

TMCM-100

Stepper Motor Motion Control Module

Documentation

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Version

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1 General Description

The TMCM-100 is a single axis 2, 3- or 5-phase stepper motor controller module based on the high-end TMC453 motion control chip. The module provides a complete motion control system at low cost and very small physical size by just adding the external driver. It supports incremental encoder feedback for positioning check or stabilization.

The TMCM-100 can be operated by a host via the RS232, RS485 or CAN interface. Stand alone operation is also possible. The firmware of the microcontroller can be update via the RS232 interface. The TMCM-100 provides a complete software development environment and by using the Trinamic Motion Control Language rapid and fast development of motion control applications is guaranteed. The TMCL Operations are stored in the on-board 16KByte EEPROM which is capable of storing up to 2048 TMCL instructions.

1.1 Ordering information

Order code	Features
TMCM-100-H	Horizontal mount (standard)
TMCM-100-V	Vertical mount (available on demand)

2 Main Features

- Controls 2-phase and 3-phase stepper motors with 8-Bit microstepping
- Controls 5-phase stepper motors in fullstep mode
- Supports standard motor driver ICs (e.g. TMC236 or TMC239)
- TMC453 high performance motion controller
- CAN 2.0b Interface with Transceiver
- RS-232 Interface (without level shifter)
- RS-485 Interface (without transceiver)
- Interface options
 - Analog outputs for up to 8-bit microstepping via integrated DACs
 - Step/direction output
 - Step/direction input
 - Digital outputs to drive 2-5 phase stepper motors in full- and halfstep-mode
- Trinamic Motion Control Language (TMCL) integrated
- In-system programmable microcontroller
- 16 KByte EEPROM to store TMCL programs of up to 2048 commands
- Automatic S-shaped and trapazoid ramps
- Incremental encoder interface
- Automatic stall and out-of-step correction function
- Smart multi-level current control to keep driver and motor cool
- Limit and reference switch inputs
- Single 5 VDC Supply
- Compact size: TMCM Standard Format 80x50 mm²



3 Operational Conditions

3.1 Power supply

The 5VDC supply voltage is permissible in the range of 4.75VDC to 5.25VDC. The current which is needed by the TMCM-100 module amounts typically 300 mA.

3.2 Inputs

The input voltage range for all inputs (if not labelled different) is from 0V to 5VDC or TTL level. The voltages for the differential CAN inputs ranges between –8VDC to +18VDC.

3.3 Outputs

The digital output ports are following TTL levels, with an maximum current of 50mA (μ C output ports, TMC453) and 35mA (shift register outputs).

The maximum output voltage of the analogue outputs (DACs of the TMC453) is 2.55V.

3.4 Temperature Range

The TMCM-100 is suitable for ambient temperature of up to 70°C.

4 Ramp Profiles

The speed profile is automatically worked out by the TMCM-100 from the values for the minimum speed, maximum speed acceleration and bow specified by the user with the TMCL motion parameters. 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-100 calculates the speed profile of the stepper motor from the current position and the specified parameters and immediately converts it into a motion sequence. This automatic ramp is normally S-shaped.

In Figure 1, an example of a motion sequence is shown. Here the motor accelerates from t_0 onwards with $a_{\max}$ until it reaches $v_{\max}$ in t_1 , then it moves itself with $v_{\max}$ up to t_2 , it then slows down with $a_{\max}$ until it reaches $v_{\min}$ in t_3 and then it travels with $v_{\min}$ until 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.

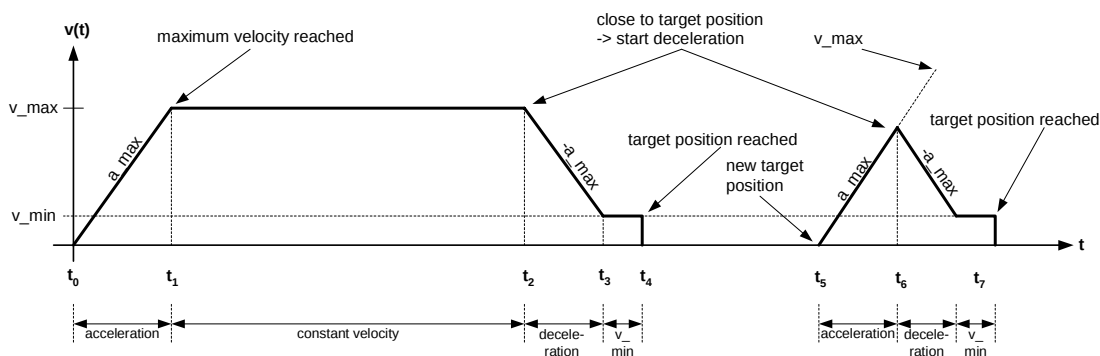


Figure 1: Velocity profile in ramp mode

- In **Velocity-Mode** the acceleration and the maximum speed is specified in the TMCM-100. Then the motor accelerates immediately with the specified value to the maximum speed and continues to run at constant speed until new values are sent to the TMCM-100.

