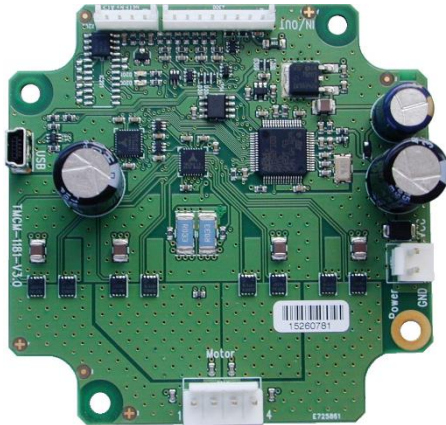


Hardware Version V3.0

# HARDWARE MANUAL

+



+

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## TMCM-1181

1-axis Stepper  
Controller / Driver  
up to 6.5 RMS / 24V DC  
USB, RS485

+

### UNIQUE FEATURES:



coolStep™

stallGuard<sup>2</sup>™

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[www.trinamic.com](http://www.trinamic.com)

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# 1 Features

The TMCM-1181 is a single axis controller/driver module for 2-phase bipolar stepper motors. It is highly integrated and can be used in many decentralized applications. The module can be mounted on the back of NEMA34 (86mm flange size) stepper motors and has been designed for coil currents up to 6.5A RMS (programmable) and 24V DC supply voltage. With its high energy efficiency from TRINAMIC's coolStep™ technology cost for power consumption is kept down. The TMCL™ firmware supports 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 (max. 1024 increments per rotation) e.g. for step-loss detection under all operating conditions and positioning supervision

### Interfaces

- inputs for stop switches (left and right) and home switch
- 2 analog inputs
- 2 general purpose outputs (open collector with freewheeling diodes)
- USB, RS485 communication interfaces

### 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.

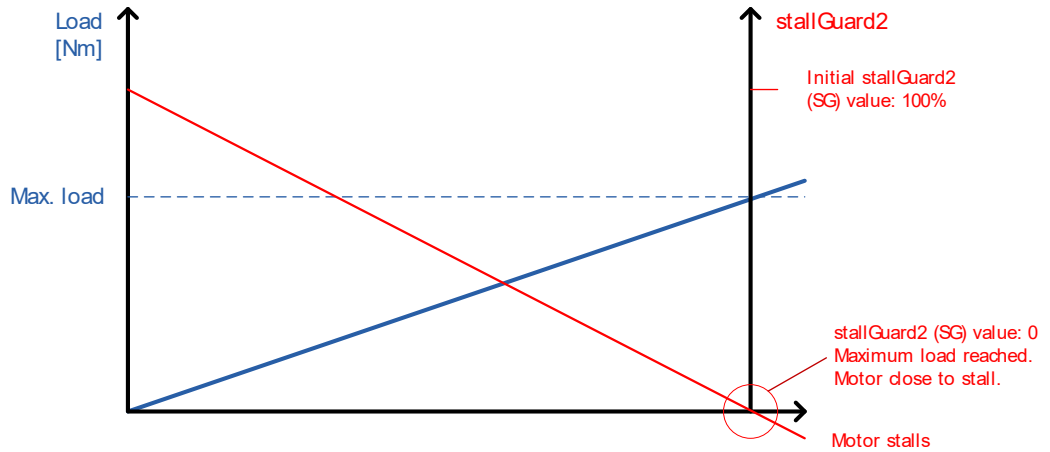
### Electrical and mechanical data

- Supply voltage: +24V DC nominal
- Motor current: up to 6.5A RMS (programmable)

*Please see separate TMCM-1181 Firmware Manual for additional information regarding firmware functionality and TMCL programming.*

