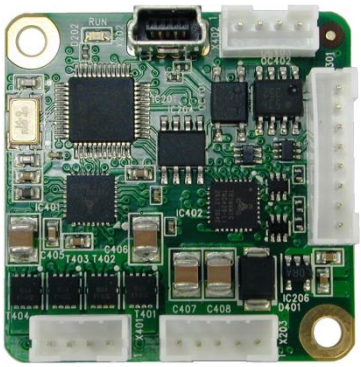
Hardware Version V1.3

HARDWARE MANUAL



TMCM-1141

1-Axis Stepper
Controller / Driver
24 V DC
up-to 1.1 A / 2A RMS
USB, RS485, and S/D Interface

UNIQUE FEATURES

coolStep™

stallGuard2™

TRINAMIC Motion Control GmbH & Co. KG
Hamburg, Germany

www.trinamic.com

TRINAMIC
MOTION CONTROL

Table of Contents

1 Features ... 3
2 Order Codes ... 5
3 Mechanical and Electrical Interfacing ... 6
3.1 Dimensions and Mounting Holes ... 6
3.2 Connectors of TMCM-1141 ... 7
3.2.1 Power and RS485 Connector ... 8
3.2.2 Mini-USB Connector ... 10
3.2.3 Multipurpose I/O Connector ... 11
3.2.4 Step/Direction Connector ... 15
3.2.5 Motor Connector ... 16
4 Motor driver current ... 17
5 Reset to Factory Defaults ... 20
6 On-Board LED ... 20
7 Operational Ratings ... 21
8 Functional Description ... 23
9 TMCM-1141 Operational Description ... 24
9.1 Calculation: Velocity and Acceleration vs. Microstep and Fullstep Frequency ... 24
10 Life Support Policy ... 26
11 Revision History ... 27
11.1 Document Revision ... 27
11.2 Hardware Revision ... 27
12 References ... 28

1 Features

The TMCM-1141 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 1.1 A RMS RMS (low current range, programmable) or 2A RMS (high current range, programmable, new additional range since hardware version 1.3) 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 remote control (direct mode) and standalone operation (with TMCL program being executed on the TMCM-1141 itself).

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

Interfaces

- RS485 2-wire communication interface
- USB full speed (12Mbit/s) device interface
- Step/Direction/Enable interface (optically isolated) for external control of driver circuit
- 4 multipurpose inputs:
  - 3x general-purpose digital inputs
    (Alternate functions: STOP_L / STOP_R / HOME switch inputs)
  - 1x dedicated analog input
- 2 general purpose outputs
  - 2x open-drain 100 mA max.

Software

- TMCL: standalone operation or remote controlled operation,
  program memory (non volatile) for up to 1024 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 1.1 A RMS / 1.6 A peak (low current range, programmable) or 2A RMS / 2.8A peak (high current range, programmable, new additional range since hardware version 1.3)

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.

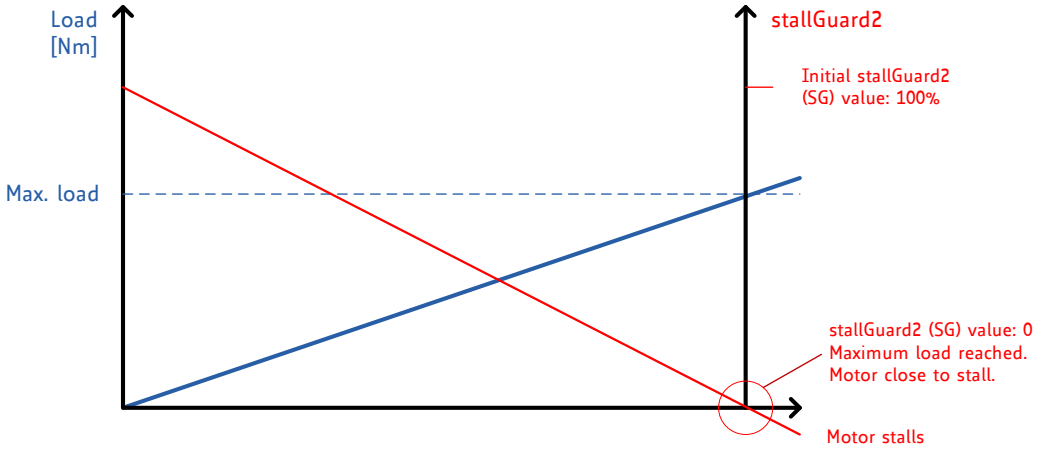


Figure 1.1 stallGuard2 load measurement SG as a function of load

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.

