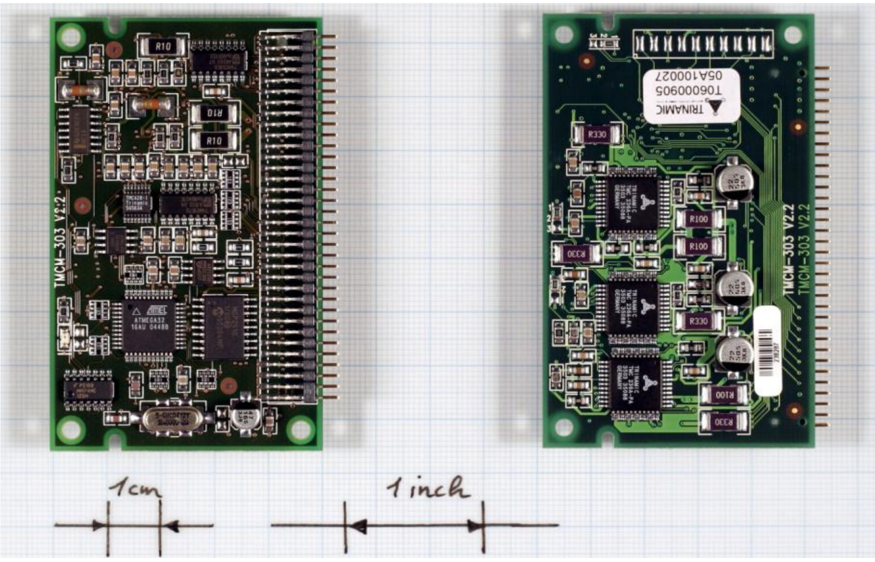
TMCM-303

3 - Axis Stepper Motor Motion Control Module
1.1A / 34V



Manual

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TRINAMIC
MOTION CONTROL

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Table of Contents

List of Figures

List of Tables

1 Features

The TMCM-303 is a compact and versatile triple axis 2-phase stepper motor controller and driver module. It provides a complete motion control solution at a very small size for embedded applications. Using the integrated additional I/Os it even can do complete system control applications. The board can be connected to a baseboard or customized electronics with a pin connector. The TMCM-303 comes with the PC based software development environment TMCL-IDE. Using predefined TMCL (Trinamic Motion Control Language) high level commands like "move to position" or "constant rotation" rapid and fast development of motion control applications is guaranteed. Host communication is possible via the serial UART interface (e.g. using a RS-232 or RS-485 level shifter) or via CAN. All time critical operations, e.g. ramp calculation are performed onboard. A user TMCL program can be stored in the on board EEPROM for stand-alone operation. The firmware of the module can be updated via the serial interface. With the optional StallGuard™ feature it is possible to detect overload and stall of the motor.

Applications
- Controller / driver board for control of up to 3 Axis
- Versatile possibilities of applications in stand alone or pc controlled mode

Motor type
- Coil current from 300mA to 1.1A RMS (1.5A peak)
- 8V to 34V nominal supply voltage

Highlights
- Automatic ramp generation in hardware
- StallGuard™ option for sensorless motor stall detection
- Full step frequencies up to 20kHz
- On the fly alteration of motion parameters (e.g. position, velocity, acceleration)
- Local reference move using sensorless StallGuard™ feature or reference switch
- Coil current adjustable by software
- Up to 16 times microstepping
- TRINAMIC driver technology: No heatsink required
- Many adjustment possibilities make this module the solution for a great field of demands

Software
- Stand-alone operation using TMCL or remote controlled operation
- TMCL program storage: 16 KByte EEPROM (2048 TMCL commands)
- PC-based application development software TMCL-IDE included

Other
- 68 pin connector carries all signals
- RoHS compliant latest from 1 July 2006
- Size: 80x50mm²

Order code	Description
TMCM-303/SG (-option)	3-axis controller/driver 1.1 / 34V
Related products	BB-303, TMCM-EVAL
Option	
-H	horizontal pin connector (standard)
-V	vertical pin connector (on request)

Table 1.1: Order codes

2 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.

Information given in this data sheet is believed to be accurate and reliable. However no responsibility is assumed for the consequences of its use nor for any infringement of patents or other rights of third parties, which may result form its use.

Specifications subject to change without notice.

3 Electrical and Mechanical Interfacing

3.1 Dimensions

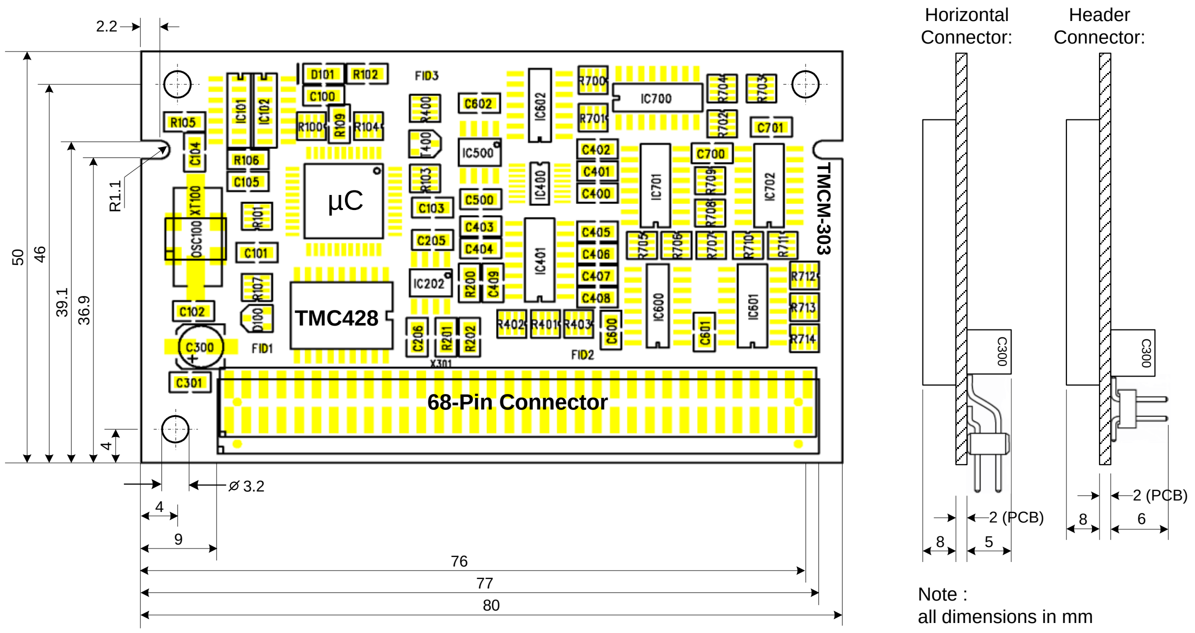

Figure 3.1: Dimensions

The size of the module (80x50mm) is the same as of the other Trinamic motion control modules. It also uses the same connector.
The 68 pin connector has a 2.0mm pitch.

