# TMCM-1638 Hardware Manual

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The TMCM-1638 is a single axis controller/driver module for single phase DC motors, two phase bipolar stepper motors and three phase BLDC motors. The TMCM-1638 can either be used with TMCL firmware supporting standalone operation as well as direct mode control using the TMCL™ protocol or with CANopen firmware supporting control using the CANopen® protocol.
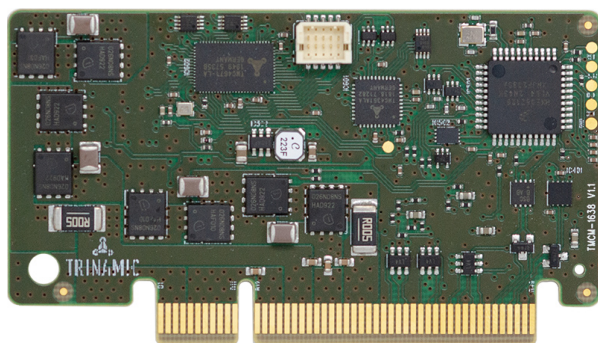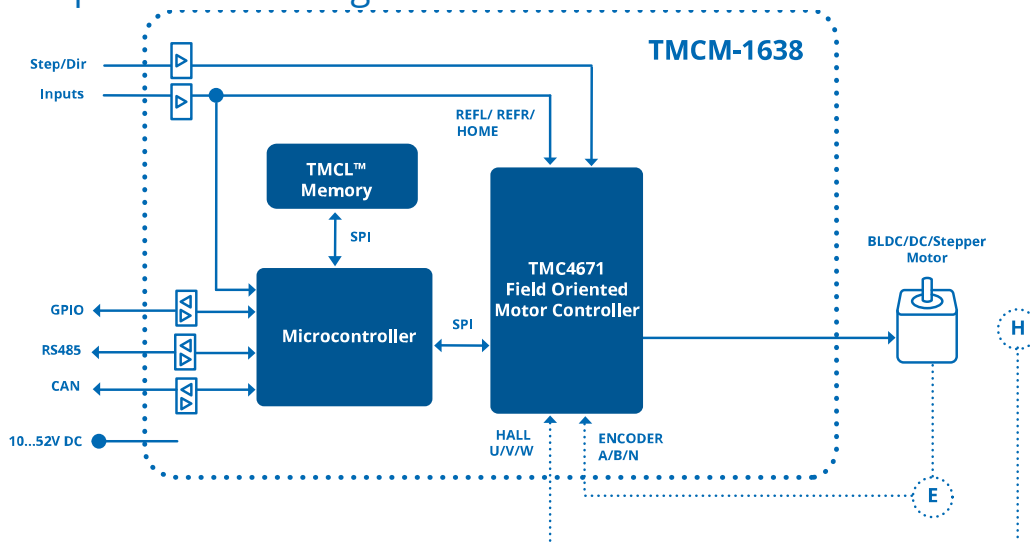
Features

- Single axis controller/driver with field oriented control
- +10…52V DC motor supply voltage
- Up to 7A RMS motor current (short term up to 14A)
- RS485 and CAN interface
- Single-ended ABN encoder interface
- Hall sensor inputs
- Step/direction inputs
- Stop switch and home switch inputs
- General purpose inputs and outputs

Applications

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

Simplified Block Diagram

Read entire documentation.

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Contents

1   Features

The TMCM-1638 is a single axis field oriented motor controller/driver board. It supports single phase DC motors, two phase bipolar stepper motors and three phase BLDC motors with up to 7A RMS (10A peak) motor coil current. For motor commutation and position feedback, hall sensors or incremental ABN encoders can be used. For driver-only applications, the TMCM-1638 offers Step/Direction inputs. The TMCM-1638 is also equipped with two analog inputs (0...5V range), two digital inputs and two digital (TTL level) outputs. For communication, RS485 and CAN bus interfaces are available.

Motion Controller

- Motion profile calculation in real-time.

- On the fly alteration of motor parameters (e.g. position, velocity, acceleration).

- Linear ramps controlled by firmware.

- Encoder interface.

- Hall sensor interface.

- Home switch and stop switch inputs.

Driver

- Motor current: up to 7A RMS (10A peak, programmable in software).

- Short term load up to 14A.

- Motor supply voltage: +48V DC (+10... +52V DC).

- Logic supply voltage: +5V DC.

