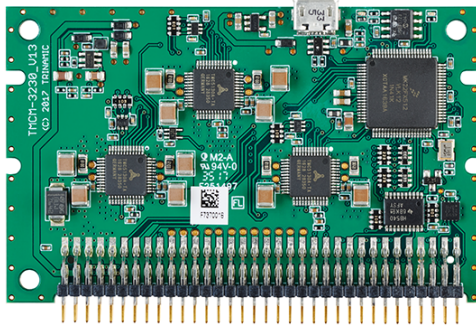


# TMCM-3230 Hardware Manual

Hardware Version V1.30 | Document Revision V1.10 • 2017-NOV-02

The TMCM-3230 is a compact and easy to use 3-axes stepper motor controller and driver unit for embedded applications. It offers CAN bus, UART and USB interfaces for communication and supports stand-alone operation, also. The TMCM-3230 features stealthChop™ for absolute silent motor control, spreadCycle™ for high speed stepper motor commutation, a fully integrated hardware motion controller with sixPoint™ motion ramps, as well as stallGuard2™ and coolStep™.



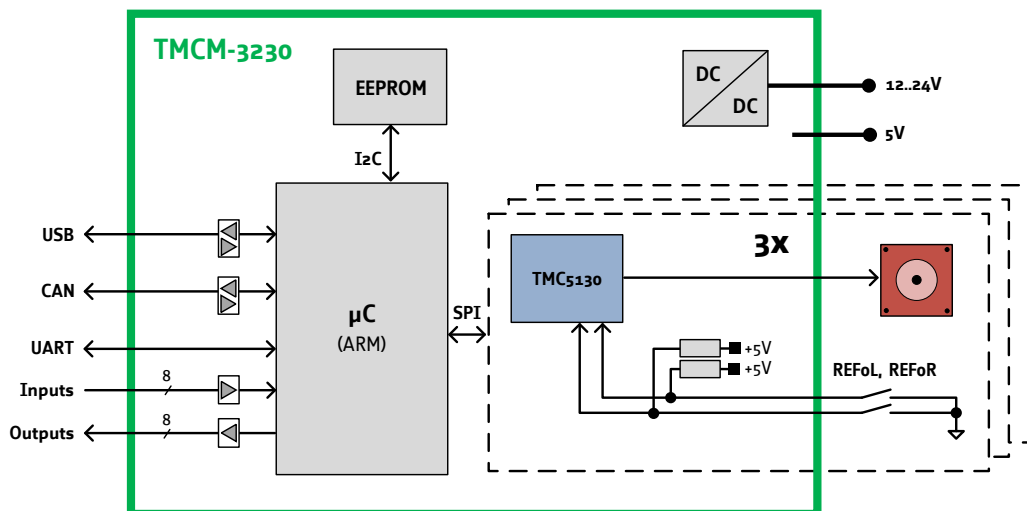
## Features

- 3-axes stepper motor controller / driver
- Supply Voltage +12 to +24V DC (9V .. 28.5V max.)
- CAN, UART and USB interfaces
- TMCL or CANopen protocol
- Integrated **sixPoint™** ramp motion controller
- **stealthChop™** silent PWM mode
- **spreadCycle™** smart mixed decay
- **stallGuard2™** load detection
- **coolStep™** autom. current scaling

## Applications

- Laboratory Automation
- Manufacturing
- Semiconductor Handling
- Robotics
- Factory Automation
- Test & Measurement
- Life Science
- Biotechnology
- Liquid Handling

## Simplified Block Diagram



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# 1 Features

The TMCM-3230 is a compact three axes 2-phase stepper motor controller and driver module. It provides a complete motion control solution at a very small size for embedded applications. The board can be easily plugged into a customized baseboard offering a single 68pin connector.

Host communication is possible via the serial UART interface (e.g. using a standard RS232 or RS485 level shifter) or via CAN (CAN controller is already integrated on board). An additional USB interface (Micro-USB) may be used for firmware updates, download of TMCL programs or setting of parameters - either in system or stand-alone without any further connections.

The TMCM-3230 is supported by the integrated development environment TMCL-IDE v3.0. It supports stand-alone TMCL program execution (on-board EEPROM) and remote controlled operation.

The TMCM-3230 has been designed with compatibility in mind with previous generation TMCM-343/TMCM-303 modules - keeping similar mechanical and electrical characteristics (drop-in replacement for many applications) while offering advanced features.