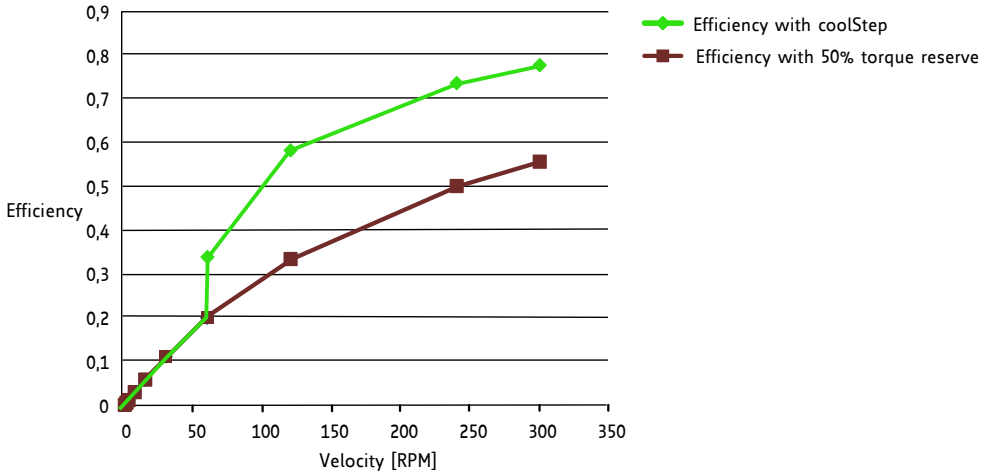


Figure 1.2 Energy efficiency example with coolStep

2 Order Codes

Order code	Description	Size (mm^3)
TMCM-1141-*option*	Single axis bipolar stepper motor controller / driver electronics with 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-1141-*TMCL*

Table 2.2 Firmware options

A cable loom set is available for this module:

Order code	Description
TMCM-1141-CABLE	Cable loom for TMCM-1141: - 1x cable loom for power and RS485 connector (length 200mm) 1x cable loom for multi-purpose I/O connector (length 200mm) - 1x cable loom for S/D connector (length 200mm) - 1x cable loom 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-1141 is available with NEMA17 stepper motors, too. Refer to the PD-1141 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.

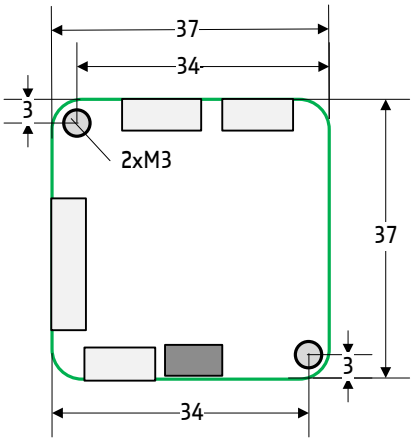


Figure 3.1 Dimensions of TMCM-1141 and position of mounting holes

3.2 Connectors of TMCM-1141

The TMCM-1141 controller/driver board offers five connectors including the motor connector which is used for attaching the motor coils to the electronics. Further, there is a connector for power and for the RS485 interface. The USB interface and the step/direction interface have their own connectors. The 8pin multipurpose I/O connector offers four multipurpose inputs and two general purpose outputs.

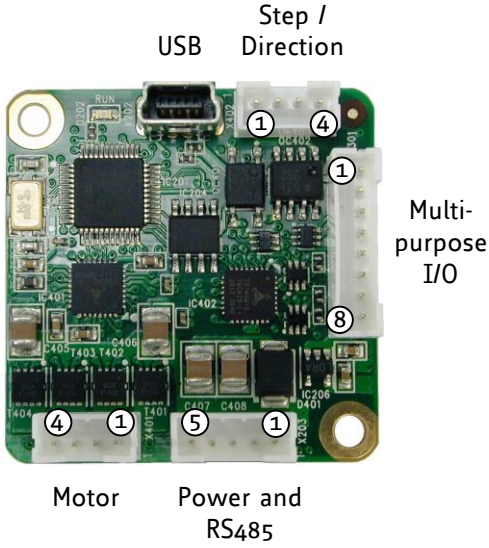


Figure 3.2 Overview connectors

Label	Connector type	Mating connector type
Power and RS485 Connector	CI0105P1VK0-LF CVIlux CI01 series, 5 pins, 2mm pitch	Connector housing CVIlux: CI01055000-A Contacts CVIlux: CI01T011PE0-A *or* Connector housing JST: PHR-5 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm²
Multi-purpose 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
Step/Direction 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
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

3.2.1 Power and RS485 Connector

A 5pin single row connector is used for power supply and RS485 serial communication.



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

Table 3.2 Connector for power supply and RS485

3.2.1.1 Power Supply

For proper operation care has to be taken with regard to power supply concept and design. Due to space restrictions the TMCM-1141 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 24V 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. 1000µF/35V) to the power supply lines next to the TMCM-1141 especially if the distance to the power supply is large (i.e. more than 2-3m)! In larger systems a zener diode circuitry might be required in order to limit the maximum voltage when the motor is operated at high velocities.

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.



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.

3.2.1.2 RS485

For remote control and communication with a host system the TMCM-1141 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.

