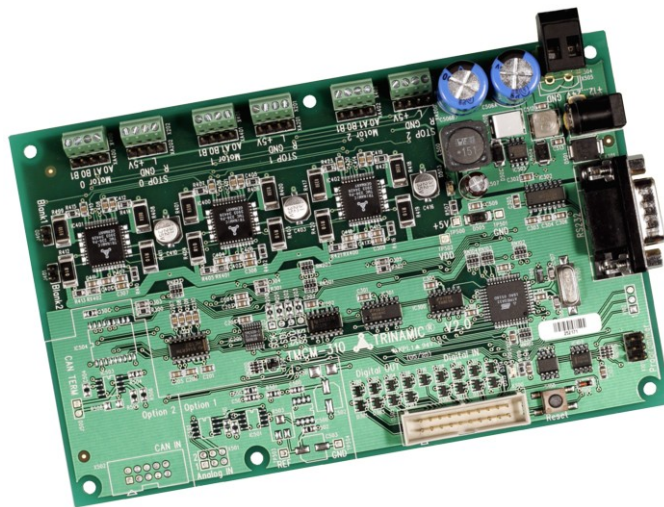


TMCM-310

3 - Axis Stepper Motor Motion Control Module



Manual

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MOTION CONTROL

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1 Features

The TMCM-310 is a triple axis 2-phase stepper motor controller and driver module. It provides a complete single board motion control solution at low cost. Using the integrated additional I/Os it even can do complete system control applications. The motors and switches can be connected easily with screw terminals. The connection of the multi purpose I/Os can be done via a dual-in-line pin connector. The TMCM-310 comes with the PC based software developer environment TMCL-IDE for the TRINAMIC Motion Control Language (TMCL). Using predefined TMCL high level commands like "move to position" or "constant rotation" rapid and fast development of motion control applications guaranteed. The TMCM-310 can be controlled via the RS-232 or the CAN interface. Communication traffic is very low since all time critical operations, e.g. ramp calculation are performed on board. A user TMCL program can be stored in the onboard 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
- Fully protected drive
- 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
- 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

- Pluggable / screw terminal connectors
- RoHS compliant latest from 1 July 2006
- Size: 160x100mm²

Order code	Description
TMCM-310	3-axis controller/driver, RS-232
TMCM-310-CAN	3-axis controller/driver, RS-232 & CAN
TMCM-310/SG	3-axis controller/driver, StallGuard, RS-232
TMCM-310/SG-CAN	3-axis controller/driver, StallGuard, RS-232 & CAN

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.

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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 from its use.

Specifications subject to change without notice.

3.2 Connecting the Module

Figure 3.2 gives an overview of the module and helps to locate all important parts. It also shows how to connect the stepper motors and reference switches (if needed).