## 1.1 General Features

### Main Characteristics

- Supply Voltage +12V to +24V DC nom. (9V..28.5V abs. max.)
- 1A RMS phase current (approx. 1.4A peak phase current)
- Up to 256 micro steps per full step
- Permanent onboard parameter storage (EEPROM)
- Advanced sixPoint™ ramp hardware motion controller (for each axis)
- 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

- 8 general purpose inputs (0..5V) - either analog or digital
- 8 general purpose outputs (+5V level)
- L+R reference switch inputs (for all three axes)
- Shutdown input to power-on/-off drivers
- Alarm output
- Reset input

### Communication Interfaces

- Standard CAN Bus Interface for control and configuration
- UART interface supporting e.g. RS232, RS422 or RS485 with external transceiver
- SPI master interface



## 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.

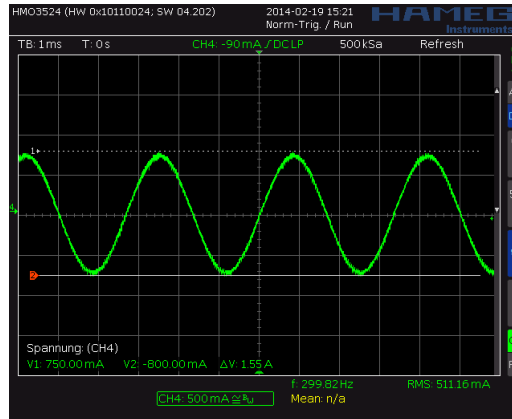


Figure 1: Motor coil sine wave current using stealthChop (measured with current probe)