- Step/Direction interface.

Encoder

- Input for ABN incremental encoder.

- Programmable encoder scaling and support for motor stop on encoder deviation.

Interfaces

- RS485 interface (up to 1Mbit/s).

- CAN interface (up to 1Mbit/s).

- Step/Dir input.

- Left and Right stop switch inputs.

- Two general purpose digital inputs.

- Encoder input for incremental ABN encoder signals.

- Hall sensor interface.

- Two analog inputs (0...5V input range).

- Home switch input.

Mechanical data

- Board size: 80mm x 40/45mm, height 7mm max.

- 98-pin slot type connector

Software

- TMCL™ remote (direct mode) and standalone operation (memory for up to 2047 TMCL™ commands), fully supported by TMCL-IDE (PC based integrated development environment). Please see TMCM-1638 TMCL firmware manual for more details.

- CANopen firmware with CANopen standard protocol stack for the CAN interface. Please see TMCM-1638 CANopen firmware manual for more details.

2 Order Codes

The standard version of the TMCM-1638 is pre-programmed with either TMCL™ firmware or CANopen® firmware.

Order Code	Description	Size
TMCM-1638-TMCL	1-axis field oriented motor controller/driver, up-to 7A RMS motor current, 48V nom. supply, ABN encoder input, hall sensor input, S/D input, stop/home switch inputs, 1 analog input , 2 digital inputs, 1 digital output, CAN and RS485 interfaces	80mm x 40mm (connector: 45mm)
TMCM-1638-CANopen	1-axis field oriented motor controller/driver, up-to 7A RMS motor current, 48V nom. supply, ABN encoder input, hall sensor input, S/D in-put,stop/home switch inputs, 1 analog input , 2 digital inputs, 1 digital output, CAN and RS485 in-terfaces	80mm x 40mm (connector: 45mm)

Table 1: TMCM-1638 Order Codes

3 Mechanical and Electrical Interfacing

3.1 Size of the board

The board has an overall size of 80mm x 40mm without the connector. Together with the slot type connector the board size is 80mm x 45mm. The thickness of the board with components is max. 7mm. There is one 5mm diameter mounting hole.
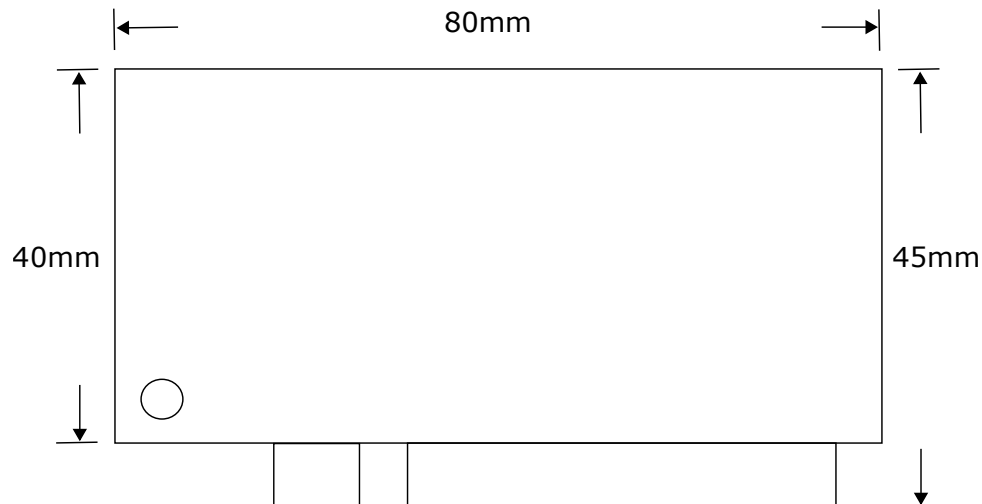

Figure 1: Board dimensions, position of mounting holes and position (pin 1) of connectors (all values in mm)

4 Connectors

The TMCM-1638 is equipped with an 98-pin slot type connector. As a mating connector on base boards an 98-pin PCIe slot can be used (but please do not try to plug the module into the PCIe slot of a PC main board). All signals of the module are routed via the slot type connector. These are the supply voltages, the CAN and RS485 interface, motor coils, encoder inputs and all other signals needed by the module. The pins located on the top side of the module PCB are labeled B1…B48 and the pins located on the bottom side of the PCB are labeled A1…A48.

