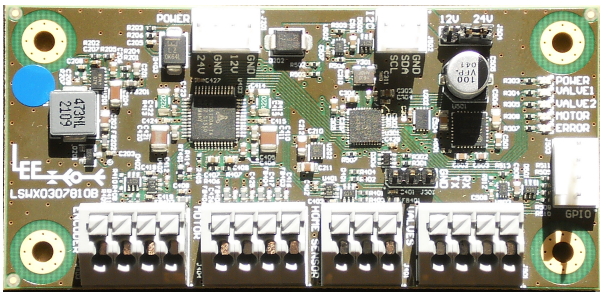
# TMCM-1247 Hardware Manual

Hardware Version V1.0 | Document Revision V1.00 • 2021-SEP-13

**The TMCM-1247-TLC is a controller/driver module for a 2-phase bipolar stepper motor with with coil currents of up to 1A RMS plus a dual solenoid driver. The TMCM-1247 TMCL firmware allows to control the module using TMCL™ commands, supporting standalone operation as well as direct mode control, making use of the Trinamic TMC5130 motion controller and motor driver and the MAX22200 solenoid driver. Dynamic current control, and quiet, smooth and efficient operation are combined with StealthChop™, DcStep™, StallGuard™ and CoolStep™ features.**



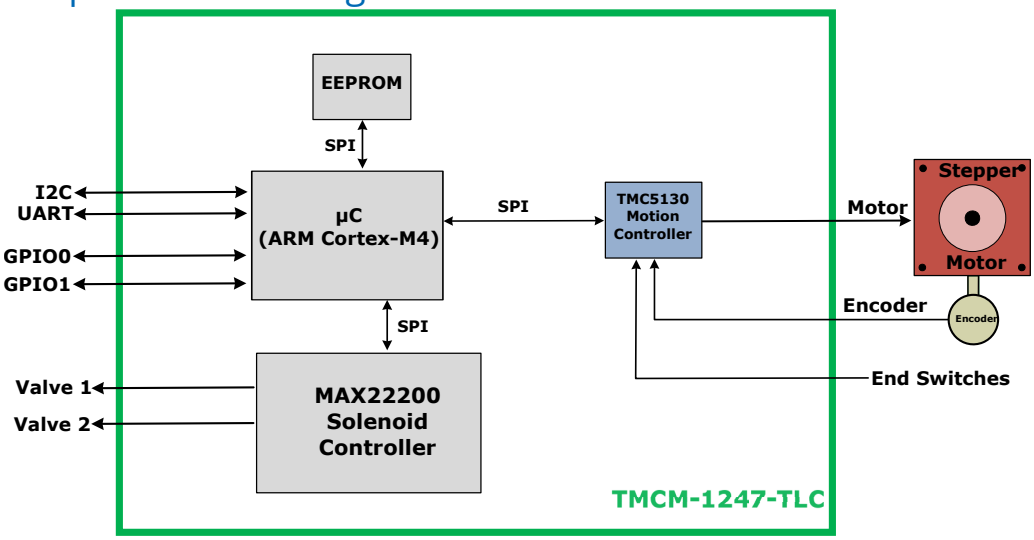
## Features

- Single Axis Stepper motor control
- Supply voltage 10…30V DC
- TMCL™
- I2C™ Interface
- SixPoint™ ramp motion controller
- Quadrature Encoder Input
- Advanced Solenoid Control for two Solenoids
- General Purpose Inputs/Outputs

## Applications

- Laboratory Automation
- Pump Control
- Solenoid Valve Control
- Life Science
- Biotechnology
- Liquid Handling
- Precision Fluid Control

## Simplified Block Diagram



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# Contents





# 1 Features

The TMCM-1247 is a single axis controller/driver module for 2-phase bipolar stepper motors with state of the art feature set. It has been designed for coil currents up to 1A RMS and 24V DC supply voltage. A solenoid controller allows advanced control of two solenoid valves. It is also equipped with two general purpose inputs/outputs and two end switch inputs (the left end switch input is usable as an end-of-stroke sensor input). With its high energy efficiency from TRINAMIC's CoolStep™, technology cost for power consumption is kept down. The TMCL firmware allows for both standalone and direct mode operation.

## 1.1 General Features

**Main Characteristics**

- Supply Voltage +24V nom. (+10V to +30V DC)
- 1A RMS phase current (ca. 1.4A peak phase current)
- Highest micro step resolution, up to 256 micro steps per full step
- Permanent onboard parameter storage
- Advanced SixPoint™ ramp hardware motion controller
- Noiseless StealthChop™ chopper mode for slow to medium velocities
- High performance SpreadCycle™ chopper mode
- High-precision sensorless load measurement with StallGuard2™
- Automatic current scaling algorithm CoolStep™ to save energy and keep your drive cool

**I/Os**

- End switch inputs
- Two general purpose inputs/outputs (configurable either as outputs or as inputs)
- Incremental encoder inputs (quadrature channels A and B only, no N channel)