3.2 Connecting the Module

The 68-pin connector provides communication to a host, configuration of the EEPROM and connection of motors as well as connection of reference switches. Pin 1 of this connector is located in the lower left corner on the top site, while the connector is pointing towards the user.

Pin	Direction	Description	Pin	Direction	Description
1	In	+5VDC (+/- 5%) I_{max}=300mA	35	-	Reserved
2	In	GND	36	Out	Motor2 A0
3	In	+5VDC (+/- 5%)	37	-	Reserved
4	In	GND	38	Out	Motor2 A1
5	In	V_Motor (+7 to 34VDC)	39	-	Reserved
6	In	GND	40	Out	Motor2 B0
7	In	V_Motor (+7 to 34VDC)	41	-	Reserved
8	In	GND	42	Out	Motor2 B1
9	In	V_Motor (+7 to 34VDC)	43	-	Reserved
10	In	GND	44	In	Shutdown
11	Out	SPI Select 0	45	In	General Purpose input 0
12	Out	SPI Clock	46	Out	General Purpose output 0
13	Out	SPI Select 1	47	In	General Purpose input 1
14	In	SPI MISO	48	Out	General Purpose output 1
15	Out	SPI Select 2	49	In	General Purpose input 2
16	Out	SPI MOSI	50	Out	General Purpose output 2
17	In	Reset, active low	51	In	General Purpose input 3
18	Out	Alarm	52	Out	General Purpose output 3
19	In	Reference Switch Motor 0 right	53	In	General Purpose input 4
20	Out	Motor0 A0	54	Out	General Purpose output 4
21	In	Reference Switch Motor 0 left	55	In	General Purpose input 5
22	Out	Motor0 A1	56	Out	General Purpose output 5
23	In	Reference Switch Motor 1 right	57	In	General Purpose input 6
24	Out	Motor0 B0	58	Out	General Purpose output 6
25	In	Reference Switch Motor 1 left	59	In	General Purpose input 7
26	Out	Motor0 B1	60	Out	General Purpose output 7
27	In	Reference Switch Motor 2 right	61	In	GND
28	Out	Motor1 A0	62	In	GND
29	In	Reference Switch Motor 2 left	63	-	Reserved
30	Out	Motor1 A1	64	Out	RS-485 Direction
31	-	Reserved	65	InOut	CAN -
32	Out	Motor1 B0	66	In	RS-232 RxD
33	-	Reserved	67	InOut	CAN +
34	Out	Motor1 B1	68	Out	RS-232 TxD

Table 3.1: Pinout 68-Pin Connector

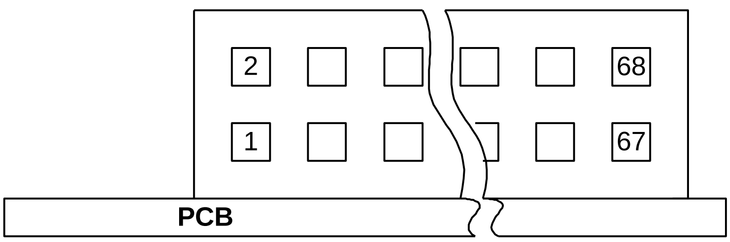

Figure 3.2: Pin order of the connector

3.3 Power supply requirements

Two different power supplies have to be provided for the TMCM-303: +5VDC for the controller part and +7..34VDC for the motor supply. Please connect all listed pins for the power supply inputs and ground in parallel. It is recommended to use capacitors of some 1000µF and a choke close to the module for the motor supply. This ensures a stable power supply and minimizes noise injected into the power supply cables. The choke especially becomes necessary with larger distributed systems using a common power supply.

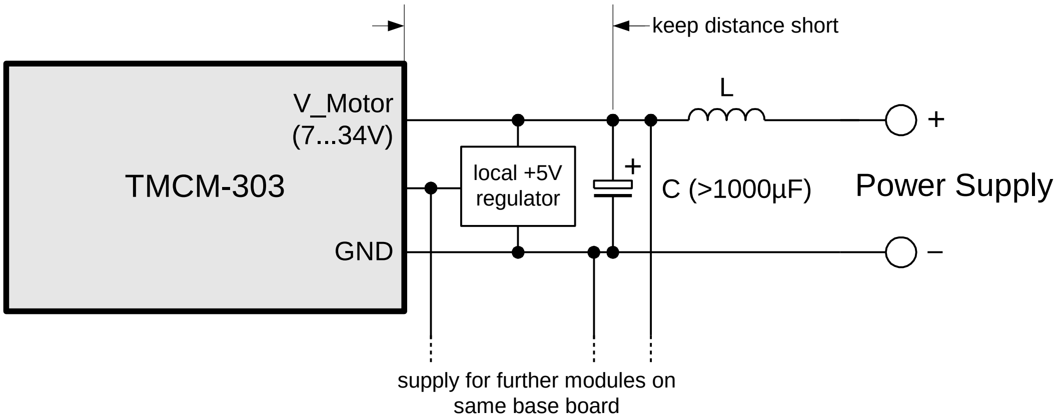

Figure 3.3: Power supply requirements for TMCM-303

Especially with bus controlled systems (e.g. CAN or RS485) it is important to ensure a stable ground potential of all modules. The stepper driver modules draw peak currents of some Ampere from the power supply. It has to be made sure, that this current does not cause a substantial voltage difference on the interface lines between the module and the master, as disturbed transmissions could result.

