadCycle offers optimal zero crossing performance compared to other current controlled chopper algorithms and thereby allows for highest smoothness. The true target current is powered into the motor coils.

Figure 2: spreadCycle principle

1.3   stallGuard2

stallGuard2 is a high-precision sensorless load measurement using the back EMF of the motor coils. It can be used for stall detection as well as other uses at loads below those which stall the motor. The stallGuard2 measurement va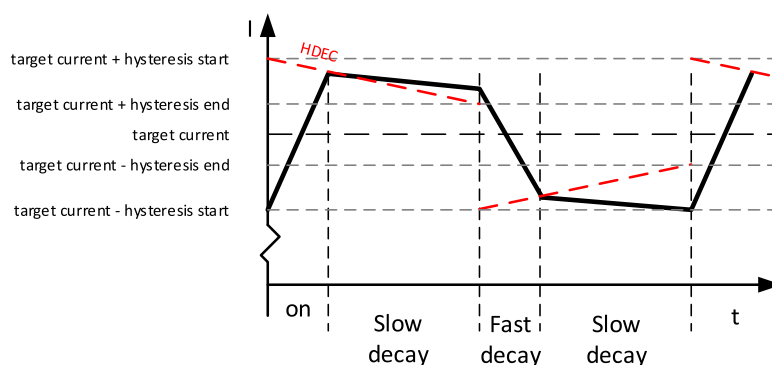lue changes linearly over a wide range of load, velocity, and current settings. At maximum motor load, the value reaches zero or is near zero. This is the most energy-efficient point of operation for the motor.
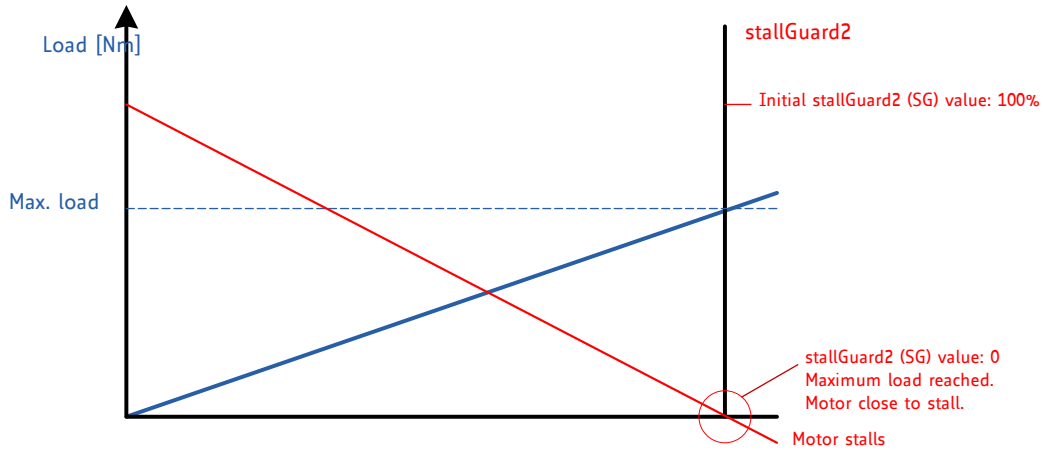
Figure 3: stallGuard2 Load Measurement as a Function of Load

1.4   coolStep

coolStep is a load-adaptive automatic current scaling based on the load measurement via stallGuard2. coolStep adapts the required current to the load. Energy consumption can be reduced by as much as 75%. coolStep allows substantial energy savings, especially for motors which see varying loads or operate at a high duty cycle. Because a stepper motor application needs to work with a torque reserve of 30% to 50%, even a constant-load application allows significant energy savings because coolStep automatically enables torque reserve when required. Reducing power consumption keeps the system cooler, increases motor life, and allows for cost reduction.