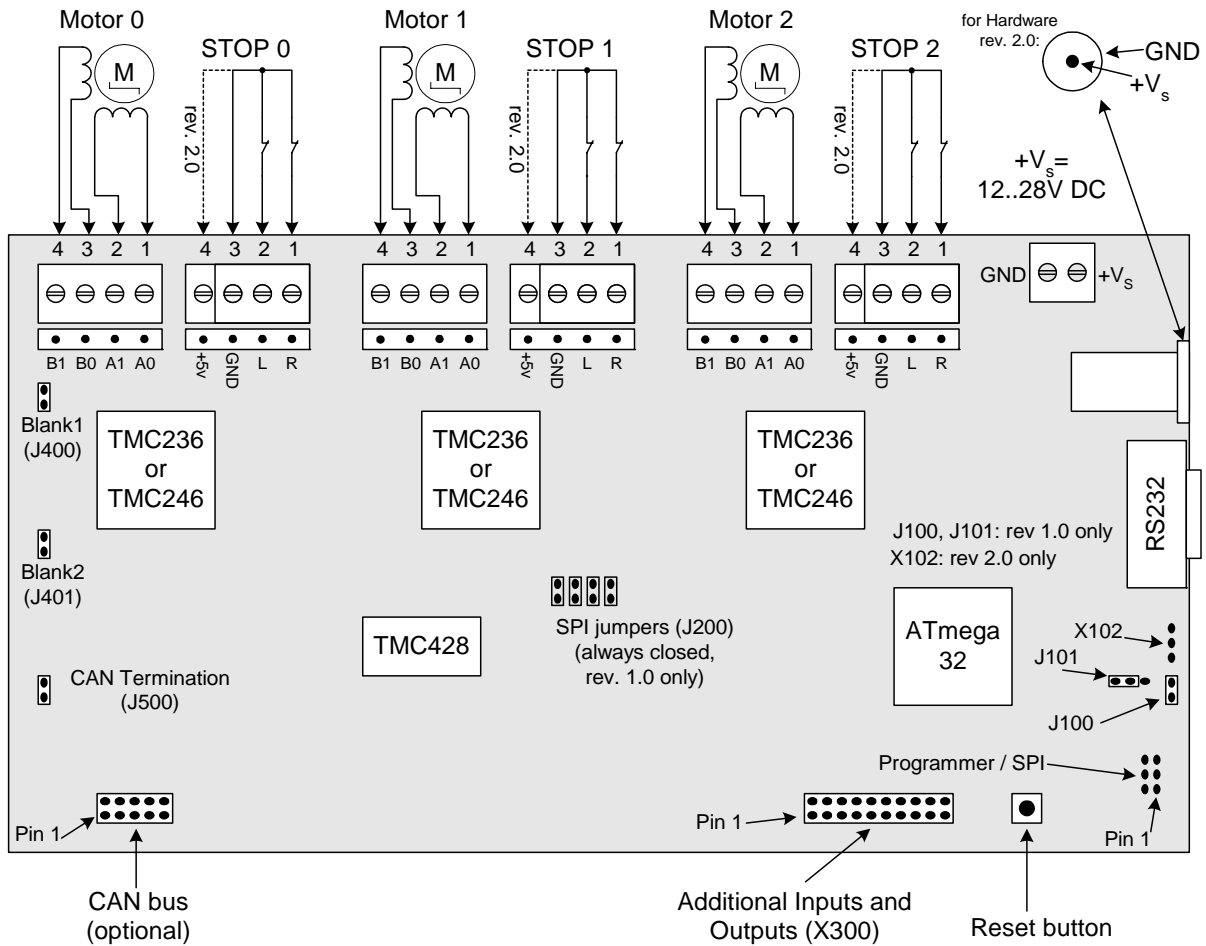


Figure 3.2: TMCM-310 Overview

3.2.1 Power supply

The power supply can either be connected to the screw terminal X504 or to the power socket X500 (industry standard power socket with 2.1mm pin diameter). Both connections are electrically identical.

Screw terminal	Power socket	Function
VS	Pin	+7..34V DC power supply (V2.0)
GND	Ring	Ground

Table 3.1: Pinning of Power supply

3.2.2 Motor and STOP / Reference Switches

Warning: Never connect or disconnect the motors while the TMCM-310 Module is switched on. Doing this will destroy the driver ICs!

The TMCM-310 controls up to three 2-phase stepper motors. The screw terminals for the motors are marked on the board with "Motor 0", "Motor 1" and "Motor 2". Additionally there are electrically identical 4-pin connectors for motor and stop switches. Connect one coil of the motor to the terminals marked with "A0" and "A1" and the other coil to the terminals marked with "B0" and "B1". If a stepper motor should run in the wrong direction just change the polarity of one (not both) of its coils. Before connecting a motor please make sure which cable belongs to which coil. Wrong connections may lead to damage of the driver chips or the motor.