**Solenoid Control**

- Two solenoid outputs
- Voltage control or current control selectable
- Configurable spike level, spike time and hold level

**I2C Bus Interface**

- Standard I2C Bus Interface for control and configuration
- 7-bit address
- Up to 400kHz clock speed
- TMCL protocol

## 1.2 TRINAMIC's Unique Features

### 1.2.1 stealthChop™

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

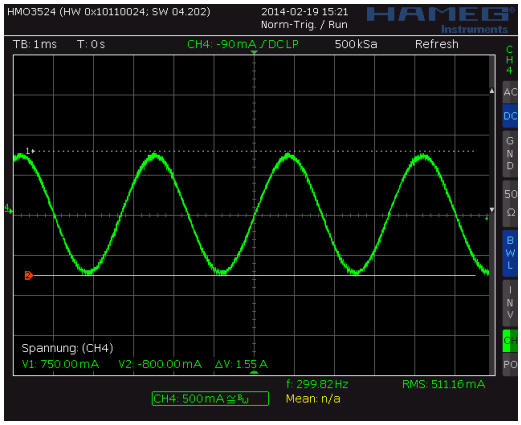


*Figure 1: Motor coil sine wave current using stealthChop (measured with current probe)*

### 1.2.2 spreadCycle™

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

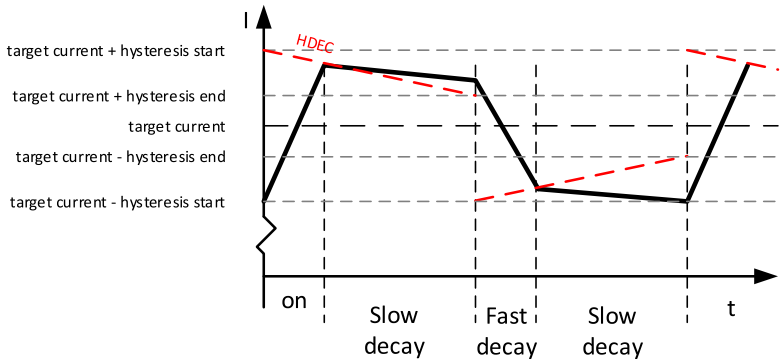


*Figure 2: spreadCycle principle*

### 1.2.3 stallGuard2

stallGuard2 is a high-precision sensorless load measurement using the back EMF of the motor coils. It can be used for stall detection as well as other uses at loads below those which stall the motor. The

stallGuard2 measurement value changes linearly over a wide range of load, velocity, and current settings. At maximum motor load, the value reaches zero or is near zero. This is the most energy-efficient point of operation for the motor.