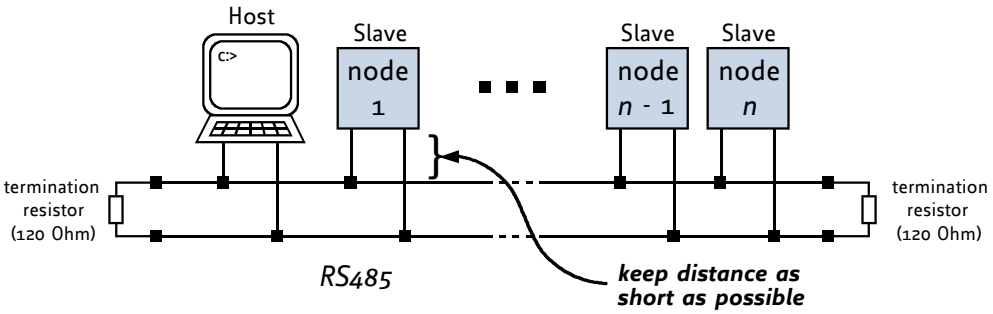


Figure 3.3: Bus structure

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-1141 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-1141 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-1141 is 115200 bit/s for hardware version 1.2 and 1Mbit/s for hardware version 1.3. Factory default is 9600 bit/s. *Please see separate TMCM-1141 TMCL firmware manual for information regarding other possible communication speeds.*

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):

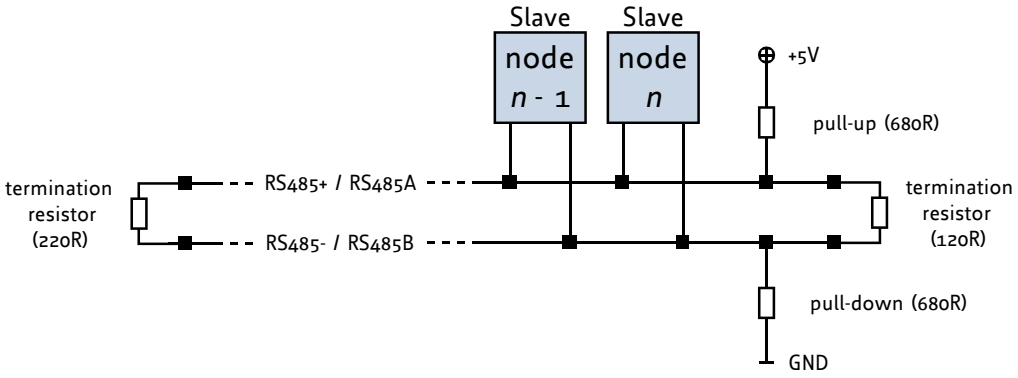


Figure 3.4: Bus lines with resistor (Bias) network on one side, only

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

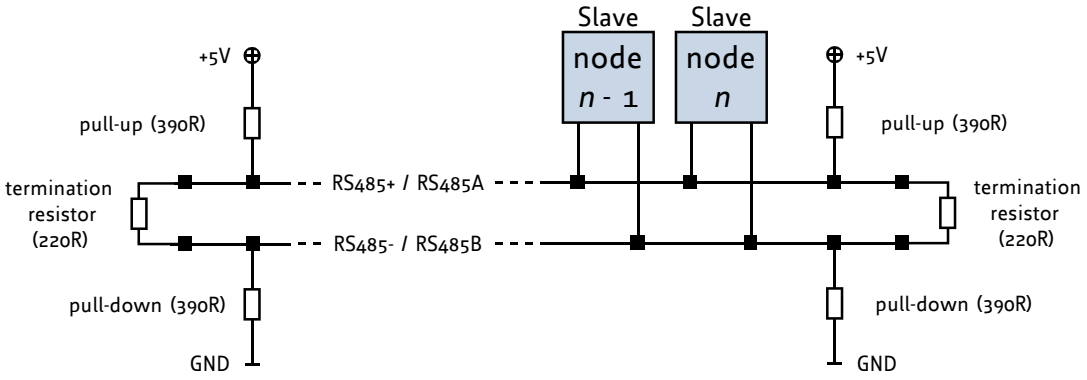


Figure 3.5: Bus lines with resistor (Bias) network at both ends

3.2.2 Mini-USB Connector

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



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 3.3 Connector for USB

For remote control and communication with a host system the TMCM-1141 provides a USB 2.0 full-speed (12Mbit/s) device 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-1141 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).

During USB bus powered operation the on-board digital core logic will be powered, only. The digital core logic consists of 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 during USB bus powered operation! Apply power to the power connector (USB self powered operation) in order to be able to move the motor.

3.2.3 Multipurpose I/O Connector

An 8pin 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 RS485 connector
3	OUT_0	Output	Open-drain output (max. 100 mA) Integrated freewheeling diode to VDD
4	OUT_1	Output	Open-drain output (max. 100 mA) Integrated freewheeling diode to VDD
5	IN_0	Input	Dedicated analog input, Input voltage range: 0… +10V Resolution: 12bit (0… 4095)
6	IN_1	Input	General purpose digital input (+24 V compatible)
			Alternate function: left stop switch input
7	IN_2	Input	General purpose digital input (+24 V compatible)
			Alternate function: right stop switch input
8	IN_3	Input	General purpose digital input (+24 V compatible)
			Alternate function: home switch input

Table 3.4 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 1k pull-up resistor to +5V can be activated. In this case 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).