Pinning for Motors 0, 1 and 2 and Stop-switches 0, 1 and 2:

Terminal	Pin	Name	Function
Motor X	1	A0	Connection for motor coil A
	2	A1	Connection for motor coil A
	3	B0	Connection for motor coil B
	4	B1	Connection for motor coil B
STOP X	1	R	Right limit switch input (integrated pullup to 5V)
	2	L	Left limit switch input (integrated pullup to 5V)
	3	GND	Ground
	4	+5V	+5V power supply (Rev.2.0 only)

Table 3.2: Pinning of Motors and Stop-Switches

3.2.3 Interfaces RS-232 and CAN

The module is equipped with an RS-232 interface and optionally with a CAN interface. To connect the RS232 interface of the module to a PC you can use a standard null modem cable (with female plugs at both ends). The optional CAN interface uses an industry standard 10-way box header with the following pin assignments (all other pins are not connected). Pin 1 is marked with an arrow on the board.

Pin	RS232	CAN
1		
2	RxD	CAN_L
3	TxD	GND
4		
5	GND	
6		GND (optional)
7		CAN_H
8		
9		
10	----- Not available -----	

Table 3.3: Pinning of Interfaces RS-232 and CAN

3.2.4 SPI / Programmer

Either for reprogramming the CPU or for attaching other external devices with SPI interface. See 5.6.2 and 5.6.3.

Pin	Number	Function
MISO	1	SPI master in slave out (pin 1 marked on board)
+5V	2	+5V
SCK	3	SPI serial clock
MOSI	4	SPI serial output (master out slave in)
nSCS	5	SPI low active device select
GND	6	GND (0V)

Table 3.4: SPI / Programmer pinning

3.2.5 Additional Inputs and Outputs

An industry standard 20-way (2x10, 2.54mm pitch) box header is used. Pin 1 is marked by an arrow on the board. The row near the edge of the board contains the pins with odd numbers and the other row contains the pins with even numbers.

Pin	Signal	Pin	Signal
1	Output 0	2	Output 1
3	Output 2	4	Output 3
5	Output 4	6	Output 5
7	Output 6	8	Output 7
9	rev. 2.0: Alarm Input rev 1.1: +5V (Output)	10	GND
11	Input 0	12	Input 1
13	Input 2	14	Input 3
15	Input 4	16	Input 5
17	Input 6	18	Input 7
19	+5V (Output)	20	GND

Table 3.5: Pinning of additional In- and Outputs

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 (V1.x)	DC Power supply voltage for operation	9	12 ... 28	28	V
V_S (V2.0)	DC Power supply voltage for operation	7	12 ... 28	34	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		25		kHz
I_S	Power supply current (per motor)		$\ll I_{COIL}$	$1.4 * I_{COIL}$	A
U_{+5V}	+5V output (max. 150mA load)	4.8	5.0	5.2	V
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 of the TMCM-301 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 (RS232 and CAN).

