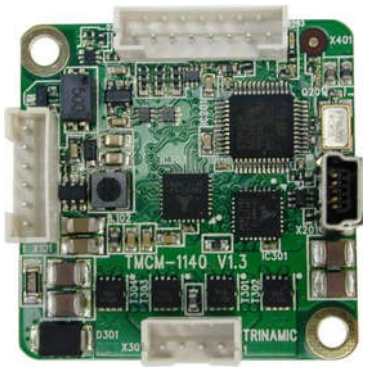
Hardware Version V1.3

HARDWARE MANUAL



TMCM-1140

1-Axis Stepper
Controller / Driver
2 A / 24 V
sensOstep™ Encoder
USB, RS485, and CAN

UNIQUE FEATURES:

coolStep™

stallGuard2™

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TRINAMIC
MOTION CONTROL

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1 Features

The TMCM-1140 is a single axis controller/driver module for 2-phase bipolar stepper motors with state of the art feature set. It is highly integrated, offers a convenient handling and can be used in many decentralized applications. The module can be mounted on the back of NEMA 17 (42mm flange size) stepper motors and has been designed for coil currents up to 2 A RMS and 24 V DC supply voltage. With its high energy efficiency from TRINAMIC's coolStep™ technology cost for power consumption is kept down. The TMCL™ firmware allows for both, standalone operation and direct mode.

MAIN CHARACTERISTICS

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

Bipolar stepper motor driver
- Up to 256 microsteps per full step
- High-efficient operation, low power dissipation
- Dynamic current control
- Integrated protection
- stallGuard2 feature for stall detection
- coolStep feature for reduced power consumption and heat dissipation

Encoder
- sensOstep magnetic encoder (1024 increments per rotation) e.g. for step-loss detection under all operating conditions and positioning supervision

Interfaces
- RS485 2-wire communication interface
- CAN 2.0B communication interface
- USB full speed (12Mbit/s) device interface
- 4 multipurpose inputs:
  - 3x general-purpose digital inputs
    (Alternate functions: STOP_L / STOP_R / HOME switch inputs or A/B/N encoder input)
  - 1x dedicated analog input
- 2 general purpose outputs
  - 1x open-drain 1A max.
  - 1x +5V supply output (can be switched on/off in software)

Software
- TMCL: standalone operation or remote controlled operation,
  program memory (non volatile) for up to 2048 TMCL commands, and
  PC-based application development software TMCL-IDE available for free.

Electrical and mechanical data
- Supply voltage: +24 V DC nominal (9... 28 V DC)
- Motor current: up to 2 A RMS / 2.8 A peak (programmable)

Refer to separate TMCL Firmware Manual, too.

TRINAMICs Unique Features – Easy to Use with TMCL

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

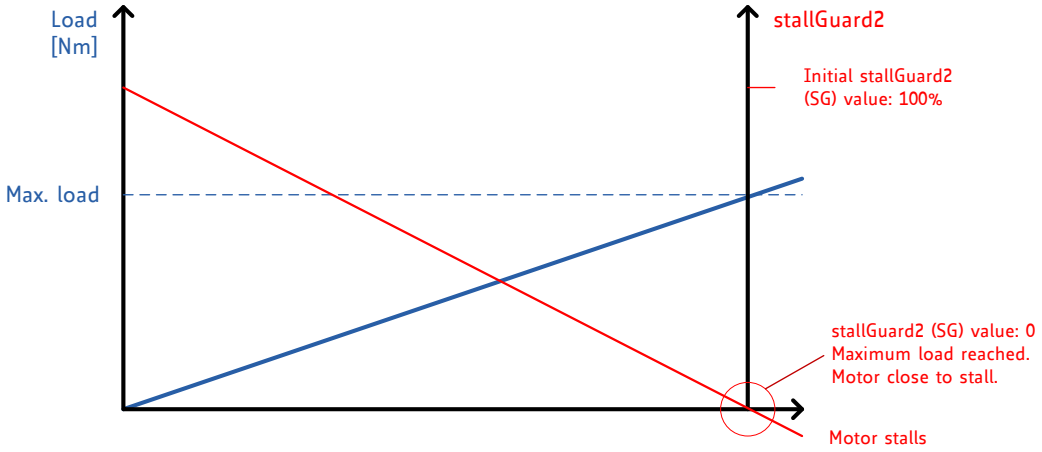


Figure 1.1 stallGuard2 load measurement SG as a function of load

coolStep™ coolStep is a load-adaptive automatic current scaling based on the load measurement via stallGuard2 adapting 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 reducing cost.

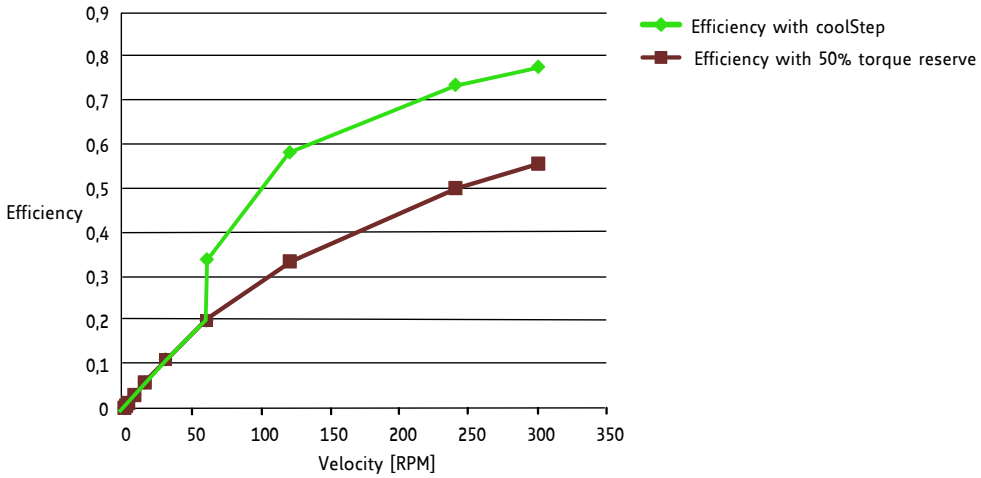


Figure 1.2 Energy efficiency example with coolStep

2 Order Codes

Order code	Description	Size (mm³)
TMCM-1140-*option*	Single axis bipolar stepper motor controller / driver electronics with integrated sensOstep encoder and coolStep feature	37 x 37 x 11.5

Table 2.1 Order codes

The following options are available:

Firmware option	Description	Order code example:
-TMCL	Module pre-programmed with TMCL firmware	TMCM-1140-*TMCL*
-CANopen	Module pre-prgrammed with CANopen firmware	TMCM-1140-*CANopen*

Table 2.2 Firmware options

A cable loom set is available for this module:

Order code	Description
TMCM-1140-CABLE	Cable loom for TMCM-1140: - 1x cable for power and communication connector (length 200mm) - 1x cable for multipurpose In/Out connector (length 200mm) - 1x cable for motor connector (length 200mm) - 1x USB type A connector to mini-USB type B connector cable (length 1.5m)

Table 2.3 Cable loom order codes

Please note that the TMCM-1140 is available with NEMA17 stepper motors, too. Refer to the PD-1140 documents for more information about these products.

