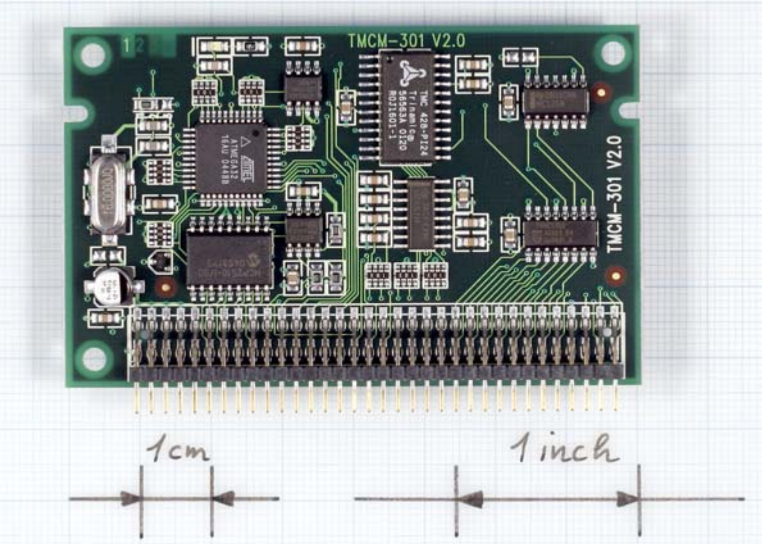
TMCM-301

3 - Axis Controller Module
for SPI drivers



Manual

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1 Features

The TMCM-301 is a triple axis stepper motor controller module for external power drivers with SPI interface. With its very small size it is dedicated to embedded applications, where a compact solution is required. The board can be connected to a baseboard or customized electronics with a pin connector. The TMCM-301 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. The TMCM-301 can be controlled via the serial UART interface (e.g. using a RS-232 or RS-485 level shifter) or via CAN. A user TMCL program can be stored in the on board EEPROM for stand-alone applications. Communication traffic is kept very low since all time critical operations, e.g. ramp calculation, are performed on board. The TMCL operations can be stored in the onboard EEPROM for stand- alone operation. The firmware of the module can be updated via the serial interface.

Applications

- Controller board for control of up to 3 two-phase bipolar motors using SPI drivers (e.g. TMCM-035 or TMC249)
- Versatile possibilities of applications in stand alone or pc controlled mode

Electrical Data

- 5V DC logic power supply

Interface

- RS-232, RS-485 or CAN 2.0b host interface
- Inputs for reference and stop switches, general purpose analog and digital I/Os

Highlights

- Up to 64 times microstepping
- Automatic ramp generation in Hardware
- On the fly alteration of motion parameters (e.g. position, velocity, acceleration)
- High dynamics: full step frequencies up to 90kHz, microstep frequency up to 460kHz
- Supports StallGuard™ option for sensorless motor stall detection
- Can be adapted to any SPI driver type

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 (2*34 pins, 2mm pitch)
- RoHS compliant latest from 1 July 2006
- Size: 80x50mm²

Order code	Description
TMCM-301 (-option)	3-axis controller module with SPI out
Related products	BB-301, TMCM-EVAL, BB-323-02
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.