### 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.

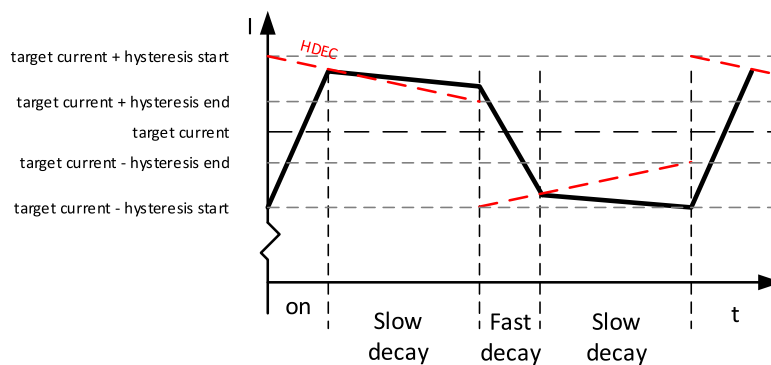


Figure 2: spreadCycle principle

### 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.

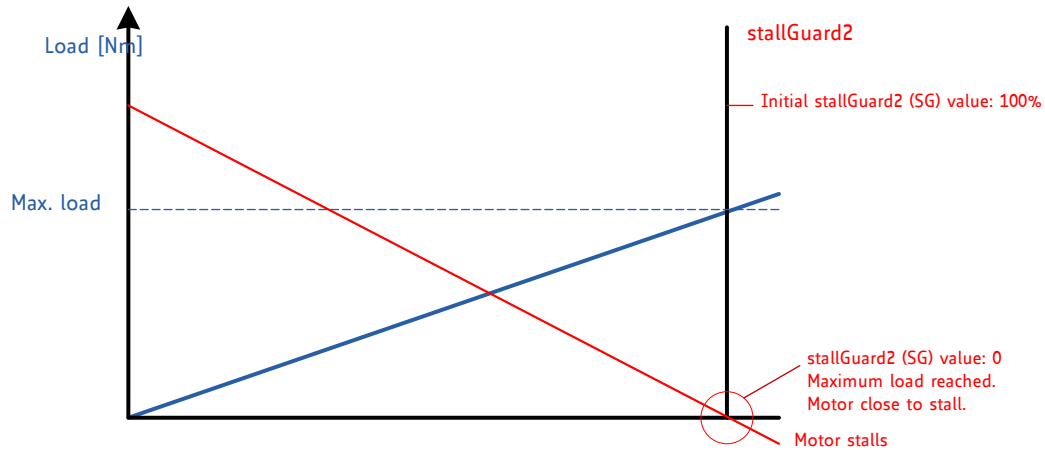


Figure 3: stallGuard2 Load Measurement as a Function of Load

### 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.

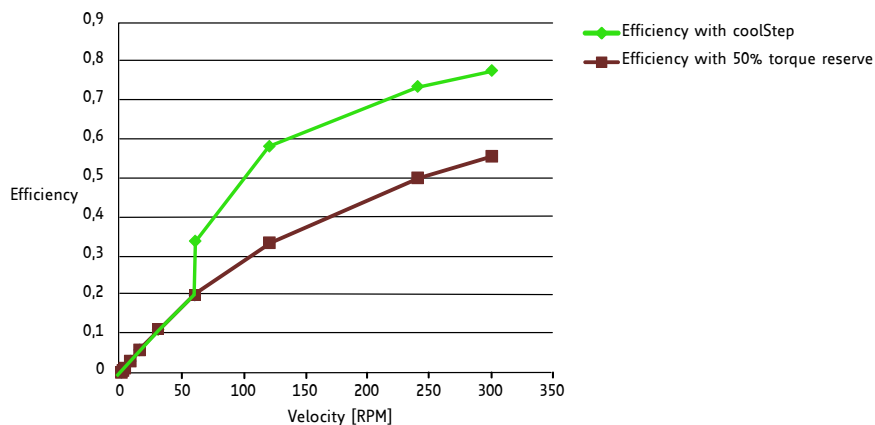


Figure 4: Energy Efficiency Example with coolStep

### 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

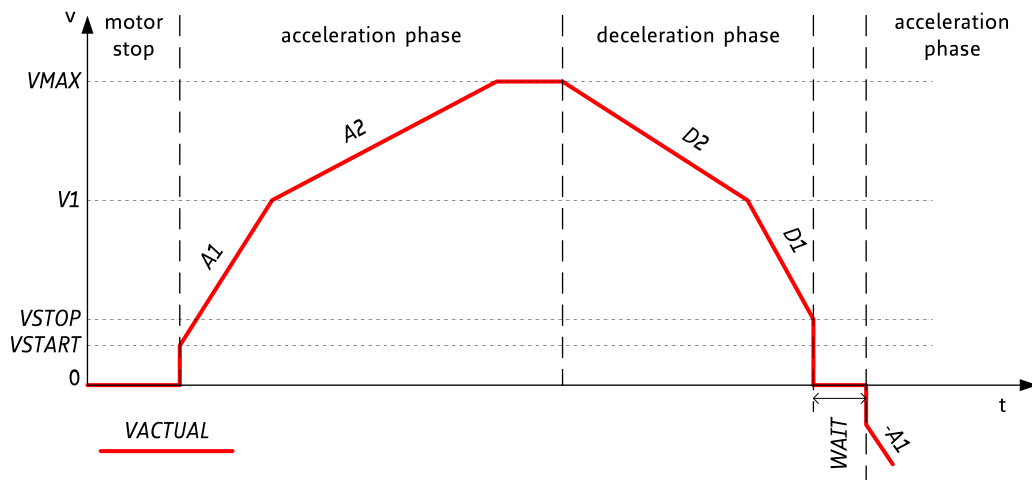


Figure 5: Typical motion profile with TRINAMIC's sixPoint motion controller



## 2 Order Codes

| Order Code        | Description   | Size (LxWxH)      |
|-------------------|---|-------------------|
| TMCM-3230-TMCL    | 3-axes stepper motor controller / driver<br>+24V / 1A RMS<br>TMCL firmware installed    | 80mm x 50mm x 6mm |
| TMCM-3230-CANopen | 3-axes stepper motor controller / driver<br>+24V / 1A RMS<br>CANopen firmware installed | 80mm x 50mm x 6mm |

*Table 1: Order Codes*



### 3 Mechanical and Electrical Interfacing

#### 3.1 TMCM-3230 Dimensions

The dimensions of the controller/driver unit are approx. 80mm x 50mm. There are three mounting holes for M3 screws and two slots on each side for optional card holders.