The following hints help avoiding transmission problems in larger systems. Not all hints have to be followed:

- Use power supply filter capacitors of some 1000µF on the base board for each module in order to take over current spikes. A choke in the positive power supply line will prevent current spikes from changing the GND potential of the base board, especially when a central power supply is used.
- Optionally use an isolated power supply for the TMCM-Modules (no earth connection on the power supply, in case the CAN master is not optically decoupled)
- Do not supply modules with the same power supply which are mounted in a distance of more than a few meters.
- For modules working on the same power supply (especially the same power supply as the master) use a straight and thick, low-resistive GND connection.
- Use a local +5V regulator on each base-board.

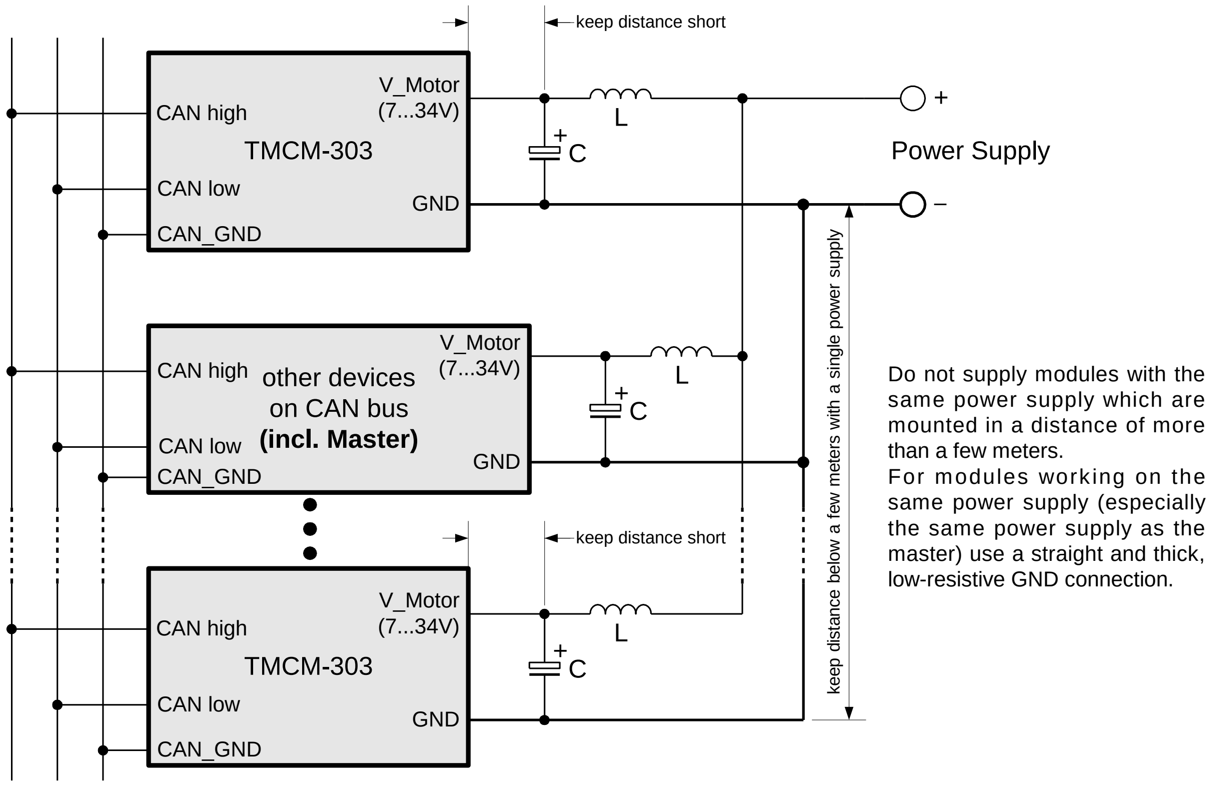

Figure 3.4: Power supply requirements for TMC-Modules in a bus system

For large systems, an optically decoupled CAN bus for each number of nodes, e.g. for each base board with a number of TMCM-30X modules may make sense, especially when a centralized power supply is to be used. Be aware that different ground potentials of the CAN sender (e.g. a PC) and the power supply may damage the modules. Please make sure that the GND lines of the CAN sender and the module(s) and power supplies are connected by a cable.

4 Operational Ratings

The operational ratings show the intended / the characteristic range for the values and should be used as design values. In no case shall the maximum values be exceeded.

Symbol	Parameter	Min	Typ	Max	Unit
V_S	DC Power supply voltage for operation	7	12 … 28	34	V
V_{+5V}	+5V DC input (max. 50mA / no OUT load)	4.8	5.0	5.2	V
I_{COIL}	Motor coil current for sine wave peak (chopper regulated, adjustable via software)	0	0.3 … 1.5	1.5	A
f_{CHOP}	Motor chopper frequency		36.8		kHz
I_S	Power supply current (per motor)		<< I_{COIL}	1.4 * I_{COIL}	A
V_{INPROT}	Input voltage for StopL, StopR, GPIo (internal protection diodes)	-0.5	0 … 5	V_{+5V}+0.5	V
V_{ANA}	INx analog measurement range		0 … 5		V
V_{INLO}	INx, StopL, StopR low level input		0	0.9	V
V_{INHI}	INx, StopL, StopR high level input (integrated 10k pullup to +5V for Stop)	2	5		V
I_{OUTI}	OUTx max +/- output current (CMOS output) (sum for all outputs max. 50mA)			+/-20	mA
T_{ENV}	Environment temperature at rated current (no cooling)	-40		+80	°C

Table 4.1: Operational Ratings

5 Functional Description

In Figure 5.1 the main parts oft the TMCM-303 module are shown. The module mainly consists of a TMC428 motion controller, three TMC236 or TMC246 stepper motor driver, the TMCL program memory (EEPROM) and the host interfaces (RS-232, RS-485 and CAN).