3 Electrical and Mechanical Interfacing

3.1 Dimensions

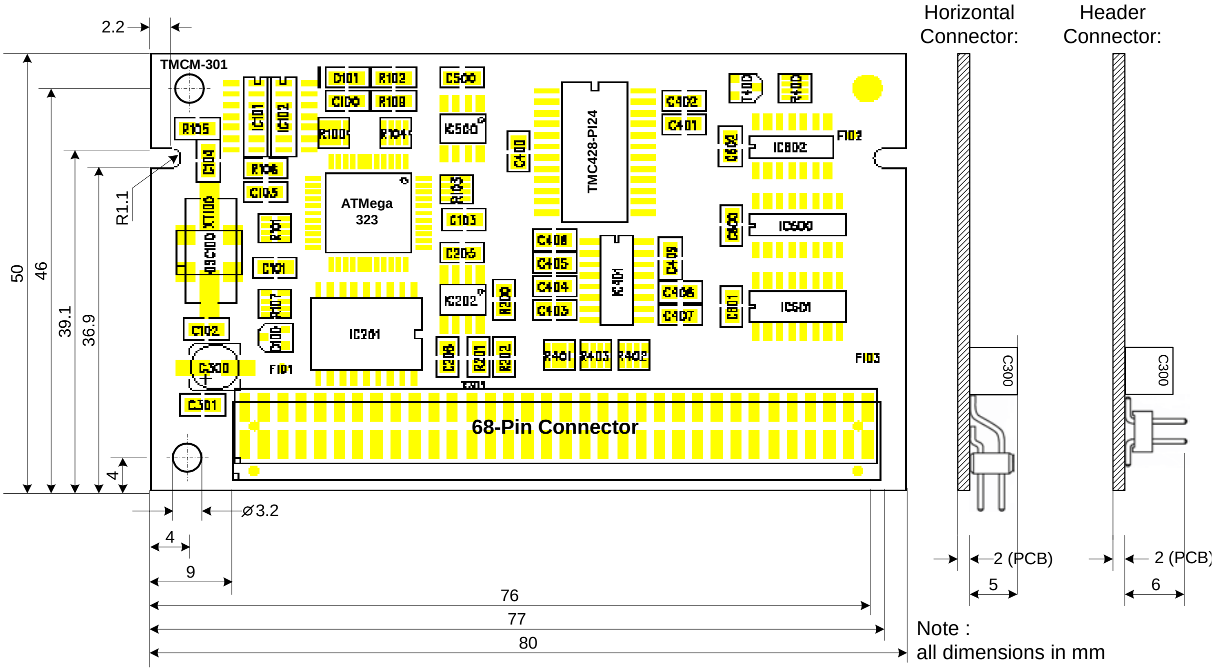


Figure 3.1: Dimensions

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 step / direction drivers 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}=50mA	35	Out	PWM output motor 3
2		GND	36	-	Reserved
3	In	+5VDC (+/- 5%)	37	-	Reserved
4		GND	38	-	Reserved
5		Internally not connected	39	-	Reserved
6		GND	40	-	Reserved
7		Internally not connected	41	-	Reserved
8		GND	42	-	Reserved
9		Internally not connected	43	-	Reserved
10		GND	44	-	Reserved
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	nSCS0	54	Out	General Purpose output 5
21	In	Reference Switch Motor 0 left	55	In	General Purpose input 5
22	Out	nSCS1	56	Out	General Purpose output 6
23	In	Reference Switch Motor 1 right	57	In	General Purpose input 6
24	Out	nSCS2	58	Out	General Purpose output 7
25	In	Reference Switch Motor 1 left	59	In	General Purpose input 7
26	Out	SDO_S	60	Out	General Purpose
27	In	Reference Switch Motor 2 right	61		GND
28	In	SDI_S	62		GND
29	In	Reference Switch Motor 2 left	63	-	Reserved
30	Out	SCK_S	64	Out	RS-485 Direction
31	Out	PWM output motor 1	65	InOut	CAN -
32	Out	Shutdown	66	In	RS-232 RxD
33	Out	PWM output motor 2	67	InOut	CAN +
34	-	Reserved	68	Out	RS-232 TxD

Table 3.1: Pinout 68-Pin Connector

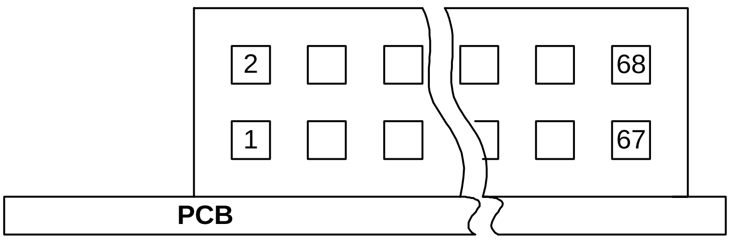


Figure 3.2: Pin order of the connector

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_{+5V}	+5V DC input (max. 300mA)	4.75	5.0	5.25	V
f_{STEP}	Maximum fullstep frequency			90	kHz
$f_{MICROSTEP}$	Maximum microstep frequency			460	kHz
V_{INPROT}	Input voltage for StopL, StopR, GPI0 (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		+70	°C

Table 4.1: Operational Ratings

5 Functional Description

In Figure 5.1 the main parts oft the TMCM-301 module are shown. The module mainly consists of a TMC428 motion controller, the TMCL program memory (EEPROM) and the host interfaces (RS-232, RS-485 and CAN).