3 Mechanical and Electrical Interfacing

3.1 Dimensions and Mounting Holes

The dimensions of the controller/driver board are approx. 37 mm x 37 mm x 11.5 mm in order to fit on the back of a 42 mm stepper motor. Maximum component height (height above PCB level) without mating connectors is around 8mm above PCB level and 2 mm below PCB level. There are two mounting holes for M3 screws for mounting to a NEMA17 stepper motor.

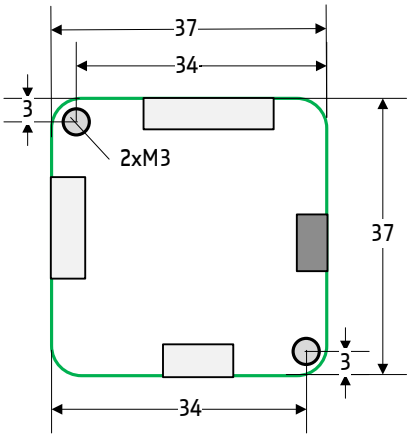


Figure 3.1 Dimensions of TMCM-1140 and position of mounting holes

3.2 Board mounting considerations

The TMCM-1140 offers two metal plated mounting holes. Both mounting holes are connected to system and signal ground (same as power supply ground).
In order to minimize distortion of signals and radiation of HF signals (improve EMC compatibility) especially in sensitive / noisy environments it is important to ensure a solid ground connection within the system. In order to support this, it is recommended to connect both mounting holes of the board in addition to the supply ground connection to system power supply ground.
Nevertheless, this might not always be an option e.g. in case the metal system chassis / TMCM-1140 mounting plate is already connected to earth and a direct connection between supply ground (secondary side) and mains supply earth (primary side) is not desired / not an option. In this case plastic (e.g. made of nylon) spacers / distance bolts and screws should be used.

3.3 Connectors of TMCM-1140

The controller/driver board of the TMCM-1140 offers four connectors including the motor connector which is used for attaching the motor coils to the electronics. The power and communication connector is used for power supply, CAN interface, and RS485 interface. The 8pin multipurpose I/O connector offers four multipurpose inputs and two general purpose outputs. Further, there is a connector for the USB interface.

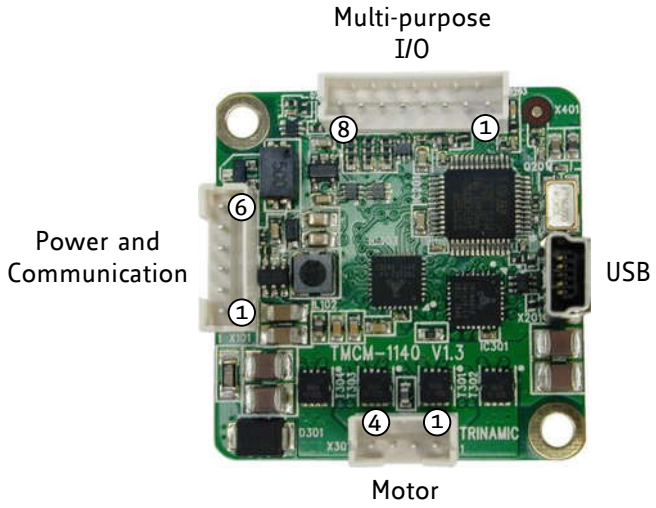


Figure 3.2 Overview connectors

Label	Connector type	Mating connector type
Power and Communication Connector	CI0106P1VK0-LF CVIlux CI01 series, 6 pins, 2mm pitch	Connector housing CVIlux: CI01065000-A Contacts CVIlux: CI01T011PE0-A *or* Connector housing JST: PHR-6 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm²
Multipurpose I/O Connector	CI0108P1VK0-LF CVIlux CI01 series, 8 pins, 2mm pitch	Connector housing CVIlux: CI01085000-A Contacts CVIlux: CI01T011PE0-A *or* Connector housing JST: PHR-8 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm²
Motor Connector	CI0104P1VK0-LF CVIlux CI01 series, 4 pins, 2mm pitch	Connector housing CVIlux: CI01045000-A Contacts CVIlux: CI01T011PE0-A *or* Connector housing JST: PHR-4 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm²
Mini-USB Connector	Molex 500075-1517 Mini USB Type B vertical receptacle	Any standard mini-USB plug

Table 3.1 Connectors and mating connectors, contacts and applicable wire

3.3.1 Power and Communication Connector

A 6pin CVIlux CI0106P1VK0-LF 2mm pitch single row connector is used for power supply, RS485 and CAN serial communication. Please note the additional power supply information in chapter 3.3.1.1.

Note: CAN interface will be de-activated in case USB is connected due to internal sharing of hardware resources.



Pin	Label	Direction	Description
1	GND	Power (GND)	System and signal ground
2	VDD	Power (Supply)	VDD (+9V...+28V)
3	RS485+	Bidirectional	RS485 interface, diff. signal (non-inverting)
4	RS485-	Bidirectional	RS485 interface, diff. signal (inverting)
5	CAN_H	Bidirectional	CAN interface, diff. signal (non-inverting)
6	CAN_L	Bidirectional	CAN interface, diff. signal (inverting)

Table 3.2 Connector for power supply and interfaces

3.3.1.1 Power Supply

For proper operation care has to be taken with regard to power supply concept and design. Due to space restrictions the TMCM-1140 includes about 40µF/35V of supply filter capacitors. These are ceramic capacitors which have been selected for high reliability and long life time. The module includes a 28V suppressor diode for over-voltage protection.

CAUTION!