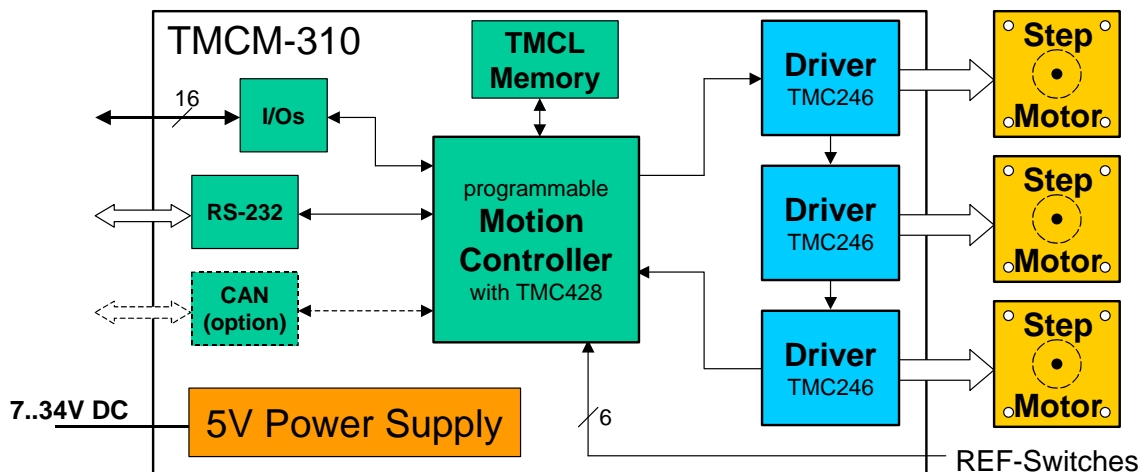


Figure 5.1: Main parts of the TMCM-310

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 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 or 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-310 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 (on this module, only one motor can be used). 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

The stepper motor drivers used on the TMCM-310 module without the StallGuard options are 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.

On TMCM-310 modules with StallGuard option (TMCM-310/SG or TMCM-310/SG-CAN) the TMC246 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.

5.2 Power Supply

The TMCM-310 is equipped with a switching voltage regulator that generates the 5V supply voltage for the digital components of the module from the motor power supply. So only one supply voltage is needed for the module. The current hardware revision 2.0 of the TMCM-310 module is equipped with a protection diode against reverse polarity that shorts the power supply if it is connected with wrong polarity. The supply voltage must be 7..28V DC.

The old hardware revision 1.0 of the TMCM-310 is also equipped with a bridge rectifier. So for this version of the module the power supply voltage can be 9..30 V DC or 7..21 V AC. For compatibility with the new hardware revision 2.0 of the TMCM-310 also the old version 1.0 should not be powered with AC.

The power supply can either be connected to the screw terminal X504 or to the power socket X500 (industry standard power socket with 2.1mm pin diameter). Both connections are electrically identical. Hardware revision and supply voltage polarity are printed on the PCB.

5.2.1 Communication Interface

The communication between the host and the module can be done via the RS232 interface or the optional CAN Interface. Communication with the TMCM-310 module is done using TMCL commands. The interfaces on the board are ready-to-use, so there are no external drivers or level shifters necessary.

Please see chapter 3.2.3 for the pin assignments of the interfaces.

To connect the RS232 interface of the module to a PC you can use a standard null modem cable (with female plugs at both ends) or you can make a cable yourself that connects pin 2 of the TMCM-310 with pin 3 of the PC, pin 3 of the TMCM-310 with pin 2 of the PC and pin 5 of the TMCM-310 with pin 5 of the PC (so you have to cross pin 2 and 3). The baud rate of the RS232 interface can be set by software, as described in the TMCL Reference and Programming Manual. The default baud rate is default 9600bps, max. 115200bps (software selectable).

To connect the CAN interface an industry standard 10-way (2x5) ribbon cable plug (2.54mm pitch) can be used. Closing the jumper J500 terminates the CAN bus with a 120 ohms resistor.

The CAN bit rate and CAN ID can be set by software (please see the TMCL Reference and Programming Manual). The maximum CAN bit rate is 500kBit/s.

5.3 StallGuard™ - Sensorless Motor Stall Detection

The TMCM-310/SG and TMCM-310/SG-CAN 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 too 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. When switching on StallGuard, the motor operation mode is changed and microstep resolution may be worse. Thus, StallGuard should be switched off when not in use.

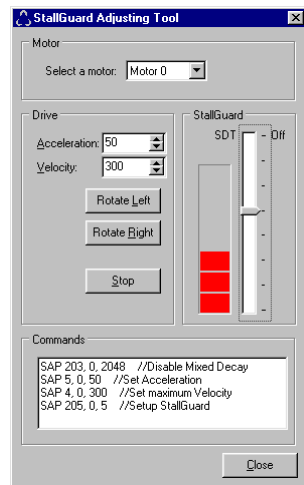
Mixed decay should be switched off when StallGuard is operational in order to get usable results.