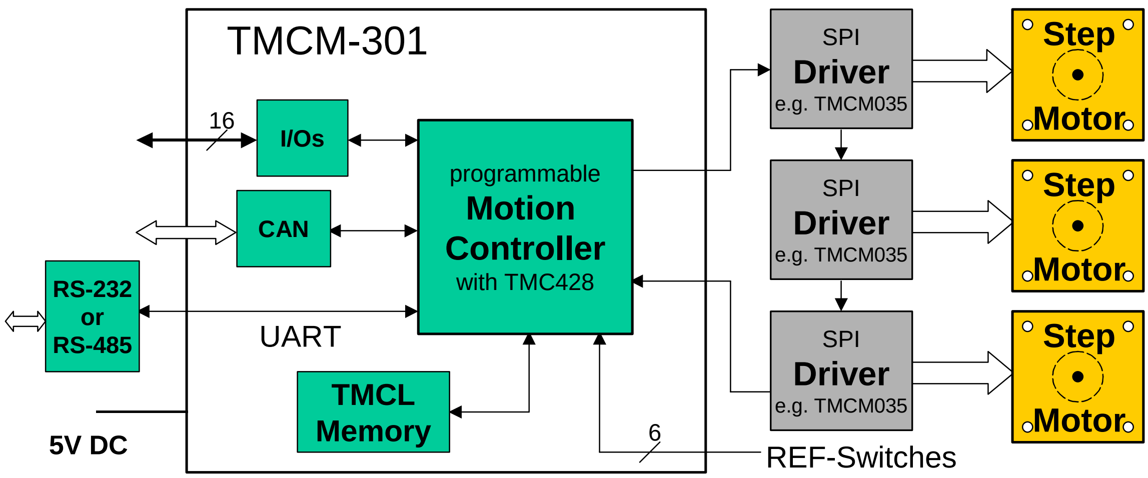


Figure 5.1: Main parts of the TMCM-301

5.1 System Architecture

The TMCM-301 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 communicate with the host and the EEPROM 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. These commands are interpreted by the microcontroller and then converted into SPI-datagrams which are then sent to the TMC428.
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 Interface to the external drivers

Drivers are not included on the module. To drive stepper motors with this module, stepper motor drivers have to be added externally. The drivers are attached via an SPI interface.

5.2 Power Supply

The power supply for the TMCM-301 is +5VDC for module functionality. Please use all listed pins for the power supply inputs and ground in parallel. Refer to chapter 6 Putting the TMCM-301 into Operation.

Pin	Function
1, 3	+5V DC (+/- 5%), I_{max}=50mA power supply (plus current required for outputs)
2, 4, 6, 8, 10	Ground

Table 5.1: Pinning of Power supply

5.3 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.

5.3.1 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 5.2: Pinout for CAN Connection

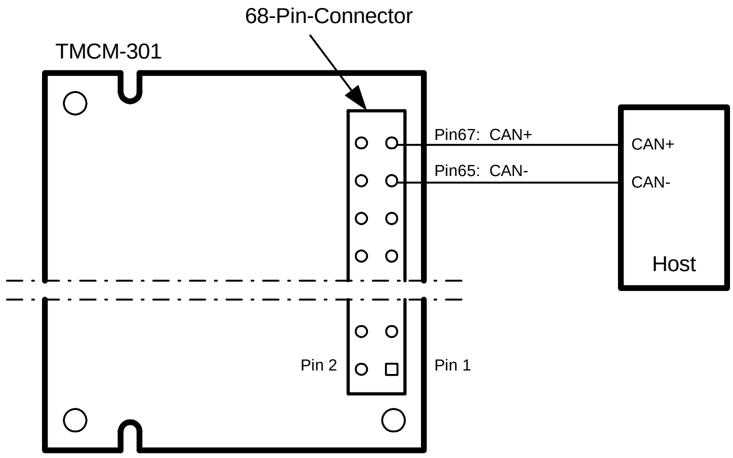


Figure 5.2: Connecting CAN

5.3.2 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 5.3: Pinout for RS-232 Connection

Note: The RS-232 must be operated with TTL-Levels (0V, 5V), since there is no level shifter onboard!

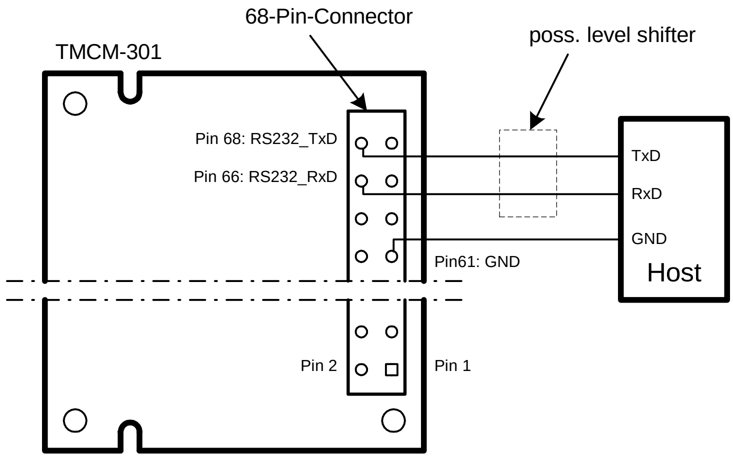


Figure 5.3: Connecting RS-232

5.3.3 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 5.4: Pinout for RS-485 Connection

Note: The TMCM-301 Module does not contain any RS-485 transceivers!