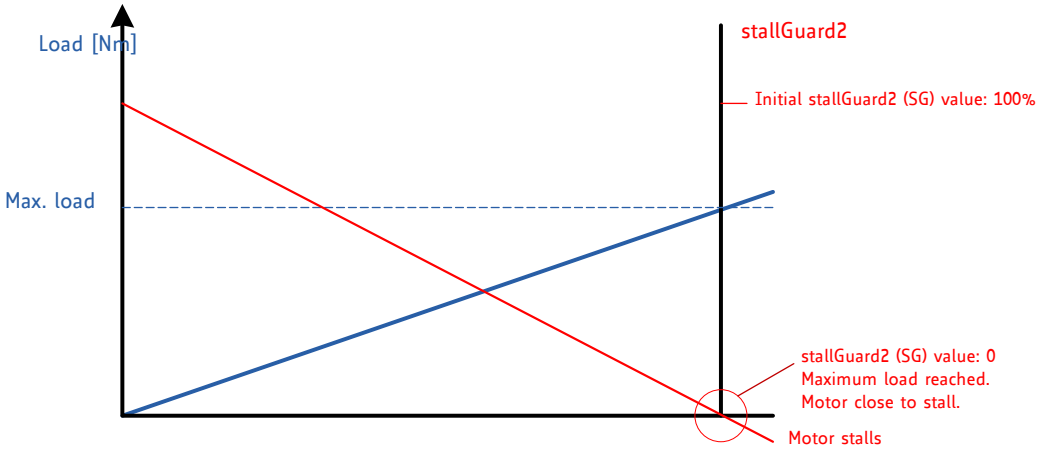


*Figure 3: stallGuard2 Load Measurement as a Function of Load*

### 1.2.4 coolStep

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

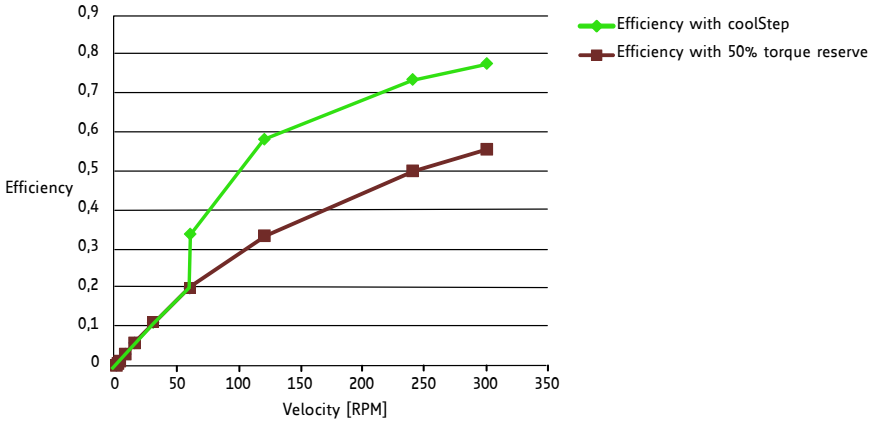


*Figure 4: Energy Efficiency Example with coolStep*

### 1.2.5 sixPoint Motion Controller

TRINAMIC's sixPoint motion controller is a new type of ramp generator, which offers faster machine operation compared to the classical linear acceleration ramps. The sixPoint ramp generator allows adapting the

acceleration ramps to the torque curves of a stepper motor and uses two different acceleration settings each for the acceleration phase and for the deceleration phase

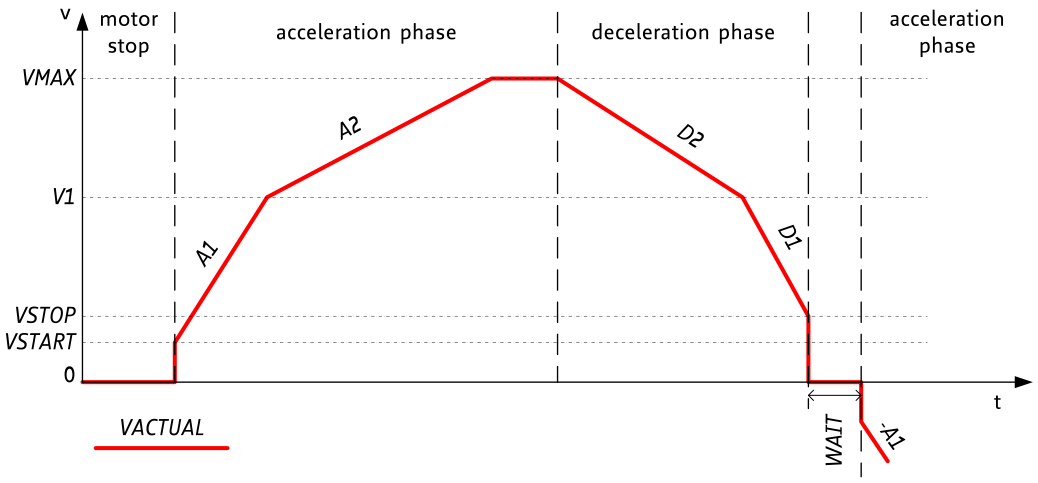


*Figure 5: Typical motion profile with TRINAMIC's sixPoint motion controller*

# 2 Order Codes

| Order Code | Description | Size (LxWxH) |
|---|---|---|
| TMCM-1247-TLC | Controller/Driver Module for one stepper motor and two solenoids, +24V DC, I2C bus interface, TMCL firmware, weight ca. 150g | 85mm x 43mm x 16mm |

*Table 1: Order codes*

# 3 Mechanical and Electrical Interfacing

## 3.1 TMCM-1247 Dimensions

The dimensions of the TMCM-1247 are approx. 85mm x 43mm x 16mm. There are four mounting holes for M3 screws for mounting the TMCM-1247.