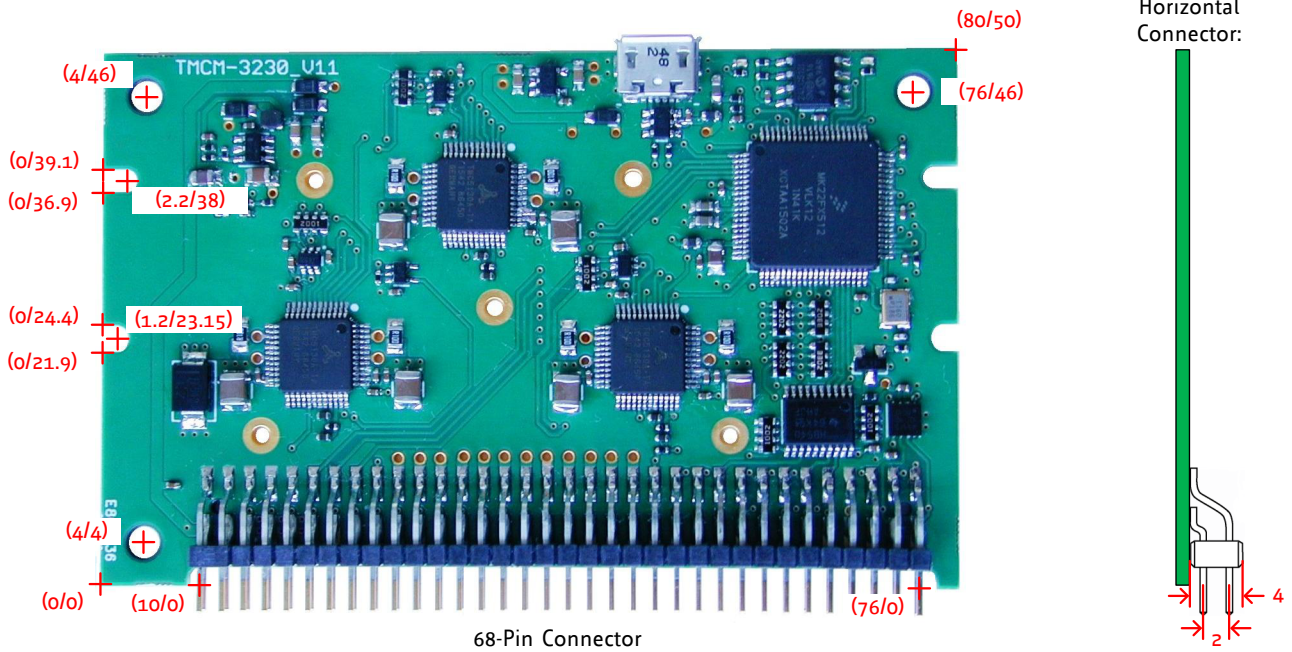


Figure 6: TMCM-3230 mechanical dimensions (all values in mm, (x/y))





## 4 Connectors and LEDs

### 4.1 Main Connector

The TMCM-3230 has been designed as plug-in module. It offers one 68pin connector with 2mm pitch for connection of supply (driver and optional +5V digital supply), communication interfaces (CAN, UART - e.g. RS232, RS422 or RS485 with external transceiver), up-to eight digital outputs (0..+5V), up-to eight analog or digital inputs (0..+5V), reference switch inputs for all three axes (may be used as Step/Direction inputs) and motor driver outputs for three axes.