	***Add external power supply capacitors!*** It is recommended to connect an electrolytic capacitor of significant size (e.g. at least 470µF/35V) to the power supply lines next to the TMCM-1140! Rule of thumb for size of electrolytic capacitor: $c = 1000 \frac{\mu F}{A} \times I_{SUPPLY}$ In addition to power stabilization (buffer) and filtering this added capacitor will also reduce any voltage spikes which might otherwise occur from a combination of high inductance power supply wires and the ceramic capacitors. In addition it will limit slew-rate of power supply voltage at the module. The low ESR of ceramic-only filter capacitors may cause stability problems with some switching power supplies.
	***Do not connect or disconnect motor during operation!*** Motor cable and motor inductivity might lead to voltage spikes when the motor is disconnected / connected while energized. These voltage spikes might exceed voltage limits of the driver MOSFETs and might permanently damage them. Therefore, always disconnect power supply before connecting / disconnecting the motor.
	***Keep the power supply voltage below the upper limit of 28V!*** Otherwise the driver electronics will seriously be damaged! Especially, when the selected operating voltage is near the upper limit a regulated power supply is highly recommended. Please see also chapter 7, operating values.
	***There is no reverse polarity protection!*** The module will short any reversed supply voltage due to internal diodes of the driver transistors.

3.3.1.2 RS485

For remote control and communication with a host system the TMCM-1140 provides a two wire RS485 bus interface. For proper operation the following items should be taken into account when setting up an RS485 network:

1. *BUS STRUCTURE*:
   The network topology should follow a bus structure as closely as possible. That is, the connection between each node and the bus itself should be as short as possible. Basically, it should be short compared to the length of the bus.

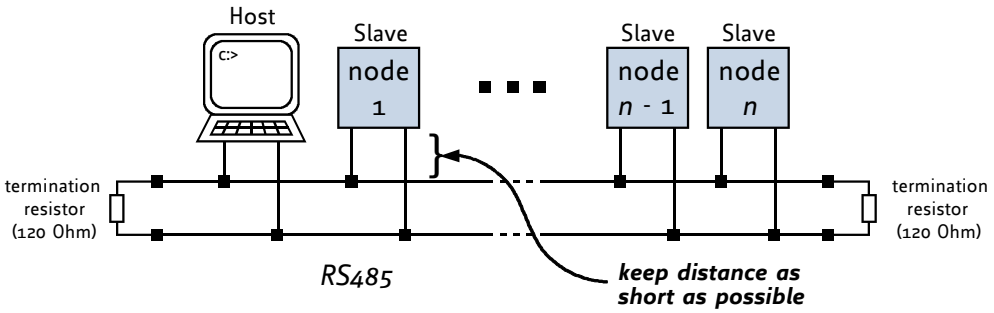


Figure 3.3: Bus structure

2. *BUS TERMINATION*:
   Especially for longer busses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-1140 does not integrate any termination resistor. Therefore, 120 Ohm termination resistors at both ends of the bus have to be added externally.

3. *NUMBER OF NODES*:
   The RS485 electrical interface standard (EIA-485) allows up to 32 nodes to be connected to a single bus. The bus transceivers used on the TMCM-1140 units (hardware V1.2: SN65HVD3082ED, since hardware V1.3: SN65HVD1781D) have a significantly reduced bus load and allow a maximum of 255 units to be connected to a single RS485 bus using TMCL firmware. *Please note: usually it cannot be expected to get reliable communication with the maximum number of nodes connected to one bus and maximum supported communication speed at the same time. Instead, a compromise has to be found between bus cable length, communication speed and number of nodes.*

4. *COMMUNICATION SPEED:*
   The maximum RS485 communication speed supported by the TMCM-1140 hardware V1.2 is 115200 bit/s and 1Mbit/s since hardware V1.3. Factory default is 9600 bit/s. *Please see separate TMCM-1140 TMCL firmware manual for information regarding other possible communication speeds below the upper limit in hardware.*

5. *NO FLOATING BUS LINES:*
   Avoid floating bus lines while neither the host/master nor one of the slaves along the bus line is transmitting data (all bus nodes switched to receive mode). Floating bus lines may lead to communication errors. In order to ensure valid signals on the bus it is recommended to use a resistor network connecting both bus lines to well defined logic levels.

   There are actually two options which can be recommended:
   Add resistor (Bias) network on **one** side of the bus, only (120R termination resistor still at **both** ends):

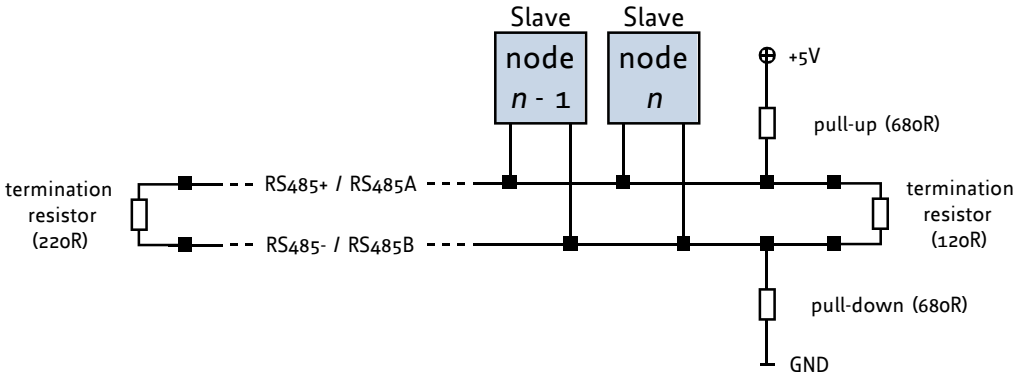


Figure 3.4: Bus lines with resistor (Bias) network on one side, only

Or add resistor (Bias) network at **both** ends of the bus (like Profibus™ termination):

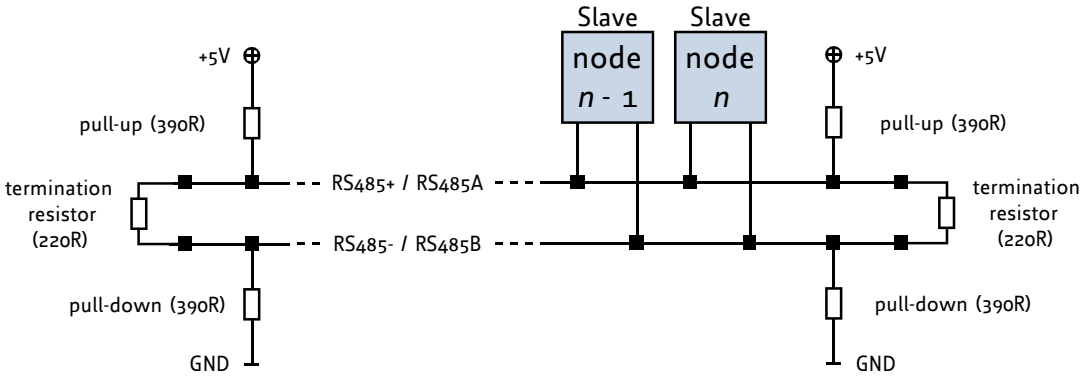


Figure 3.5: Bus lines with resistor (Bias) network at both ends

Certain RS485 interface converters available for PCs already include these additional resistors (e.g. USB-2-485 with bias network at one end of the bus).