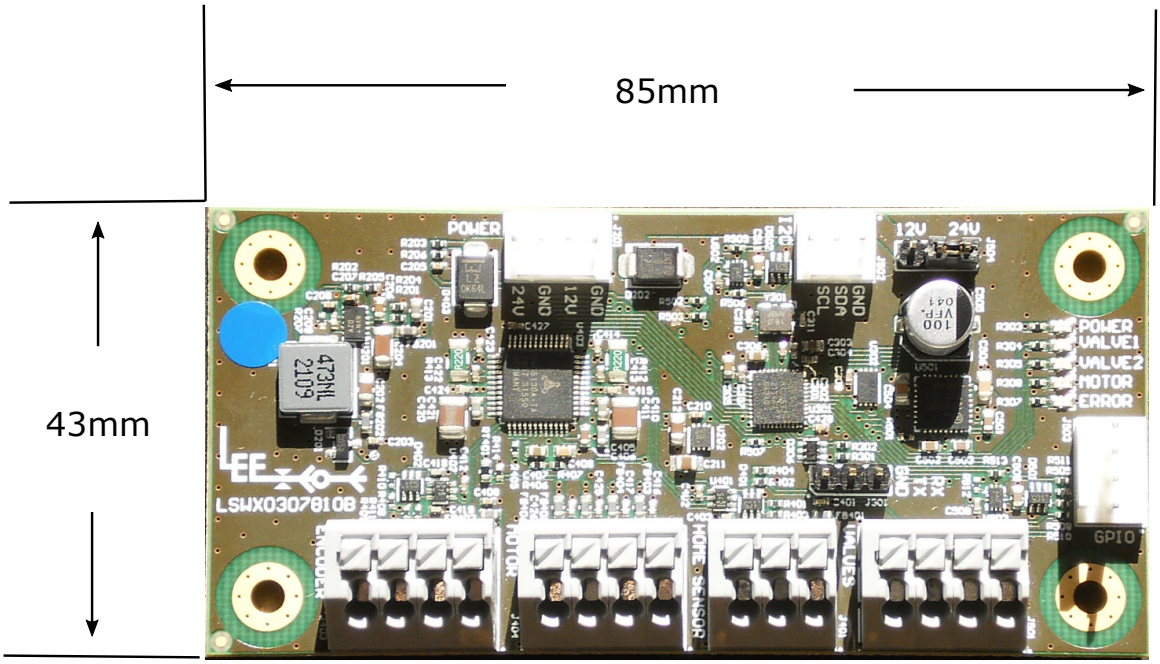


*Figure 6: TMCM-1247 top view mechanical dimensions*

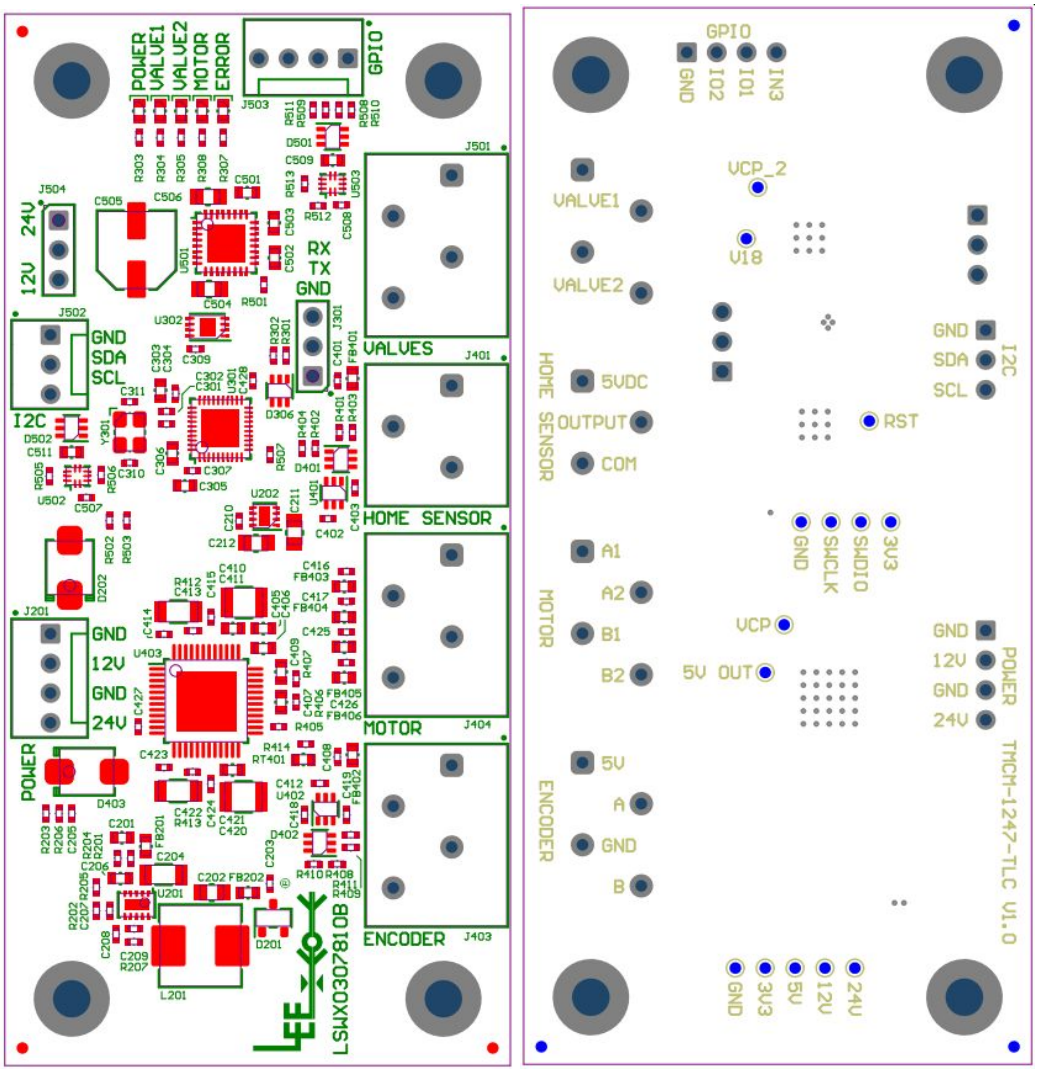


*Figure 7: TMCM-1247 top and bottom side*

# 4 Connectors and LEDs

The TMCM-1247 module is equipped with connectors for power, I2C, general purpose I/O, two solenoid valves, end-of-stroke sensor, stepper motor and encoder.