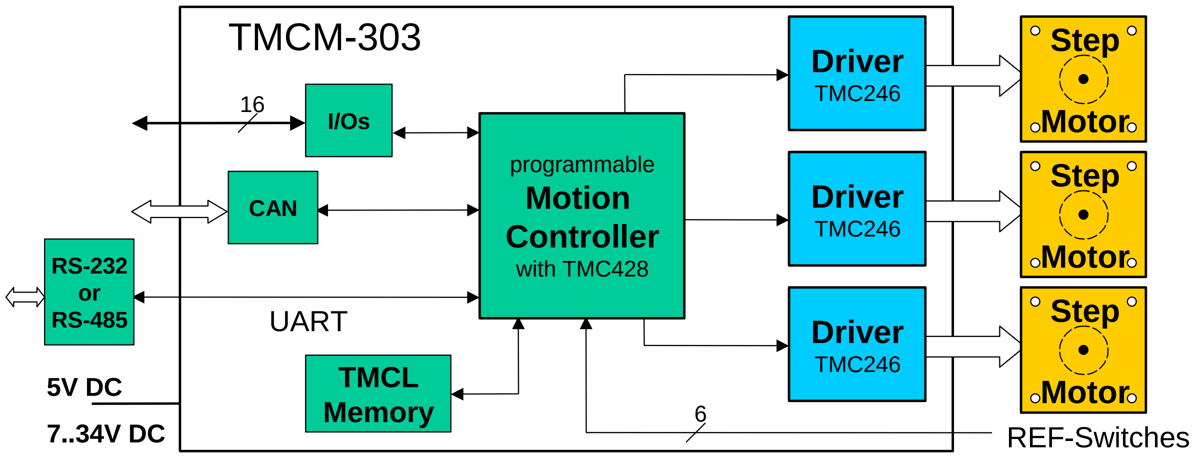

Figure 5.1: Main parts of the TMCM-303

5.1 System Architecture

The TMCM-303 integrates a microcontroller with the TMCL (Trinamic Motion Control Language) operating system. The motion control real-time tasks are realized by the TMC428.

5.1.1 Microcontroller

On this module, the Atmel ATmega32 is used to run the TMCL operating system and to control the TMC428. The CPU has 32Kbyte flash memory and a 1Kbyte EEPROM. The microcontroller runs the TMCL (Trinamic Motion Control Language) operating system which makes it possible to execute TMCL commands that are sent to the module from the host via the RS232, RS-485 and CAN interface. The microcontroller interprets the TMCL commands and controls the TMC428 which executes the motion commands.
The flash ROM of the microcontroller holds the TMCL operating system and the EEPROM memory of the microcontroller is used to permanently store configuration data.
The TMCL operating system can be updated via the RS232 interface. Use the TMCL IDE to do this.

5.1.2 TMCL EEPROM

To store TMCL programs for stand alone operation the TMCM-303 module is equipped with a 16kByte EEPROM attached to the microcontroller. The EEPROM can store TMCL programs consisting of up to 2048 TMCL commands.

5.1.3 TMC428 Motion Controller

The TMC428 is a high-performance stepper motor control IC and can control up to three 2-phase-stepper-motors. Motion parameters like speed or acceleration are sent to the TMC428 via SPI by the microcontroller. Calculation of ramps and speed profiles are done internally by hardware based on the target motion parameters.

5.1.4 Stepper Motor Drivers

On TMCM-303 modules with StallGuard option (TMCM-303/SG) the TMCM246 chips are used. These chips are fully compatible with the TMC236 chips, but have the additional StallGuard feature.
As the power dissipation of the TMC236 and TMC246 chips is very low no heat sink or cooling fan is needed. The temperature of the chips does not get high. The coils will be switched off automatically when the temperature or the current exceeds the limits and automatically switched on again when the values are within the limits again.
Discontinued product: The stepper motor drivers used on the TMCM-303 without the StallGuard options were the TMC236 chips. These drivers are very easy to use. They can control the currents for the two phases of the stepper motors. 16x microstepping and maximum output current of 1500mA are supported by these driver ICs.

5.2 Power Supply

Two different power supplies have to be provided for the TMCM-303. First +5VDC for module functionality and second +7..34VDC for the motor supply. Please use all listed pins for the power supply inputs and ground parallel. Refer to 6 Putting the TMCM-303 into Operation.

Pin	Function
1, 3	+5V DC (+/- 5%), I_{max}=50mA power supply
2, 4	Ground
5, 7, 9	+7..34V DC motor power supply
6, 8, 10	Ground

Table 5.1: Pinning of Power supply

5.3 Motor Connection

Warning: Never connect or disconnect the motors while the TMCM-303 Module is switched on. Doing this will destroy the driver ICs!

The TMCM-303 controls up to three 2-phase stepper motors. The connections between the motors and the 68-pin connector must be done as shown in Table 5.2.

Pin Number	Direction	Name	Motor Numbers and Coils
20	Out	Motor0_A0	Motor #0, Coil A0
22	Out	Motor0_A1	Motor #0, Coil A1
24	Out	Motor0_B0	Motor #0, Coil B0
26	Out	Motor0_B1	Motor #0, Coil B1
28	Out	Motor1_A0	Motor #1, Coil A0
30	Out	Motor1_A1	Motor #1, Coil A1
32	Out	Motor1_B0	Motor #1, Coil B0
34	Out	Motor1_B1	Motor #1, Coil B1
36	Out	Motor2_A0	Motor #2, Coil A0
38	Out	Motor2_A1	Motor #2, Coil A1
40	Out	Motor2_B0	Motor #2, Coil B0
42	Out	Motor2_B1	Motor #2, Coil B1