Figure 4: Energy Efficiency Example with coolStep

2   Order Codes

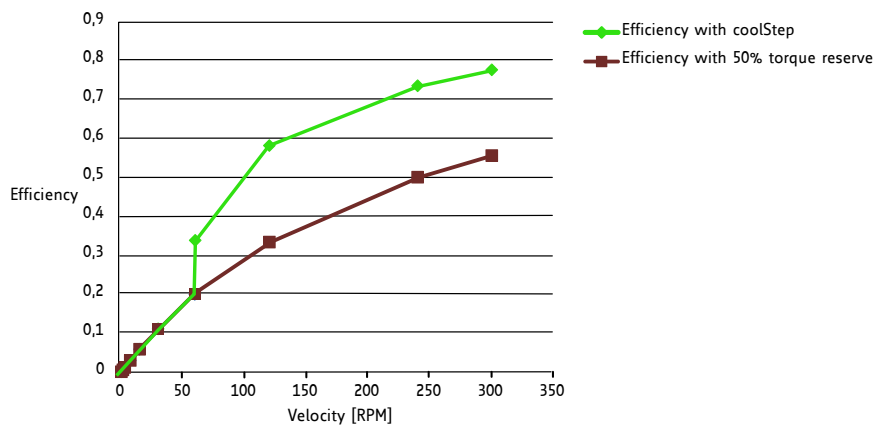| Order Code	Description	Size (LxWxH)
PD42-1-1070	PANdrive, 0.27Nm, 1.0A RMS, +24V DC, TTL UART interface, S/D interface, Enable, Mode Select	42mm x 42mm x 45,5mm
PD42-2-1070	PANdrive, 0.35Nm, 1.0A RMS, +24V DC, TTL UART interface, S/D interface, Enable, Mode Select	42mm x 42mm x 50mm
PD42-3-1070	PANdrive, 0.49Nm, 1.0A RMS, +24V DC, TTL UART interface, S/D interface, Enable, Mode Select	42mm x 42mm x 59mm
TMCM-1070	Controller/Driver Module without motor, +24V DC, TTL UART interface, S/D interface, Enable, Mode Select	42mm x 42mm x 12mm

Table 1: Order codes modules

Order Code	Description
TMCM-1070-CABLE	Cable loom for TMCM-1070. Contains: • 1x cable loom for motor connector with 4-pin JST PH female connector • 1x cable loom for I/O connector with 9-in JST PH female connector
PD42-1070-CABLE	Cable loom for PD42-x-1070. Contains: • 1x cable loom for I/O connector with 9-in JST PH female connector
TMCM-KAMINO-CLIP	Self-Adhesive top hat rail mounting clip for TMCM-1070 base module (not available with PANdrive versions PD42-x-1070)
TMCM-KAMINO-AP23	Aluminum adapter plate kit for mounting of TMCM-1070 base module to NEMA23 size motors (not available with PANdrive versions PD42-x-1070)
TMCM-KAMINO-AP24	Aluminum adapter plate kit for mounting of TMCM-1070 base module to NEMA24 size motors (not available with PANdrive versions PD42-x-1070)

Table 2: Order codes cable loom

3   Mechanical and Electrical Interfacing

3.1   PD42-1070 Dimensions and Weight

The PD42-1070 includes the TMCM-1070 stepper motor driver module and a NEMA17 bipolar stepper motor. Depending on the motor size the lengt varies.
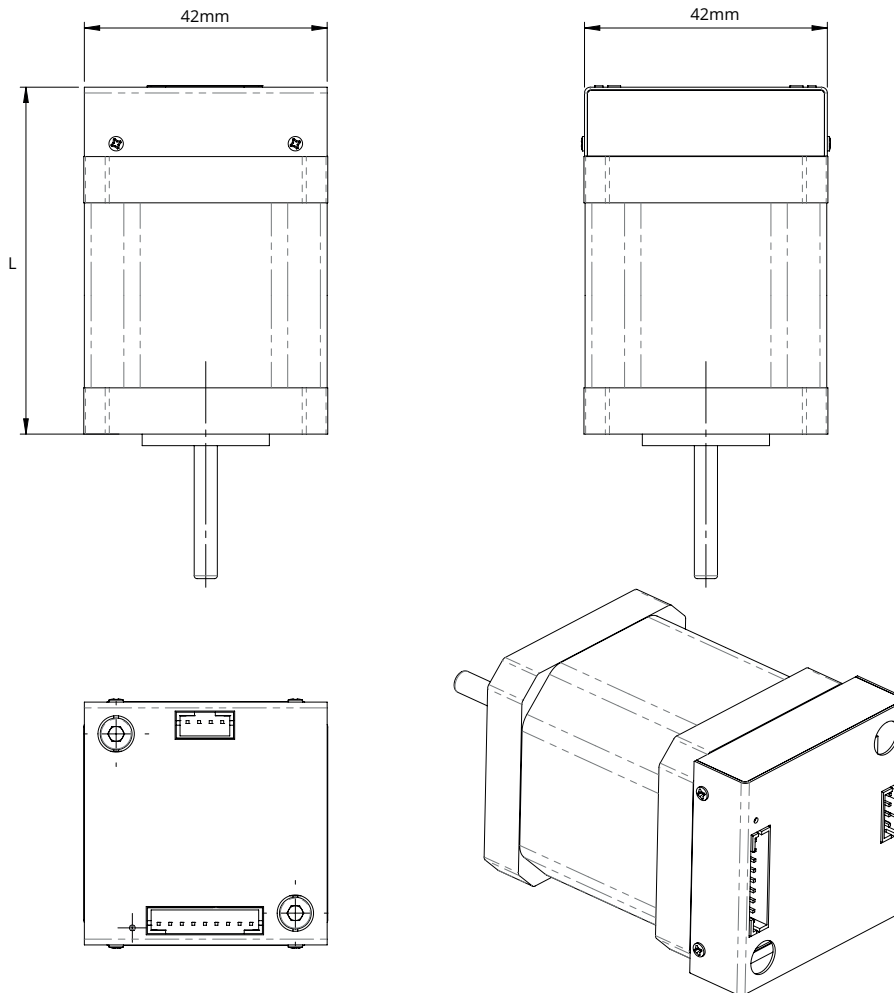
Figure 5: PD42-1070 mechanical dimensions with motor