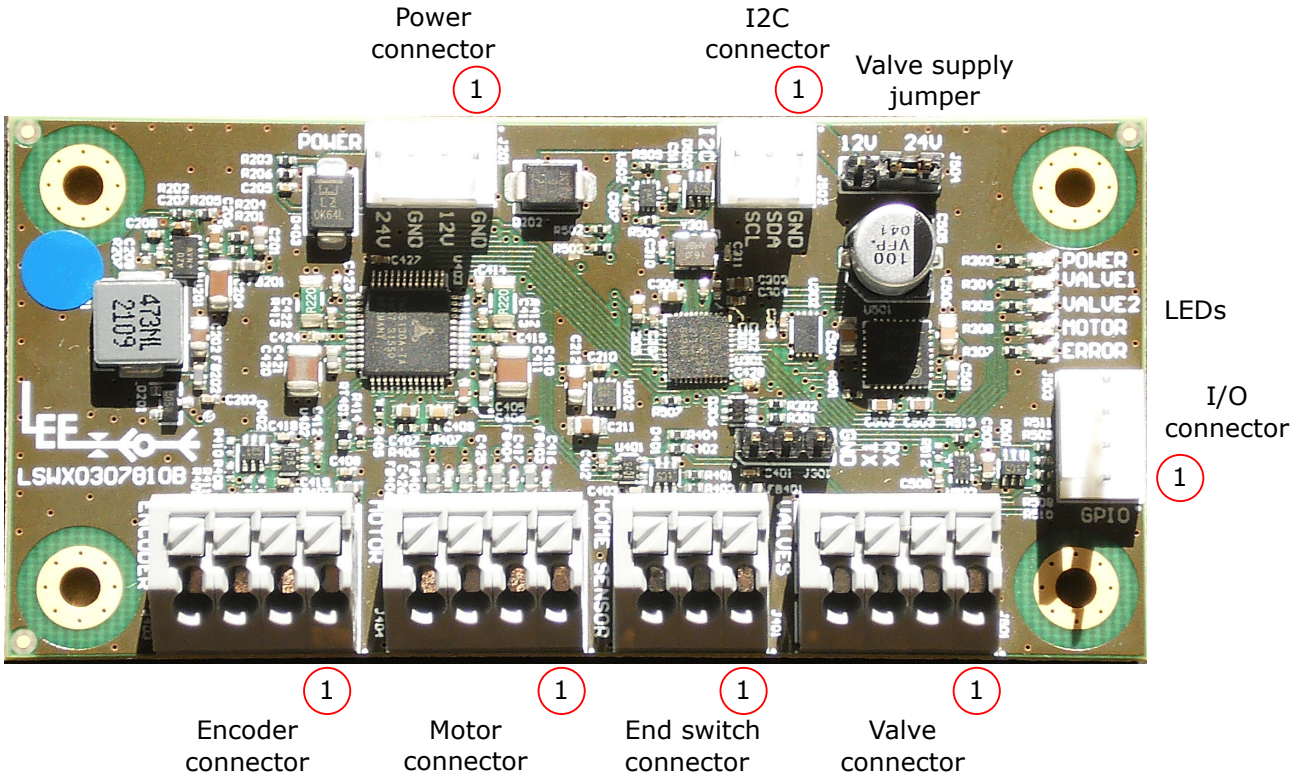


*Figure 8: TMCM-1247 connectors*

## 4.1 Power Connector

Connector Type:

- Manufacturer: Molex
- MPN: 0022232041
- Description: Series KK254 / 6373, Header, vertical, lock, 4 pins, 2.54mm, tin, 4A, 500V, TH
- Link: https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf

Mating Connector:

- Manufacturer: Molex
- MPN: 0022012047
- Description: Series KK254 / 6373, Housing, lock, 4 pins, 2.54mm
- Link: https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf

| Power Connector Pin Assignment | | |
|---|---|---|
| Pin number | Pin name | Description |
| 1 | GND | Power supply ground |
| 2 | 12V | Optional +12V input for solenoids |
| 3 | GND | Power supply ground |
| 4 | 24V | Power supply voltage input (+10V…+30VDC) |

*Table 2: Power Connector Pin Assignment*

**NOTICE**

**Always keep the power supply voltage below the upper limit of 30V!** 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.

**NOTICE**

**Add external power supply capacitors!** It is recommended to connect an electrolytic capacitor of significant size (e.g. 470$\mu$F/35V) to the power supply lines next to the TMCM-1247!
Rule of thumb for size of electrolytic capacitor: $C = \frac{1000\mu F}{A} \times I_{SUPPLY}$
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.