In Figure 2 the motion sequence for the velocity mode is shown as an example. Here the motor accelerates with $a_{\max}$ until it reaches the maximum velocity and then continues to run at constant speed with $v_{\max}$ until new $a_{\max}$ and $v_{\max}$ is specified. On the right side and at t_5 the $v_{\max}$ is not reached if a new parameter is prematurely given.

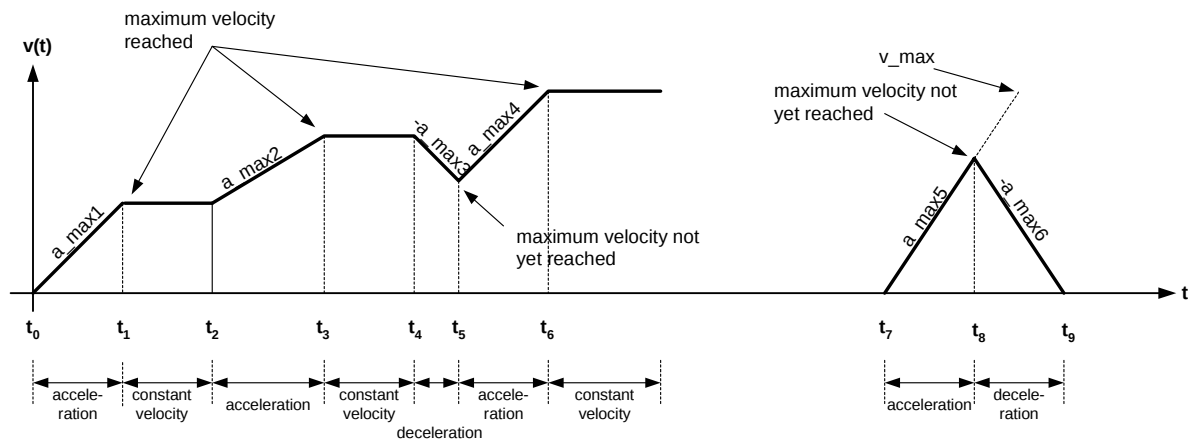


Figure 2: Velocity profile in velocity mode

A detailed explanation of the parameters and its calculation is given in the TMCL Reference and Programming Manual which is also available from the TRINAMIC web site (www.trinamic.com).

5 Getting started

5.1 The TMCM-100 Module

Front:

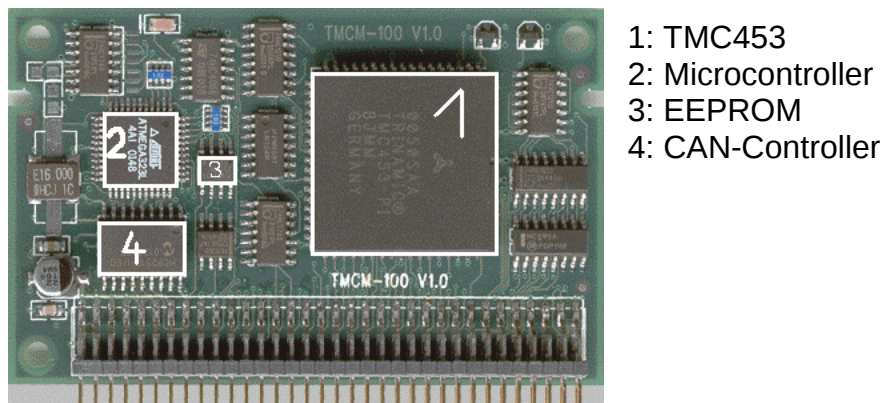


Figure 3: TMCM-100 Top Side

5.4 Functional Description

Communication Interface

The communication between the host and the module can be done via RS232, RS485 or CAN Interface. These interfaces are used to send motion commands to the microcontroller. Additionally they can be used to program the microcontroller and the on-board-EEPROM using TMCL. A ready-to-use CAN-Interface is included on the board. The level-shifter and transceiver for the UART-interfaces have to be added.

Microcontroller (μ C)

On this module, the Atmel ATmega32 is used to control the communication with the host and the EEPROM and to control the TMC453. The μ C has 32Kbyte flash memory and a 1Kbyte EEPROM. The firmware of the microcontroller implements the TMCL language and can be

In normal operation the microcontroller receives TMCL (Trinamic Motion Control Language) commands. These commands are interpreted by the microcontroller and then converted into SPI-datagrams which are then sent to the TMC453.

EEPROM

To use the module without a host or to store special data permanently, the EEPROM can be used. One example is to store a program written in TMCL in the EEPROM, which will be automatically executed after powering up the module. The EEPROM can be programmed has a capacity of 16 Kbyte, which makes it possible to store TMCL programs of up to 2048 commands.

TMC453

The TMC453 is a powerful stepper motor control IC for demanding point-to-point and speed control applications. The TMC453 controls 2-, 3- and 5-phase bipolar stepper motors providing the ramp generation and microstep sequencing. All time critical tasks are handled by the TMC453. Internal DACs allow direct connection of analog interface motor driver ICs. A digital step/direction signal output is also available, as well as step/direction input interface for use as a sequencer. The TMC453 can automatically generate S-shaped ramp profiles.