Table 5.2: Pinout for Motor Connections

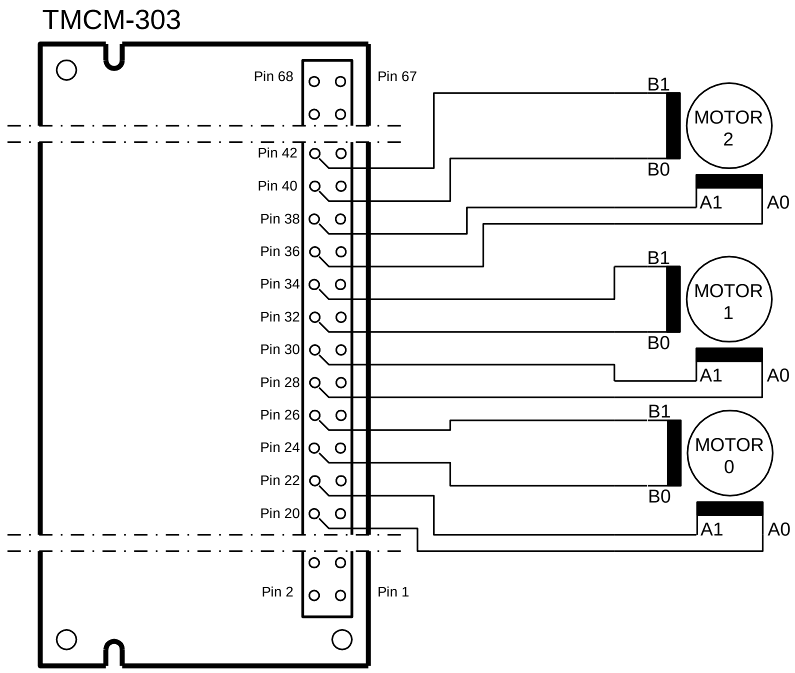

Figure 5.2: Connecting the Motors

5.4 Host Communication

Communication to a host takes place via one or more of the onboard interfaces. The module provides a wide range of different interfaces, like CAN, RS-232 and RS-485. The following chapters explain how the interfaces are connected with the 68-pin connector.

5.4.1 CAN 2.0b

Pin Number	Direction	Name	Limits	Description
65	InOut	CAN -	-8…+18V	CAN Input / Output
67	InOut	CAN +	-8…+18V	CAN Input / Output

Table 5.3: Pinout for CAN Connection

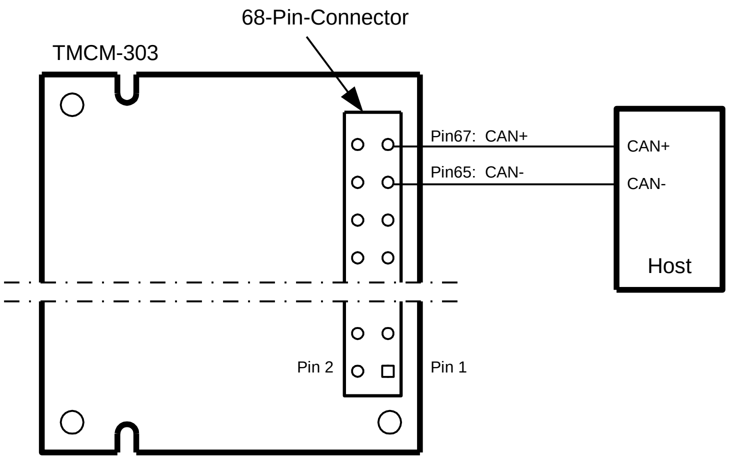

Figure 5.3: Connecting CAN

5.4.2 RS-232

Pin Number	Direction	Name	Limits	Description
66	In	RxD	TTL	RS-232 Receive Data
68	Out	TxD	TTL	RS-232 Transmit Data
2, 4, 6, 8, 10	In	GND	0V	Connect to ground

Table 5.4: Pinout for RS-232 Connection

Note: The RS-232 must be operated with inverted TTL-Levels (0V, 5V). It is recommended to use an inverting level shifter like the MAX202.

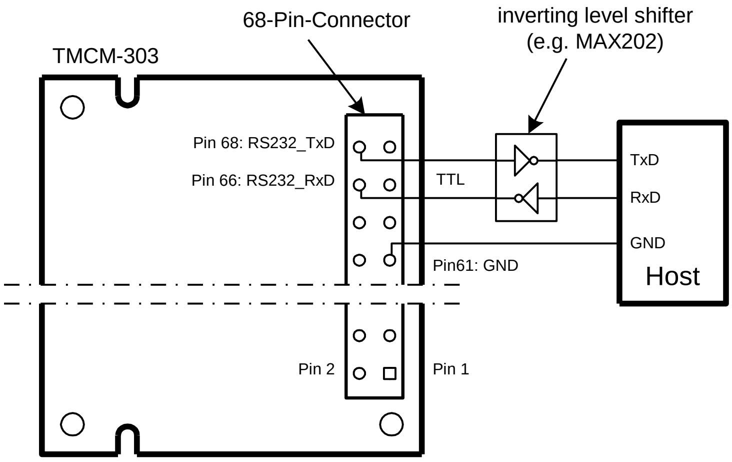

Figure 5.4: Connecting RS-232

5.4.3 RS-485

Pin Number	Direction	Name	Limits	Description
64	Out	RS485_DIR	TTL	Driver / Receiver enable for RS-485 Transceiver. 0: Receiver enable 1: Driver enable
66	In	RxD	TTL	RS-485 Receive Data
68	Out	TxD	TTL	RS-485 Transmit Data
2, 4, 6, 8, 10	In	GND	0V	Connect to ground

Table 5.5: Pinout for RS-485 Connection

Note: The TMCM-303 Module does not contain any RS-485 transceivers!