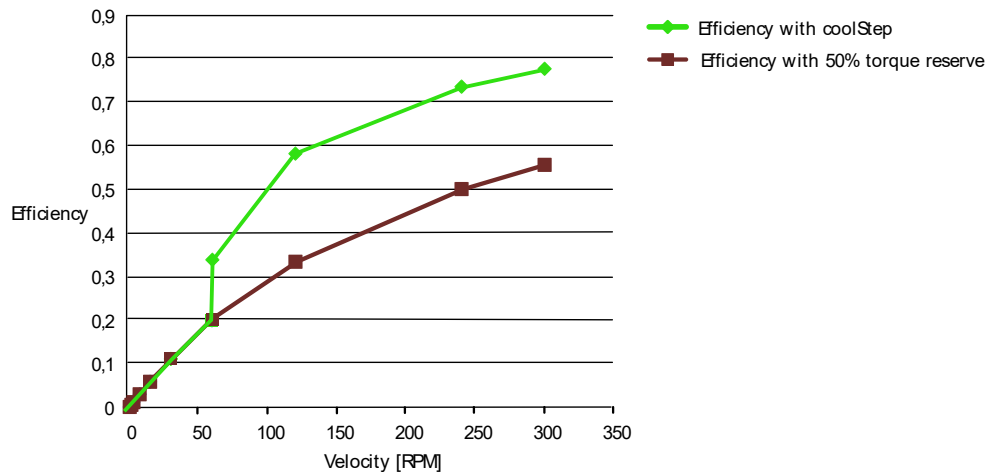
**TRINAMICS UNIQUE FEATURES – EASY TO USE WITH TMCL**

**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 (mm <sup>3</sup> ) |
|------------|--|-------------------------|
| TMCM-1181  | 1-Axis bipolar stepper motor controller / driver, up-to 6.5A RMS, 24V DC, with integrated sensOstep encoder and coolStep feature | 86 x 86 x 27            |

**Table 2.1: TMCM-1181 order codes**

A cable loom set is available for this module:

| Order code      | Description  |
|-----------------|--|
| TMCM-1181-CABLE | Cable loom for TMCM-1181 <ul style="list-style-type: none"><li>- 1x cable loom for interface connector</li><li>- 1x cable loom for In/Out connector</li><li>- 1x cable loom for motor connector</li><li>- 1x cable loom for power connector</li><li>- 1x USB type A connector to mini-USB type B connector cable</li></ul> |

**Table 2.2 Cable loom order code**

### 3 Mechanical and Electrical Interfacing

#### 3.1 TMCM-1181 Dimensions and Mounting Holes

The dimensions of the controller/driver board are approx. 86mm x 86mm x 27mm in order to fit on the back of a 86mm stepper motor. Maximum component height (height above PCB level) is around 22mm above PCB level and 3mm below PCB level. There are four mounting holes for M4 screws (4.2mm diameter) for mounting the board to a NEMA34 / 86mm stepper motor.