3.2.3.1 Digital Inputs IN_1, IN_2, IN_3

The eight pin connector of the TMCM-1141 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).*

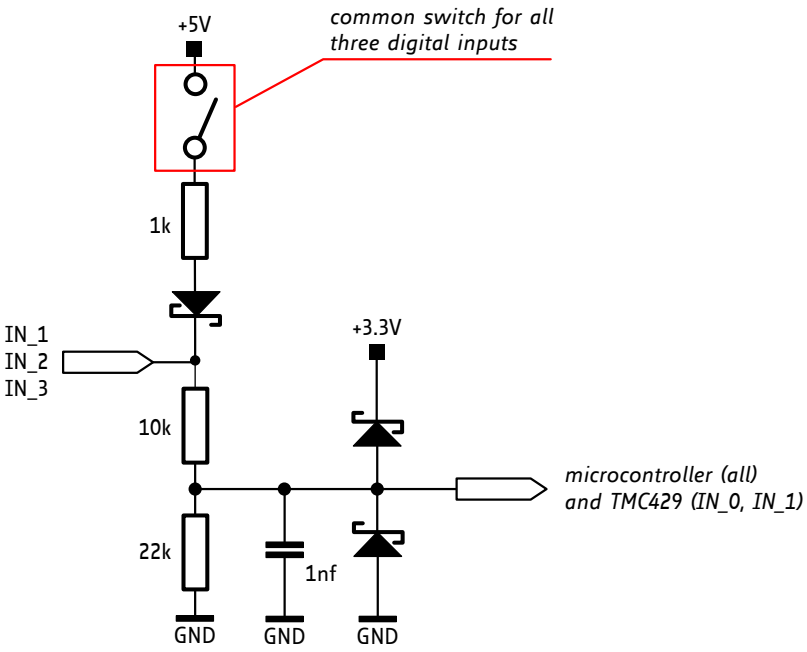


Figure 3.6 General purpose inputs (simplified input circuit)

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

Label (pin)	Default function	Alternate function 1
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*
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*
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*

Table 3.5 Multipurpose inputs / alternate functions

- All three digital inputs are connected to the on-board processor and can be used as general purpose digital inputs.
- 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.

3.2.3.2 Analog Input IN_0

The eight pin connector of the TMCM-1141 provides one dedicated analog input IN_0.

This dedicated analog input offers a full scale input range of 0... +10V (0..+10.56V nom.) with a resolution of the internal analog-to-digital converter of the microcontroller of 12 bit (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).

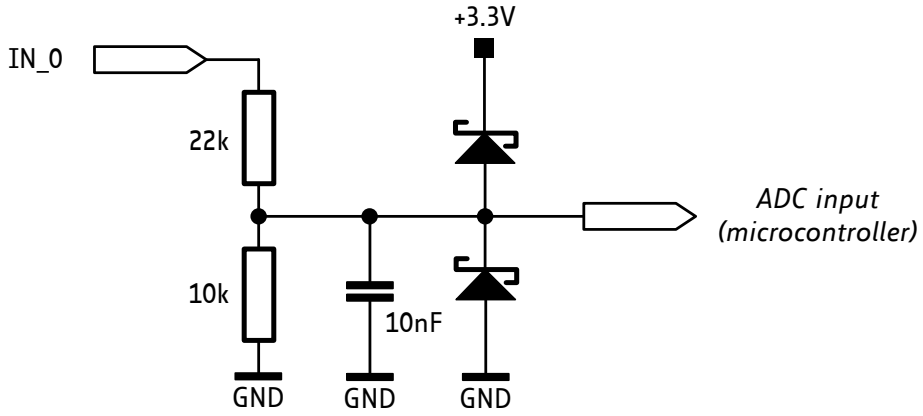


Figure 3.7 General purpose inputs (simplified input circuit)

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).

3.2.3.3 Outputs OUT_0, OUT_1

The eight pin connector of the TMCM-1141 offers two general purpose outputs OUT_0 and OUT_1. These two outputs are open-drain outputs and can sink up to 100 mA each. The outputs of the N-channel MOSFET transistors are connected to freewheeling diodes each for protection against voltage spikes especially from inductive loads (relais etc.) above supply voltage (see figure below).

OUT_0 and OUT_1 should not be connected to any voltage above supply voltage of the module due to the internal freewheeling diodes.