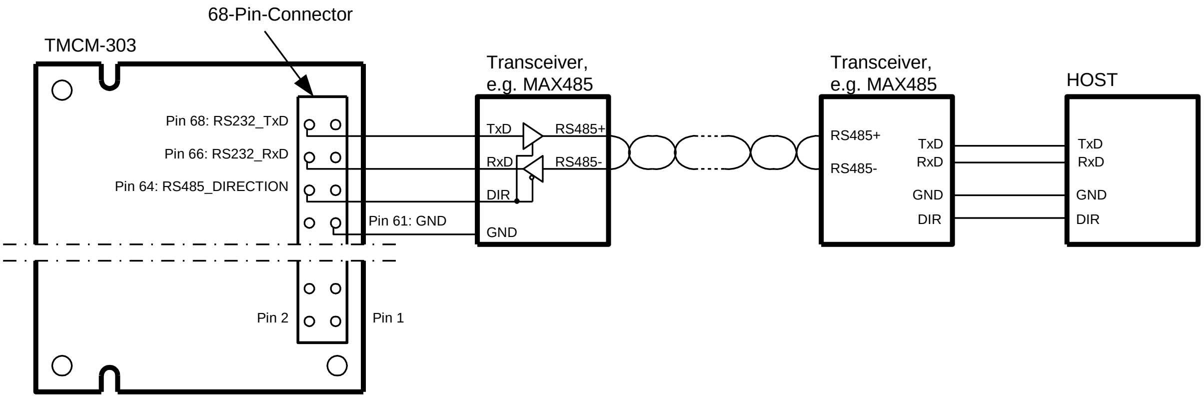

Figure 5.5: Connecting the RS-485 interface

5.5 StallGuard™ - Sensorless Motor Stall Detection

The TMCM-303/SG modules are equipped with the StallGuard option. The StallGuard option makes it possible to detect if the mechanical load on a stepper motor is too high or if the traveler has been obstructed. The load value can be read using a TMCL command or the module can be programmed so that the motor will be stopped automatically when it has been obstructed or the load has been to high.

StallGuard can also be used for finding the reference position without the need for a reference switch: Just activate StallGuard and then let the traveler run against a mechanical obstacle that is placed at the end of the way. When the motor has stopped it is definitely at the end of its way, and this point can be used as the reference position.

To use StallGuard in an actual application, some manual tests should be done first, because the StallGuard level depends upon the motor velocities and on the occurrence of resonances.

Mixed decay should be switched off while StallGuard is turned on in order to get usable results.

Value	Description
0	StallGuard function is deactivated (default)
1..7	Motor stops when StallGuard value is reached

Table 5.6: StallGuard parameter SAP 205

To activate the StallGuard feature use the TMCL-command SAP 205 and set the StallGuard threshold value according to Table 5.6. The actual load value is given by GAP 206. The TMCL IDE has some tools which let you try out and adjust the StallGuard function in an easy way. They can be found at "StallGuard" in the "Setup"-menu and are described in the following chapters.

5.5.1 StallGuard adjusting tool

The StallGuard adjusting tool helps to find the necessary motor parameters when StallGuard is to be used. This function can only be used when a module is connected that features StallGuard. This is checked when the StallGuard adjusting tool is selected in the "Setup" menu. After this has been successfully checked the StallGuard adjusting tool is displayed.

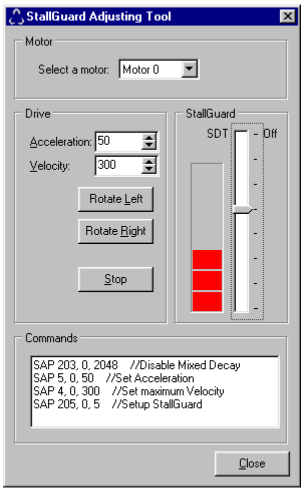

Figure 5.6: StallGuard adjusting tool

First, select the axis that is to be used in the "Motor" area.

Now you can enter a velocity and an acceleration value in the "Drive" area and then click "Rotate Left" or "Rotate Right". Clicking one of these button will send the necessary commands to the module so that the motor starts running. The red bar in the "StallGuard" area on the right side of the windows displays the actual load value. Use the slider to set the StallGuard threshold value. If the load value reaches this value the motor stops. Clicking the "Stop" button also stops the motor.

All commands necessary to set the values entered in this dialogue are displayed in the "Commands" area at the bottom of the window. There, they can be selected, copied and pasted into the TMCL editor.

5.5.2 StallGuard profiler

The StallGuard profiler is a utility that helps you find the best parameters for using stall detection. It scans through given velocities and shows which velocities are the best ones. Similar to the StallGuard adjusting tool it can only be used together with a module that supports StallGuard. This is checked right after the StallGuard profiler has been selected in the "Setup" menu. After this has been successfully checked the StallGuard profiler window will be shown.

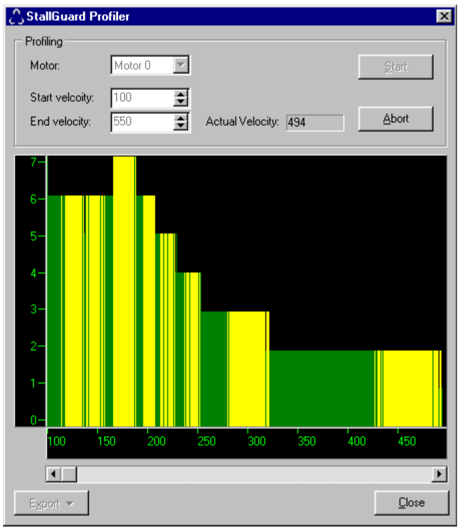

Figure 5.7: The StallGuard Profiler

First, select the axis that is to be used. Then, enter the "Start velocity" and the "End velocity". The start velocity is used at the beginning of the profile recording. The recording ends when the end velocity has been reached. Start velocity and end velocity must not be equal. After you have entered these parameters, click the "Start" button to start the StallGuard profile recording. Depending on the range between start and end velocity this can take several minutes, as the load value for every velocity value is measured ten times. The "Actual velocity" value shows the velocity that is currently being tested and so tells you the progress of the profile recording. You can also abort a profile recording by clicking the "Abort" button.

The result can also be exported to Excel or to a text file by using the "Export" button.

5.5.2.1 The result of the StallGuard profiler

The result is shown as a graphic in the StallGuard profiler window. After the profile recording has finished you can scroll through the profile graphic using the scroll bar below it. The scale on the vertical axis shows the load value: a higher value means a higher load. The scale on the horizontal axis is the velocity scale. The colour of each line shows the standard deviation of the ten load values that have been measured for the velocity at that point. This is an indicator for the vibration of the motor at the given velocity. There are three colours used:

- Green: The standard deviation is very low or zero. This means that there is effectively no vibration at this velocity.
- Yellow: This colour means that there might be some low vibration at this velocity.
- Red: The red colour means that there is high vibration at that velocity.