Order Code	**L** in mm	Weight in g
PD42-1-1070	45,5 $\pm$1	$\approx$ 260
PD42-2-1070	50 $\pm$1	$\approx$ 320
PD42-3-1070	59 $\pm$1	$\approx$ 395

Table 3: PD42-x-1070 length and weight

3.2 PD42-1070 Motor Parameters

Specifications	Parameter	Unit	PD-1-1070	PD-2-1070	PD-3-1070
Step angle		°	1.8	1.8	1.8
Step angle accuracy		%	± 5	± 5	± 5
Ambient temperature	T_{amb}	°C	-20...+50	-20...+50	-20...+50
Max. motor temperature	$T_{motor_{max}}$	°C	80	80	80
Shaft radial play (450g load)		mm	0,02	0,02	0,02
Shaft axial play (450g load)		mm	0,08	0,08	0,08
Max radial force (20mm from front flange)		N	28	28	28
Max axial force		N	10	10	10
Rated voltage	V_{RATED}	V	2.0	2.4	2.4
Rated phase current	$I_{RMSRATED}$	A	1.0	1.0	1.0
Phase resistance at 20°C	R_{COIL}	Ω	1.0	1.2	1.4
Phase inductance (typ.)	L_{COIL}	mH	1.6	2.2	2.1
Holding torque		Nm	0.22	0.36	0.44
Insulation class			B	B	B
Rotor inertia		g cm2	35	57	68
Weight	M	kg	0.22	0.24	0.35

Table 4: PD42-1070 Motor Parameters

3.3   PD42-1070 Torque Curves

The following diagrams show the torque vs. speed curves for the PD42-1-1070, the PD42-2-1070, and the PD42-3-1070 at three different typical conditions. All measurements have been done in spreadCycle chopper mode. The measurement conditions are:

1. $VDD =$+24V, $I_{COILRMS} =$1A, 1/16 microstep with interpolation to 1/256 microstep

2. $VDD =$+24V, $I_{COILRMS} =$1A, half stepping
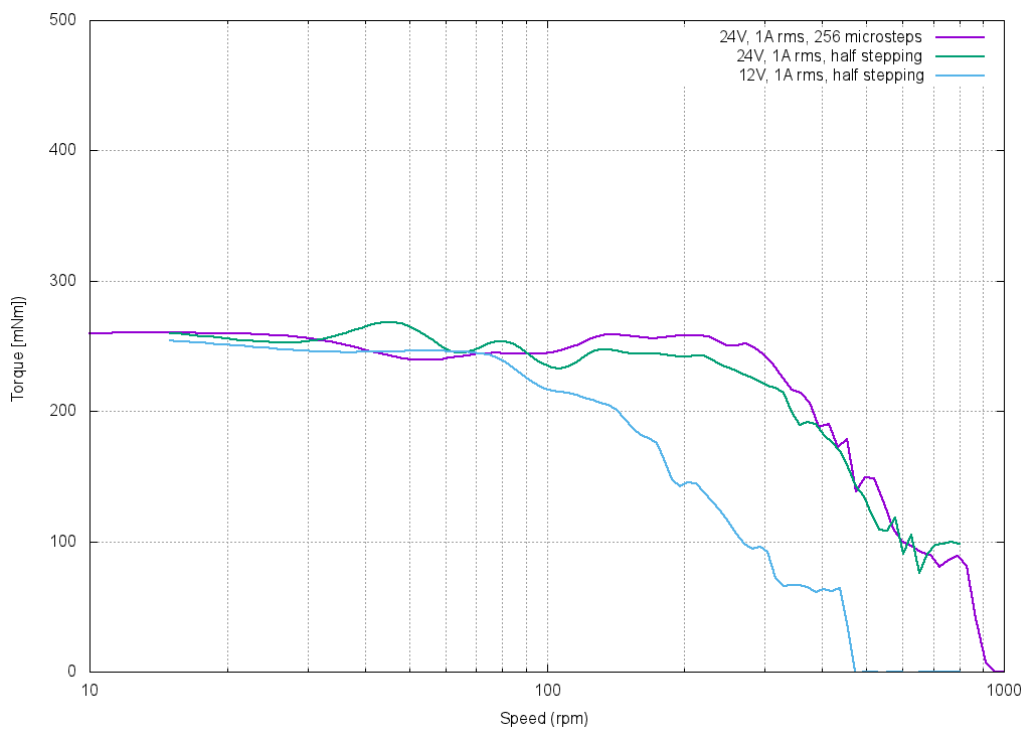
3. $VDD =$+12V, $I_{COILRMS} =$1A, half stepping