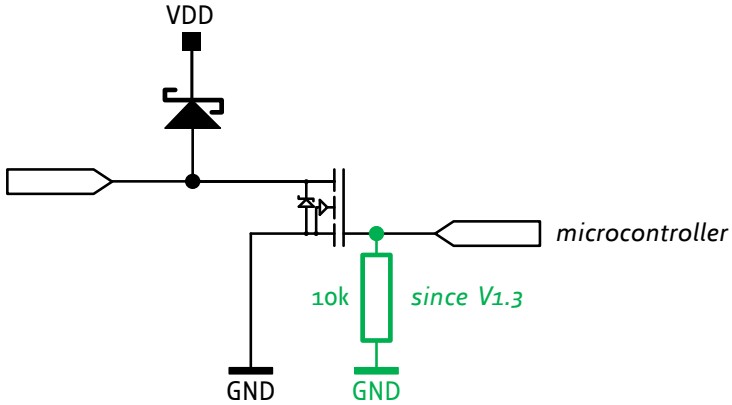


Figure 3.8 General purpose outputs

Since hardware version 1.3 the gate inputs of the MOSFETs are pulled-low during power-up and while the processor is still in reset / output pins not initialized. This way, the outputs will not briefly switch on at power-up.

*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**. Quite similar OUT_1 can be switched **on** (OUT_1 pulled low) using command SIO 1, 2, **1** and off again (OUT_1 floating) using command SIO 1, 2, **0**. Factory default setting for both outputs is off (floating). In case a floating output is not desired in the application an external resistor to e.g. supply voltage may be added.*

3.2.4 Step/Direction Connector

A 4pin 2mm pitch single row connector is available for the Step/Dir interface. This interface can be used for connecting an external motion controller to the on-board driver stage instead of the integrated motion controller.

All three Step/Dir/Enable signals are optically isolated. Therefore, an additional supply input (COMMON) is available which has to be connected to a supply voltage between +5 V and +24 V for proper operation.



Pin	Label	Direction	Description
1	COMMON	Power (Supply input)	Power supply input for the three Step / Direction / Enable signals. Accepts voltages between +5V and +24V nom.
2	/ENABLE	Input	Enable input (function depends on firmware)
3	STEP	Input	Step pulse input (connected to step input of TMC262 driver IC)
4	DIRECTION	Input	Direction input (connected to direction input of TMC262 driver IC)

Table 3.6: Step/Direction connector

3.2.4.1 Step / Direction / Enable inputs

The inputs Step / Direction / Enable are electrically (optically) isolated from the power supply and all other signals of the TMCM-1141 module. These inputs have one common reference input COMMON (see Figure 3.). The COMMON input should be connected to a positive supply voltage between +5V and +24V. Step / Direction / Enable signals might be driven either by open-collector / open-drain outputs or by push-pull outputs. In case of push-pull outputs the COMMON supply voltage should be equal / similar to the high signal voltage level of the push-pull drivers (otherwise the LEDs will not be turned off during signal high-level). There is no need to add external resistors in line with the "Enable", "Step" or "Direction" inputs. The internal current sources (Figure 3.8) will adjust the current through the LEDs of the optical isolation to approx. 8mA for signal input voltages between nom. +5V and +24V.

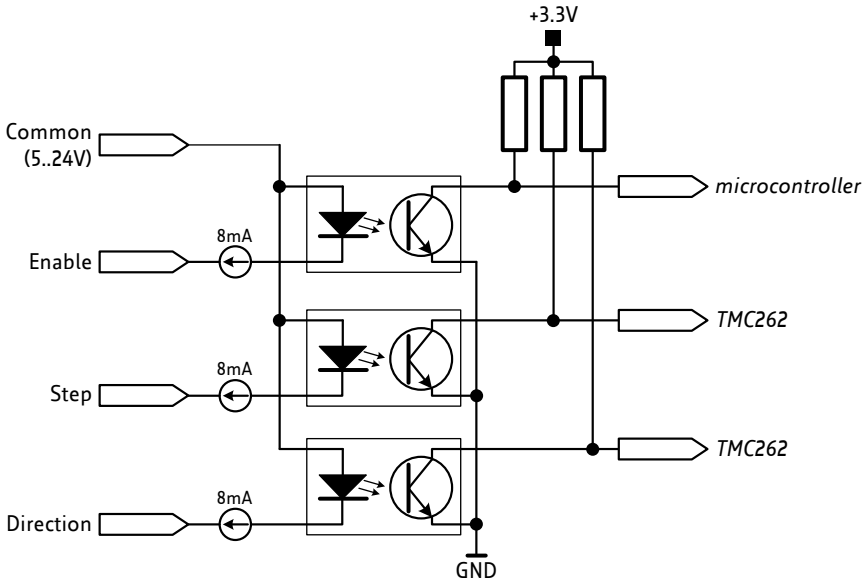


Figure 3.9 Step/Dir/Enable inputs

3.2.5 Motor Connector

As motor connector a 4pin 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 3.7 Motor connector



Do not connect or disconnect motor during operation!

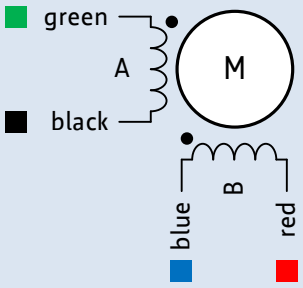
Motor cable and motor inductivity might lead to voltage spikes when the motor is disconnected / connected while energized. These voltage spikes might exceed voltage limits of the driver MOSFETs and might permanently damage them. Therefore, always disconnect power supply before connecting / disconnecting the motor.