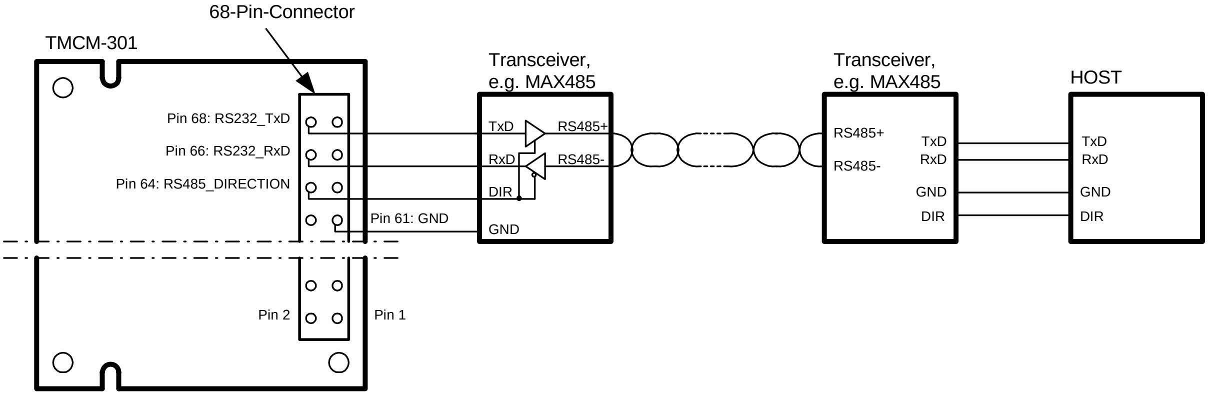


Figure 5.4: Connecting the RS-485 interface

Via RS-485 Interface it is possible to build up systems with of 31 (with repeater 254) modules, which are adressable by one host.

5.4 Connecting the drivers

Because there are no stepper motor drivers included on the TMCM-301, an add-on-board with drivers has to be developed to drive the stepper motors. An example with one of Trinamic´s driver IC TMC249 and driver module TMCM-035 is added below. Please refer to www.trinamic.com for more information (compare TMCM-302 with step / direction interface).
By factory default the TMCM-301 module is configured for use with the motor drivers Trinamic TMC236, TMC246, TMC239 or TMC249. For other drivers and for advanced settings use the "Configure Module" function of the TMCL IDE to configure the module.

The pins connecting the TMCM-301 with the add-on-board using the SPI-Interface are listed in Table 5.5.

Pin Number	Direction	Name	Limits	Description
20	Out	nSCS0	TTL	Chip Select for Driver 0
22	Out	nSCS1	TTL	Chip Select for Driver 1
24	Out	nSCS2	TTL	Chip Select for Driver 2
26	Out	SDO_S	TTL	Data output for SPI (tristate)
28	In	SDI_S	TTL	Data input for SPI
30	Out	SCK_S	TTL	Clock input for SPI

Table 5.5: Pinout for the connections using the SPI-Interface

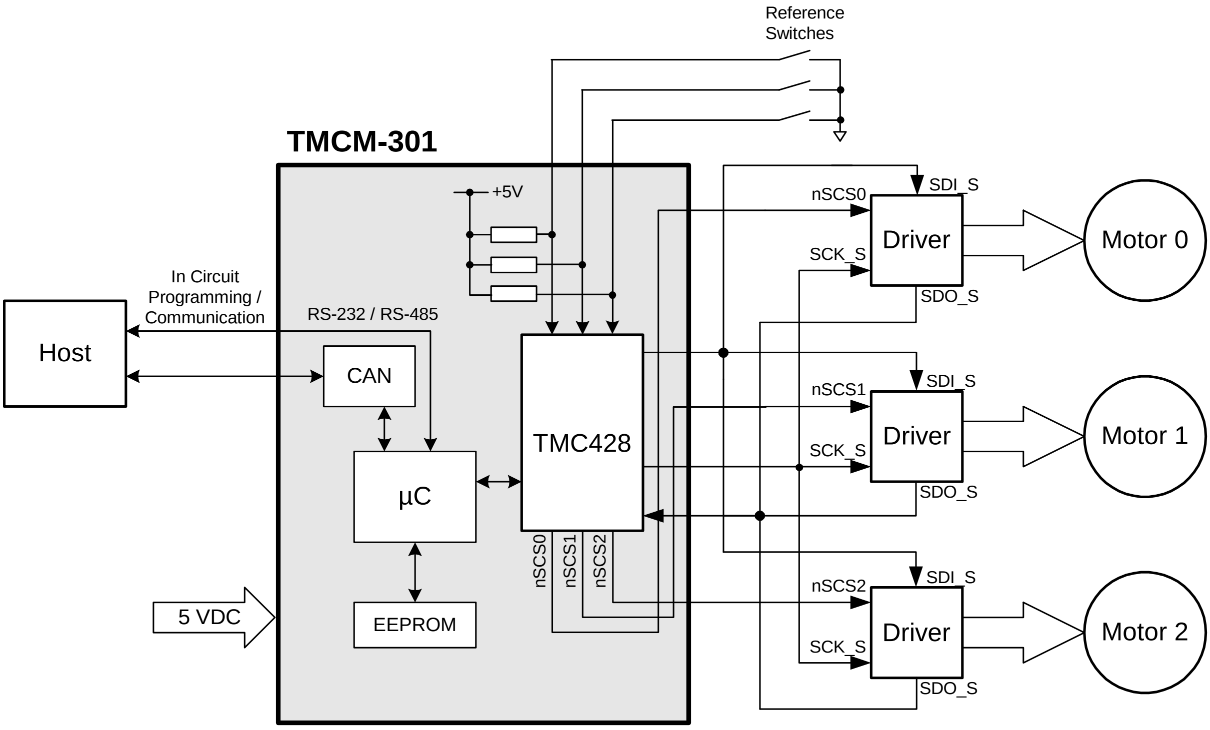


Figure 5.5: Application Environment using the SPI-Interface

With different chip selects for each driver the SPI data lines SDI_S and SDO_S have to be connected in parallel to the TMCM-301.