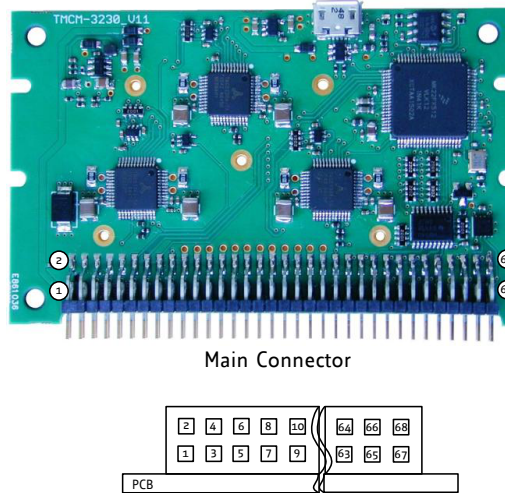


Figure 7: TMCM-3230 main connector

| Main Connector Pin Assignment |           |                             |     |           |                      |
|-------------------------------|-----------|-----------------------------|-----|-----------|----------------------|
| Pin                           | Direction | Description                 | Pin | Direction | Description          |
| 1                             | In        | +5V DC digital supply in    | 2   | In        | GND                  |
| 3                             | In        | +5V DC digital supply in    | 4   | In        | GND                  |
| 5                             | In        | +12V..+24V driver supply in | 6   | In        | GND                  |
| 7                             | In        | +12V..+24V driver supply in | 8   | In        | GND                  |
| 9                             | In        | +12V..+24V driver supply in | 10  | In        | GND                  |
| 11                            | Out       | SPI Select 0 (EtherCAT)     | 12  | Out       | SPI Clock (EtherCAT) |
| 13                            | -         | Reserved                    | 14  | In        | SPI MISO (EtherCAT)  |
| 15                            | In        | SPI IRQ (EtherCAT)          | 16  | Out       | SPI MOSI (EtherCAT)  |
| 17                            | In        | Reset, active low           | 18  | Out       | Alarm                |
| 19                            | In        | Motor 0 REFR / DIR          | 20  | Out       | Motor 0 A0           |
| 21                            | In        | Motor 0 REFL / STEP         | 22  | Out       | Motor 0 A1           |
| 23                            | In        | Motor 1 REFR / DIR          | 24  | Out       | Motor 0 B0           |
| 25                            | In        | Motor 1 REFL / STEP         | 26  | Out       | Motor 0 B1           |



| Pin | Direction  | Description             | Pin | Direction | Description                   |
|-----|------------|-------------------------|-----|-----------|-------------------------------|
| 27  | In         | Motor 2 REFR / DIR      | 28  | Out       | Motor 1 A0                    |
| 29  | In         | Motor 2 REFL / STEP     | 30  | Out       | Motor 1 A1                    |
| 31  | -          | Reserved                | 32  | Out       | Motor 1 B0                    |
| 33  | -          | Reserved                | 34  | Out       | Motor 1 B1                    |
| 35  | -          | Reserved                | 36  | Out       | Motor 2 A0                    |
| 37  | -          | Reserved                | 38  | Out       | Motor 2 A1                    |
| 39  | -          | Reserved                | 40  | Out       | Motor 2 B0                    |
| 41  | -          | Reserved                | 42  | Out       | Motor 2 B1                    |
| 43  | -          | Reserved                | 44  | In        | Shutdown (2k2 pull-up to +5V) |
| 45  | In         | General purpose input 0 | 46  | Out       | General purpose output 0      |
| 47  | In         | General purpose input 1 | 48  | Out       | General purpose output 1      |
| 49  | In         | General purpose input 2 | 50  | Out       | General purpose output 2      |
| 51  | In         | General purpose input 3 | 52  | Out       | General purpose output 3      |
| 53  | In         | General purpose input 4 | 54  | Out       | General purpose output 4      |
| 55  | In         | General purpose input 5 | 56  | Out       | General purpose output 5      |
| 57  | In         | General purpose input 6 | 58  | Out       | General purpose output 6      |
| 59  | In         | General purpose input 7 | 60  | Out       | General purpose output 7      |
| 61  | In         | GND                     | 62  | In        | GND                           |
| 63  | -          | Reserved                | 64  | Out       | RS485 Direction               |
| 65  | In and Out | CAN-                    | 66  | In        | UART_RxD                      |
| 67  | In and Out | CAN+                    | 68  | Out       | UART_TxD                      |

*Table 2: Main Connector Pin Assignment*

## NOTICE

Do not plug-in or remove TMCM-3230 during operation! Voltage spikes and / or partly connected supply pins might lead to permanent damage of the module.

## 4.2 USB Connector

The TMCM-3230 offers one Micro-USB connector. This connector is located at the upper end of the plug-in module. It has been integrated for quick and easy parameter setting and firmware updates of the module - either in-system or even while the main connector is un-plugged. The USB device interface (Full-speed) supports USB bus powered operation. During this mode the processor and the on-board non-volatile memory (EEPROM) are powered and firmware updates, download of TMCL programs and parameter setting is possible without any further connection - apart from USB. In addition, UART communication, the SPI interface, all general purpose inputs and the dedicated Reset input are operational while all other connections - motor driver outputs, general purpose outputs, Shutdown input, Alarm output, the CAN interface and all REF / Step / Dir inputs are not operational.

In self powered mode when the TMCM-3230 is plugged into its mainboard and power via the 68pin connector is applied communication via USB is possible, also. In this configuration USB might be used as



an alternative to the other serial interfaces. Please note that the module might draw current via the USB connection in this mode, also.