## 4.2 I2C Bus Connector

Connector Type:

- Manufacturer: Molex
- MPN: 0022232031
- Description: Series KK254 / 6373, Header, vertical, lock, 3 pins, 2.54mm, tin, 4A, 500V, TH
- Link: https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf

Mating Connector:

- Manufacturer: Molex
- MPN: 0022012037
- Description: Series KK254 / 6373, Housing, lock, 3 pins, 2.54mm
- Link: https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf

| I2C Bus Connector Pin Assignment | | |
|---|---|---|
| Pin number | Pin name | Description |
| 1 | GND | Signal ground |
| 2 | SDA | Serial data |
| 3 | SCL | Serial clock |

*Table 3: I2C Bus Connector Pin Assignment*

## 4.3 I/O Connector

Connector Type:

- Manufacturer: Molex
- MPN: 0022232041
- Description: Series KK254 / 6373, Header, vertical, lock, 4 pins, 2.54mm, tin, 4A, 500V, TH
- Link: https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf

Mating Connector:

- Manufacturer: Molex
- MPN: 0022012047
- Description: Series KK254 / 6373, Housing, lock, 4 pins, 2.54mm
- Link: https://www.molex.com/pdm_docs/ps/PS-10-07-001.pdf

| I/O Connector Pin Assignment | | |
|---|---|---|
| Pin number | Pin name | Description |
| 1 | GND | Signal ground |
| 2 | IO2 | General purpose I/O 1 (GPIO1) |
| 3 | IO1 | General purpose I/O 0 (GPIO0) |
| 4 | IN3 | Optional right end switch input |

*Table 4: I/O Connector Pin Assignment*

## 4.4 Valve Connector

Connector Type:

- Manufacturer: WAGO
- MPN: 250-204
- Description: Series 250, 4-pos spring terminal block, 3.5mm, 45deg, grey, 1.5 $mm^2$, 320V, 8A
- Link: https://www.farnell.com/datasheets/35974.pdf

Mating Connector:

- No mating connector. Use direct wires of size AWG 24 to AWG 16.

| Valve Connector Pin Assignment | | |
|---|---|---|
| Pin number | Pin name | Description |
| 1 | VALVE1 | Valve 1 Solenoid |
| 2 | VALVE1 | Valve 1 Solenoid |
| 3 | VALVE2 | Valve 2 Solenoid |
| 4 | VALVE2 | Valve 2 Solenoid |

*Table 5: Valve Connector Pin Assignment*

## 4.5 End Switch Connector

Connector Type:

- Manufacturer: WAGO
- MPN: 250-203
- Description: Series 250, 3-pos spring terminal block, 3.5mm, 45deg, grey, 1.5 $mm^2$, 320V, 8A
- Link: https://www.farnell.com/datasheets/35974.pdf

Mating Connector:

- No mating connector. Use direct wires of size AWG 24 to AWG 16.

| End Switch Connector Pin Assignment | | |
|---|---|---|
| Pin number | Pin name | Description |
| 1 | 5VDC | +5V supply output |
| 2 | OUTPUT | Left end switch input (output of the sensor) |
| 3 | COM | Ground |

*Table 6: End Switch Connector Pin Assignment*

## 4.6 Motor Connector

Connector Type:

- Manufacturer: WAGO
- MPN: 250-204
- Description: Series 250, 4-pos spring terminal block, 3.5mm, 45deg, grey, 1.5 $mm^2$, 320V, 8A
- Link: https://www.farnell.com/datasheets/35974.pdf

Mating Connector:

- No mating connector. Use direct wires of size AWG 24 to AWG 16.

| Motor Connector Pin Assignment | | |
|---|---|---|
| Pin number | Pin name | Description |
| 1 | A1 | Motor coil A pin 1 |
| 2 | A2 | Motor coil A pin 2 |
| 3 | B1 | Motor coil B pin 1 |
| 4 | B2 | Motor coil B pin 2 |

*Table 7: Motor Connector Pin Assignment*

**NOTICE**

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

## 4.7 Encoder Connector

Connector Type:

- Manufacturer: WAGO
- MPN: 250-204
- Description: Series 250, 4-pos spring terminal block, 3.5mm, 45deg, grey, 1.5 $mm^2$, 320V, 8A
- Link: https://www.farnell.com/datasheets/35974.pdf

Mating Connector:

- No mating connector. Use direct wires of size AWG 24 to AWG 16.

| Encoder Connector Pin Assignment | | |
|---|---|---|
| Pin number | Pin name | Description |
| 1 | 5V | +5V supply output |
| 2 | A | Encoder channel A input |
| 3 | GND | Signal and power supply ground |
| 4 | B | Encoder channel B input |

*Table 8: Encoder Connector Pin Assignment*

## 4.8 LEDs

The TMCM-1247 is equipped with five LEDs. Each LED is labelled to show its functionality.

| LED Functionality | |
|---|---|
| Label | Description |
| POWER | On when power (on the 24V pin) is applied to the module. |
| VALVE1 | On when solenoid valve 1 is energized.<br>Off when solenoid valve 1 is not energized. |
| VALVE2 | On when solenoid valve 2 is energized.<br>Off when solenoid valve 2 is not energized. |
| MOTOR | Flashing with 100ms on, 900ms off: motor moving in negative direction.<br>Flashing with 900ms on, 100ms off: motor moving in positive direction.<br>Flashing with 500ms on, 500ms off: motor not moving. |
| ERROR | On when an error has occurred. |

*Table 9: LED Functionality*

When the module is in bootloader mode all LEDs are constantly on.