Figure 6: PD42-1-1070 torque vs. speed
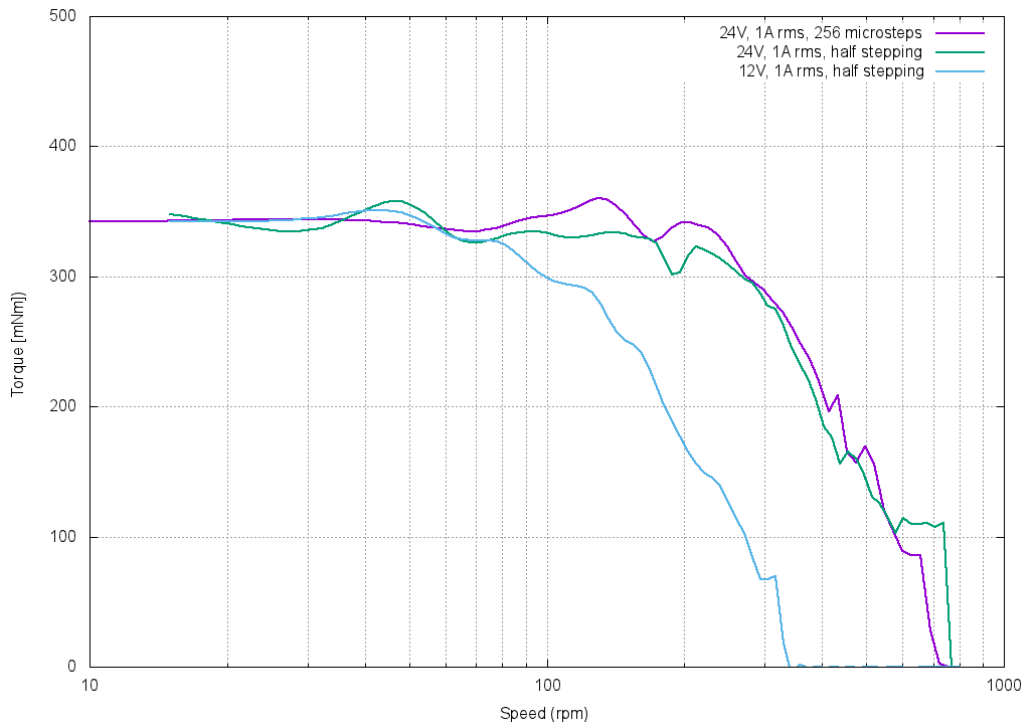
Figure 7: PD42-2-1070 torque vs. speed
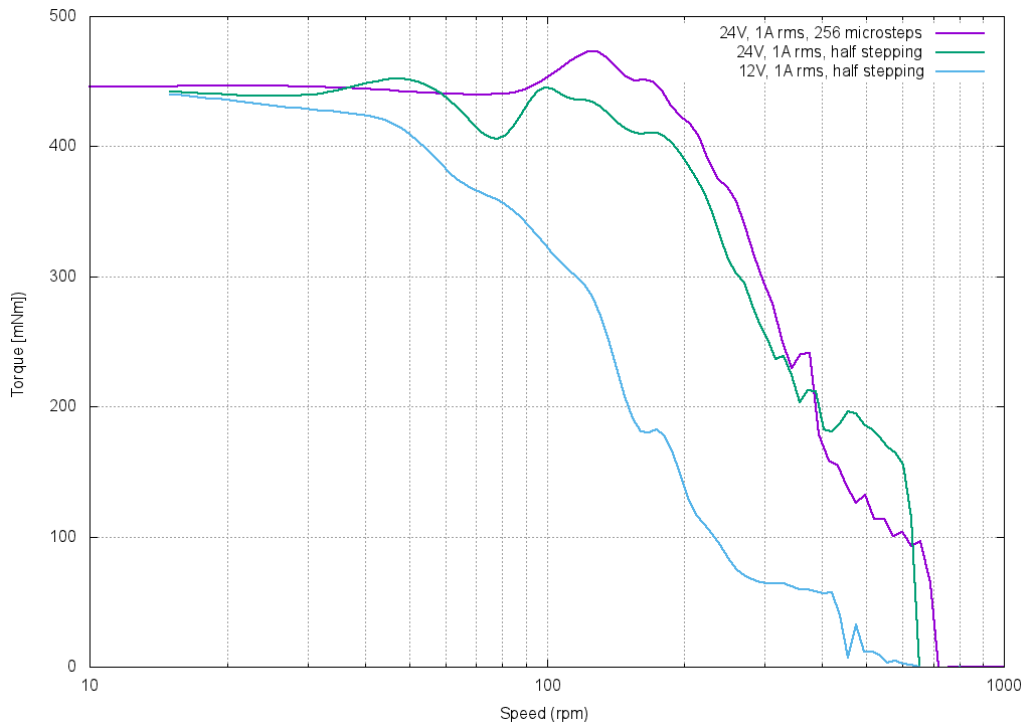
Figure 8: PD42-3-1070 torque vs. speed