Furthermore an incremental encoder interface is implemented that can also be used with TMCL.



5.5 Connecting the Module

5.5.1 Pinout of the 68-Pin connector

The 68-pin connector provides all the pins necessary for host communication, connection of the motor driver and reference switches and the incremental encoder interface. Pin 1 of this connector is located in the lower left corner on the top site, while the connector is pointing towards the user. (See Figure 4).

Pin	Direction	Description	Pin	Direction	Description
1	In	+5VDC	35	Out	Digital Motor Control 5
2	In	GND	36	Out	Digital Motor Control 9
3	In	+5VDC	37	Out	Digital Motor Control 6
4	In	GND	38	Out	Digital Control of Motor Current 0
5	-	Reserved	39	Out	Output of DAC 0
6	In	GND	40	Out	Digital Control of Motor Current 1
7	-	Reserved	41	Out	Output of DAC 1
8	In	GND	42	Out	General Purpose Output 0
9	-	Reserved	43	Out	Output of DAC 2
10	In	GND	44	Out	General Purpose Output 1
11	Out	SPI Select 0	45	In	General Purpose Input 0
12	Out	SPI Clock	46	Out	General Purpose Output 2
13	Out	SPI Select 1	47	In	General Purpose Input 1
14	In	SPI MISO	48	Out	General Purpose Output 3
15	Out	SPI Select 2	49	In	General Purpose Input 2
16	Out	SPI MOSI	50	Out	General Purpose Output 4
17	In	Reset, active low	51	In	General Purpose Input 3
18	Out	Alarm	52	Out	General Purpose Output 5
19	Out	External Step Output: Direction	53	In	General Purpose Input 4
20	Out	External Step Output: Step (with prog. Delay)	54	In	Reference Switch Left
21	Out	Synchronization Output for Command FIFO	55	In	General Purpose Input 5
22	In	Synchronization Input for Command FIFO	56	In	Reference Switch Right
23	In	External Step Input: Direction	57	In	General Purpose Input 6
24	In	External Step Input: Step	58	In	Emergency Stop Input
25	Out	Digital Motor Control 0	59	In	General Purpose Input 7
26	In	Incremental Encoder Interface Channel A	60	In	Reserved
27	Out	Digital Motor Control 1	61	In	GND
28	In	Incremental Encoder Interface Channel B	62	In	GND
29	Out	Digital Motor Control 2	63	-	Reserved
30	In	Incremental Encoder Interface Channel N	64	Out	RS-485 Direction
31	Out	Digital Motor Control 3	65	InOut	CAN -
32	Out	Digital Motor Control 7	66	In	RS-232 Rx/D
33	Out	Digital Motor Control 4	67	InOut	CAN +
34	Out	Digital Motor Control 8	68	Out	RS-232 Tx/D

Table 1: Pinout 68-Pin Connector

5.5.2 Host Communication

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

5.5.2.1 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 2: Pinout for CAN Connection

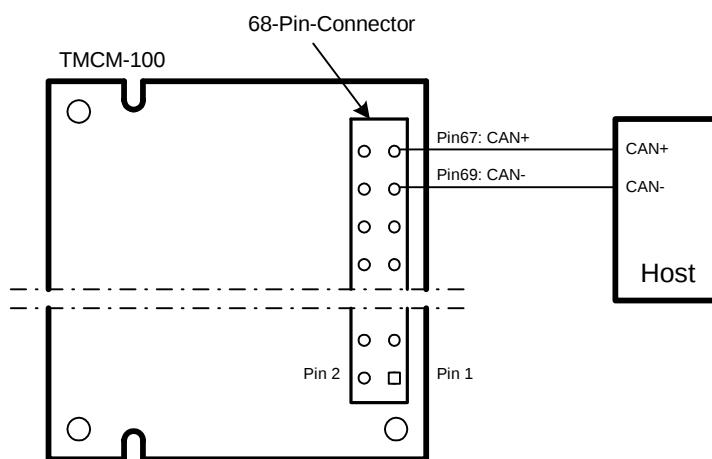


Figure 6: Connecting CAN

5.5.2.2 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 3: Pinout for RS-232 Connection

Note: The RS-232 must operated with TTL-Levels (0V, 5V), since there is no level shifter onboard! To connect the module to an RS232 interface like on a PC a level shifter (e.g. MAX202 or MAX232) has to be added!

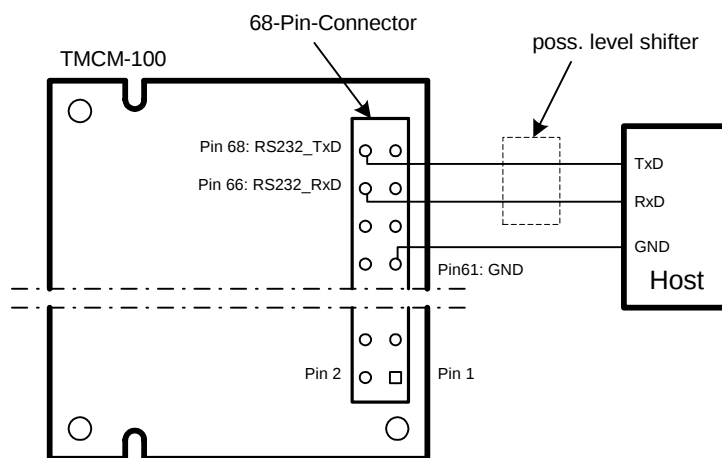


Figure 7: Connecting RS-232

5.5.2.3 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 4: Pinout for RS-485 Connection

Note: The TMCM-100 Module does not contain any RS-485 transceivers! A suitable RS485 transceiver chip has to be added (e.g. MAX485 or SN75176).