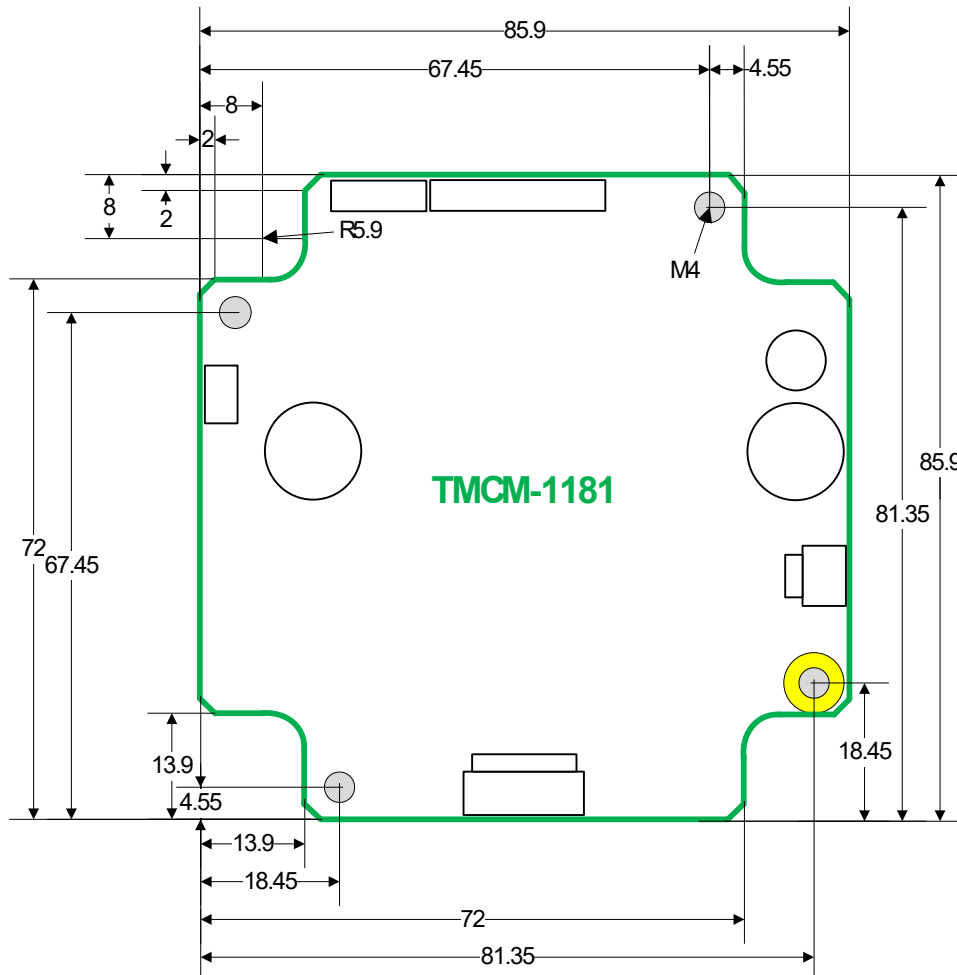


Figure 3.1: Dimensions of TMCM-1181 and position of mounting holes

#### 3.2 Board mounting considerations

The TMCM-1181 offers one metal plated mounting hole close to the power supply connector (marked yellow in figure 3.1 above). This mounting hole is connected to board supply ground. Please keep this in mind when mounting the board to the rear side of a motor. All other mounting holes are isolated.

### 3.3 Connectors of TMCM-1181

The TMCM-1181 offers five connectors including the motor connector which is used for attaching the motor coils to the electronics. There is one power connector, two connectors for serial communication (one for USB and one for RS485) and one connector for I/O signals and switches.