4 Connectors and LEDs

Motor Connector

Figure 9: PD42-1070 connectors (pin 1 highlighted in red)

I/O Connector

4.1 Motor Connector

Pin no.	Pin name	Description
1	A1	Motor phase A pin 1
2	A2	Motor phase A pin 2
3	B1	Motor phase B pin 1
4	B2	Motor phase B pin 2

Table 5: Motor connector pinning

NOTICE	**Do not connect or disconnect motor during operation!** Motor cable and motor inductivity might lead to voltage spikes when the motor is (dis)connected while energized. These voltage spikes might exceed voltage limits of the driver MOSFETs and might permanently damage them. Therefore, always switch off or disconnect power supply before (dis)connecting the motor.

4.2   I/O Connector

Pin no.	Pin name	Description
1	GND	Supply ground connection, also used for USB serial converter ground connection
2	V+	Supply voltage (VDD) +9V to +28V DC
3	DIR	Optically isolated direction input of S/D interface
4	STEP	Optically isolated step input of S/D interface
5	EN	Optically isolated enable input of motor driver H-bridges
6	CHOP	Optically isolated chopper mode selection input
7	COMM	Opto-coupler common anode or cathode, connect to ground or VCCIO (3.3V to 24V)
8	RXD	TTL-level UART receive line, use with USB serial converter TXD line to connect to PC
9	TXD	TTL-level UART transmit line, use with USB serial converter RXD line to connect to PC

Table 6: I/O connector pinning

NOTICE

Supply Voltage Buffering / Add External Power Supply Capacitors
A sufficiently buffered power supply or an external electrolyte capacitor connected between V+ and GND is recommended for stable operation.
It is recommended to connect an electrolytic capacitor of significant size to the power supply lines next to the PD42-1070.

Rule of thumb for size of electrolytic capacitor: $C = 1000 \frac{\mu F}{A} * I_{SUPPLY}$

The PD42-1070 comes with approximately 40μF of onboard ceramic capacitors.

NOTICE

There is no reverse polarity protection on the supply input!
The module will short any reversed supply voltage and board electronics will get damaged.

NOTICE

Power Up Sequence
We suggest to power up the PD42-1070 only with disabled H-bridges. That is, depending on your configuration the EN input should be logically OFF.

4.3   TTL UART Connection

To connect via the TTL UART interface to a host PC, we suggest using a USB serial converter from TTL-UART (5V) to USB interface.
Communication with the host PC, for example when using TRINAMIC's TMCL-IDE, is done via the Virtual COM port installed by the converter driver.
More information on the TMCL-IDE and the latest release can be found here: www.trinamic.com

The converter cable must be connected to pins 1, 8, and 9 (GND, RXD, TXD) of the I/O connector.