For hardware version 1.3: please note the additional high current range for motor currents up-to 2A RMS!

Setting motor current too high might lead to excessive power dissipation inside the motor, overheating and even permanent damage of the motor. Therefore, make sure the motor current is properly set. Also with hardware version 1.3 the low current range is set as default.

TMCM-1141	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



4 Motor driver current

The on-board stepper motor driver operates current controlled. The driver current may be programmed in software in two ranges (low current range up-to 1.1A RMS and high current range up-to 2A RMS) with 32 effective scaling steps in hardware for each range.

Please note: the high current range is available with hardware revision V1.3, only and should not be activated / used with hardware revision V1.2! The high current range should not be used with motor currents above 2A RMS – this will violate specification of the module - please note limitations at the end of this chapter!

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-1141 firmware manual for further information)

Range setting in software (TMCL)

This is the value for TMCL axis parameter 179 (Vsense). This value defines the current range. This value can be set using the following TMCL command:

```
SAP 179, 0, <value> // = 0 high current range
                    // = 1 low current range
```

For `<value>` either 0 (high current range) or 1 (low current range) is supported (see table) since hardware revision V1.3. For hardware revision V1.2 this parameter should not be changed to any value other than "1" (low current range).
(read-out value with `GAP` instead of `SAP`. Please see separate TMCM-1141 firmware manual for further information)

Motor current I_{RMS} [A]

Resulting motor current based on range and motor current setting

Motor current setting in software (TMCL)	Range setting in software (TMCL)	Current scaling step (CS)	Motor current $I_{COIL\ PEAK}$ [A]	Motor current $I_{COIL\ RMS}$ [A]
0..7	1	0	0.052	0.036
8..15	1	1	0.103	0.073
16..23	1	2	0.155	0.109
24..31	1	3	0.206	0.146
32..39	1	4	0.258	0.182
40..47	1	5	0.309	0.219
48..55	1	6	0.361	0.255
56..63	1	7	0.413	0.292
64..71	1	8	0.464	0.328
72..79	1	9	0.516	0.365
80..87	1	10	0.567	0.401

Motor current setting in software (TMCL)	Range setting in software (TMCL)	Current scaling step (CS)	Motor current $I_{COIL\ PEAK}$ [A]	Motor current $I_{COIL\ RMS}$ [A]
88..95	1	11	0.619	0.438
96..103	1	12	0.670	0.474
104..111	1	13	0.722	0.510
112..119	1	14	0.773	0.547
120..127	1	15	0.825	0.583
128..135	1	16	0.877	0.620
136..143	1	17	0.928	0.656
144..151	1	18	0.980	0.693
152..159	1	19	1.031	0.729
160..167	1	20	1.083	0.766
168..175	1	21	1.134	0.802
176..183	1	22	1.186	0.839
184..191	1	23	1.238	0.875
192..199	1	24	1.289	0.912
200..207	1	25	1.341	0.948
208..215	1	26	1.392	0.984
216..223	1	27	1.444	1.021
224..231	1	28	1.495	1.057
232..239	1	29	1.547	1.094
240..247	1	30	1.598	1.130
248..255	1	31	1.650	1.167
0..7	0	0	0.095	0.067
8..15	0	1	0.191	0,135
16..23	0	2	0.286	0.202
24..31	0	3	0.381	0.270
32..39	0	4	0.477	0.337
40..47	0	5	0.572	0.404
48..55	0	6	0.667	0.472
56..63	0	7	0.763	0.539
64..71	0	8	0.858	0.607
72..79	0	9	0.953	0.674
80..87	0	10	1.048	0.741
88..95	0	11	1.144	0.809
96..103	0	12	1.239	0.876
104..111	0	13	1.334	0.944
112..119	0	14	1.430	1.011
120..127	0	15	1.525	1.078
128..135	0	16	1.620	1.146
136..143	0	17	1.716	1.213
144..151	0	18	1.811	1.281
152..159	0	19	1.906	1.348
160..167	0	20	2.002	1.415
168..175	0	21	2.097	1.483
176..183	0	22	2.192	1.550
184..191	0	23	2.288	1.618
192..199	0	24	2.383	1.685
200..207	0	25	2.478	1.752
208..215	0	26	2.573	1.820
216..223	0	27	2.669	1.887
224..231	0	28	2.764	1.954
232..239	0	29	2.859	2.022
240..247	0	30	2.955	2.089
248..255	0	31	3.050	2.157

The settings marked red in the table above from the high current range (above 2A RMS motor current) should not be used as they will violate specification of the module!

In addition to the settings in the table the motor current may be switched off completely (free-wheeling) using axis parameter 204 (see TMCM-1141 firmware manual).