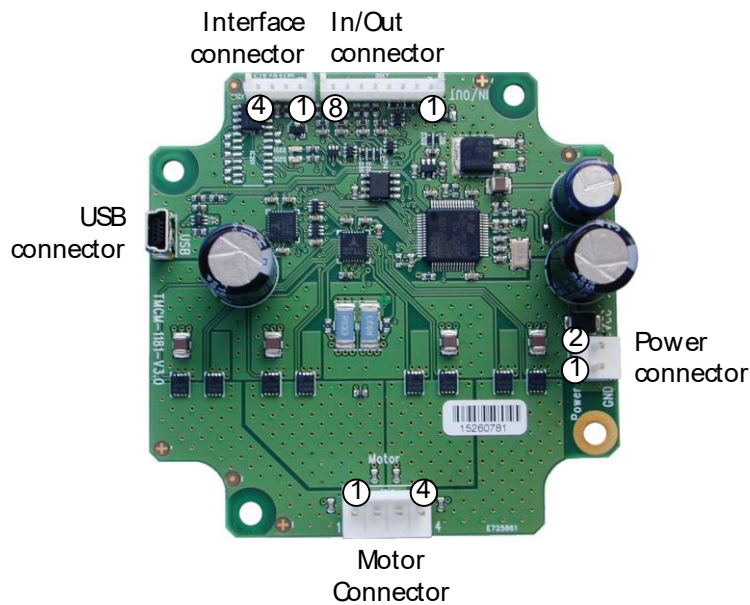


Figure 3.2 Overview connectors

| Domain    | Connector type                                       | Mating connector type   |
|-----------|--|---|
| Power     | JST B2P-VH<br>(JST VH series, 2pins, 3.96mm pitch)   | Crimp connector housing: JST VHR-2N<br>Crimp contacts: JST SVH-21T-P1.1<br>Wire: 0.83mm <sup>2</sup> , AWG 18 |
| Motor     | JST B4P-VH<br>(JST VH series, 4pins, 3.96mm pitch)   | Crimp connector housing: JST VHR-4N<br>Crimp contacts: JST SVH-21T-P1.1<br>Wire: 0.83mm <sup>2</sup> , AWG 18 |
| Interface | JST B4B-EH-A<br>(JST EH series, 4 pins, 2.5mm pitch) | Crimp connector housing: JST EHR-4<br>Crimp contacts: JST SEH-001T-P0.6<br>Wire: 0.33mm <sup>2</sup> , AWG 22 |
| In/Out    | JST B8B-EH-A<br>(JST EH series, 8 pins, 2.5mm pitch) | Crimp connector housing: JST EHR-8<br>Crimp contacts: JST SEH-001T-P0.6<br>Wire: 0.33mm <sup>2</sup> , AWG 22 |
| USB       | Mini-USB type B vertical female                      | Mini-USB type B, male   |

### 3.3.1 Power Connector

A 2pin JST VH series 3.96mm pitch connector is used for power supply.

| Pin | Label | Direction    | Description              |
|-----|-------|--------------|--------------------------|
| 1   | GND   | Power (GND)  | System and signal ground |
| 2   | VCC   | Power (+24V) | Power supply input       |

**Table 3.1** Connector for power supply

| CAUTION   |
|---|
| <p><b><i>Always keep the power supply voltage below the upper limit of 28V!</i></b><br/> <i>Otherwise the driver electronics will be seriously damaged. Especially, when the selected operating voltage is near the upper limit a regulated power supply is highly recommended.</i></p> |

#### 3.3.1.1 Power Supply

When using supply voltages near the upper limit, a regulated power supply is mandatory. The board includes around 2000 $\mu$ F / 35V of filtering capacitors. Nevertheless, especially at higher motor current settings it might be necessary to add additional filtering capacitors externally. Power supply ripple due to chopper operation of the driver should be kept at a maximum of a few 100mV.

It is important that the upper supply voltage limit is never exceeded during operation as this might seriously damage the driver stage. In this context special care has to be taken with regard to motor energy being fed back into supply voltage line when the motor works as generator. This might happen during de-acceleration or brake conditions especially when the motor is moving a larger mass (high inertia). Additional capacitors which are able to absorb energy might help here. Beyond that suppressor diodes or even brake resistors might be a solution.

##### Guidelines for power supply:

- keep power supply cables as short as possible
- use large diameters for power supply cables
- add additional filter capacitors near the motor driver unit especially if the distance to the power supply is large (i.e. more than 2-3m)

Note: there is no protection against reverse polarity integrated on the board.

### 3.3.2 Motor Connector

A 4pin JST VH series 3.96mm pitch connector is used for motor connection.

| Pin | Label | Direction | Description           |
|-----|-------|-----------|-----------------------|
| 1   | A1    | Output    | Pin 1 of motor coil A |
| 2   | A2    | Output    | Pin 2 of motor coil A |
| 3   | B1    | Output    | Pin 1 of motor coil B |
| 4   | B2    | Output    | Pin 2 of motor coil B |

**Table 3.2:** Motor connector



### 3.3.3 Interface Connector

A 4pin JST EH series 2.5mm pitch connector is used as Interface Connector.


|   | Pin | Label  | Direction      | Description  |
|---|-----|--------|----------------|--|
|  | 1   | GND    | Power (GND)    | Module ground (system and signal ground)                     |
|   | 2   | IN4    | Input          | Analog input 4, 0... 10V (analog to digital converter range) |
|   | 3   | RS485+ | Bi-directional | Differential RS485 bus signal (non-inverting)                |
|   | 4   | RS485- | Bi-directional | Differential RS485 bus signal (inverting)                    |