5.5.2.2 Interpreting the result

In order to make effective use of the StallGuard feature you should choose a velocity where the load value is as low as possible and where the colour is green. The very best velocity values are those where the load value is zero (areas that do not show any green, yellow or red line). Velocities shown in yellow can also be used, but with care as they might cause problems (maybe the motor stops even if it is not stalled).

Velocities shown in red should not be chosen. Because of vibration the load value is often unpredictable and so not usable to produce good results when using stall detection.

As it is very seldom that exactly the same result is produced when recording a profile with the same parameters a second time, always two or more profiles should be recorded and compared against each other.

5.6 Reference switches

With reference switches, an interval for the movement of the motor or the zero point can be defined. Also a step loss of the system can be detected, e.g. due to overloading or manual interaction, by using a travel-switch.

Pin Number	Direction	Name	Limits	Description
19	In	STOP0R	TTL	Right reference switch input for Motor #0
21	In	STOP0L	TTL	Left reference switch input for Motor #0
23	In	STOP1R	TTL	Right reference switch input for Motor #1
25	In	STOP1L	TTL	Left reference switch input for Motor #1
27	In	STOP2R	TTL	Right reference switch input for Motor #2
29	In	STOP2L	TTL	Left reference switch input for Motor #2

Table 5.7: Pinout reference switches

Note: 10k pullup resistors for reference switches are included on the module.

5.6.1 Left and right limit switches

The TMCM-303 can be configured so that a motor has a left and a right limit switch (Figure 5.8). *The motor then stops when the traveler has reached one of the limit switches.*

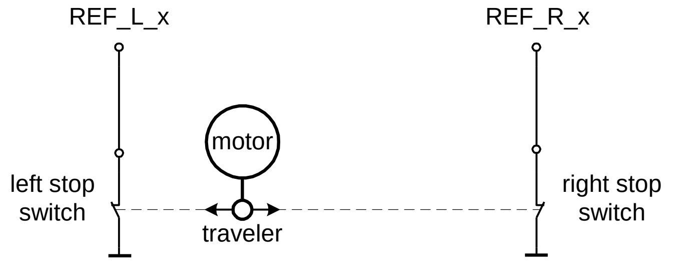

Figure 5.8: Left and right limit switches

5.6.2 Triple Switch Configuration

It is possible to program a tolerance range around the reference switch position. This is useful for a triple switch configuration, as outlined in Figure 5.9. In that configuration two switches are used as automatic stop switches, and one additional switch is used as the reference switch between the left stop switch and the right stop switch. The left stop switch and the reference switch are wired together. The center switch (travel switch) allows for a monitoring of the axis in order to detect a step loss.

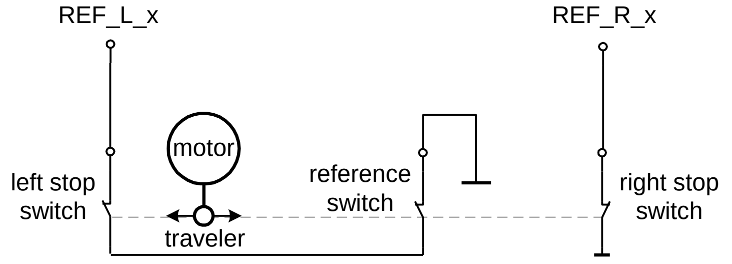

Figure 5.9: Limit switch and reference switch

5.6.3 One Limit Switch for circular systems

If a circular system is used (Figure 5.10), only one reference switch is necessary, because there are no end-points in such a system.

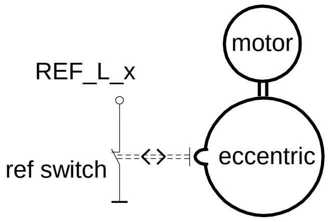

Figure 5.10: One reference switch

5.7 Serial Peripheral Interface (SPI)

On-board communication is performed via the Serial Peripheral Interface (SPI), where the microcontroller acts as master. For adaptation to user requirements, the user has access to this interface via the 68-pin connector. Furthermore three chip select lines can be used for addressing of external devices.

Pin Number	Direction	Name	Limits	Description
11	Out	SPI_SEL0	TTL	Chip Select Bit0
13	Out	SPI_SEL1	TTL	Chip Select Bit1
15	Out	SPI_SEL2	TTL	Chip Select Bit2
12	Out	SPI_CLK	TTL	SPI Clock
14	In	SPI_MISO	TTL	SPI Serial Data In
16	Out	SPI_MOSI	TTL	SPI Serial Data Out

Table 5.8: Pinout Serial Peripheral Interface

5.8 Port Expansion

For further expansion and adaptation to user requirements the module provides a port expansion for the microcontroller. The expansion includes eight TTL input pins and eight TTL output pins, which are accessible via the 68-pin connector.

Pin Number	Direction	Name	Limits	Description
45	In	INP_0	TTL	Port expansion Pin 0, input
47	In	INP_1	TTL	Port expansion Pin 1, input
49	In	INP_2	TTL	Port expansion Pin 2, input
51	In	INP_3	TTL	Port expansion Pin 3, input
53	In	INP_4	TTL	Port expansion Pin 4, input
55	In	INP_5	TTL	Port expansion Pin 5, input
57	In	INP_6	TTL	Port expansion Pin 6, input
59	In	INP_7	TTL	Port expansion Pin 7, input
46	Out	Out_0	TTL	Port expansion Pin 0, output
48	Out	Out_1	TTL	Port expansion Pin 1, output
50	Out	Out_2	TTL	Port expansion Pin 2, output
52	Out	Out_3	TTL	Port expansion Pin 3, output
54	Out	Out_4	TTL	Port expansion Pin 4, output
56	Out	Out_5	TTL	Port expansion Pin 5, output
58	Out	Out_6	TTL	Port expansion Pin 6, output
60	Out	Out_7	TTL	Port expansion Pin 7, output

Table 5.9: Pinout port expansion

5.9 Miscellaneous Connections

Pin Number	Direction	Name	Limits	Description
17	In	Reset	TTL	Reset, active low
18	Out	Alarm	TTL	Alarm, active high
44	In	Shutdown	TTL	Shutdown TMCM-303

Table 5.10: Miscellaneous Connections

5.10 Microstep Resolution

The microstep resolution can be set using TMCL software. The default setting is 64 microsteps which is the highest resolution.
To set the microstep resolution with TMCL use instruction 5: SAP, type 140: microstep resolution. You can find the appropriate value in Table 5.11.