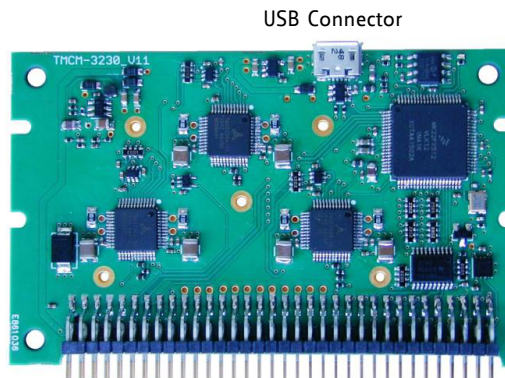


Figure 8: TMCM-3230 USB Connector

### 4.3 CAN Connection

For remote control and communication with a host system the TMCM-3230 provides a CAN bus interface with on-board CAN transceiver. For proper operation the following items should be taken into account when setting up a CAN network:

**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.

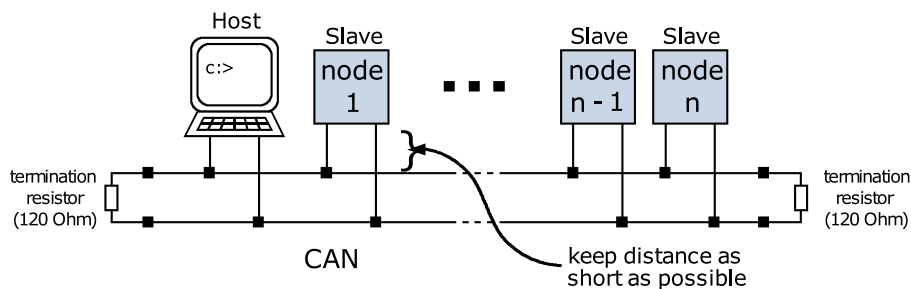


Figure 9: CAN Bus Structure

**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-3230 does not integrate any termination resistor. Therefore, 120 Ohm termination resistors at both ends of the bus have to be added externally.

**Number of Nodes** The bus transceiver used on the TMCM-3230 (TJA1051) supports at least 100 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).



## 4.4 LEDs

The TMCM-3230 offers two LEDs: one green and one red LED. Both LEDs are connected to the processor. Function of the LEDs depends on the firmware version / type of firmware (e.g. TMCL / CANopen). See figure 10 for the LED location.

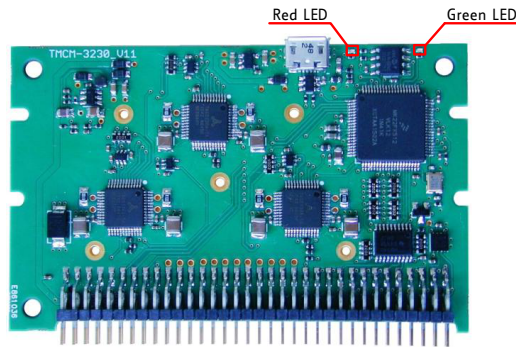


Figure 10: TMCM-3230 Location of LEDs

| Status LEDs with TMCL Firmware |         |                                    |
|--------------------------------|---------|------------------------------------|
| Green LED                      | Red LED | TMCL Firmware                      |
| Blinking                       | Off     | Operational, firmware is running.  |
| On                             | On      | Bootloader / firmware update mode. |
| Off                            | Off     | Power Off                          |

Table 3: Status LEDs with TMCL Firmware



## 5 Motor driver current

The on-board stepper motor driver operates current controlled. The driver current may be programmed in software with 32 effective current scaling steps (CS) in hardware.

*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-3230 firmware manual for further information)
- Current scaling**      This is the effective current scaling in hardware. 32 different scaling steps are available in hardware.
- Motor current**      Resulting motor current based on motor current setting. Motor current is listed as peak (sine peak) value ( $I_{PEAK}$ ) and RMS-value ( $I_{RMS}$ ). For stepper motors rated current is usually listed as  $I_{RMS}$  value.