Example : Using the TMC249 stepper motor driver with an SPI-interface. Please see Trinamic´s driver module TMCM-035 on www.trinamic.com. The baseboard BB-301 provides an easy way to combine one TMCM-301 with up to three TMCM-035 driver modules.

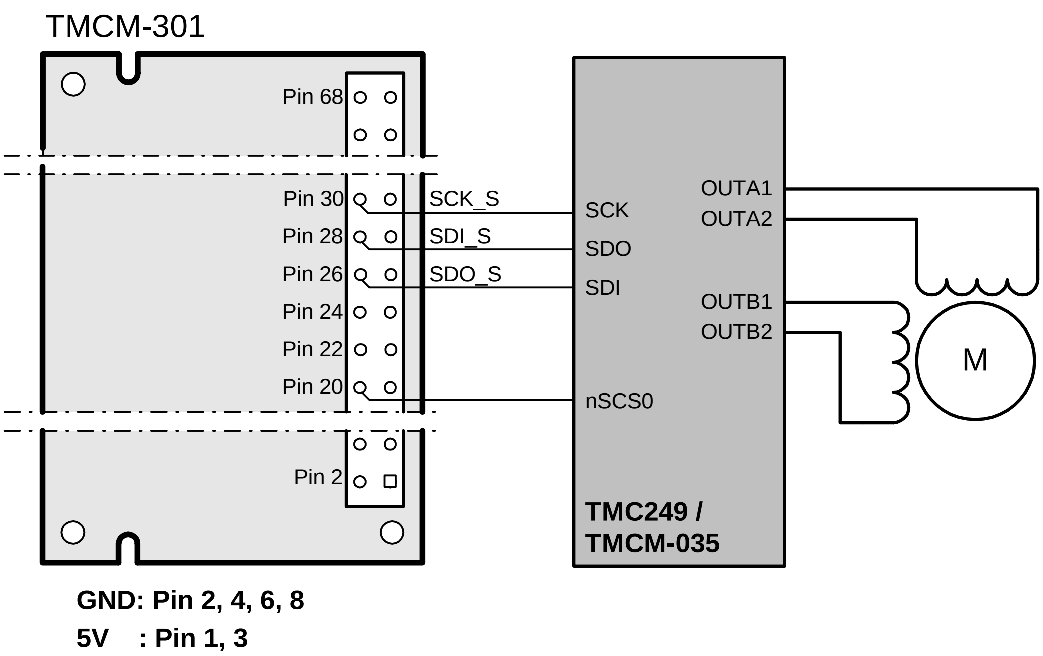


Figure 5.6: Application with one SPI-stepper motor driver

Table 5.6 shows how to connect a TMCM-035 to the TMCM-301. The SPI pins of the TMCM-035 are directly connected to the onboard driver chip TMC239 or TMC249 (refer to Figure 5.6).

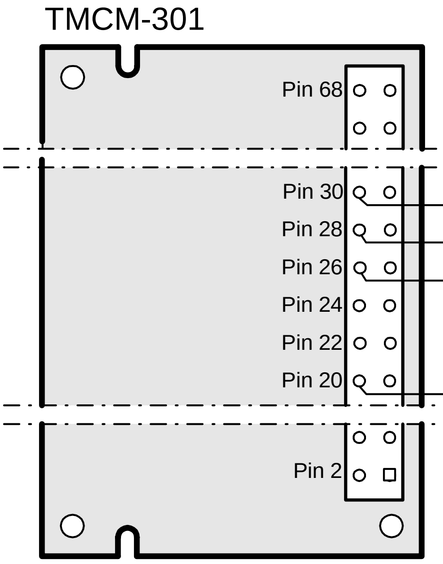
TMCM-035 pin number	TMCM-301 pin number	Signal name (TMCM-035)
1, 3	1, 3	+5V
2, 4, 6, 8, 10	2, 4, 6, 8, 10	GND
11	--	Enable, connect to GND
12	30	CLK
13	20	CSN
14	28	SDO
16	26	SDI