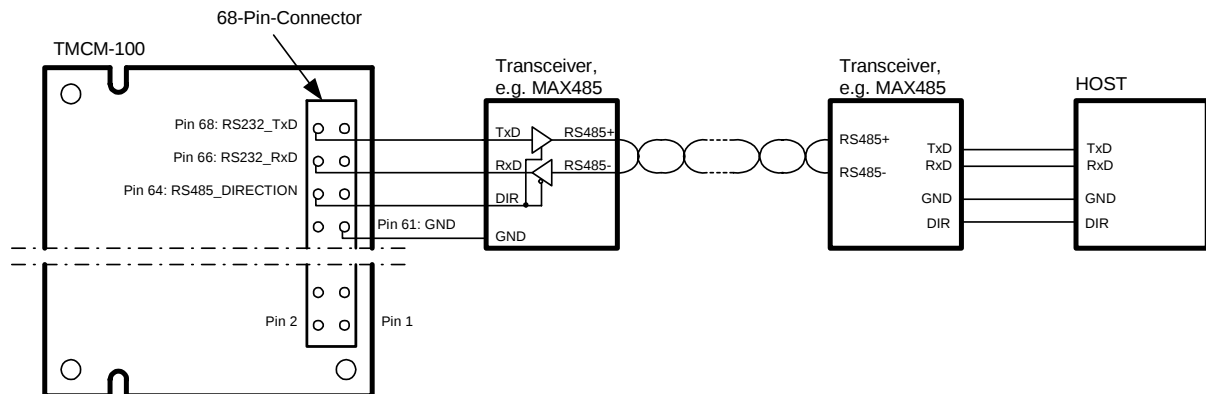


Figure 8: Connecting the RS-485

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

5.5.3 Connecting the Incremental Encoder

The TMCM-100 provides an interface to connect an incremental encoder. The encoder can be used for position verification. Three signals are generated by the encoder:

Channel A+B are used to determine the position and if the motor turns clockwise or counterclockwise. Channel N is the null event channel which can be used to initialize the encoder interface.

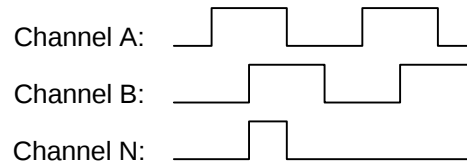


Figure 9: Output waveforms of an incremental encoder

Pin Number	Direction	Name	Limits	Description
26	In	Channel A	TTL	Channel A
28	In	Channel B	TTL	Channel B
30	In	Channel N	TTL	Null event Channel

Figure 10: Pinout of 68-pin connector for incremental encoder

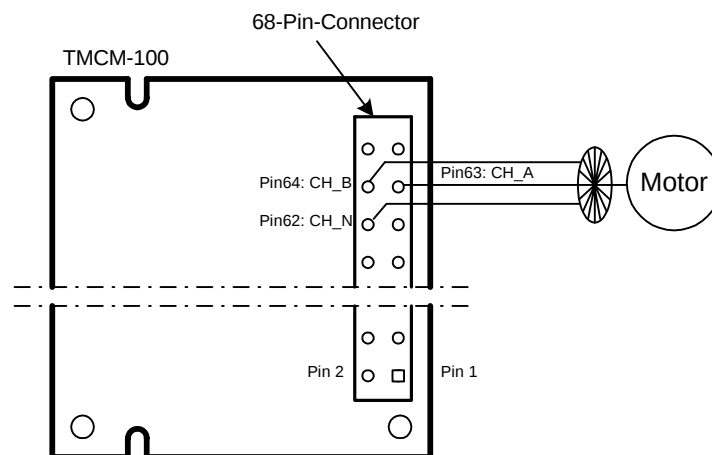


Figure 11: Connecting the Encoder

5.5.4 Connecting the Driver (Full- and Halfstep Operation)

Warning: Never disconnect the motors while the TMCM-100 Module is switched on.
Doing this will destroy the external driver ICs!