5 Reset to Factory Defaults

It is possible to reset the TMCM-1141 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.
Now, 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

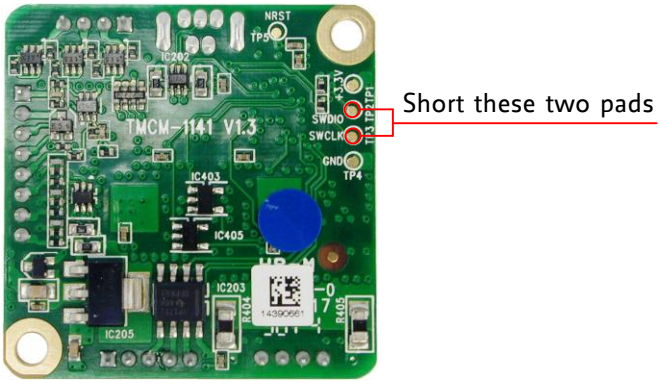


Figure 5.1 Reset to factory default settings

6 On-Board LED

The board offers an LED in order to indicate board status. The function of the LED is dependent on the firmware version. With standard TMCL firmware the green LED should be flashing slowly during operation. When there is no valid firmware programmed into the board or during firmware update the green LED is permanently on.

BEHAVIOR OF LEDS WITH STANDARD TMCL FIRMWARE

Status	Label	Description
Heartbeat	Run	This green LED flashes slowly during operation.

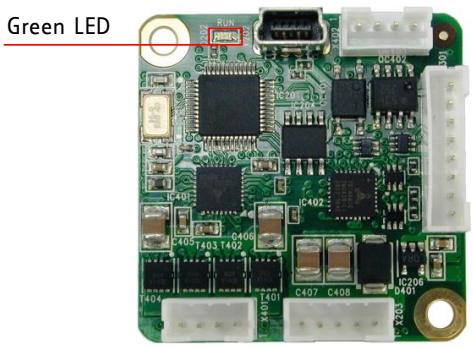


Figure 6.1 On-board LED

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!

GENERAL OPERATIONAL RATINGS

Symbol	Parameter	Min	Typ	Max	Unit
VDD	Power supply voltage for operation	9	12… 24	28	V
$I_{COIL_PEAK_L}$	Motor coil current for sine wave **peak** (**low range** setting, chopper regulated, adjustable via software)	0		1.6	A
$I_{COIL_RMS_L}$	Continuous motor current (**RMS**) (**low current range** setting, chopper regulated, adjustable via software)	0		1.1	A
$I_{COIL_PEAK_H}$*)	Motor coil current for sine wave **peak** (**high current range** setting, chopper regulated, adjustable via software)	0		2.8*)	A
$I_{COIL_RMS_H}$*)	Continuous motor current (**RMS**) (**high current range** setting, chopper regulated, adjustable via software)	0		2*)	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		+40	°C

Table 7.1 General operational ratings of module

) High current range available as new additional range with hardware revision V1.3 – **not with hardware revision V1.2. Please note: motor coil currents above 2A RMS are not recommended and will violate specification of the module.*

OPERATIONAL RATINGS OF MULTIPURPOSE I/OS

Symbol	Parameter	Min	Typ	Max	Unit
$V_{OUT_0/1}$	Voltage at open drain output	0		+VDD	V
$I_{OUT_0/1}$	Output sink current of open drain output			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		1.2	V
$V_{IN_H\ 1/2/3}$	High level voltage for IN_1, IN_2 and IN_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*

8 Functional Description

The TMCM-1141 is a highly integrated mechatronic device 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. Nominal supply voltage of the unit is 24V DC. The PANdrive is designed for both: direct mode and standalone operation. 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-1141 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, and
- the MOSFET driver stage