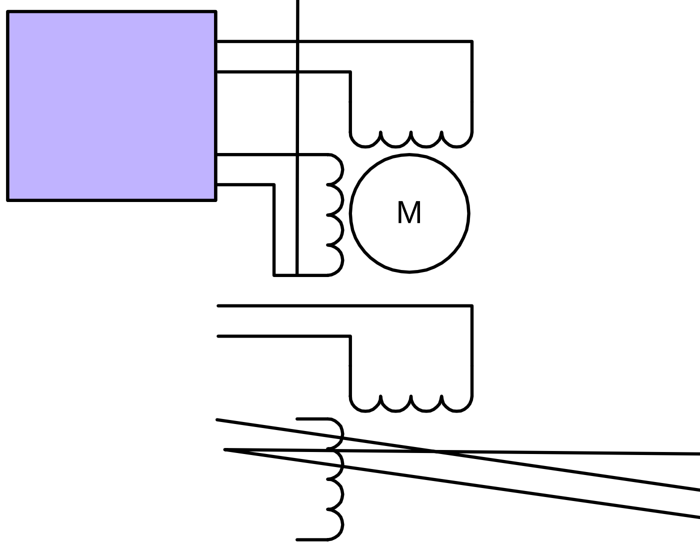
Table 5.6: Connecting a TMCM-035 to the TMCM-301

Using three drivers with a 64x microstep resolution the status bits for the last module are not readable. 3*20 bits are sent back but only 48 bits can be read out. So it is possible to use only two TMCM-035 with 64 microsteps or three TMCM-035 where one has 64x and two 16x microstep resolution.
It is not possible to use separate chip selects with 64x microstep resolution and the TMCM-035. The drivers / modules have to be cascaded.
The bit named cs_Comm_Ind (in TMCL-IDE menu “Setup - Configure module” and tab “Drivers(TMCM-301)”) defines either if a single chip select signal nSCS_S is used in common for all stepper motor driver chips or three chip select signals nSCS0, nSCS1, nSCS2 are used to select the stepper motor driver chips individually. The one common chip select signal nSCS_S is used if the bit named cs_Comm_Ind = ‘0’.

Refer to [TMCM-035] and [TMC236/239/246/249 FAQ] for information how to use 64x microstepping with the TMCM-035.

Example : Using three TMC249 stepper motor drivers in a row with an SPI-interface the TMC drivers have to be controlled with only one chip select for all drivers. If a TMC driver is unselected its SDO line will become tri-stated. This is the same for three TMCM-035, too.