5.5.4.1 2-Phase Stepper Motor

Pin Number	Direction	Name	Limits	Description
25	Out	STO 0	TTL	Phase Coil A
27	Out	STO 1	TTL	Current Coil A
29	Out	STO 2	TTL	Phase Coil B
31	Out	STO 3	TTL	Current Coil B
43	Out	DAC2_OUT	Analog Out	Reference Voltage for Driver

Table 5: Pinout 2-Phase Motor (Full-/ Halfstep Operation)

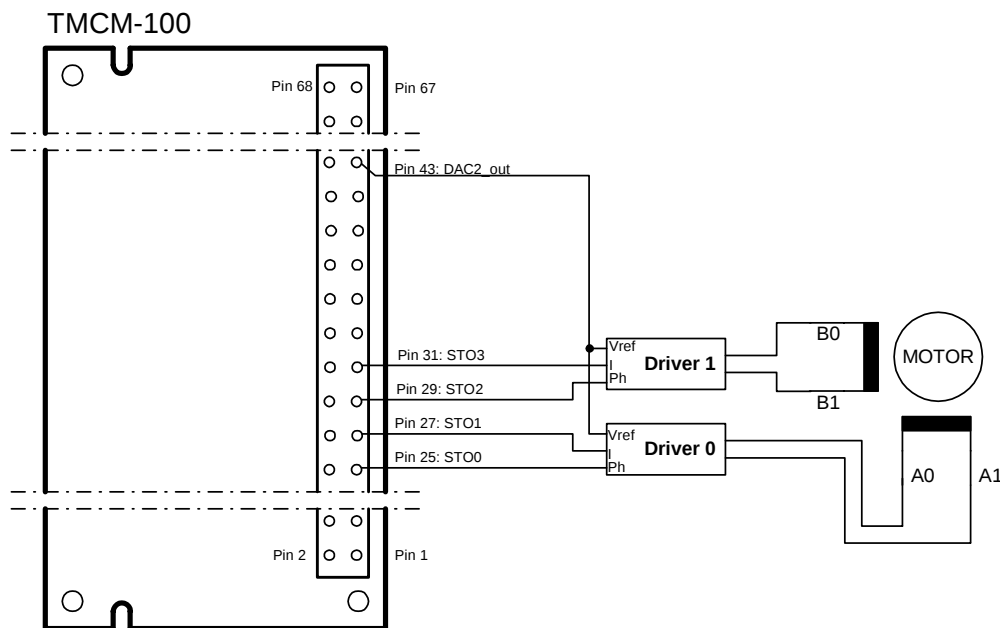


Figure 12: 2-Phase Motor (Full-/ Halfstep Operation)

5.5.4.2 3-Phase Stepper Motor

Pin Number	Direction	Name	Limits	Description
25	Out	STO 0	TTL	Phase Coil A
27	Out	STO 1	TTL	Current Coil A
29	Out	STO 2	TTL	Phase Coil B
31	Out	STO 3	TTL	Current Coil B
33	Out	STO 4	TTL	Phase Coil C
35	Out	STO 5	TTL	Current Coil C
43	Out	DAC2_OUT	Analog Out	Reference Voltage for Driver

Table 6: Pinout 3-Phase Motor (Full-/ Halfstep Operation)

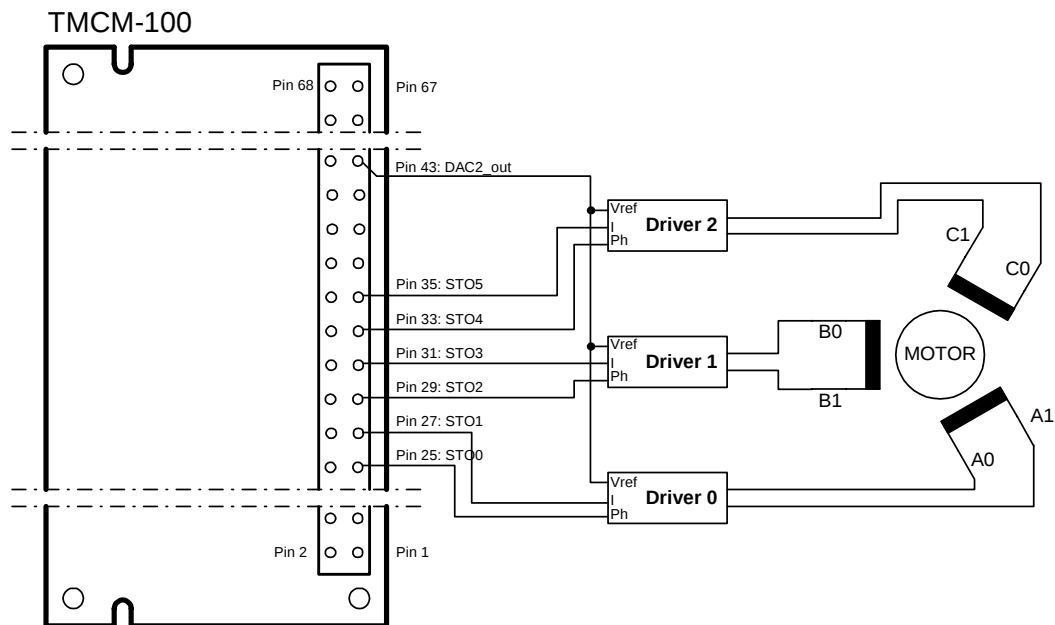


Figure 13: 3-Phase Motor (Full-/ Halfstep Operation)