3.3.1.3 CAN

For remote control and communication with a host system the TMCM-1140 provides a CAN bus interface. Please note that the CAN interface is not available in case USB is connected. For proper operation the following items should be taken into account when setting up a CAN network:

1. *BUS STRUCTURE*:
   The network topology should follow a bus structure as closely as possible. That is, the connection between each node and the bus itself should be as short as possible. Basically, it should be short compared to the length of the bus.

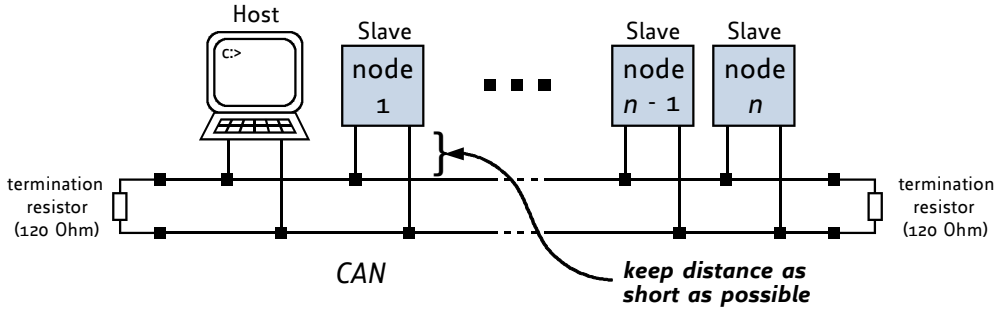


Figure 3.6 CAN bus structure

2. *BUS TERMINATION*:
   Especially for longer busses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-1140 does not integrate any termination resistor. Therefore, 120 Ohm termination resistors at both ends of the bus have to be added externally.

3. *NUMBER OF NODES*:
   The bus transceiver used on the TMCM-1140 units (TJA1050T) supports at least 110 nodes under optimum conditions. Practically achievable number of nodes per CAN bus highly depend on bus length (longer bus -> less nodes) and communication speed (higher speed -> less nodes).

3.3.2 Multipurpose I/O Connector

An 8pin CVIlux CI0108P1VK0-LF 2mm pitch single row connector is available for all multipurpose inputs and outputs.



Pin	Label	Direction	Description
1	GND	Power (GND)	System and signal ground
2	VDD	Power (Supply)	VDD, connected to VDD pin of the power and communication connector
3	OUT_0	Output	Open-drain output (max. 1A) Integrated freewheeling diode to VDD
4	OUT_1	Output	+5V supply output (max. 100mA) Can be switched on/off in software
5	IN_0	Input	Dedicated analog input, Input voltage range: 0..+10V Resolution: 12bit (0..4095)
6	IN_1, STOP_L, ENC_A	Input	General purpose digital input (+24V compatible)
			Alternate function 1: left stop switch input
			Alternate function 2: external incremental encoder channel A input
7	IN_2, STOP_R, ENC_B	Input	General purpose digital input (+24V compatible)
			Alternate function 1: right stop switch input
			Alternate function 2: external incremental encoder channel B input
8	IN_3, HOME, ENC_N	Input	General purpose digital input (+24V compatible)
			Alternate function 1: home switch input
			Alternate function 2: external incremental encoder index / zero channel input

Table 3.3 Multipurpose I/O connector

Note:

- All inputs have resistor based voltage input dividers with protection diodes. These resistors also ensure a valid GND level when left unconnected.
- For all digital inputs (IN_1, IN_2, IN_3) a 2k2 pull-up resistor to +5V can be activated (default setting with all more recent TMCL firmware versions). Then these inputs have a default (unconnected) logic level of 1 and an external switch to GND can be connected. This might be especially interesting in case these inputs are used as STOP_L / STOP_R and HOME switch inputs (alternate function 1) or as encoder input for an external incremental A/B/N encoder with open-collector outputs (pull-ups are not necessary for encoder with push-pull outputs).

3.3.2.1 Digital Inputs IN_1, IN_2, IN_3

The eight pin connector of the TMCM-1140 provides three multipurpose digital inputs IN_1, IN_2 and IN_3. All three inputs accept up to +24V (nom.) input signals and offer the same input circuit with voltage resistor dividers, limiting diodes against over- and under-voltage and programmable 2k2 pull-up resistors. The pull-ups can be switched on or off for all three inputs at once in software.

*With TMCL firmware command SIO 0, 0, **0** will switch-off the pull-ups and command SIO 0, 0, **1** will switch them on (see separate TMCL firmware manual, command SIO for more detailed information).*

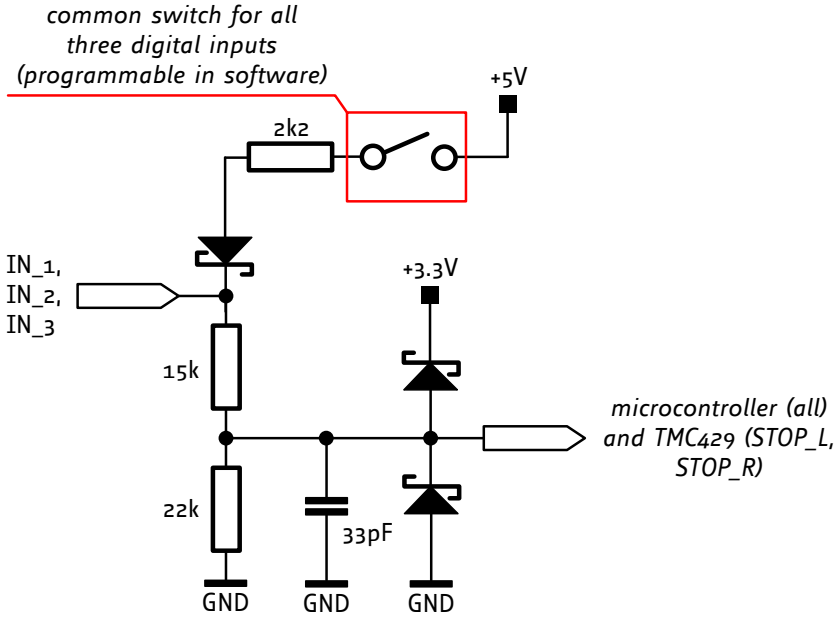


Figure 3.7 General purpose inputs (simplified input circuit)