GND: Pin 2, 4, 6, 8
5V : Pin 1, 3

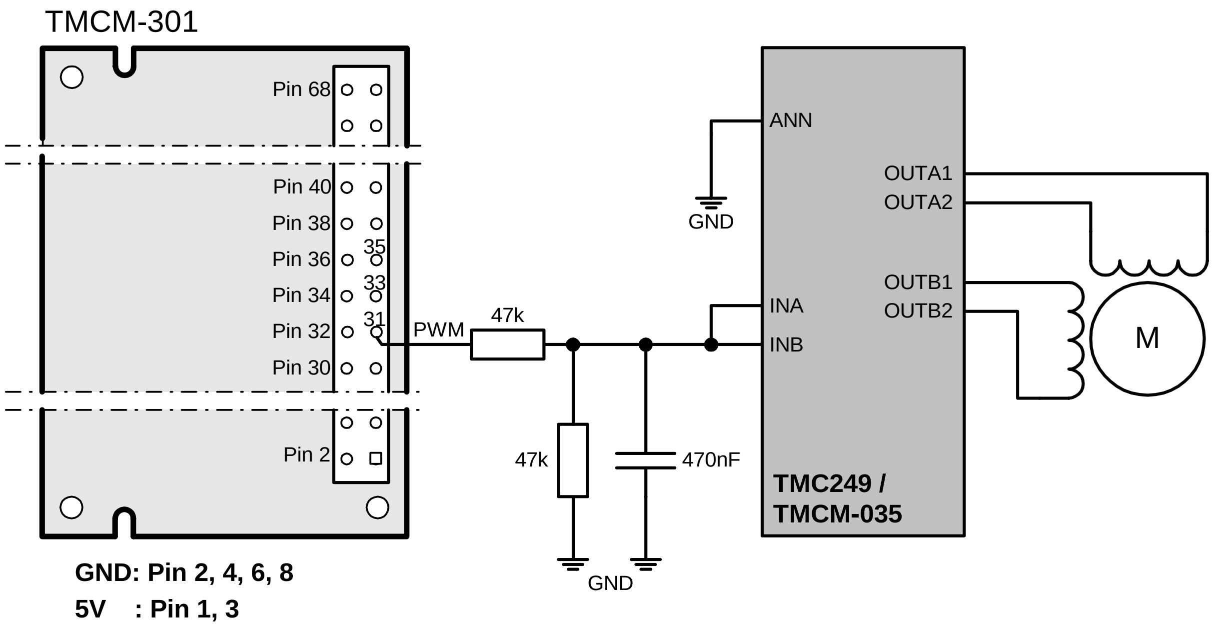


Figure 5.8: Application example for a TMCM-301 with analog current control

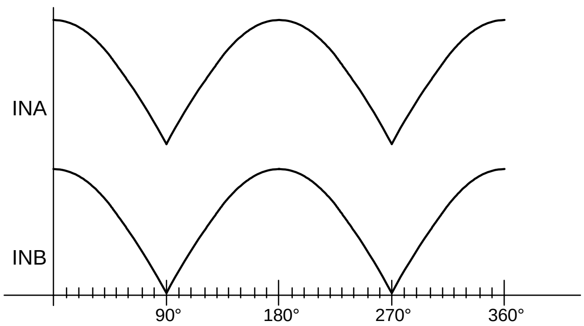


Figure 5.9: Waves for example with analog current control

5.6 Ramp Profiles

The speed profile is automatically worked out by the TMCM-301 from the values for the minimum speed, maximum speed and acceleration specified by the user with the TMCL. Two modes of operation for the course of velocity are available for selection.

- In the **Ramp-Mode** the maximum acceleration (a_max), maximum (v_max) and minimum (v_min) speed and the target position (x_target) are specified to calculate the actual velocity. By giving the target position, the TMCM-301 calculates the speed profile of each stepper motor from the current position and the specified parameters and immediately converts it into a motion sequence.
  In Figure 5.10, an example of the motion sequence is shown. Here the motor accelerates from t_0 onwards with a_max till it reaches v_max in t_1, then it moves itself with v_max up to t_2, it then slows down with a_max till it reaches v_min in t_3 and then it travels with v_min till it reaches its target (x_target) in t_4.
  On the right side of the Figure it can be seen that v_max cannot be reached if a_max is too small or the target (x_target) is too close.

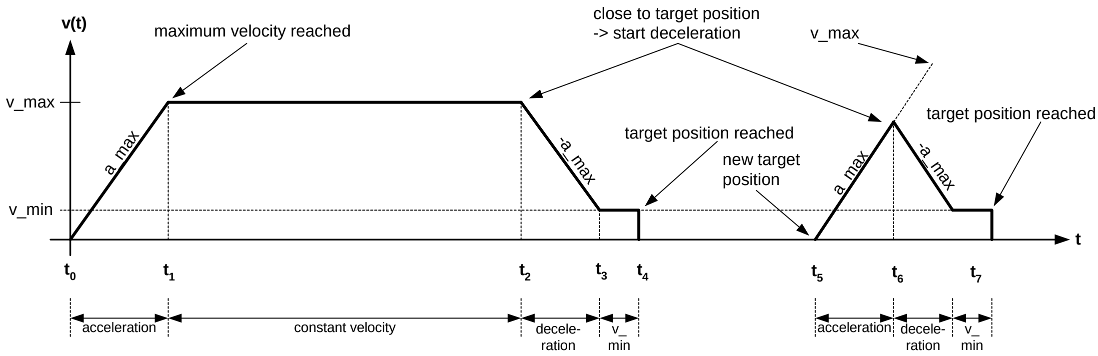


Figure 5.10: Velocity profile in ramp mode

- In **Velocity-Mode** the acceleration and the maximum speed is specified in the TMCM-301. Then the motor accelerates immediately with the specified value to the maximum speed and continues to run at constant speed till new values are sent to the TMCM-301.
  In Figure 5.11 the motion sequence for the velocity mode is shown as an example. Here the motor accelerates with a_max till it reaches the maximum velocity and then continues to run at constant speed with v_max till new a_max and v_max is specified. On the right side and at t_5 the v_max is not distinctly reached if a new parameter is prematurely given.

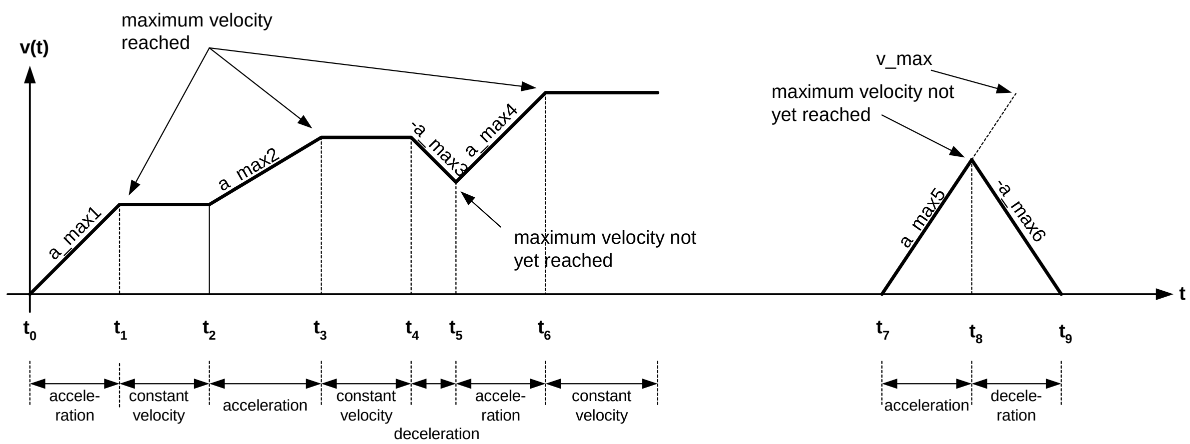


Figure 5.11: Velocity profile in velocity mode

A detailed explanation of the parameters and its calculation is given in the software description.