## 4.9 Valve Supply Jumper

The valve supply jumper selects between 24V and 12V solenoid power supply. When the jumper is in the 24V position (pin 1 linked with pin 2) the solenoids are supplied via the main 24V power supply input. When the jumper is in its 12V position (pin 3 linked with pin 2) the solenoids are powered via the optional 12V supply input.

# 5 Functional Description

## 5.1 Typical Application Wiring

The TMCM-1247 driver/controller's wiring is straightforward:

- Power supply must be connected to 24V and GND.
- I2C - use appropriate I2C interface (for example the Landungsbruecke made up as I2C master).
- Motor - connect two-phase bipolar stepper motor (1A RMS).

## 5.2 General Purpose I/O

The GPIO pins (IO1 and IO2) can be used either as inputs or as outputs. Each one can be configured seperately using TMCL commands. They are both 5V TTL compatible. The additional right end switch input is also 5V TTL compatible.

## 5.3 End-of-Stroke Sensor Input

The left end switch input is made for use with a 5V TTL compatible end-of-stroke sensor. It also provides a 5V output to power the sensor.

## 5.4 I2C Interface

The I2C interface is used to control the module using TMCL commands. It is 5V TTL compatible with up to 400kHz clock frequency. The I2C address is configurable. The 7-bit addressing mode is used. Please see the firmware manual for information about the TMCL protocol.

## 5.5 Solenoid Valves

Two solenoid valves can be connected. They are either powered by the main 24V power supply or by an optional 12V power supply. This can be selected using the valve supply selection jumper. The solenoids ae controlled by a MAX22200 solenoid controller/driver. The hold level, spike level, spike time and voltage or current driven mode are selectable independantly for each solenoid.

## 5.6 Encoder Input

Any encoder with single ended quadrature output and 5V TTL level can be used. The module is equipped with a 4.7K pull-up resistor for each encoder channel. There is no null channel input.

# 6 Reset to Factory Default

In some cases (e.g. if the I2C address of the module is unknown) it might be necessary to reset the TMCM-1247 module to factory default settings. This can be done the following way:

1. Make sure that the supply power is turned off.
2. Locate the test pads labelled SWDIO and SWDCLK on the bottom side of the board.
3. Short the SWDIO pad with the SWDCLK pad (using a small cable for example).
4. Turn on the supply power and wait until the MOTOR LED and the ERROR LED are flashing rapidly.
5. Turn off the supply power and remove the short between the SWDIO and the SWCLK pad.
6. Turn on the supply power again. After some seconds, the MOTOR LED starts flashing normally. The module is now working with factory default settings.