Table 3.3: Interface connector

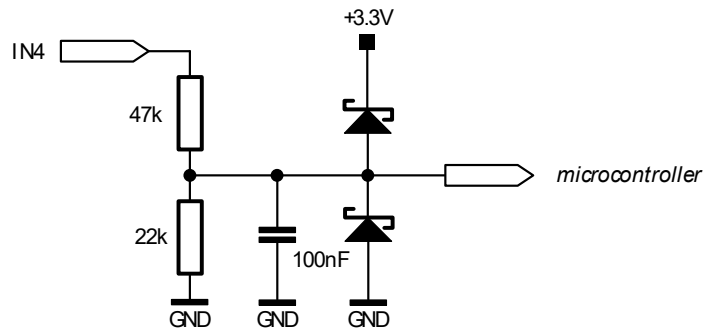


Figure 3.3 Internal circuit of analog input IN4

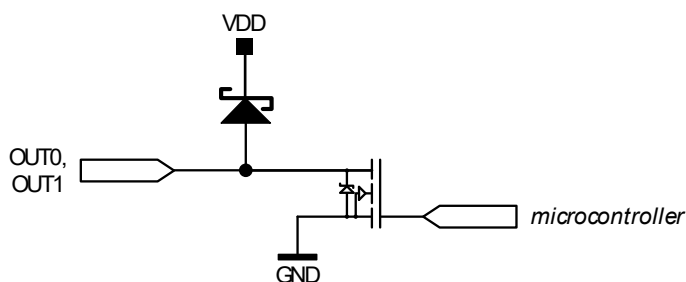
### 3.3.4 In/Out Connector

An 8pin JST EH series 2.5mm pitch connector is used as In/Out Connector.

| Pin | Label                   | Direction           | Description  |
|-----|-------------------------|---------------------|--|
| 1   | GND                     | Power (GND)         | Module ground (system and signal ground)   |
| 2   | VCC_OUT                 | Power supply output | Power supply output connected to VCC (pin 2) of power supply connector via 0.2A polyfuse. This way up-to 200mA (polyfuse protected) may be used from this pin for supply of external circuits (e.g. limit / home switches, load connected to OUT0/1 etc.)  |
| 3   | OUT0                    | Output              | General purpose output, open collector   |
| 4   | OUT1                    | Output              | General purpose output, open collector   |
| 5   | INO                     | Input               | Analog input 0, 0... 10V (analog to digital converter range)   |
| 6   | STOP_L/<br>STEP/<br>IN1 | Input               | Digital input, +24V compatible, programmable internal pull-up.*<br>Functionality can be selected in software:<br>a) Left stop switch input (connected to REF1 input of TMC429 motion controller)<br>b) Step signal (connected to step input of TMC262 stepper driver)<br>c) General purpose input 1 (connected to processor)           |
| 7   | STOP_R/<br>DIR/<br>IN2  | Input               | Digital input +24V compatible, programmable internal pull-up.*<br>Functionality can be selected in software:<br>a) Right stop switch input (connected to REF3 input of TMC429 motion controller)<br>b) Direction signal (connected to direction input of TMC262 stepper driver)<br>c) General purpose input 2 (connected to processor) |
| 8   | HOME/<br>ENABLE/<br>IN3 | Input               | Digital input +24V compatible, programmable internal pull-up.*<br>Functionality can be chosen in software:<br>a) Home switch input (connected to processor)<br>b) Enable signal (connected to processor)<br>c) General purpose input 3 (connected to processor)  |

**Table 3.4 In/Out connector**

\* It is possible to enable / disables pull-ups (1k to +5V) in software for all three digital inputs. Pull-ups are always enabled / disabled for all three together / at the same time.