5.5.4.3 5-Phase Stepper Motor

Pin Number	Direction	Name	Limits	Description
25	Out	STO 0	TTL	Phase Coil A
27	Out	STO 1	TTL	Current Coil A
29	Out	STO 2	TTL	Phase Coil B
31	Out	STO 3	TTL	Current Coil B
32	Out	STO 7	TTL	Current Coil D
33	Out	STO 4	TTL	Phase Coil C
34	Out	STO 8	TTL	Phase Coil E
35	Out	STO 5	TTL	Current Coil C
36	Out	STO 9	TTL	Current Coil E
37	Out	STO 6	TTL	Phase Coil D
43	Out	DAC2_OUT	Analog Out	Reference Voltage for Driver

Table 7: Pinout 5-Phase Motor (Full-/ Halfstep Operation)

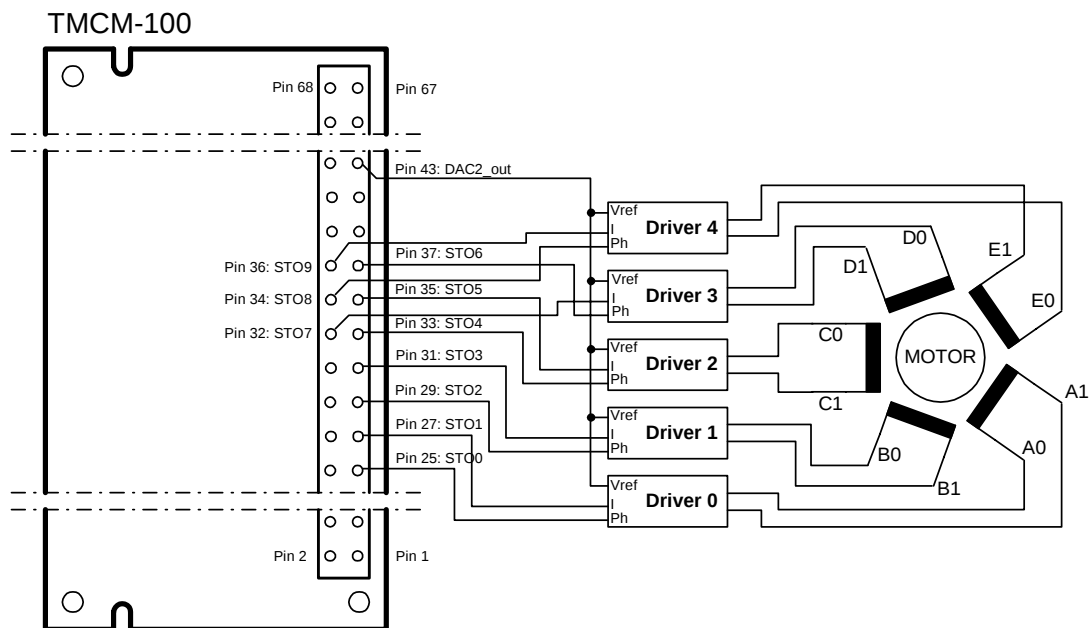


Figure 14: 5-Phase Motor (Full-/ Halfstep Operation)

5.5.5 Connecting the Driver (Microstep Operation)

5.5.5.1 2-Phase Stepper Motor

Pin Number	Direction	Name	Limits	Description
25	Out	STO 0	TTL	Phase Coil A
29	Out	STO 2	TTL	Phase Coil B
38	Out	IB0	TTL	Reference Voltage for Driver
39	Out	DAC0_OUT	Analog Out	Current Coil A
40	Out	IB1	TTL	Reference Voltage for Driver
41	Out	DAC1_OUT	Analog Out	Current Coil B

Table 8: Pinout 2-Phase Motor (Microstep Operation)

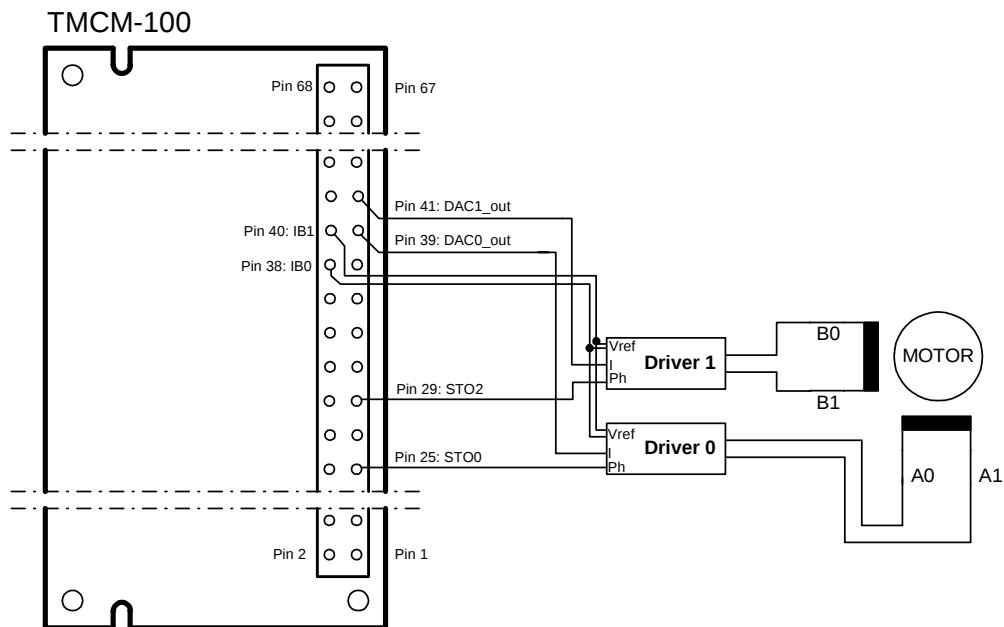


Figure 15: 2-Phase Motor (Microstep Operation)