For trying out the TMCM-1638 for the first time we recommend using a Trinamic base board. But a base board can also be designed by the user.

NOTICE	**Start with power supply OFF and do not connect or disconnect motor during operation!** Motor cable and motor inductivity might lead to voltage spikes when the motor is (dis)connected while energized. These voltage spikes might exceed voltage limits of the driver MOSFETs and might permanently damage them. Therefore, always switch off / disconnect power supply or at least disable driver stage before connecting / disconnecting motor.

Slot Type Connector Pin Assignment (PCB Top Side)			
Pin	Label	Direction	Description
B1	+48V	input	Motor supply voltage
B2	+48V	input	Motor supply voltage
B3	+48V	input	Motor supply voltage
B4	+48V	input	Motor supply voltage
B5	GND	—	Power and signal ground
B6	GND	—	Power and signal ground
B7	GND	—	Power and signal ground
B8	GND	—	Power and signal ground
B9	NC	—	Not connected
B10	NC	—	Not connected
B11	NC	—	Not connected
B12	OA2	output	Stepper motor: coil A pin 2
B13	OA2	output	Stepper motor: coil A pin 2
B14	OA2	output	Stepper motor: coil A pin 2
B15	OA2	output	Stepper motor: coil A pin 2
B16	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W
B17	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W
B18	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W

Pin	Label	Direction	Description
B19	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W
B20	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
B21	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
B22	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
B23	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
B24	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U
B25	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U
B26	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U
B27	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U
B28	NC		not connected
B29	GND	—	Power and signal ground
B30	HALL_U	input	Hall sensor U
B31	HALL_V	input	Hall sensor V
B32	HALL_W	input	Hall sensor W
B33	GND	—	Power and signal ground
B34	SYNC	input	Synchronization signal input
B35	IRQ	output	Interrupt output
B36	ENABLE	input	Motor coil enable input
B37	GND	—	Power and signal ground
B38	IN0	input	General purpose digital input #3
B39	IN1	input	General purpose digital input #2
B40	GND	—	Power and signal ground
B41	RS485B_4671	input	Direct RS485 interface to the TMC4671 chip
B42	OUT0	output	General purpose digital output #0
B43	GND	—	Power and signal ground
B44	RS485_A	in/out	RS485+ (non-inverted) signal
B45	RS485_B	in/out	RS485- (inverted) signal
B46	CAN_L	in/out	CAN bus low

Pin	Label	Direction	Description
B47	CAN_H	in/out	CAN bus high
B48	GND	—	Power and signal ground
B49	+5V	input	Logic supply voltage

Table 2: Top Side Slot Connector Pin Assignment

Slot Type Connector Pin Assignment (PCB Bottom Side)			
Pin	Label	Direction	Description
A1	+48V	input	Motor supply voltage
A2	+48V	input	Motor supply voltage
A3	+48V	input	Motor supply voltage
A4	+48V	input	Motor supply voltage
A5	GND	—	Power and signal ground
A6	GND	—	Power and signal ground
A7	GND	—	Power and signal ground
A8	GND	—	Power and signal ground
A9	—	—	not connected
A10	—	—	not connected
A11	—	—	not connected
A12	OA2	output	Stepper motor: coil A pin 2
A13	OA2	output	Stepper motor: coil A pin 2
A14	OA2	output	Stepper motor: coil A pin 2
A15	OA2	output	Stepper motor: coil A pin 2
A16	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W
A17	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W
A18	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W
A19	OA1/W	output	Stepper motor: coil A pin 1 BLDC motor: phase W
A20	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
A21	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
A22	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
A23	OB2/V	output	Stepper motor: coil B pin 2 BLDC motor: phase V
A24	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U
A25	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U
A26	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U

Pin	Label	Direction	Description
A27	OB1/U	output	Stepper motor: coil B pin 1 BLDC motor: phase U
A28	NC		not connected
A29	GND	—	Power and signal ground
A30	ENC_A	input	Encoder signal A (A channel)
A31	ENC_B	input	Encoder signal B (B channel)
A32	ENC_N	input	Encoder signal N (null channel)
A33	GND	—	Power and signal ground
A34	STOP_L	input	Left stop switch
A35	STOP_R	input	Right stop switch
A36	HOME	input	Home switch
A37	GND	—	Power and signal ground
A38	DIR	input	direction signal input
A39	STEP	input	step signal input
A40	GND	—	Power and signal ground
A41	RS485A_4671	input	Direct RS485 interface to the TMC4671 chip
A42	AIN0	input	General purpose analog/digital input #0
A43	GND	—	Power and signal ground
A44	ADDR3	input	Module address bit 3
A45	ADDR2	input	Module address bit 2
A46	ADDR1	input	Module address bit 1
A47	ADDR0	input	Module address bit 0
A48	GND	—	Power and signal ground
A49	+5V	input	Logic supply voltage