Note	**Default Baud Rates**
	The default baud rate is 9600 bps.
	In bootloader mode, the baud rate is 115200 bps.

❶ *Info*	**USB to UART converter**
	For example, the TTL-232R-5V from FTDI is working with the module and has been tested. More information on this converter is available on the FTDI website: www.ftdichip.com

NOTICE	**5V TTL UART Level**
	The TTL UART interface works with 5V level. Take special care when selecting a converter cable for USB connection.

4.4   Status LEDs

The PD42-1070 has one green status LED. See figure 9 for its location.

State	Description
Blinking	Heartbeat, MCU active, normal operation
Permanent on	Bootloader mode
Off	Power Off

Table 7: LED state description

5 Functional Description

5.1 Typical Application Wiring

Wire the PD42-1070 as shown in the following figures.

- Connect the the power supply to V+ and GND.

- Connect the Step and Direction signals to your motion controller.

- Optional: Connect UART to a TTL UART interface with 5V logic levels. To configure your PD42-1070 connect start the TMCL-IDE and use the parameterization tools. For detailed instructions refer to the PD42-1070-firmware-manual.

Note   **The TTL UART interface is *not* optically isolated. It requires 5V level signals.** Nevertheless, it provides basic ESD and rail-to-rail signal line protection for the PD42-1070.
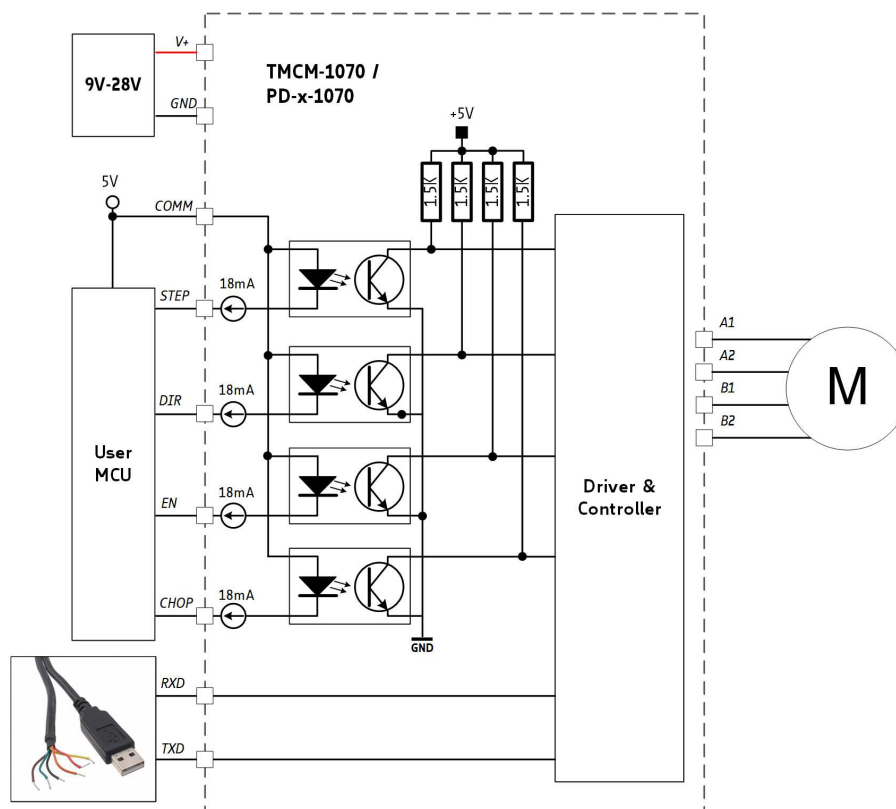