5.7 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

5.7.1 Left and right limit switches

The TMCM-301 can be configured so that a motor has a left and a right limit switch (Figure 5.12). *The motor stops when the traveler has reached one of the limit switches.*

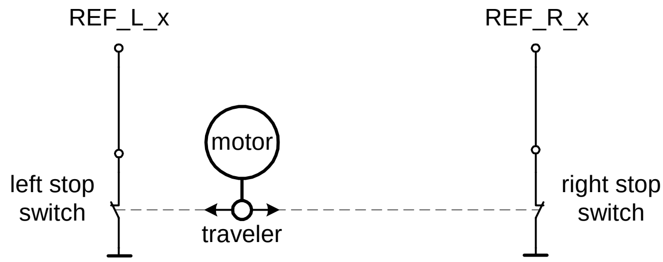


Figure 5.12: Left and right limit switches

5.7.2 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 5.13. 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.

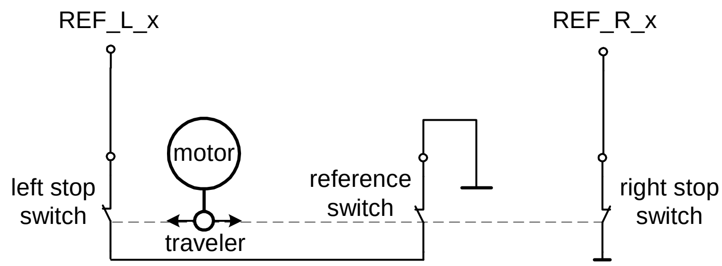


Figure 5.13: Limit switch and reference switch

5.7.3 One Limit Switch for circular systems

If a circular system is used (Figure 5.14), only one reference switch is necessary, because there are no end-points in such a system.

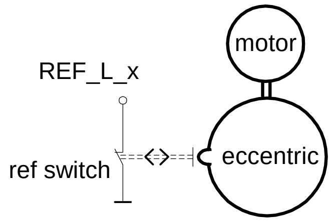


Figure 5.14: One reference switch

Note: In the actual TMCL, a function is available, which turns the motor left until the reference switch has been detected. Then the actual and target position are set to zero. In the future, two and three limit switches will also be supported.

5.8 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

5.9 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

5.10 Miscellaneous Connections

Pin Number	Direction	Name	Limits	Description
17	In	Reset	TTL	Reset, active low
18	Out	Alarm	TTL	Alarm, active high
32	In	Shutdown	TTL	Shutdown TMCM-301

Table 5.10: Miscellaneous Connections

6 Putting the TMCM-301 into Operation

On the basis of a small example it is shown step by step how the TMCM-301 is set into operation. Experienced users could skip this chapter and proceed to chapter 6:

Example: The following application is to implement with the TMCL-IDE Software development environment in the TMCM-301 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 chapter 7.1.

- 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 5.3.2.

Step 2: Connect the motor drivers as specified in 5.4
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 to your driver module

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-301 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 "TMCL Reference and Programming Manual". The next chapter discusses additional operations to turn the TMCM-301 into a high performance motion control system.

7 TMCM-301 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

$$usf[Hz] = \frac{f_{CLK}[Hz] \cdot velocity}{2^{pulse\_div} \cdot 2048 \cdot 32}$$ where "usf" means microstep-frequency

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

$$fsf[Hz] = \frac{usf[Hz]}{2^{usrs}}$$ where "fsf" means 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:

$$af = \frac{a}{2^{usrs}}$$ where "af" means 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:

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

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

8 TMCL and further Documentation

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 by request to info@trinamic.com

9 Revision History

9.1 Documentation Revision

Version	Date	Author	Description
0.1	01.07.2002	ME/AR	Initial Version
1.00	01.09.2003	OK	Error corrections
1.01	03.09.2003	OK	Further error corrections
1.03	01.10.2004	OK	Address change
1.04	13.02.2005	OK	Ordering information added
1.10	19.05.2006	HC	Major Revision
1.11	23.08.2006	HC	Minor updates
1.12	21.02.2007	HC	Added 2.0mm pitch connector info
1.13	13.06.2007	HC	Figure 5.5 and Figure 5.7 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

10 References

[TMCL] TMCL manual (see http://www.trinamic.com)
[TMCM-035] TMCM-035 manual (see http://www.trinamic.com)
[TMC236/239/246/249 FAQ] TMC239/249 FAQ (see http://www.trinamic.com)