Value	microsteps
0	Do not use: for fullstep please see "fullstep threshold"
1	Halfstep (not recommended)
2	4
3	8
4	16
5	32
6	64

Table 5.11: Microstep resolution setting

Despite the possibility to set up to 64 microsteps, the motor physically will be positioned to a maximum of about 24 Microsteps, when operated in 32 or 64 microstep setting.

6 Putting the TMCM-303 into Operation

On the basis of a small example it is shown step by step how the TMCM-303 is set into operation. Experienced users could skip this chapter and proceed to chapter 7:

Example: The following application is to implement with the TMCL-IDE Software development environment in the TMCM-303 module. For data transfer between the host PC and the module the RS-232 interface is employed.

A formula how "speed" is converted into a physical unit like rotations per seconds can be found in Calculation: Velocity and Acceleration vs. Microstep- and Fullstep-Frequency

- Turn Motor 0 left with speed 500
- Turn Motor 1 right with speed 500
- Turn Motor 2 with speed 500, acceleration 5 and move between position +10000 and –10000.

Step 1: Connect the RS-232 Interface as specified in 5.7.

Step 2: Connect the motors as specified in 5.3.

Step 3: Connect the power supply.
+5 VDC to pins 1 or 3
Ground to pins 2, 4, 6, 8 or 10

Step 4: Connect the motor supply voltage
+10 to 30 VDC to pins 5, 7, 9

Step 5: Switch on the power supply and the motor supply. An on-board LED should starting to flash. This indicates the correct configuration of the microcontroller.

Step 6: Start the TMCL-IDE Software development environment. Open file test2.tmc. The following source code appears on the screen:
A description for the TMCL commands can be found in Appendix A.

```
//test2.tmc – A simple example for using TMCL and TMCL-IDE

        SAP Mode, 0, VelocityMode   //Set velocity Mode
        ROL 0, 500                  //Rotate motor with speed 500
        WAIT TICKS, 0, 500
        MST 0
        SAP Mode, 1, VelocityMode   //Set velocity Mode
        ROR 1, 500                  //Rotate to other direction with same speed
        WAIT TICKS, 0, 500
        MST 1

        SAP Mode, 2, RampMode       //Set Ramp Mode
        SAP VMax, 2, 500            //Set max. Velocity
        SAP AMax, 2, 5              //Set max. Acceleration
Loop:   MVP ABS, 2, 10000           //Move to Position 10000
        WAIT POS, 2, 0              //Wait until position reached
        MVP ABS, 2, -10000          //Move to Position -10000
        WAIT POS, 2, 0              //Wait until position reached
        JA Loop                     //Infinity Loop
```

Step 7: Click on Icon "*Assemble*" to convert the TMCL into machine code.
Then download the program to the TMCM-303 module via the Icon "Download".

Step 8: Press Icon "Run". The desired program will be executed.

A documentation about the TMCL operations can be found in the TMCL documentation. The next chapter discusses additional operations to turn the TMCM-303 into a high performance motion control system.

7 TMCM-303 Operational Description

7.1 Calculation: Velocity and Acceleration vs. Microstep- and Fullstep-Frequency

The values of the parameters, sent to the TMC428 do not have typical motor values, like rotations per second as velocity. But these values can be calculated from the TMC428-parameters, as shown in this document. The parameters for the TMC428 are:

Signal	Description	Range
f_{CLK}	clock-frequency	0..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..7 (a value of 7 is internally mapped to 6 by the TMC428)

Table 7.1: TMC428 Velocity parameters

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

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

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

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

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

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

This results in an acceleration in fullsteps of:

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

Example:
f_CLK = 16 MHz
velocity = 1000
a_max = 1000
pulse_div = 1
ramp_div = 1
usrs = 6

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

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

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

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

If the stepper motor has e.g. 72 fullsteps per rotation, the number of rotations of the motor is:

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

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

8 TMCL

TMCL, the TRINAMIC Motion Control Language, is described in a separate documentation, the TMCL Reference and Programming Manual. This manual is provided on the TMC TechLib CD and on the web site of TRINAMIC: www.trinamic.com.
Please refer to these sources for updated data sheets and application notes.

The TMC TechLib CD-ROM including data sheets, application notes, schematics of evaluation boards, software of evaluation boards, source code examples, parameter calculation spreadsheets, tools, and more is available from TRINAMIC.

9 Revision History

9.1 Documentation Revision

Version	Date	Author	Description
0.1	01.07.2002	ME/AR	Initial Version
1.00	19.05.2003	OK	Some figures corrected
1.01	23.07.2003	OK	Pin assignments corrected
1.02	19.08.2003	OK	Slight corrections
1.04	03.09.2003	OK	Error corrections
1.05	01.10.2004	OK	Company address changed
1.06	13.02.2005	OK	Ordering information added
1.07	03.06.2005	OK	Error in table 1 corrected
1.10	19.05.2006	HC	Major Revision, StallGuard documentation added
1.11	21.02.2007	HC	Added 2.0mm pitch connector information
1.12	30.05.2007	HC	TMCM-303/SG replaces TMCM-303 (discontinued)
1.13	20.06.2007	HC	Added chapter 5.10 Microstep Resolution
1.14	08.08.2007	HC	RS232 interface (page 13): use inverting level shifter
1.15	17.10.2007	HC	Power supply requirements added (chapter 3.3)
1.16	24.6.2009	OK	Chapter 5.5 corrected

Table 9.1: Documentation Revisions

9.2 Firmware Revision

Version	Comment	Description
3.24	Initial Release	Please refer to TMCL documentation

Table 9.2: Firmware Revisions