Value	Description
-7..-1	Motor stops when StallGuard value is reached and position is set zero (useful for reference run).
0	StallGuard function is deactivated (default)
1..7	Motor stops when StallGuard value is reached and position is not set zero.

Table 5.1: StallGuard parameter SAP 205

To activate the StallGuard feature use the TMCL-command SAP 205 and set the StallGuard threshold value according to Table 5.1. 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.

5.3.1 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.

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

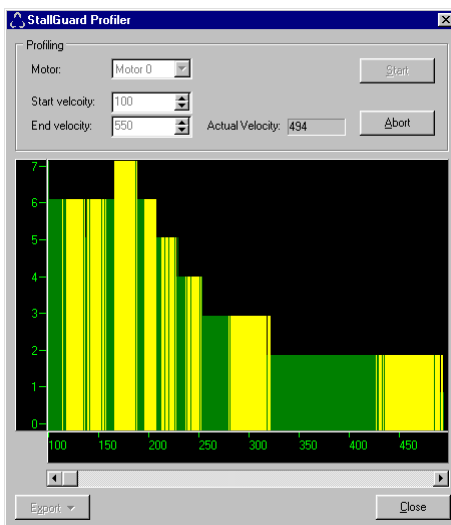
Now you can enter a velocity and an acceleration value in the “Drive” area and then click “Rotate Left” or “Rotate Right”. Clicking one of these buttons will send the necessary commands to the module so that the motor starts running. The red bar in the “StallGuard” area on the right side of the window 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.

Figure 5.2: StallGuard adjusting tool

5.3.2 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.



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.

Figure 5.3: The StallGuard Profiler

5.3.2.1 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.

5.3.2.2 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.

5.4 Reference switches

Reference switches can be used to find the reference point at startup of a system. They can be connected to the screw terminals marked “STOP 0 L/R”, “STOP 1L/R” and “STOP 2 L/R”. Each of the reference switch screw terminal blocks also has a GND terminal which is connected to ground and in rev.2.0 a +5V terminal for power supply for use of opener switches. Also a step loss of the system can be detected, e.g. due to overloading or manual interaction, by using a travel-switch.

Pull up resistors for reference switches are included on the module.

In TMCL, a reference search function is available. This reference search function supports one, two or three switches. Please see the TMCL Reference and Programming Manual for more information about the reference search function of TMCL.

5.4.1 Left and right limit switches

The TMCM-310 can be configured so that a motor has a left and a right limit switch (Figure 5.4). The motor then stops when the traveler has reached one of the limit switches.

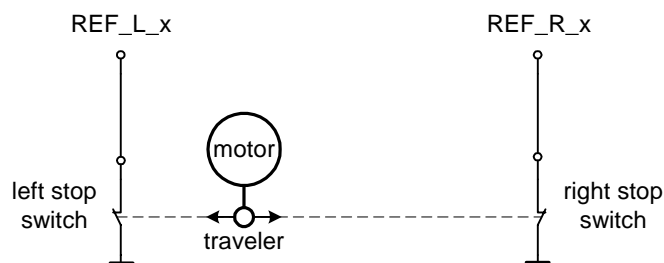


Figure 5.4: Left and right limit switches

5.4.2 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 5.5. 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.

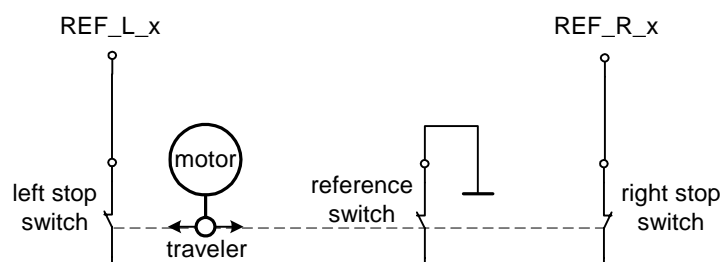


Figure 5.5: Limit switch and reference switch

5.4.3 One reference switch

If a circular system is used (Figure 5.6), but also with some linear traveling systems only one reference switch is used. When using only one reference switch, connect it to the left limit switch input (the terminal marked "L") and leave the other limit switch input open.