5.5.5.2 3-Phase Stepper Motor

Pin Number	Direction	Name	Limits	Description
25	Out	STO 0	TTL	Phase Coil A
29	Out	STO 2	TTL	Phase Coil B
33	Out	STO 4	TTL	Phase Coil C
38	Out	IB0	TTL	Reference Voltage for Driver
39	Out	DAC0_OUT	Analog Out	Current Coil A
40	Out	IB1	TTL	Reference Voltage for Driver
41	Out	DAC1_OUT	Analog Out	Current Coil B
43	Out	DAC2_OUT	Analog Out	Current Coil C

Table 9: Pinout 3-Phase Motor (Microstep Operation)

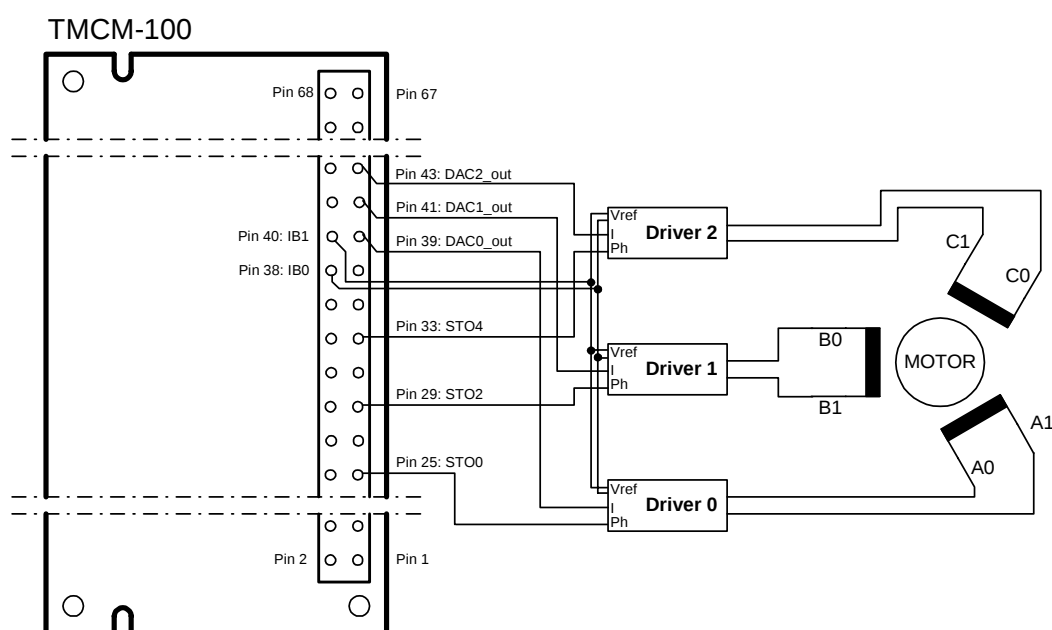
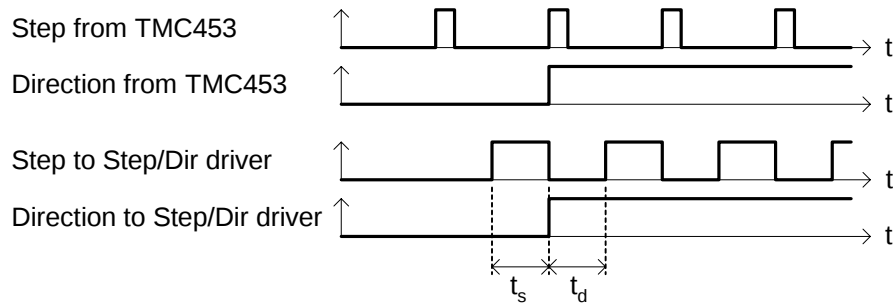


Figure 16: 3-Phase Motor (Microstep Operation)