**Figure 3.4 Internal circuit of OUT0 and OUT1**

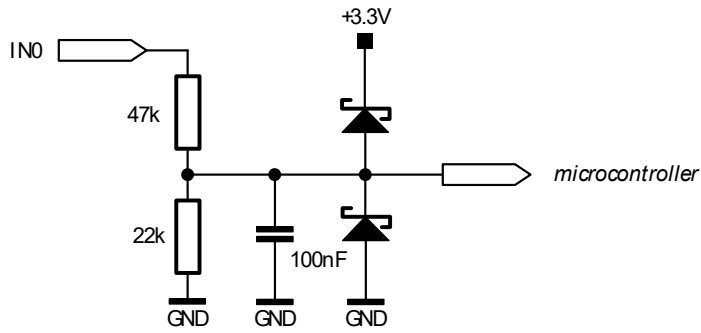


Figure 3.5 Internal circuit of analog input IN0

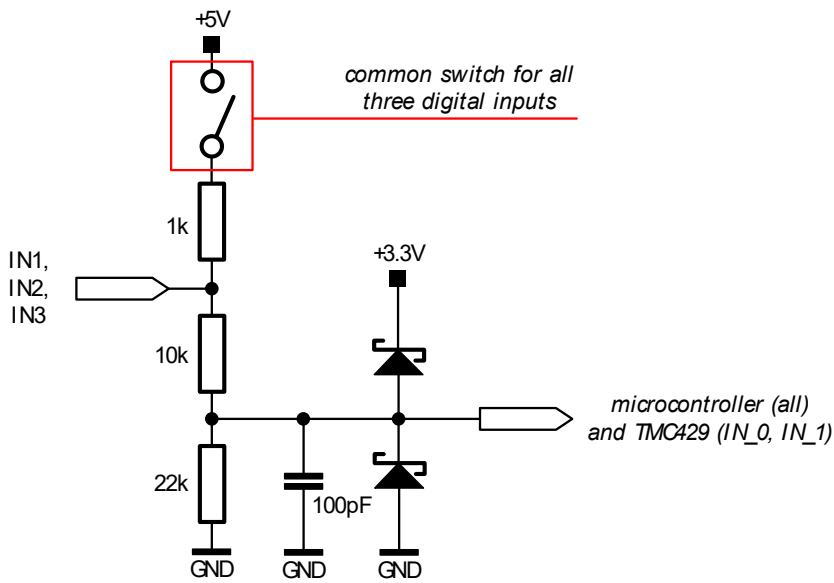


Figure 3.6 Internal circuit of digital inputs IN1, IN2 and IN3

### 3.3.5 USB Connector

| Pin | Label | Description   |
|-----|-------|---------------|
| 1   | VBUS  | +5V power     |
| 2   | D-    | Data -        |
| 3   | D+    | Data +        |
| 4   | ID    | not connected |
| 5   | GND   | ground        |

Table 3.5 Mini USB connector

## 4 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 slowly flashing 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 | Status LED (green) | This green LED flashes slowly during operation. |
| Error     | Error LED (red)    | This red LED lights up if an error occurs.      |