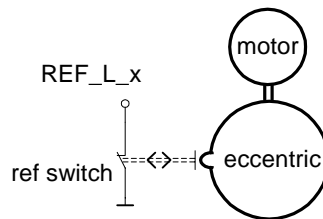


Figure 5.6: One reference switch

5.5 Additional inputs and outputs

The module also provides 8 digital (TTL) outputs and 8 inputs that can be used as digital (TTL) or as analogue inputs (0..5V, 10 bit accuracy). All in- and outputs are fully protected. Hardware revision 2.0 also provides an alarm input which is also a digital TTL level input. The functionality of this input can be selected by the TMCL command "SGP 80, 0, n". These inputs and outputs are located on the 20-way box header on the module. For the pin assignments refer to 3.2.5.

5.6 Jumpers, other connectors and LEDs

5.6.1 Blank time

The blank time of the TMC236 or TMC246 motor drivers can be set using the jumpers "Blank1" and "Blank2". The following blank times can be set:

Blank1	Blank2	Blank time
close	close	0.6µs
open	close	0.9µs
close	open	1.2µs
open	open	1.5µs

Table 5.2: Blank time settings

Normally the shortest blank time (both jumpers closed) gives best microstepping results, but with some motors or for EMC reasons it can be necessary to set a longer blank time. Please see the TMC236 or TMC246 data sheet for more information about this matter.

5.6.2 Programmer connector and jumper J101 (rev. 1.1)

On hardware rev. 1.1, the programmer connector (2x3-way header marked with "Programmer" on the board) serves for two purposes: either for reprogramming the CPU or for attaching other external devices with SPI interface.

- If jumper J101 connects pins 1 and 2, the programmer connector can be used to reprogram the microcontroller using an Atmel ISP programmer. **This is to be done by TRINAMIC only!** Do not use an ISP to update the TMCL operating system. **Updating can be done by the user only via the RS232 interface, using the TMCL IDE.**
- If the jumper J101 connects its pins 2 and 3 the programmer port can be used to attach external devices with SPI interface. To access such a device special software drivers must be written. Please get in touch with the Trinamic customer support if you wish to attach external SPI devices.

For pin assignment of the SPI connector refer to 3.2.4.

5.6.3 Programmer connector (rev. 2.0)

On hardware rev. 2.0, the programmer connector also serves for two purposes: for reprogramming the CPU (by Trinamic only) and for connecting external SPI devices (together with the soldering holes X102).

- For reprogramming the CPU, an Atmel ISP programmer can be connected here. **This is to be done by TRINAMIC only!** Do not use an ISP to update the TMCL operating system. **Updating can be done by the user only via the RS232 interface, using the TMCL IDE.**
- To use this connector for connecting external SPI devices, the SPI MISO, MOSI and CLK lines must be connecting to this port. The +5V and GND pins of this connector can also be used for powering the external SPI device. The connector X102 (soldering holes) provides the chip select lines for the external SPI devices (Pin 1 = SPI_SELECT0, Pin 2 = SPI_SELECT1, Pin 3 = SPI_SELECT2). To access such a device special software drivers must be written. Please get in touch with the Trinamic customer support if you wish to attach external SPI devices.

For pin assignment of the SPI connector refer to 3.2.4.

5.6.4 SPI jumpers

With hardware revision 1.1 of the TMCM-310, the jumpers marked SCK, SDI, SDO and SCS can be used to disconnect the TMC428 from the microcontroller. This feature can be used to connect the TMC428 to a different CPU. Please get in touch with the Trinamic customer support if you wish to do so. Normally this is not needed and all these jumpers always have to be closed.