The three digital inputs have alternate functionality depending on configuration in software. The following functions are available:

Label (pin)	Default function	Alternate function 1	Alternate function 2
IN_1 (6)	General purpose digital input *TMCL: GIO 1, 0 // get digital value of input IN_1*	STOP_L - left stop switch input, connected to processor and TMC429 REF input (supporting left stop functionality in hardware) *TMCL: GAP 11, 0 // get digital value of STOP_L input*	ENC_A - external incremental encoder input channel A, connected to processor encoder counter input
IN_2 (7)	General purpose digital input *TMCL: GIO 2, 0 // get digital value of input IN_2*	STOP_R - right stop switch input, connected to processor and TMC429 REF input (supporting right stop switch functionality in hardware) *TMCL: GAP 10, 0 // get digital value of STOP_R input*	ENC_B - external incremental encoder input channel B, connected to processor encoder counter input
IN_3 (8)	General purpose digital input *TMCL: GIO 3, 0 // get digital value of input IN_3*	HOME - home switch input, connected to processor *TMCL: GAP 9, 0 // get digital value of HOME input*	ENC_N - external incremental encoder input index / zero channel, connected to processor interrupt input

Table 3.4 Multipurpose inputs / alternate functions

- All three digital inputs are connected to the on-board processor and can be used as general purpose digital inputs (default).
- In order to use IN_1 and IN_2 as STOP_L and STOP_R inputs, this function has to be enabled explicitly in software (factory default: switched off). With TMCL firmware the stop switch functionality can be enabled using SAP 12, 0, 0 (STOP_R / right limit switch) and SAP 13, 0, 0 (STOP_L / left limit switch). As the names already indicate: the status of the left limit switch (STOP_L) will be significant during motor left turns and the status of the right limit switch during motor right turns (positive direction), only. Reading out input values using the GAP commands as listed in the table above is possible at any time. Please see separate TMCL firmware manual for additional information.
- External encoder: an external incremental A/B/N encoder can be connected to the TMCM-1140 and used in addition or as an alternative to the internal sensOstep™ encoder. Using TMCL the encoder counter value for this second encoder can be read out via TMCL command GAP 216, 0 (see separate TMCL firmware manual for more details). Factory default scaling of the encoder counter is 1:1 - that is, after one encoder rotation the encoder counter will be incremented / decremented by the number of encoder ticks (encoder lines x 4). When using an external encoder connect encoder channel A to IN_1, channel B to IN_2, the N or zero channel to IN_3 (optional), encoder ground to module supply ground (e.g. Pin 1 of the Multipurpose I/O connector) and the +5V supply input of the encoder to OUT_1 (all on the Multipurpose I/O connector). Please note that in order to supply the encoder with +5V the output OUT_1 has to be activated first using SIO 1, 2, 1 (see also chapter 3.3.2.3).

3.3.2.2 Analog Input IN_0

The eight pin connector of the TMCM-1140 provides one dedicated analog input IN_0. This dedicated analog input offers a full scale input range of approx. 0... +10 V (0..+10.56V nom.) with a resolution of the internal analog-to-digital converter of the microcontroller of 12bit (0... 4095).

The input is protected against higher voltages up to +24 V using voltage resistor dividers together with limiting diodes against voltages below 0 V (GND) and above +3.3 V DC (see figure below).

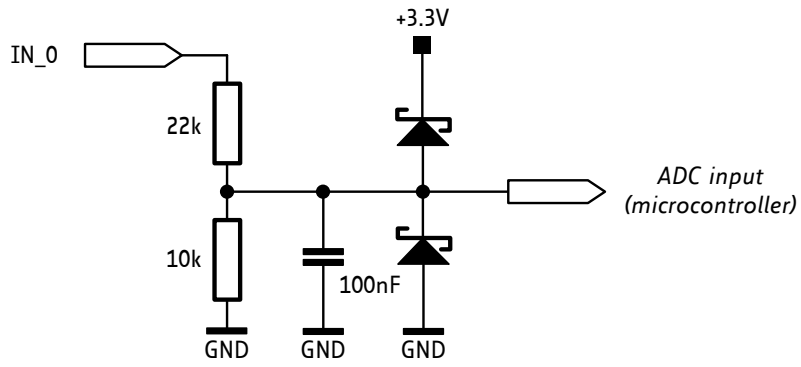


Figure 3.8 General purpose inputs (simplified input circuit)

With TMCL firmware the analog value of this input may be read using command GIO 0, 1. The command will return the raw value of the 12bit analog-to-digital converter between 0 .. 4095. It is also possible to read the digital value of this input using TMCL command GIO 0, 0. The trip point (between 0 and 1) will be at approx. +5V input voltage (half the analog input range).

3.3.2.3 Outputs OUT_0, OUT_1

The eight pin connector of the TMCM-1140 offers two general purpose outputs OUT_0 and OUT_1. OUT_0 is an open-drain output capable of switching (sinking) up to 1A. The output of the N-channel MOSFET transistors is connected to a freewheeling diode for protection against voltage spikes especially from inductive loads (relais etc.) above supply voltage (see figure below).

OUT_0 should not be connected to any voltage above supply voltage of the module due to the internal freewheeling diode.

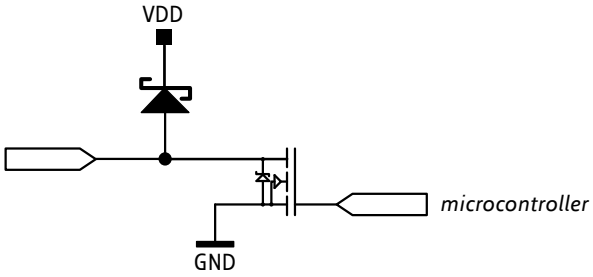


Figure 3.9 General purpose output OUT_0 (simplified circuit)

*With TMCL firmware OUT_0 can be switched **on** (OUT_0 pulled low) using command SIO 0, 2, **1** and off again (OUT_0 floating) using command SIO 0, 2, **0** (this is also the factory default setting of this output). In case a floating output is not desired in the application an external resistor to e.g. supply voltage may be added.*

In contrast OUT_1 is able to supply +5V (sourcing 100mA max.) to an external load. An integrated P-channel MOSFET allows switching on / off this +5V supply in software (see figure below). This output might be used in order to supply +5V to an external encoder circuit. Please note that the +5V supply has to be activated explicitly in software.