Figure 10: Typical application scenario with 5V inputs

5.2 Optically Isolated Inputs with Common Anode Input

The control inputs of the PD42-1070 are optically isolated (not the TTL UART interface). All optocouplers share one common anode (COMM) input as shown in the figure above.
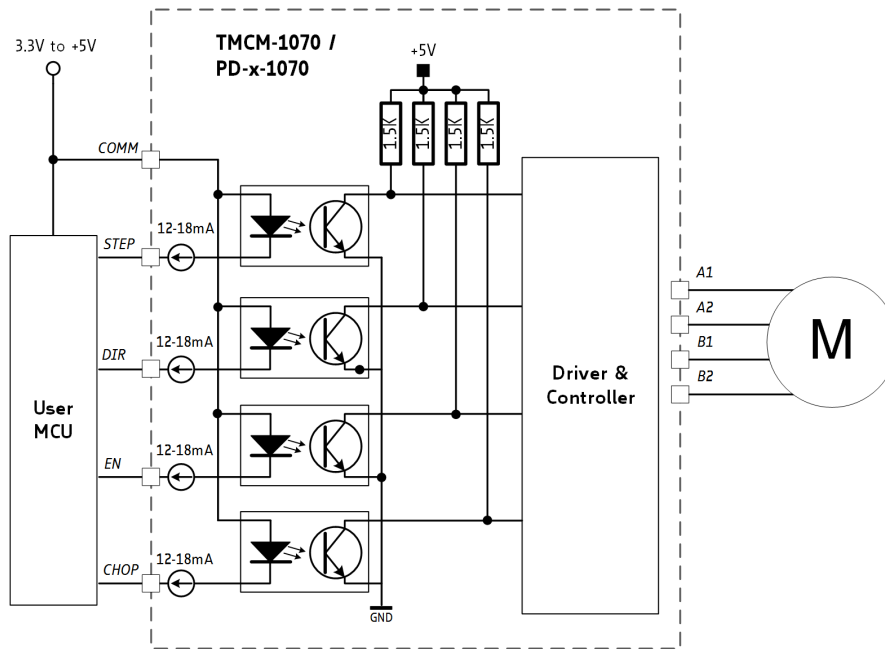
Figure 11: Inputs with common anode input with 3.3V to 5V

The typical voltage at COMM input is 5V. Nevertheless, 3.3V or voltages higher than 5V can also be used as long as the current is through the optocouplers' emitter is between 5mA to 20mA. For 3.3V operation the controller must be carefully selected with respect to its I/O ports, its actual output voltage, and the series resistor of the I/O ports. The user must make sure that the current through the optocouplers' emitter is between 5mA to 20mA.

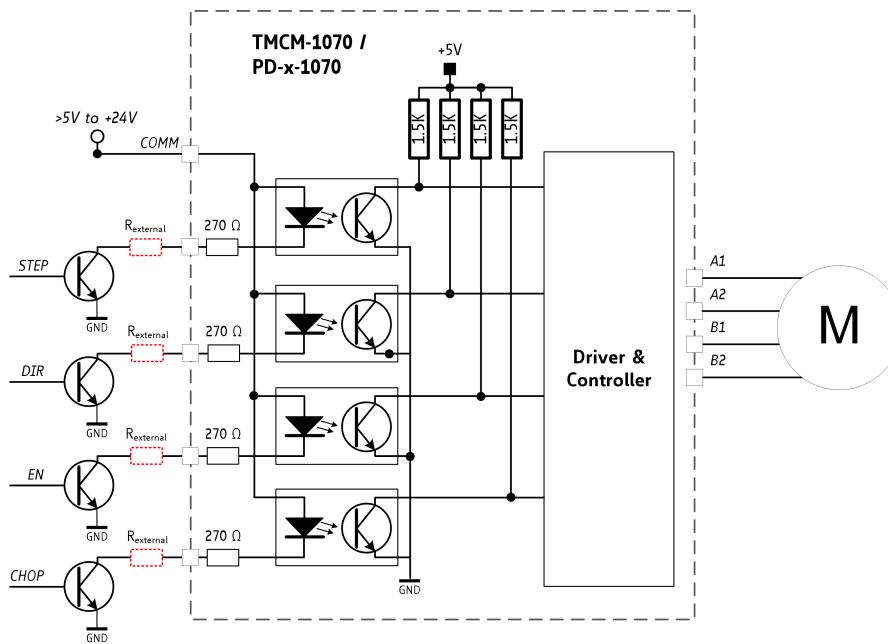| *Note*	**Step pulse width**
	Width of the step pulses should be between 2µs and 4µs, for maximum step frequency.
	With a larger step pulse width, for example 50% duty cycle coming from a frequency generator, the maximum input frequency will be lower at ca. 9kHz..

Figure 12: Inputs with common anode input with >5V to 24V

The series resistors in the PD42-1070 are 270mOhms. For operation with voltages higher than 5V an additional external resistor $R_{external}$ is required per input to limit the current. See Table 8 as reference for additional external resistor values.

COMM Voltage (V)	Value of $R_{external}$ (Ω)
3.3	-
5	-
9	300
12	500
15	700
24	1K5

Table 8: Additional resistor reference values

5.3   Optically Isolated Inputs with Common Cathode Input

The optocouplers inside PD42-1070 are bidirectional types (AC/DC). Thus, COMM can also be used as common cathode connection.