On hardware revision 2.0 these jumpers have been eliminated, but it is still possible to connect a different CPU, by cutting four wires on the PCB. Please get in touch with Trinamic if you wish to do this.

5.6.5 Shutdown jumper

The shutdown jumper only exists on hardware revision 1.1 of the TMCM-310. When this jumper is closed, the motor drivers are always enabled. When this jumper is open the enable signal of the motor drivers can be controlled by the CPU so that the CPU can shut down the drivers (using the shutdown functions in TMCL). Normally this jumper is closed.

On hardware revision 2.0 of the module the shutdown jumper has been replaced by the alarm input on the additional input/output connector of the module. Please see chapter 5.5 for more information about this input.

5.6.6 Reset button

Pressing the reset button interrupts all tasks and re-starts the TMCL operating system which then re-initializes the module. So, pressing the reset button has the same effect as cycling the supply voltage.

5.6.7 Power LED

The power LED (D503) lights steadily when the TMCM-310 is powered.

5.6.8 Activity LED

The activity LED (D100) flashes when the TMCM-310 is running normally. During a firmware upgrade process the LED lights steadily.

6 Putting the TMCM-310 into Operation

On the basis of a small example it is shown step by step how the TMCM-310 is set into operation. Users who are already familiar with TMCL and other Trinamic modules may skip this chapter.

Example: The following application is to be implemented on the TMCM-310 module using the TMCL-IDE Software development environment. 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.

The simple application is:

- 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.

To implement this simple application on the TMCM-310 it is necessary to do the following things:

- Step 1:** Connect the RS-232 Interface to the PC
- Step 2:** Connect the motors to the motor connectors
- Step 3:** Connect the power supply voltage to the power connector
- Step 4:** Switch on the power supply. The power LED should light up and the activity LED should start to flash. This indicates the correct configuration of the microcontroller.
- Step 5:** Start the TMCL-IDE Software development environment. Open file test2.tmc or enter the program shown in the following listing manually.
A description of the TMCL commands can be found in the TMCL Reference and Programming Manual.

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

    ROL 0, 500                //Rotate motor with speed 500
    WAIT TICKS, 0, 500
    MST 0
    ROR 1, 500                //Rotate to other direction with same speed
    WAIT TICKS, 0, 500
    MST 1