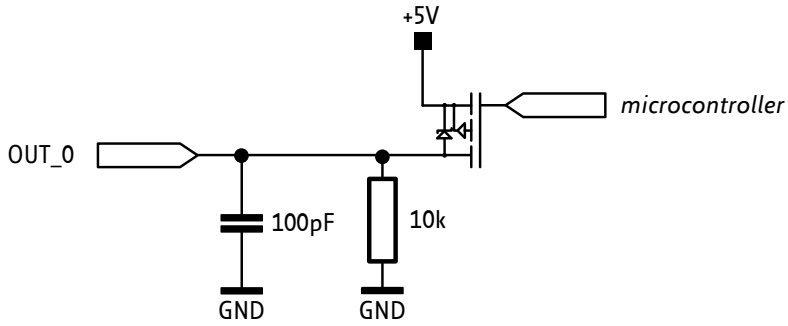


Figure 3.10 General purpose output OUT_1 (simplified circuit)

*With TMCL firmware OUT_1 can be switched **on** (supply +5V to external circuit) using command SIO 1, 2, **1** and **off** (output pulled low via 10k pull-down resistor) using command SIO 1, 2, **0** (this is also the factory default setting of this output).*

3.3.3 Motor Connector

As motor connector a 4pin CVIlux CI0104P1VK0-LF 2mm pitch single row connector is available. The motor connector is used for connecting the four motor wires of the two motor coils of the bipolar stepper motor to the electronics.



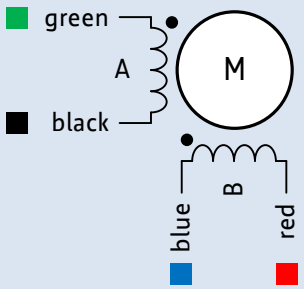
Pin	Label	Direction	Description
1	OB2	Output	Pin 2 of motor coil B
2	OB1	Output	Pin 1 of motor coil B
3	OA2	Output	Pin 2 of motor coil A
4	OA1	Output	Pin 1 of motor coil A

Table 3.5 Motor connector

Example for connecting the QSH4218 NEMA 17 / 42mm stepper motors:

TMCM-1140	QS4218 Motor

Motor connector pin	Cable color	Coil	Description
1	Red	B	Motor coil B pin 1
2	Blue	B-	Motor coil B pin 2
3	Green	A-	Motor coil A pin 2
4	Black	A	Motor coil A pin 1



3.3.4 Mini-USB Connector

A 5pin mini-USB connector is available on-board for serial communication (as alternative to the CAN and RS485 interface). This module supports USB 2.0 Full-Speed (12Mbit/s) connections.

CAN interface will be de-activated as soon as USB is connected due to internal sharing of hardware resources.



Pin	Label	Direction	Description
1	VBUS	Power (supply input)	+5V supply from host
2	D-	Bidirectional	USB Data –
3	D+	Bidirectional	USB Data +
4	ID	Power (GND)	Connected to signal and system ground
5	GND	Power (GND)	Connected to signal and system ground

Table 3.6 Connector for USB

For remote control and communication with a host system the TMCM-1140 provides a USB 2.0 full-speed (12Mbit/s) interface (mini-USB connector). As soon as a USB-Host is connected the module will accept commands via USB.

USB Bus Powered Operation Mode

The TMCM-1140 supports both, USB self powered operation (when an external power is supplied via the power supply connector) and USB bus powered operation, (no external power supply via power supply connector).

On-board digital core logic will be powered via USB in case no other supply is connected (USB bus powered operation). The digital core logic includes the microcontroller itself and also the EEPROM. The *USB bus powered operation mode* has been implemented to enable configuration, parameter settings, read-outs, firmware updates, etc. by just connecting an USB cable between module and host PC. No additional cabling or external devices (e.g. power supply) are required.

Please note that the module might draw current from the USB +5V bus supply even in USB self powered operation depending on the voltage level of this supply.

Motor movements are not possible in this mode. Therefore, always connect a power supply to the *Power and Communication Connector* for motor movements.

4 Motor driver current

The on-board stepper motor driver operates current controlled. The driver current may be programmed in software for motor coil currents up-to 2A RMS with 32 effective scaling steps in hardware (CS in table below).

Explanation of different columns in table below:

Motor current setting in software (TMCL) These are the values for TMCL axis parameter 6 (motor run current) and 7 (motor standby current). They are used to set the run / standby current using the following TMCL commands:

```
SAP 6, 0, <value> // set run current

SAP 7, 0, <value> // set standby current
```

(read-out value with `GAP` instead of `SAP`. Please see separate TMCM-1140 firmware manual for further information)

Motor current I_{RMS} [A] Resulting motor current based on motor current setting

Motor current setting in software (TMCL)	Current scaling step (CS)	Motor current $I_{COIL\ PEAK}$ [A]	Motor current $I_{COIL\ RMS}$ [A]
0..7	0	0.092	0.065
8..15	1	0.184	0.130
16..23	2	0.276	0.195
24..31	3	0.368	0.260
32..39	4	0.460	0.326
40..47	5	0.552	0.391
48..55	6	0.645	0.456
56..63	7	0.737	0.521
64..71	8	0.829	0.586
72..79	9	0.921	0.651
80..87	10	1.013	0.716
88..95	11	1.105	0.781
96..103	12	1.197	0.846
104..111	13	1.289	0.912
112..119	14	1.381	0.977
120..127	15	1.473	1.042
128..135	16	1.565	1.107
136..143	17	1.657	1.172
144..151	18	1.749	1.237
152..159	19	1.842	1.302
160..167	20	1.934	1.367
168..175	21	2.026	1.432
176..183	22	2.118	1.497
184..191	23	2.210	1.563
192..199	24	2.302	1.628
200..207	25	2.394	1.693
208..215	26	2.486	1.758
216..223	27	2.578	1.823
224..231	28	2.670	1.888
232..239	29	2.762	1.953
240..247	30	2.854	2.018
248..255	31	2.946	2.083

In addition to the settings in the table the motor current may be switched off completely (free-wheeling) using axis parameter 204 (see TMCM-1140 firmware manual).