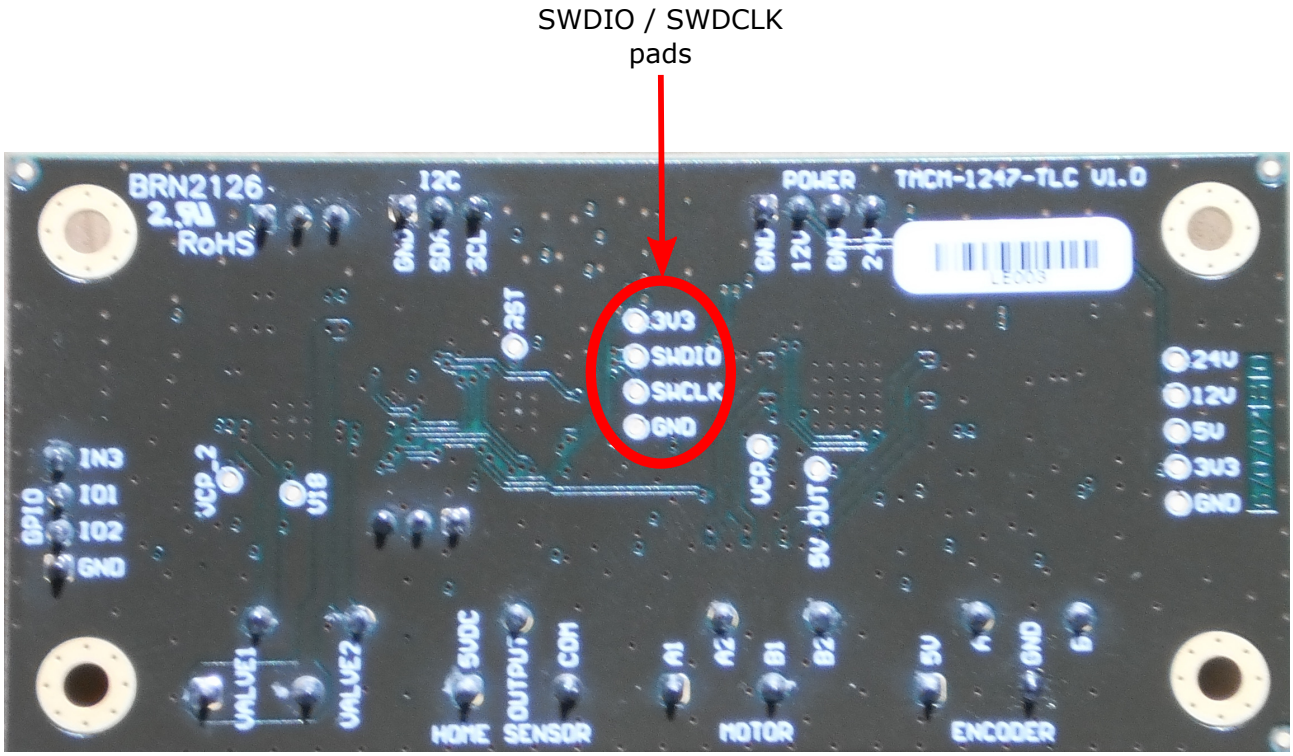


*Figure 9: TMCM-1247 Programming Pads*

# 7 Operational Ratings and Characteristics

## 7.1 Absolute Maximum Ratings

| Parameter | Min | Max | Unit |
|---|---|---|---|
| Supply voltage | +10 | +30 | V |
| Working temperature | -10 | +50 | ° C |
| Motor coil current / sine wave **peak** | | 1.4 | A |
| Continuous motor current (**RMS**) | | 1 | A |

*Table 10: Absolute Maximum Ratings*

**NOTICE**

Stresses above those listed under "'Absolute Maximum Ratings"' may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

## 7.2 Electrical Characteristics (Ambient Temperature 25° C)

| Parameter | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Supply voltage | $VDD$ | 10 | 24 | 30 | V |
| Motor coil current / sine wave **peak** (chopper regulated, adjustable in software) | $I_{COILpeak}$ | 0 | | 1.4 | A |
| Continuous motor current (**RMS**) | $I_{COILRMS}$ | 0 | | 1 | A |
| Power supply current | $I_{DD}$ | | $\ll I_{COIL}$ | $1.7{*}I_{COIL}$ | A |

*Table 11: Electrical Characteristics*

*Please note: maximum motor current settings may require appropriate cooling of the unit.*

## 7.3 I/O Ratings (Ambient Temperature 25° C)

| Parameter | Symbol | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Input voltage | $V_{IN}$ | | 5 | 5.5 | V |
| Low level voltage | $V_L$ | 0 | | 1.5 | V |
| High level voltage | $V_H$ | 3.5 | | 5 | V |

*Table 12: I/O ratings*

## 7.4 Other Requirements

| Specifications | Description or Value |
|---|---|
| Cooling | Free air |
| Working environment | Avoid dust, water, oil mist and corrosive gases, no condensation, no frosting |
| Storage temperature | -40° C to +60° C |

*Table 13: Other Requirements and Characteristics*

# 8 Abbreviations used in this Manual

| Abbreviation | Description |
|---|---|
| I2C, IIC | Inter-IC Bus |
| IDE | Integrated Development Environment |
| LED | Light Emmitting Diode |
| RMS | Root Mean Square value |
| SPI | Serial Peripheral Interface |
| TMCL | TRINAMIC Motion Control Language |
| TTL | Transistor Transistor Logic |
| UART | Universal Asynchronous Receiver Transmitter |
| USB | Universal Serial Bus |

*Table 14: Abbreviations used in this Manual*

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# 11 Supplemental Directives

## 11.1 Producer Information

## 11.2 Copyright



## 11.3 Trademark Designations and Symbols

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This Hardware Manual is a non-commercial publication that seeks to provide concise scientific and technical user information to the target user. Thus, trademark designations and symbols are only entered in the Short Spec of this document that introduces the product at a quick glance. The trademark designation /symbol is also entered when the product or feature name occurs for the first time in the document. All trademarks and brand names used are property of their respective owners.

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The documentation provided here, is for programmers and engineers only, who are equipped with the necessary skills and have been trained to work with this type of product.

The Target User knows how to responsibly make use of this product without causing harm to himself or others, and without causing damage to systems or devices, in which the user incorporates the product.

## 11.5 Disclaimer: Life Support Systems

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## 11.7 Collateral Documents & Tools

This product documentation is related and/or associated with additional tool kits, firmware and other items, as provided on the product page at: www.trinamic.com.

# 12 Revision History

## 12.1 Hardware Revision

| Version | Date | Author | Description |
|---|---|---|---|
| 1.00 | 2021-SEP-13 | MM/OK | First prototypes. |

*Table 15: Hardware Revision*

## 12.2 Document Revision

| Version | Date | Author | Description |
|---|---|---|---|
| 1.00 | 2021-SEP-13 | OK/SK | First release. |

*Table 16: Document Revision*