    SAP 4, 2, 500            //Set max. Velocity
    SAP 5, 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                //Infinite Loop
```

- Step 6:** Click the “Assemble” icon to convert the TMCL program into byte code. Then download the program to the TMCM-310 module by clicking the “Download” icon.

- Step 7:** Click the “Run” icon. The downloaded program will now be executed.

A detailed documentation about the TMCL operations and the TMCL IDE can be found in the TMCL Reference and Programming Manual. The next chapter shows how the velocity and acceleration values are calculated.

7 TMC310 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:

Parameter	Description	Range
f _{CLK}	Clock frequency	16 MHz
velocity		0..2047
a _{max}	Maximum acceleration	0..2047
pulse_div	Velocity pre-divider. The higher the value is, the less is the maximum velocity. Default value = 3 Can be changed in TMCL using SAP 154.	0..13
ramp_div	Acceleration pre-divider. The higher the value is, the less is the maximum acceleration default value = 7 Can be change in TMCL using SAP 153.	0..13
Usrs	Microstep resolution (microsteps per fullstep = 2 ^{usrs}). Can be changed in TMCL using SAP 140.	0..6

Table 7.1: TMC428 Velocity parameters

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

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

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

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

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

$$a = \frac{f_{\text{CLK}}^2 \cdot a_{\text{max}}}{2^{\text{pulse_div} + \text{ramp_div} + 29}}$$

This results in an acceleration in fullsteps of:

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

Example:

f_CLK = 16 MHz on the TMCM-310 module
 velocity = 1000
 a_max = 1000
 pulse_div = 1
 ramp_div = 1
 usrs = 6

$$msf = \frac{16 \text{ MHz} \cdot 1000}{2^1 \cdot 2048 \cdot 32} = \underline{\underline{122070.3125 \text{ Hz}}}$$

$$fsf[\text{Hz}] = \frac{122070.3125}{2^6} = \underline{\underline{1907.35 \text{ Hz}}}$$

$$a = \frac{(16 \text{ Mhz})^2 \cdot 1000}{2^{1+1+29}} = \underline{\underline{119.208 \frac{\text{MHz}}{\text{s}}}}$$

$$af = \frac{119.208 \frac{\text{MHz}}{\text{s}}}{2^6} = \underline{\underline{1,863 \frac{\text{MHz}}{\text{s}}}}$$

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

$$RPS = \frac{fsf}{\text{fullsteps per rotation}} = \frac{1907.35}{72} = 26.49$$

$$RPM = \frac{fsf \cdot 60}{\text{fullsteps per rotation}} = \frac{1907.35 \cdot 60}{72} = 1589.458$$

8 TMCL

TMCL, the Trinamic Motion Control Language is used to send commands from the host to the TMCM-310 module and to write programs that can be stored in the EEPROM of the module so that the module can execute the TMCL commands in a stand-alone mode.

TMCL is described in a separate documentation, the TMCL Reference and Programming Manual. This document also describes the TMCL Integrated Development Environment (TMCL IDE), a program running on Windows which allows easy development of TMCL applications.

All the manuals are provided on the TMC TechLib CD and on the web site of Trinamic (<http://www.trinamic.com>). Also the latest versions of the firmware (TMCL operating system) and PC software (TMCL IDE) can be found there.

9 Differences between Hardware rev. 1.1 and 2.0

There are two versions of the TMCM-310: hardware rev 1.1 and hardware rev. 2.0. Both of these versions of the TMCM-310 are compatible with each other, but there are some slight differences. These differences are listed here:

- Power supply: rev. 1.1 is equipped with a bridge rectifier, and thus the polarity of the supply voltage does not matter and can even be alternating current. But as this caused problems when connecting external SPI devices (grounding problems), the rectifier has been eliminated on hardware revision 2.0. The rev. 2.0 module is equipped with a diode that protects the module against wrong polarity (the supply voltage will be shorted if the polarity is wrong!).
- Alarm input: rev 1.1 is equipped with a jumper that controls the shutdown functions of the motor drivers. On rev. 2.0 this jumper has been eliminated. Instead, an alarm input has been introduced on the additional I/O connector. This leads to more flexibility, as the functionality of this input can be configured by TMCL. It also makes the external I/O connector fully compatible with the one on the TMCM-610 and TMCM-612.
- Connecting external SPI devices: This has been simplified on hardware rev.2.0 of the TMCM-310 module. Please see chapter 5.6.3 for more information about this.
- SPI jumpers: As these jumpers were hardly needed they have been eliminated on hardware rev. 2.0 and replaced by cuttable PCB wires and soldering pads.
- Voltage regulator: The voltage regulator of the module has been improved for better EMC behavior.

The hardware revision number is printed on the back of the PCB.

10 Revision History

10.1 Documentation Revision

Version	Date	Author	Description
1.00	13-Jun-03	OK	Initial version
1.01	7-Nov-03	OK	Chapter 3.3.4 added
1.10	21-Jul-04	OK	Revised, updated and extended
1.11	27-Jul-04	OK	Mounting hole drawing added
1.12	1-Oct-04	OK	Address changed
1.13	11-Jan-06	OK	Covers hardware rev. 1.1 and 2.0
1.20	15-May-06	HC	Major Revision, StallGuard added

Table 10.1: Documentation Revisions

10.2 Firmware Revision

Version	Comment	Description
3.24	Initial Release	Please refer to TMCL documentation

Table 10.2: Firmware Revisions