5 Reset to Factory Defaults

It is possible to reset the TMCM-1140 to factory default settings without establishing a communication link. This might be helpful in case communication parameters of the preferred interface have been set to unknown values or got accidentally lost.

For this procedure two pads on the bottom side of the board have to be shortened.

Please perform the following steps:

1. Power supply off and USB cable disconnected
2. Short two pads as marked in Figure 5.1
3. Power up board (power via USB is sufficient for this purpose)
4. Wait until the on-board red and green LEDs start flashing fast (this might take a while)
5. Power-off board (disconnect USB cable)
6. Remove short between pads
7. After switching on power-supply / connecting USB cable all permanent settings have been restored to factory defaults

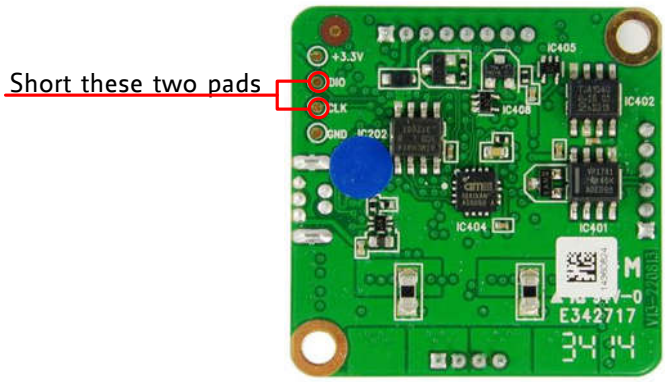


Figure 5.1 Reset to factory default settings

6 On-Board LEDs

The board offers two LEDs in order to indicate board status. The function of both LEDs is dependent on the firmware version. With standard TMCL firmware the green LED should be flashing slowly during operation and the red LED should be off.

When there is no valid firmware programmed into the board or during firmware update the red and green LEDs are permanently on.

BEHAVIOR OF LEDS WITH STANDARD TMCL FIRMWARE

Status	Label	Description
Heartbeat	Run	This green LED flashes slowly during operation.
Error	Error	This red LED lights up if an error occurs.

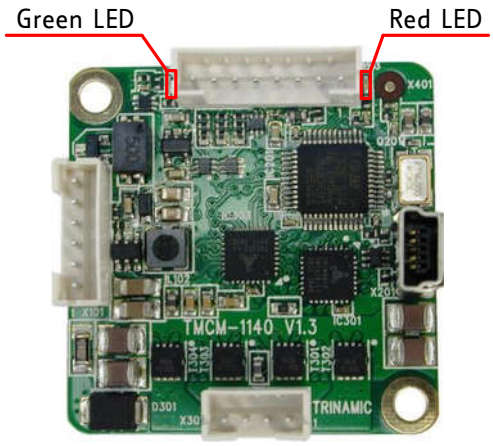


Figure 6.1 On-board LEDs

7 Operational Ratings

The operational ratings show the intended or the characteristic ranges and should be used as design values.

In no case shall the maximum values be exceeded!

Symbol	Parameter	Min	Typ	Max	Unit
VDD	Power supply voltage for operation	9	12… 24	28	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		2.0	A
I_{DD}	Power supply current		<< I_{COIL}	1.4 * I_{COIL}	A
T_{ENV}	Environment temperature at rated current (no forced cooling required)	-30		+50	°C
T_{ENV_1A}	Environment temperature at **1A RMS** motor current / half max. current (no forced cooling required)	-30		+70	°C

Table 7.1 General operational ratings of module

OPERATIONAL RATINGS OF MULTIPURPOSE I/OS

Symbol	Parameter	Min	Typ	Max	Unit
V_{OUT_0}	Voltage at open drain output OUT_0	0		+VDD	V
I_{OUT_0}	Output sink current of open drain output OUT_0			1	A
V_{OUT_1}	Voltage at output OUT_1 (when switched on)		+5		V
I_{OUT_1}	Output source current for OUT_1			100	mA
$V_{IN_1/2/3}$	Input voltage for IN_1, IN_2, IN_3 (digital inputs)	0		+VDD	V
$V_{IN_L\ 1/2/3}$	Low level voltage for IN_1, IN_2 and IN_3	0		1.1	V
$V_{IN_H\ 1/2/3}$	High level voltage for IN_1, IN_2 and IN_3	3.4		+VDD	V
V_{IN_0}	Measurement range for analog input IN_0	0		+10*)	V

Table 7.2 Operational ratings of multipurpose I/Os

**) approx. 0…+10.56V at the analog input IN_0 is translated to 0..4095 (12bit ADC, raw values). Above approx. +10.56V the analog input will saturate but, not being damaged (up-to VDD).*

OPERATIONAL RATINGS OF RS485 INTERFACE

Symbol	Parameter	Min	Typ	Max	Unit
N_{RS485}	Number of nodes connected to single RS485 network			256	
f_{RS485}	Maximum bit rate supported on RS485 connection		9600	115200 1000000*)	bit/s

Table 7.3: Operational ratings of RS485 interface

**) hardware revision V1.2: max. 115200 bit/s, hardware revision V1.3: max. 1Mbit/s*

OPERATIONAL RATINGS OF CAN INTERFACE

Symbol	Parameter	Min	Typ	Max	Unit
N_{CAN}	Number of nodes connected to single RS485 network			> 110	
f_{CAN}	Maximum bit rate supported on CAN connection		1000	1000	kbit/s

Table 7.4 Operational ratings of the CAN interface

8 Functional Description

The TMCM-1140 is a highly integrated controller/driver module which can be controlled via several serial interfaces. Communication traffic is kept low since all time critical operations (e.g. ramp calculations) are performed on board. The nominal supply voltage of the unit is 24V DC. The module is designed for both, standalone operation and direct mode. Full remote control of device with feedback is possible. The firmware of the module can be updated via any of the serial interfaces.

In Figure 8.1 the main parts of the TMCM-1140 are shown:

- the microprocessor, which runs the TMCL operating system (connected to TMCL memory),
- the motion controller, which calculates ramps and speed profiles internally by hardware,
- the power driver with stallGuard2 and its energy efficient coolStep feature,
- the MOSFET driver stage, and
- the sensOstep encoder with resolutions of 10bit (1024 steps) per revolution.