Table 3: Bottom Side Slot Connector Pin Assignment

NOTICE   **Do not connect or disconnect a motor during operation!** Motor cable and motor inductivity might lead to voltage spikes when the motor is (dis)connected while energized. These voltage spikes might exceed voltage limits of the driver MOSFETs and might permanently damage them. Therefore, always switch off / disconnect power supply or at least disable driver stage before connecting / disconnecting motor.

NOTICE   **Do not remove or plug in the module while the base board is powered!**

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5 Reset to Factory Defaults

It is possible to reset all settings in firmware for the TMCM-1638 to factory defaults without establishing a working communication connection. This might be helpful in case communication parameters of the preferred interface have been set to unknown values or got lost.

For this procedure two pads on the top side of the module have to be shorted (electrically connected with each other) during power-on.

Please perform the following steps:

1. Switch power supply OFF.

2. Short CLK and DIO pads of programming pads on bottom of PCB (see figure 2).

3. Switch power supply ON again.

4. Wait a few seconds.

5. Switch power supply OFF again.

6. Remove the short between the two pads.

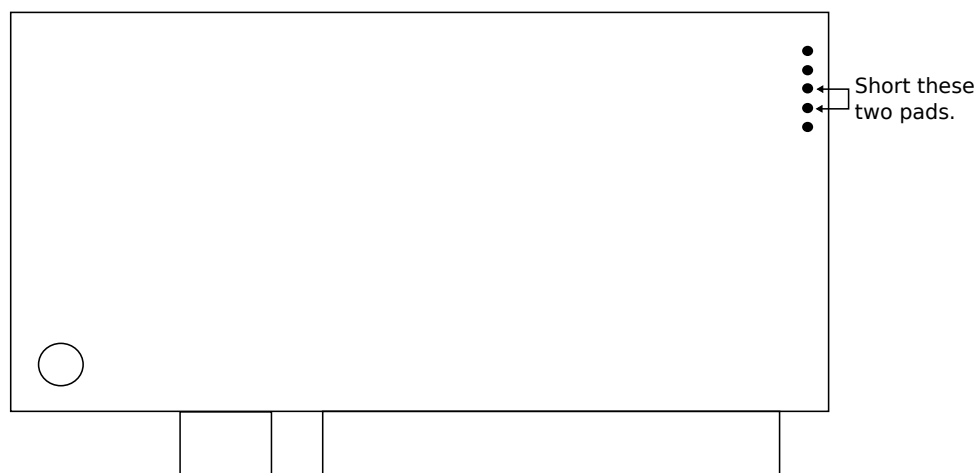7. After switching power supply ON again all permanent settings have been restored to factory defaults.

Figure 2: Reset to factory default settings

6   I/Os

The slot connector offers two analog inputs, two digital inputs and digital outputs. All inputs can be used for different purposes explained in more detail in the following subsections.

6.1   Analog input IN0

The TMCM-1638 is equipped with one analog input. The analog input voltage range is approx. 0. . . +5V. For voltages above +5V saturation takes place but, up-to 30V higher voltages are tolerated without destroying the input. For analog to digital conversion the integrated ADC of the on-board microcontroller is used. Resolution of this converter is 12bit (0..4095).
The analog inputs can also be used as digital inputs.

6.2   Digital inputs IN0 and IN1

The TMCM-1638 offers two digital inputs IN0 and IN1. Their input voltage range is 0. . . +5V. Higher voltages (up to 30V) are also tolerated without destroying the input. Voltages above 1V are recognized as logical '1' and below 1V as logical '0'.

6.3   Digital output OUT0

The TMCM-1638 is equipped with one general purpose digital output, using TTL level (0. . . +5V).

6.4   HOME/STOP_L/STOP_R switch inputs

The TMCM-1638 offers two inputs which can be used as left (STOP_L) and right (STOP_R) stop switch inputs. When enabled in software the STOP_L switch input will stop motor movement in negative direction (step counter decreasing) while activated. Likewise the STOP_R switch input will stop motor movement in positive direction (step counter increasing) while activated.