5.4   Thermal Behavior

The default configuration parameters of the PD42-1070 are set to the specified maximum current of 1A rms / 1.4A peak, which is the maximum motor phase current specified for the stepper motor options given in Table 4.

Typically, at this nominal current setting the stepper motor and the driver electronics will get hot. Continuous operation at maximum current is not guaranteed without cooling the motor since the stepper driver will switch off due to its internal over-temperature protection until temperature falls below the threshold.

Note	**Operation with Maximum Current Setting**
	For table-top testing and application bring-up the current should be reduced or the coolStep feature should be configured to keep heating on a reasonable level. Especially, when there is no other cooling option for the motor.
	For proper and continuous operation at maximum current, the motor flange must be mounted to the applications mechanical interface with good contact.

---

6 Operational Ratings and Characteristics

6.1 Absolute Maximum Ratings

Parameter	Min	Max	Unit
Supply voltage	+9	+28	V
Working temperature	-30	+40	° C
Motor coil current / sine wave **peak**		1.4	A
Continuous motor current (**RMS**)		1.0	A

> **NOTICE** **Avoid exceeding the absolute maximum rating under all circumstances.** 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.
>
> Keep the power supply voltage below the upper limit of +28V! Otherwise the board electronics will seriously be damaged! Especially, when the selected operating voltage is near the upper limit a regulated power supply is highly recommended.

6.2 Electrical Characteristics (Ambient Temperature 25° C)

Parameter	Symbol	Min	Typ	Max	Unit
Supply voltage	VDD	9	24	26	V
Motor coil current / sine wave **peak** (chopper regulated, adjustable via TTL UART interface)	$I_{COILpeak}$	0		1.4	A
Continuous motor current (**RMS**)	$I_{COILRMS}$	0		1.0	A
Power supply current	I_{DD}		$\ll I_{COIL}$	$1.4*I_{COIL}$	A

Table 10: Electrical Characteristics

6.3 I/O Ratings (Ambient Temperature 25° C)

Parameter	Symbol	Min	Typ	Max	Unit
COMM input voltage	V_{COMM}	3.3	5	$+VDD$	V
Input frequency of optically isolated I/Os	f_{in}			45	kHz
TTL UART input voltage	V_{TTL_IN}		5	5.5	V
TTL UART low level voltage	V_{TLL_L}	0		1.75	V

TTL UART high level voltage	V_{TTL_H}	3.25		5	V
TTL UART output voltage	V_{TTL_OUT}		5		V

Table 11: Operational ratings of optically isolated inputs and TTL UART interface

6.4   Functional Characteristics

Parameter	Description / Value
Control	4-wire interface with Step, Direction, Enable, and Chopper Mode Switch
Step Pulse Width	The step pulse width should be between 2µs and 4µs for maximum frequency. With a larger step pulse width, for example 50% duty cycle coming from a frequency generator, the maximum input frequency will be lower at ca. 9kHz.
Communication	2-wire TTL UART interface for configuration, 9600-115200 bps (default 57600 bps)
Driving Mode	spreadCycle and stealthChop chopper modes (selectable with CHOP input), adaptive automatic current reduction using stallGuard2 and coolStep
Stepping Resolution	Full, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256 step, default is 1/16 with internal interpolation to 1/256

Table 12: Functional Characteristics

6.5   Other Requirements

Specifications	Description or Value
Cooling	Free air
Working environment	Avoid dust, water, oil mist and corrosive gases, no condensation, no frosting
Working temperature	-30° C to +40° C

Table 13: Other Requirements and Characteristics

7   Abbreviations used in this Manual

Abbreviation	Description
COMM	Common Anode or common cathode
IDE	Integrated Development Environment
LED	Light Emmitting Diode
RMS	Root Mean Square value
TMCL	TRINAMIC Motion Control Language
TTL	Transistor Transistor Logic
UART	Universal Asynchronous Receiver Transmitter
USB	Universal Serial Bus

Table 14: Abbreviations used in this Manual

8   Figures Index

9   Tables Index

10   Supplemental Directives

10.1   Producer Information

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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.

11   Revision History

11.1   Hardware Revision

Version	Date	Description
1.00	26.06.2016	Initial release.

Table 15: Hardware Revision

11.2   Document Revision

Version	Date	Description
1.00	26.06.2016	Initial release.

Table 16: Document Revision