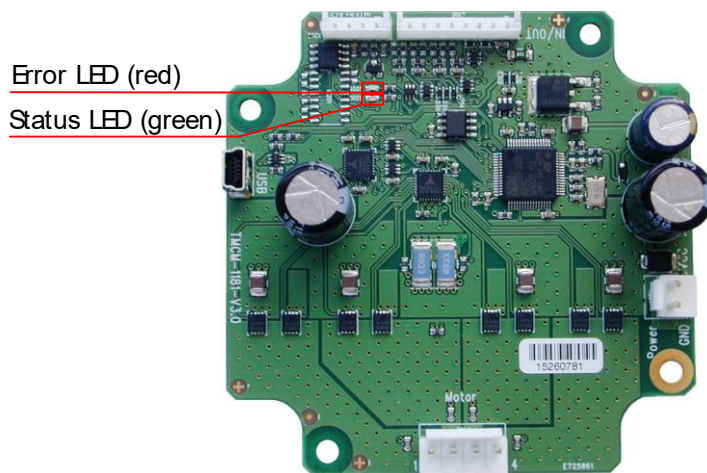


Figure 4.1 on-board LEDs

## 5 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                    | Power supply voltage for operation  | 11                | 24                   | 28                      | V DC |
| V <sub>USB</sub>       | Power supply via USB connector  |                   | 5                    |                         | V    |
| I <sub>USB</sub>       | Current withdrawn from USB supply when USB bus powered (no other supply connected)        |                   | 40                   |                         | mA   |
| I <sub>COIL_peak</sub> | Motor coil current for sine wave <b>peak</b> (chopper regulated, adjustable via software) | 0                 |                      | 9.2                     | A    |
| I <sub>COIL_RMS</sub>  | Continuous motor current ( <b>RMS</b> )   | 0                 |                      | 6.5                     | A    |
| I <sub>SUPPLY</sub>    | Power supply current  |                   | << I <sub>COIL</sub> | 1.4 * I <sub>COIL</sub> | A    |
| T <sub>ENV</sub>       | Environment temperature at rated current (no forced cooling required)                     | -30 <sup>*)</sup> |                      | +60                     | °C   |

**Table 5.1 General operational ratings of the module**

<sup>\*)</sup> limited by test equipment. Includes power-up / cold start at this temperature. It can be expected that the module will work down to -40°C.

| Symbol                       | Parameter   | Min | Typ | Max | Unit |
|------------------------------|---|-----|-----|-----|------|
| V <sub>STOP_L/R_HOME</sub>   | Input voltage for stop / home switch inputs STOP_L / STOP_R and HOME (also valid when configured for alternate function)      | 0   |     | 28  | V    |
| V <sub>STOP_L/R_HOME_L</sub> | Low level voltage for stop / home switch inputs STOP_L / STOP_R and HOME (also valid when configured for alternate function)  | 0   |     | 1.1 | V    |
| V <sub>STOP_L/R_HOME_H</sub> | High level voltage for stop / home switch inputs STOP_L / STOP_R and HOME (also valid when configured for alternate function) | 2.9 |     | 28  | V    |
| V <sub>OUT_0/1</sub>         | Voltage at open collector output OUT_0 / OUT_1  | 0   |     | VCC | V    |
| I <sub>OUT_0/1</sub>         | Output sink current for OUT_0 / OUT_1   |     |     | 100 | mA   |
| V <sub>IN_0</sub>            | Full scale input voltage range for analog input IN_0  | 0   |     | 10  | V    |

**Table 5.2 Operational ratings of general purpose I/Os**

| Symbol             | Parameter   | Min | Typ | Max | Unit |
|--------------------|---|-----|-----|-----|------|
| N <sub>RS485</sub> | Number of nodes connected to single RS485 network |     |     | 256 |      |

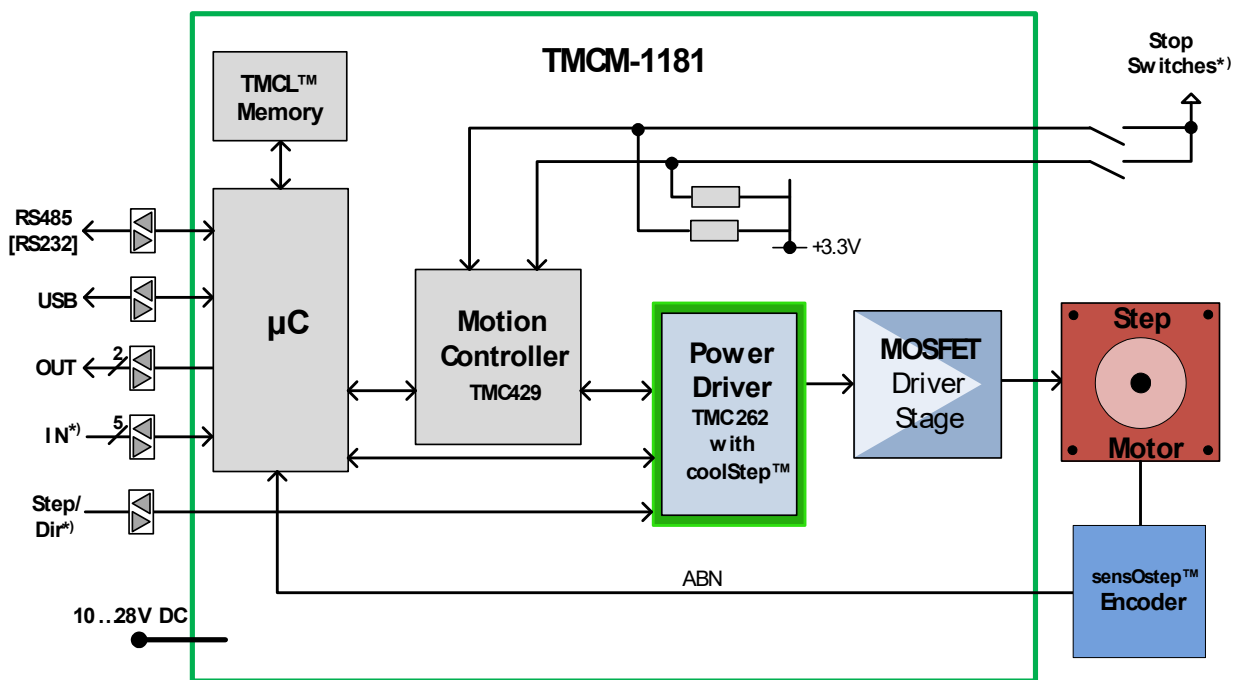
**Table 5.3 Operational ratings of the RS485 interface**