6.5   Incremental encoder input

An incremental A/B/N encoder can be connected to the encoder interface ENC_A, ENC_B and ENC_N. Encoder with push-pull signals (e.g. +5V TTL) and open-drain output signals are supported (single-ended). The module is equipped with 4k7 pull-up resistors to +5V.

6.6   Hall sensor input

Hall sensor may be connected to the inputs HALL_U, HALL_V, HALL_W. The module is equipped with 4k7 pull-up resistors to +5V.

6.7   Step/Direction inputs

The TMCM-1638 may be used as driver with an external motion controller. In this case the Step/Direction output signals of the external motion controller may be connected to the Step/Dir inputs of the TMCM-1638. Please note that these signals have to be TTL level signals.

6.8   Address pins

The address pins ADDR0, ADDR1, ADDR2 and ADDR3 can be used to set the TMCL module address or CANopen node ID of the TMCM-1638. This is useful when a base board with more than one slot is being used. In this case, every slot can be assigned to one specific TMCL module address or CANopen node ID by hardware.

When all address pins are pulled low, the address pins are not used. The TMCL module address or CANopen node ID stored in the EEPROM of the module will be used then. So in this case address / ID settings will be set in software.

When at least one of the address pins is pulled high the address or ID set by the address pins will be used. With TMCL, the module address will be determined by the address pins (1...15), and the reply address will always be 255. This is true for CAN and for RS485 communication. With CANopen, the node ID will be determined by the address pins (1...15).

6.9   Direct RS485 interface to the TMC4671 chip

The pins RS485A_4671 (A41) and RS485B_4671 (B41) are connected to the serial interface of the TMC4671 chip via an RS485 transceiver. This way, the TMC4671 chip can also be controlled directly, bypassing the CPU of the TMCM-1638 module. This RS485 interface only works as an input. So it is only possible to write to the TMC4671 registers and not possible to read from the TMC4671 via this interface. This interface is only needed for special cases. In most cases these two pins can be left unconnected.

7 Communication

7.1 RS485

For remote control and communication with a host system the TMCM-1638 provides a two wire RS485 bus interface. For proper operation the following items should be taken into account when setting up an RS485 network:

1. *BUS STRUCTURE:*
   The network topology should follow a bus structure as closely as possible. That is, the connection between each node and the bus itself should be as short as possible. Basically, it should be short compared to the length of the bus.
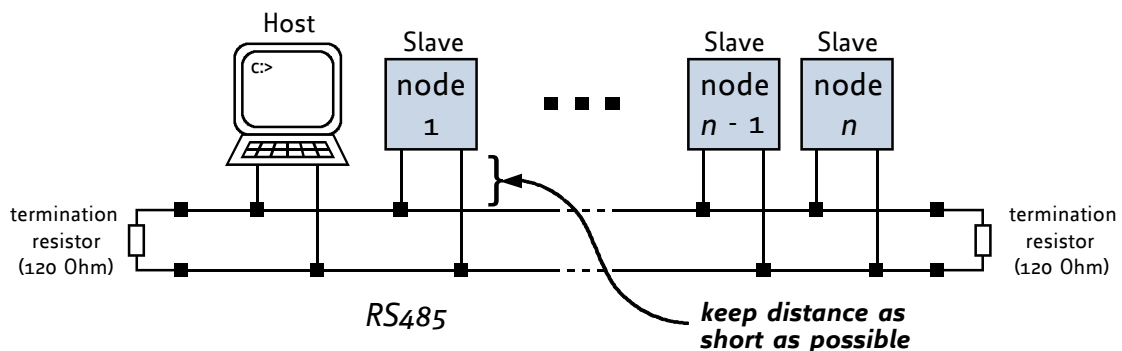

Figure 3: RS485 bus structure with termination resistors

2. *BUS TERMINATION:*
   Especially for longer buses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-1638 does not integrate any termination resistor. Therefore, 120 Ohm termination resistors at both ends of the bus have to be added externally.