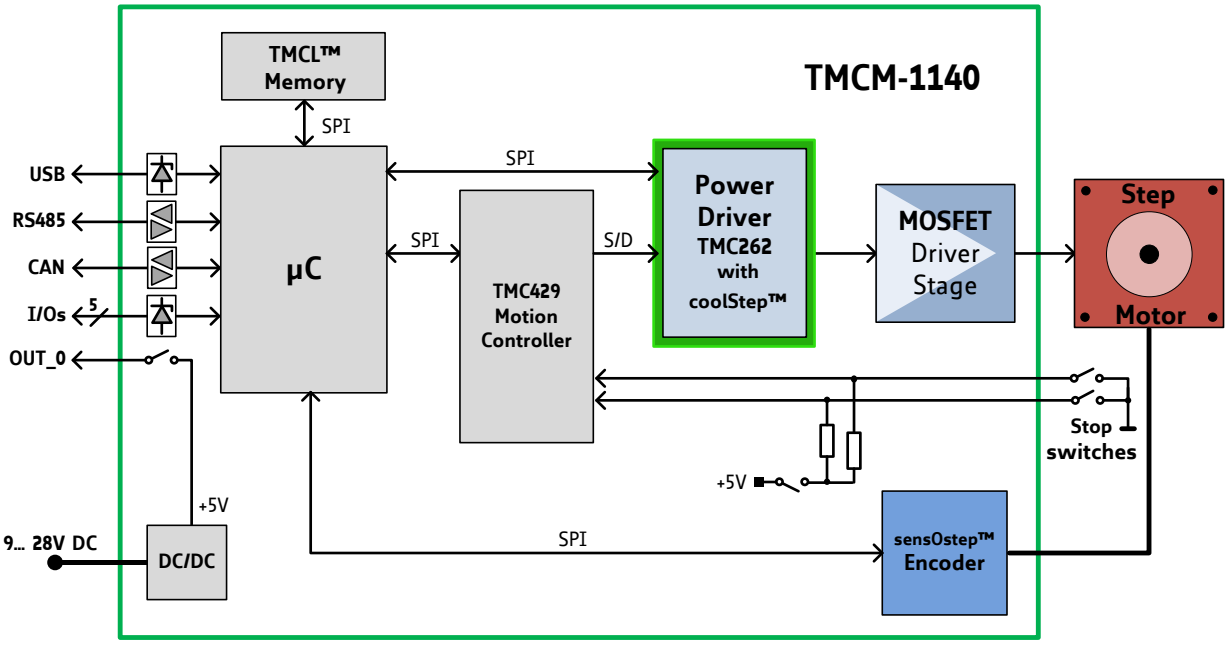


Figure 8.1 Main parts of the TMCM-1140

The TMCM-1140 comes with the PC based software development environment TMCL-IDE for the Trinamic Motion Control Language (TMCM). Using predefined TMCL high level commands like *move to position* a rapid and fast development of motion control applications is guaranteed.

Please refer to the TMCM-1140 Firmware Manual for more information about TMCL commands.

9 TMCM-1140 Operational Description

9.1 Calculation: Velocity and Acceleration vs. Microstep and Fullstep Frequency

The values of the parameters sent to the TMC429 do not have typical motor values like rotations per second as velocity. But these values can be calculated from the TMC429 parameters as shown in this section.

PARAMETERS OF TMC429

Signal	Description	Range
f_{CLK}	clock-frequency	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... 8

Table 9.1 TMC429 velocity parameters

MICROSTEP FREQUENCY

The microstep frequency of the stepper motor is calculated with

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

FULLSTEP FREQUENCY

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

$$fsf[Hz] = \frac{usf[Hz]}{2^{usrs}}$$ 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:

$$af = \frac{a}{2^{usrs}}$$ 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

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

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

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

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

CALCULATION OF THE NUMBER OF ROTATIONS

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

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

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

10 Life Support Policy

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11 Revision History

11.1 Document Revision

Version	Date	Author	Description
0.90	2011-DEC-22	GE	Initial version
0.91	2012-MAY-02	GE	Updated for TMCM-1140_V11 pcb version
1.00	2012-JUN-12	SD	First complete version including new chapters about: - reset to factory defaults, and - LEDs
1.01	2012-JUL-30	SD	Internal circuit of inputs corrected.
1.02	2013-MAR-26	SD	Names of inputs changed: ~~AIN_0~~ IN_0 ~~IN_0~~ IN_1 ~~IN_1~~ IN_2 ~~IN_2~~ IN_3 Names of outputs changed: ~~OUT_1~~ = OUT_0 ~~OUT_0~~ = OUT_1
1.03	2013-JUL-23	SD	- Connector types updated. - Chapter 3.3.1.1 updated.
1.04	2015-JAN-05	GE	- New hardware version V13 added - Motor driver current settings added (chapter 4) - Several additions

Table 11.1 Document revision

11.2 Hardware Revision

Version	Date	Description
TMCM-1040_V10*)	2011-MAR-08	Initial version
TMCM-1140_V11*)	2011-JUL-19	- Optimization of multipurpose I/O circuits - Clock generation and distribution changed (16MHz oscillator)
TMCM-1140_V12**)	2012-APR-12	- Further cost optimization incl. different sensor IC with 10bit max. resolution
TMCM-1140_V13**)	2013-AUG-22	- Stepper motor driver MOSFETs: The MOSFETs of the driver stage have been replaced. The new MOSFETs offer less heat dissipation than the previous / currently used ones. Apart from that the performance and settings including driver output current and output waveform are essentially the same. - General purpose outputs OUT_0 / OUT_1: The MOSFETs used for switching these outputs on / off have been replaced. The new MOSFETs offer less heat dissipation than the previous / currently used ones. Apart from that the functionality and ratings are essentially the same. - RS485 transceiver: the RS485 transceiver has been replaced with the SN65HVD1781 transceiver offering better fault protection (up-to 70V fault protection) and supporting higher communication speeds (up-to 1Mbit/s). - *In progress (coming soon):* Conformal coating of

Version	Date	Description
		both sides of the PCB. Provides improved protection against humidity and dust / swarf (e.g. in case of the motor mounted versions PD42-x-1140: tiny metal parts on the PCB attracted by the encoder magnet might lead to malfunction of the unprotected device).

Table 11.2 Hardware revision

**): V10, V11: prototypes only.*

***) V12: series product version. Is replaced with V13 series product version due to EOL (end-of-life) of MOSFETs. Please see "PCN_1014_08_29_TMCM-1140.pdf" on our Web-site, also*

12 References

[TMCM-1140 TMCL]	TMCM-1140 TMCL Firmware Manual
[TMC262]	TMC262 Datasheet
[TMC429]	TMC429 Datasheet
[TMCL-IDE]	TMCL-IDE User Manual

Please refer to www.trinamic.com.