## 6 Functional Description

The TMCM-1181 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 6.1 the main parts of the TMCM-1181 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 its energy efficient coolStep feature,
- the MOSFET driver stage, and
- the sensOstep encoder with resolutions of 10bit (1024 steps) per revolution.



- \*) The module offers two analog and three digital inputs.  
Functionality of the three digital inputs can be selected in software:
- a) STOP\_L / STOP\_R / HOME
  - b) STEP/DIR interface
  - c) 3 general purpose inputs IN1 / IN2 / IN3

**Figure 6.1 Main parts of the TMCM-1181**

The PC based software development environment TMCL-IDE for the Trinamic Motion Control Language (TMCM) can be downloaded free of charge from the TRINAMIC website ([www.trinamic.com](http://www.trinamic.com)). 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-1181 Firmware Manual for more information about TMCL commands.

## 7 TMC429-1181 Operational Description

### 7.1 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 <sub>CLK</sub> | clock-frequency  | 16 MHz   |
| velocity         | -  | 0... 2047  |
| a <sub>max</sub> | maximum acceleration   | 0... 2047  |
| pulse_div        | divider for the velocity. The higher the value is, the less is the maximum velocity<br>default value = 0         | 0... 13  |
| ramp_div         | divider for the acceleration. The higher the value is, the less is the maximum acceleration<br>default value = 0 | 0... 13  |
| Usrs             | microstep-resolution (microsteps per fullstep = 2 <sup>usrs</sup> )  | 0... 8 (a value of 7 or 8 is internally mapped to 6 by the TMC429) |

**Table 7.1 TMC429 velocity parameters**

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

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

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

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

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

$$a = \frac{f_{\text{CLK}}^2 \cdot a_{\text{max}}}{2^{\text{pulse\_div} + \text{ramp\_div} + 29}}$$

This results in acceleration in fullsteps of:

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

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.

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

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



## 8 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.

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## 9 Revision History

### 9.1 Document Revision

| Version | Date        | Author | Description     |
|---------|-------------|--------|-----------------|
| 0.90    | 2015-JUL-10 | GE     | Initial version |

Table 9.1 Document revision

### 9.2 Hardware Revision

| Version         | Date        | Description   |
|-----------------|-------------|---------------|
| TMC262-1181_V30 | 2013-MAY-13 | First version |

Table 9.2 Hardware revision

## 10 References

|               |                                  |
|---------------|----------------------------------|
| [TMC262-1181] | TMC262-1181 TMCL Firmware Manual |
| [TMC262]      | TMC262 Datasheet                 |
| [TMC429]      | TMC429 Datasheet                 |
| [TMCL-IDE]    | TMCL-IDE User Manual             |

Please refer to [www.trinamic.com](http://www.trinamic.com).