3. *NUMBER OF NODES:*
   The RS485 electrical interface standard (EIA-485) allows up to 32 nodes to be connected to a single bus. The bus transceiver used on the TMCM-1638 units (MAX22501E) offers a significantly reduced bus load compared to the standard and allows a maximum of 255 units to be connected to a single RS485 bus using standard TMCL firmware. *Please note: usually it cannot be expected to get reliable communication with the maximum number of nodes connected to one bus and maximum supported communication speed at the same time. Instead, a compromise has to be found between bus cable length, communication speed and number of nodes.*

4. *COMMUNICATION SPEED:*
   The maximum RS485 communication speed supported by the TMCM-1638 hardware is 1Mbit/s. Factory default is 9600 bit/s. Please see separate TMCM-1638 TMCL firmware manual for information regarding other possible communication speeds below the upper hardware limit.

5. *NO FLOATING BUS LINES:*
   Avoid floating bus lines while neither the host/master nor one of the slaves along the bus line is transmitting data (all bus nodes switched to receive mode). Floating bus lines may lead to communication errors. In order to ensure valid signals on the bus it is recommended to use a resistor network connecting both bus lines to well defined logic levels.

   There are actually two options which can be recommended: Add resistor (bias) network on one side of the bus, only (120R termination resistor still at both ends):
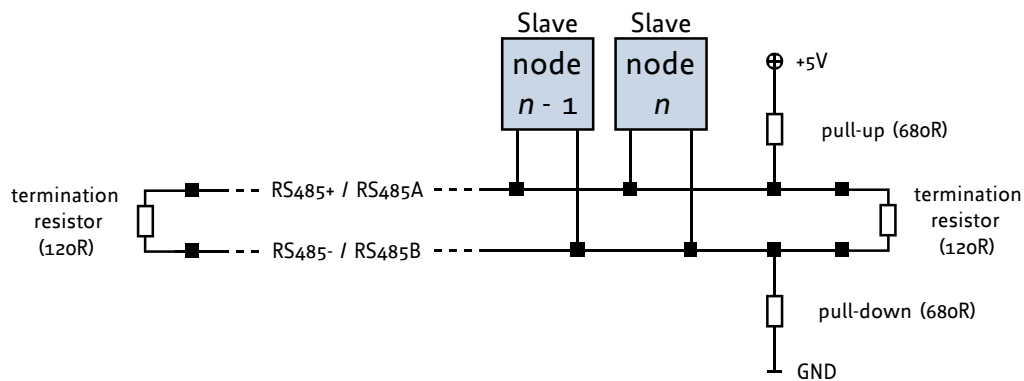
Figure 4: RS485 bus lines with resistor (bias) network on one side, only

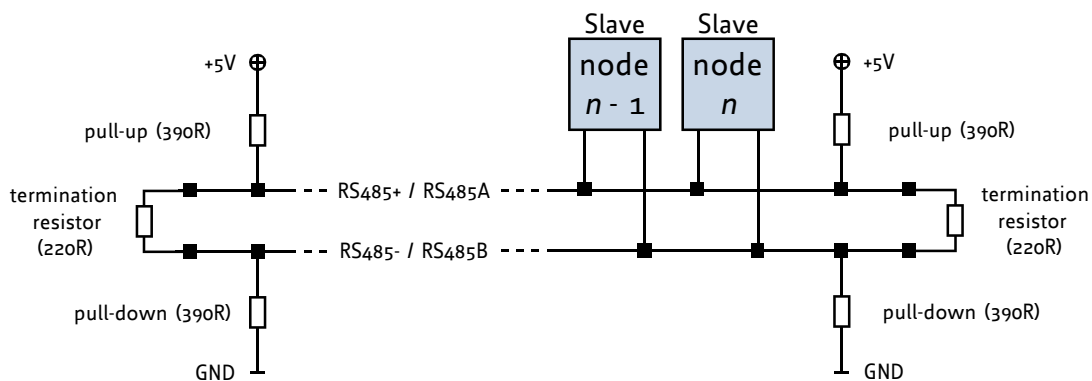Or add resistor network at both ends of the bus (like Profibus™ termination):

Figure 5: RS485 bus lines with Profibus™recommended line termination

7.2   CAN

For remote control and communication with a host system the TMCM-1638 provides a CAN bus interface. Please note that the CAN interface is not available in case USB is connected. For proper operation the following items should be taken into account when setting up a CAN network:

1. *BUS STRUCTURE:*
   The network topology should follow a bus structure as closely as possible. That is, the connection between each node and the bus itself should be as short as possible. Basically, it should be short compared to the length of the bus.
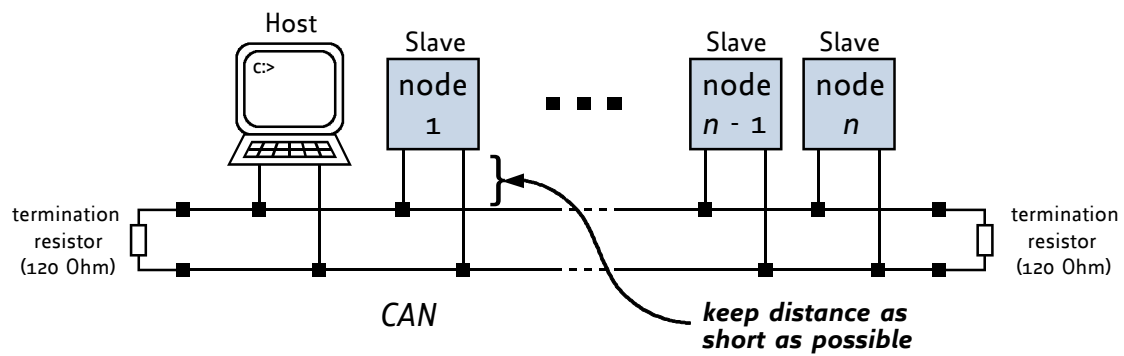
Figure 6: CAN bus structure with termination resistors

2. *BUS TERMINATION:*
   Especially for longer buses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-1638 does not integrate any termination resistor. Therefore, 120 Ohm termination resistors at both ends of the bus have to be added externally.

3. *BUS TERMINATION:*
   The bus transceiver used on the TMCM-1638 units (TJA1051TK/3) supports at least 110 nodes under optimum conditions. Practically achievable number of nodes per CAN bus highly depend on bus length (longer bus -> less nodes) and communication speed (higher speed -> less nodes).

8 Functional Description

The TMCM-1638 is a highly integrated single axis, field oriented controller/driver module for single phase DC motors, two phase stepper motors and three phase BLDC motors with up-to 7A RMS / 10A peak motor coil current. The TMCM-1638 can be controlled via RS485 or CAN interface.
The TMCM-1638 comes with the PC based software development environment TMCL-IDE for the Trinamic Motion Control Language (TMCL™). Using predefined TMCL™ high level commands like *move to position* a rapid and fast development of motion control applications is guaranteed. Whereas the boot loader is installed during production and testing at TRINAMIC and remains usually untouched throughout the whole lifetime, the firmware can be updated by the user via any serial interface.
Communication traffic is kept low since all time critical operations, e.g. ramp calculation, are perfomrmed on-board. Full remote control of the device with feedback is possible. The firmware of the module can be updated via the CAN or the RS485 interface.

The TMCM-1638 module contains the following main components:

- Microcontroller (ARM Cortex-M0+™), responsible for overall control and communication

- Highly integrated advanced field oriented motor controller supporting field oriented control in hardware.

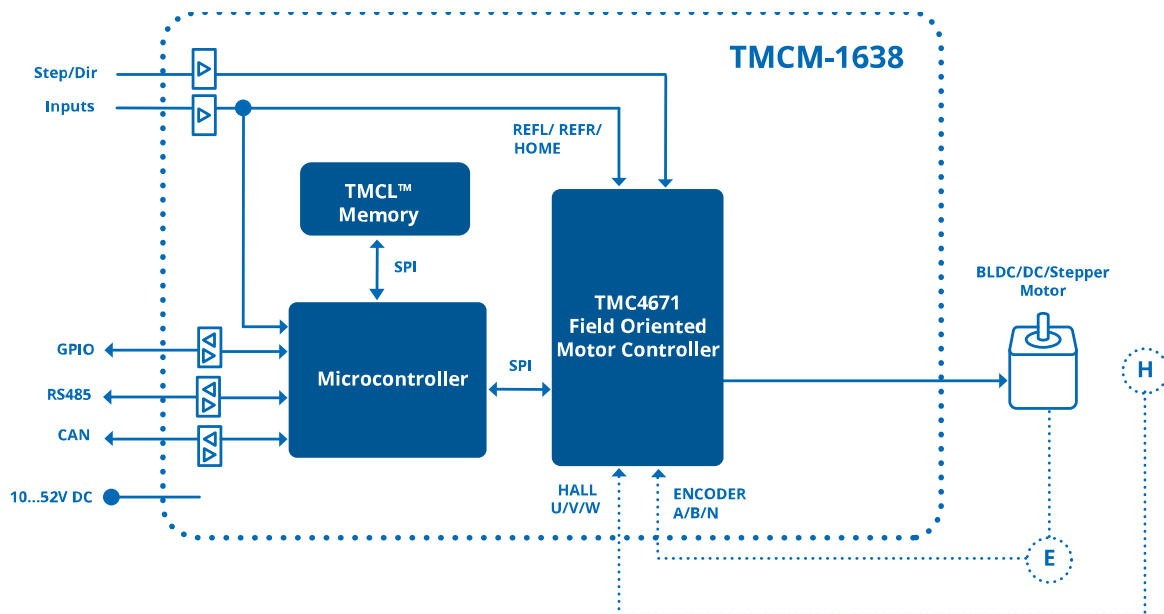- MOSFET driver stage.