5.5.6 Connecting the Step/Direction Interface

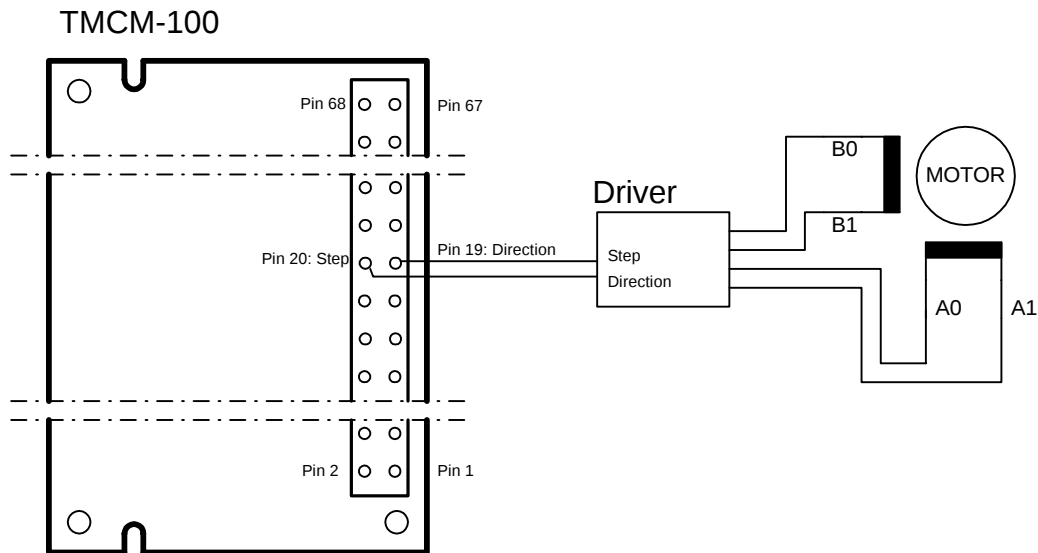
The TMCM-453 generates step and direction pulses. These pulses must be adapted to the specification of the utilized driver stage. Output pins 6 and 7 of the port expansion are used to select the delays.

**Figure 17: Step and Direction Delays**

Out_6	Out_7	R [KOhm]	$t_d / t_s [\mu s]$	f_{max} [MHz]
0	0	2,7	0,12	4
0	1	10,66	0,5	1
1	0	2,7	0,12	4
1	1	41,7	1,9	0,25

Table 10: Step and Direction Delays

Pin Number	Direction	Name	Limits	Description
19	Out	Dir	TTL	Direction Output
20	Out	Step	TTL	Step Output

Table 11: Pinout Step / Direction Interface**Figure 18: Connecting the Step/Direction Interface**

5.5.7 Reference switches

With reference switches, an interval for the movement of the motor or the zero point can be defined. Also a mechanical overloading of the system is avoided if steps are lost, e.g. due to overloading.

Pin Number	Direction	Name	Limits	Description
56	In	STOPR	TTL	Right reference switch, low active
54	In	STOPL	TTL	Left reference switch, low active

Table 12: Pinout reference switches

Note: Pullup resistors for reference switches are included on the module.

With reference switches, an interval for the movement of the motor or the zero point can be defined. Also a mechanical overloading of the system is avoided if steps are lost, e.g. due to overloading.

Left and right limit switches

The TMCM-100 is configured in the way, that every motor has a left and a right limit switch (Figure 19).

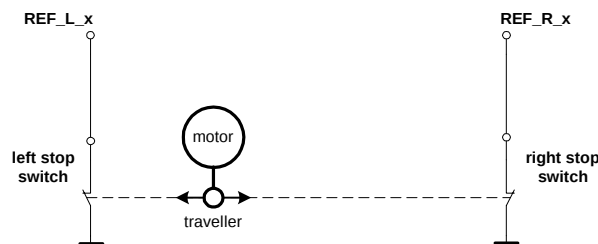


Figure 19: Left and right limit switches

One Limit Switch for circular systems

If a circular system is used (Figure 20), only one reference switch is necessary, because there are no end-points in such a system.

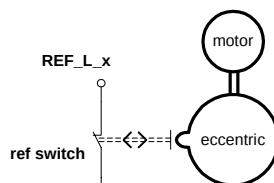


Figure 20: One reference switch

Note:

In the actual TMCL, a function is available, which turn 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.

5.5.8 Serial Peripheral Interface

On-board communication is performed via the Serial Peripheral Interface, where the microcontroller acts as master. For adaption 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 13: Pinout Serial Peripheral Interface

5.5.9 Port Expansion

For further expansion and adaption to user requirements the module provides a port expansion for the microcontroller. The expansion includes eight input pins and eight 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
42	Out	OUT_0	TTL	Port expansion Pin 0, output
44	Out	OUT_1	TTL	Port expansion Pin 1, output
46	Out	OUT_2	TTL	Port expansion Pin 2, output
48	Out	OUT_3	TTL	Port expansion Pin 3, output
50	Out	OUT_4	TTL	Port expansion Pin 4, output
52	Out	OUT_5	TTL	Port expansion Pin 5, output

5.5.10 Miscellaneous Connections

Pin Number	Direction	Name	Limits	Description
17	In	Reset	TTL	Reset, active low
18	Out	Alarm	TTL	Alarm, active high
58	In	Shutdown	TTL	Shutdown TMCM-100

Table 14: Miscellaneous Connections

Appendix A: TMCL

Please refer to www.trinamic.com for updated data sheets and application notes.

The TMCtechLIB 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 Microchips GmbH by request to info@trinamic.com