| Motor current setting in software (TMCL) | Current scaling step in hardware (CS) | Motor current $I_{PEAK}[A]$ | Motor current $I_{RMS}[A]$ |
|--|---------------------------------------|-----------------------------|----------------------------|
| 0..7                                     | 0                                     | 0.047                       | 0.033                      |
| 8..15                                    | 1                                     | 0.094                       | 0,066                      |
| 16..23                                   | 2                                     | 0.141                       | 0.099                      |
| 24..31                                   | 3                                     | 0.188                       | 0.133                      |
| 32..39                                   | 4                                     | 0.234                       | 0.166                      |
| 40..47                                   | 5                                     | 0.281                       | 0.199                      |
| 48..55                                   | 6                                     | 0.328                       | 0.232                      |
| 56..63                                   | 7                                     | 0.375                       | 0.265                      |
| 64..71                                   | 8                                     | 0.422                       | 0.298                      |
| 72..79                                   | 9                                     | 0.469                       | 0.331                      |
| 80..87                                   | 10                                    | 0.516                       | 0.365                      |
| 88..95                                   | 11                                    | 0.563                       | 0.398                      |
| 96..103                                  | 12                                    | 0.609                       | 0.431                      |
| 104..111                                 | 13                                    | 0.656                       | 0.464                      |
| 112..119                                 | 14                                    | 0.703                       | 0.497                      |
| 120..127                                 | 15                                    | 0.750                       | 0.530                      |
| 128..135                                 | 16                                    | 0.797                       | 0.563                      |
| 136..143                                 | 17                                    | 0.844                       | 0.597                      |



| Motor current setting in software (TMCL) | Current scaling step in hardware (CS) | Motor current $I_{PEAK}[A]$ | Motor current $I_{RMS}[A]$ |
|--|---------------------------------------|-----------------------------|----------------------------|
| 144..151                                 | 18                                    | 0.891                       | 0.630                      |
| 152..159                                 | 19                                    | 0.938                       | 0.663                      |
| 160..167                                 | 20                                    | 0.984                       | 0.696                      |
| 168..175                                 | 21                                    | 1.031                       | 0.729                      |
| 176..183                                 | 22                                    | 1.078                       | 0.762                      |
| 184..191                                 | 23                                    | 1.125                       | 0.795                      |
| 192..199                                 | 24                                    | 1.172                       | 0.829                      |
| 200..207                                 | 25                                    | 1.219                       | 0.862                      |
| 208..215                                 | 26                                    | 1.266                       | 0.895                      |
| 216..223                                 | 27                                    | 1.313                       | 0.928                      |
| 224..231                                 | 28                                    | 1.359                       | 0.961                      |
| 232..239                                 | 29                                    | 1.406                       | 0.994                      |
| 240..247                                 | 30                                    | 1.453                       | 1.028                      |
| 248..255                                 | 31                                    | 1.500                       | 1.061                      |

In addition to the settings in the table the motor current may be switched off completely (free-wheeling) using axis parameter 204 (see TMC3230 firmware manual).



## 6 Functional Description

The TMCM-3230 contains the following main parts:

- 3x TMC5130 combined stepper motor controller and driver
- processor running the TMCL interpreter or the CANopen stack (depending on firmware version)
- non-volatile memory for parameter and TMCL program storage (EEPROM)
- Input and output level shifter / buffer
- USB interface (with micro-USB connector), CAN interface with on-board transceiver and UART interface supporting external RS232, RS422 or RS485 connections
- SPI master interface