- RS485 and CAN transceivers.

Figure 7: TMCM-1638 block diagram

9 Operational Ratings and Characteristics

<table>
<tr><td>**NOTICE**</td><td>**Never Exceed the absolute maximum ratings!** Keep the power supply voltage below the upper limit of +30V! Otherwise the board electronics will seriously be damaged! Especially, when the selected operating voltage is near the upper limit a regulated power supply is highly recommended.</td></tr>
</table>

General Operational Ratings					
Symbol	Parameter	Min	Typ	Max	Unit
V_{Motor}	Motor power supply voltage	10	12…48	52	V
I_{Motor}	Motor power supply current		$\ll I_{COIL\_RMS}$	$1.4 \times I_{COIL\_RMS}$	A
V_{Logic}	Logic power supply voltage		5		V
I_{Logic}	Logic power supply current		tbd		mA
I_{COIL_PEAK}	Motor coil current for sine wave **peak (chopper regulated, adjustable via software)**	0	0…10	10	A
I_{COIL_RMS}	Continuous motor current (**RMS**)	0	0…7	7	A
T_{ENV}	Environmental temperature at rated current (no forced cooling reaquired)	-30		60	°C

Table 4: General operational ratings of the module

Operational Ratings of the I/Os					
Symbol	Parameter	Min	Typ	Max	Unit
V_{OUT}	Voltage at digital output OUT0	0		5	V
V_{OUT}	Current through OUT0			20	mA
$V_{IN0/1}$	Input voltage for inputs IN0…IN1	0	0…5	5	V
V_{AIN0}	Measurement range for analog input AIN0	0		5	V
$V_{IN0/1\_L}$	Low level voltage for IN0…IN1 (digital inputs)			1	V
$V_{IN0/1\_H}$	High level voltage for IN0…IN1 (digital inputs)	2.9			V
V_{STOP_L/R_L}	Low level voltage for stop and home switch inputs		1		V
V_{STOP_L/R_H}	High level voltage for stop and home switch inputs	0	2.9		V
$f_{STEP/DIR}$	Max. frequency for step/direction inputs		250		kHz

Table 5: Operational ratings of I/Os

Operational Ratings of the RS485 Interface					
Symbol	Parameter	Min	Typ	Max	Unit
N_{RS485}	Number of nodes connected to single RS485 network			256	
f_{RS485}	Max. speed for RS485 network			1Mbit/s	

Table 6: Operational ratings of the RS485 interface

Operational Ratings of the CAN Interface					
Symbol	Parameter	Min	Typ	Max	Unit
N_{CAN}	Number of nodes connected to single CAN network			>110	
f_{CAN}	Max. speed for CAN network			1Mbit/s	

Table 7: Operational ratings of the CAN interface

10   Abbreviations used in this Manual

Abbreviation	Description
FOC	Field Oriented Control
IDE	Integrated Development Environment
LED	Light Emmitting Diode
RMS	Root Mean Square value
TMCL	TRINAMIC Motion Control Language

Table 8: Abbreviations used in this Manual

11 Figures Index

12 Tables Index

13   Supplemental Directives

13.1   Producer Information

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14   Revision History

14.1   Hardware Revision

Version	Date	Author	Description
V1.0	2020-JUL-23	HH	Initial version.
V1.1	2020-OCT-13	HH	Direct interface to TMC4671 added.

Table 9: Hardware Revision

14.2   Document Revision

Version	Date	Author	Description
1.00	2020-JUN-23	OK	Initial version.
1.01	2021-JAN-05	OK	Adapted to hardware revision 1.1.

Table 10: Document Revision

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