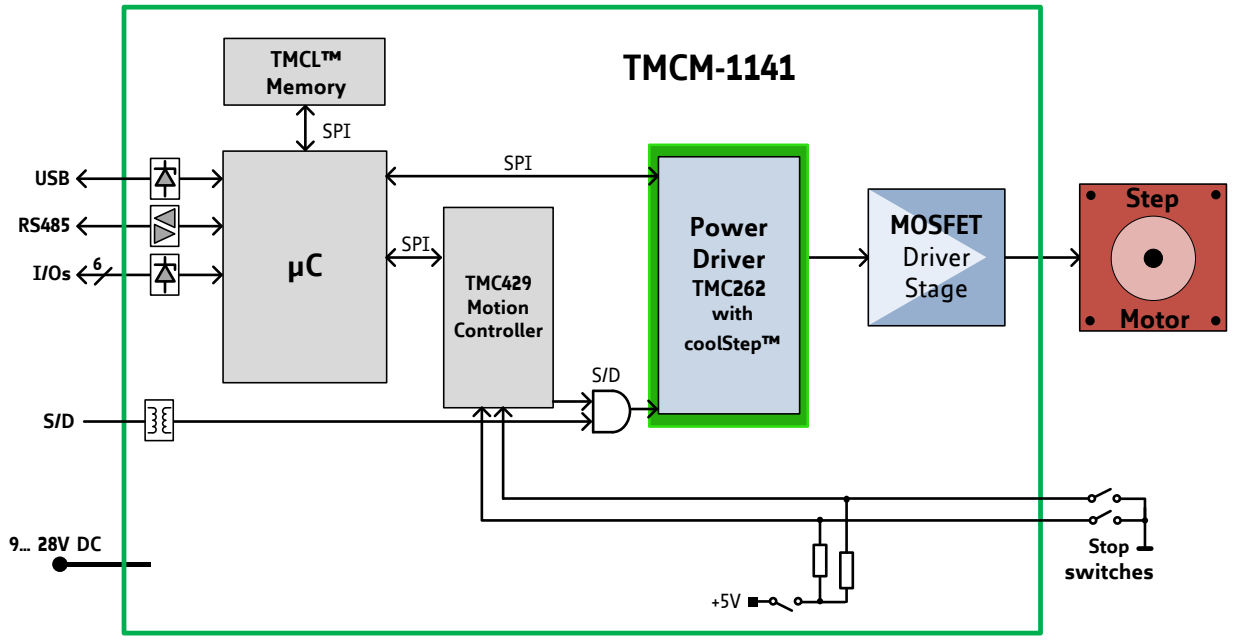


Figure 8.1 Main parts of the TMCM-1141

Remark: stop switches are an alternate function of two out of three digital inputs.

The TMCM-1141 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-1141 Firmware Manual for more information about TMCL commands.

9 TMCM-1141 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 (a value of 7 or 8 is internally mapped to 6 by the TMC429)

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

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.

© TRINAMIC Motion Control GmbH & Co. KG 2013, 2014

Information given in this data sheet is believed to be accurate and reliable. However neither responsibility is assumed for the consequences of its use nor for any infringement of patents or other rights of third parties, which may result from its use.

Specifications are subject to change without notice.

All trademarks used are property of their respective owners.



11 Revision History

11.1 Document Revision

Version	Date	Author	Description
0.90	2011-DEC-19	GE	Initial version
0.91	2011-DEC-23	GE	Connector pin assignment corrected
1.00	2012-JUN-12	SD	First complete version including the following chapters: - Reset to factory defaults, - LEDs
1.01	2012-JUL-23	SD	Information about sensOstep deleted.
1.02	2012-JUL-27	SD	Figure 3.5 (general purpose inputs) corrected.
1.03	2013-MAR-05	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
1.04	2013-JUL-23	SD	- Connector description updated - Information about power supply updated
1.05	2014-OCT-18	GE	Hardware revision 1.3 added.
1.06	2015-JAN-09	GE	- Minor addition / corrections. - TMCL commands for accessing I/Os added.

Table 11.1 Document revision

11.2 Hardware Revision

Version	Date	Description
TMCM-1041_V10*)	2011-MAR-03	Initial version
TMCM-1141_V10*)	2011-AUG-12	- Clock generation and distribution changed, 16Mhz crystal instead of 8MHz, TMC429 and TMC262 running from 16Mhz clock signal from processor - Resistor dividers at inputs changed, more compact and optimized input protection circuit - Support of USB powered operation
TMCM-1141_V11*)	2011-NOV-23	- Optimization and cost reduction for board assembly after feedback from assembly house (version 1.1 is 100% firmware compatible with V1.0)
TMCM-1141_V12**)	2011-DEC-12	- Mounting holes connected to GND
TMCM-1141_V13**)	2013-JUL-30	- 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 (incl. scaling) and output waveform are essentially the same. Nevertheless, with the new V13 hardware extended motor current settings up-to 2A RMS are supported, also. Switching between these two ranges is possible using TMCL axis parameter 179. The factory default value for this parameter is '1' (SAP 179, 0, 1) for motor currents up-to 1.1A RMS. Setting this parameter to

		zero will enable the second current range. Setting the max. motor current scaling factor to 232 (TMCL command SAP 6, 0, 232) will then increase motor driver output current to 2A RMS during movements. *Please note: changing motor current will happen immediately – therefore it is recommended to first set the current scaling value (SAP 6, 0, 232 resp. SAP 7, 0, 232) and then switch the range (SAP 179, 0, 0). Settings above 232 up-to 255 are not recommended as they might violate component specifications.* - 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). - General purpose outputs OUT0 / OUT1: the driver circuit of the open-drain output MOSFETs has been modified in order to ensure glitch-free power-up. That is, output MOSFETs will not turn briefly on while processor still in reset / processor outputs not initialized. - External S/D input. The circuit for the external STEP / DIR input has been optimized for higher step frequencies. Step frequencies above 1MHz are supported under optimum conditions.

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 the driver MOSFETs. Please see "PCN_1013_12_27_TMCM-1141.pdf" on our Web-site, also*

12 References

[TMCM-1141 TMCL]	TMCM-1141 TMCL Firmware Manual
[TMC262]	TMC262 Datasheet
[TMC429]	TMC429 Datasheet
[TMCL-IDE]	TMCL-IDE User Manual
[QSH4218]	QSH4218 Manual

Please refer to www.trinamic.com.