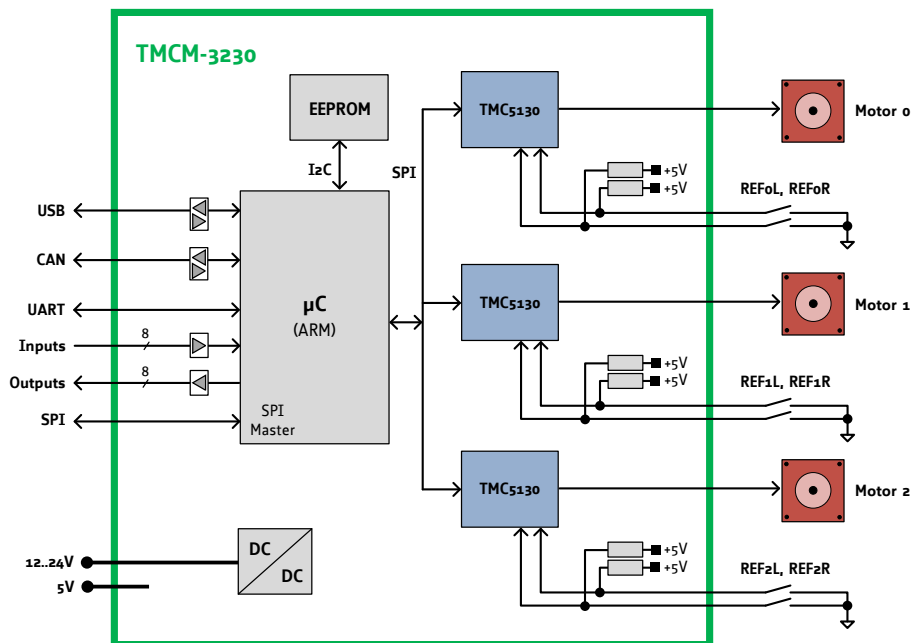


Figure 11: Typical application scenario



## 7 Operational Ratings and Characteristics

### 7.1 Absolute Maximum Ratings

| Parameter                                  | Min               | Max                | Unit |
|--|-------------------|--------------------|------|
| DC Power supply voltage for operation      | 9                 | 28.5               | V    |
| +5V DC input (optional)                    | 4.8               | 5.2                | V    |
| Motor coil current / sine wave <b>peak</b> |                   | 1.4                | A    |
| Continuous motor current ( <b>RMS</b> )    |                   | 1                  | A    |
| Working / environmental temperature        | -30 <sup>*)</sup> | +40 <sup>**)</sup> | ° C  |

Table 5: Absolute Maximum Ratings

<sup>\*)</sup> limited by test equipment. Operation down to -40° C can be expected. Test included cold start at this temperature.

<sup>\*\*)</sup> constant air flow or heat sink (e.g. mounted to the backside of the pcb (Attention: please make sure to isolate heatsink from pcb)) may be required. All components are specified for operation up-to at least +85° C

#### 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 |
|--|------------------------|-----|---------------------|-------------------------|------|
| DC Power supply voltage for operation  | VDD                    | 9   | 12..24              | 28                      | V    |
| Motor coil current / sine wave <b>peak</b> (chopper regulated, adjustable in software) | I <sub>COIL peak</sub> | 0   |                     | 1.4                     | A    |
| Continuous motor current ( <b>RMS</b> )  | I <sub>COIL RMS</sub>  | 0   |                     | 1.0                     | A    |
| Power supply current   | I <sub>DD</sub>        |     | ≪ I <sub>COIL</sub> | 1.4 * I <sub>COIL</sub> | A    |

Table 6: Electrical Characteristics

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

| Parameter                                  | Symbol           | Min | Typ  | Max | Unit |
|--|------------------|-----|------|-----|------|
| Input voltage for general purpose inputs   | V <sub>IN</sub>  | 0   | 0..5 | 5.5 | V    |
| Output voltage for general purpose outputs | V <sub>OUT</sub> | 0   | 0..5 | 5.5 | V    |

Table 7: 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 |
| Working temperature | tbd   |

*Table 8: Other Requirements and Characteristics*

## 8 Abbreviations used in this Manual

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

*Table 9: Abbreviations used in this Manual*



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## 11 Supplemental Directives

### 11.1 Producer Information

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## 12 Revision History

### 12.1 Hardware Revision

| Version | Date        | Author | Description   |
|---------|-------------|--------|---|
| 1.00    | 2016-JUN-30 | GE     | Initial prototpyes.   |
| 1.10    | 2016-NOV-11 | GE     | Major redesign.   |
| 1.20    | 2107-FEB-28 | GE     | Minor corrections in order to improve compatibility with previous generation TMCM-343 / TMCM-303    |
| 1.30    | 2017-APR-12 | GE     | Power supply buffer capacitors added and mounting holes for heatsink removed. First series version. |

Table 10: Hardware Revision

### 12.2 Document Revision

| Version | Date        | Author | Description   |
|---------|-------------|--------|---|
| 0.90    | 2016-DEC-12 | GE     | Initial release.  |
| 0.91    | 2017-JUL-12 | GE     | New hardware version added. Infos for series version added. |
| 0.92    | 2017-SEP-05 | GE     | Minimum driver supply voltage adapted to series version.    |
| 1.00    | 2017-OCT-10 | OK     | Product picture on first page changed.                      |
| 1.10    | 2017-NOV-02 | GE     | Size of module in order codes corrected                     |

Table 11: Document Revision

