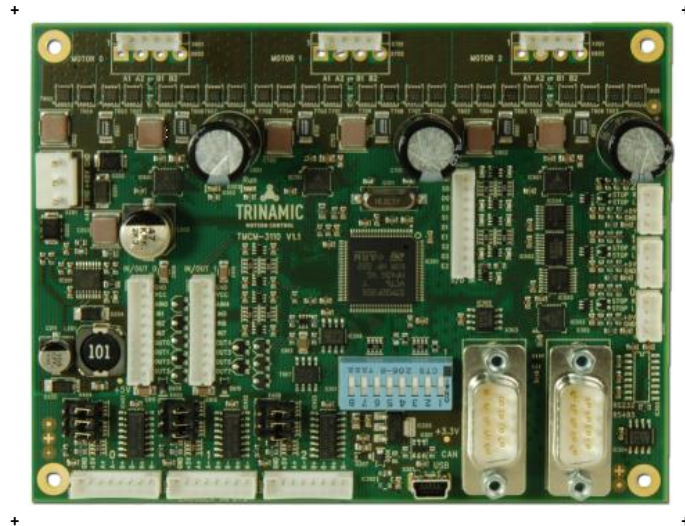**Hardware Version V1.1**

HARDWARE MANUAL

TMCM-3110

**3-Axis Stepper
Controller / Driver
2.8 A / 48 V
USB, RS485, and CAN
Step/Dir Interface
Encoder Interface**

coolStep™

stallGuard2™

TRINAMIC Motion Control GmbH & Co. KG
Hamburg, Germany

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TRINAMIC
MOTION CONTROL

Table of Contents

1   Features

The TMCM-3110 is a compact 3-axes stepper motor controller/driver module for 2-phase bipolar stepper motors. It is highly integrated, offers a convenient handling and can be used in many decentralized applications. The TMCM-3110 supports up to 3 bipolar stepper motors with up to 2.8A RMS coil current and supply voltages up to +48V DC nominal. There are separate motor and reference/end switch connectors as well as incremental encoder (a/b/n) connectors for each motor. Communication can take place via RS485, CAN, or USB interfaces. The module offers 8 general purpose inputs and 8 general purpose outputs for various application possibilities. With its high energy efficiency from TRINAMIC's coolStep™ technology cost for power consumption is kept down. The TMCL™ firmware allows for both, standalone operation and direct mode.

MAIN CHARACTERISTICS

Motion controller
- Motion profile calculation in real-time
- On the fly alteration of motor parameters (e.g. position, velocity, acceleration)
- High performance microcontroller for overall system control and serial communication protocol handling

Bipolar stepper motor driver
- Up to 256 microsteps per full step
- High-efficient operation, low power dissipation
- Dynamic current control
- Integrated protection
- stallGuard2 feature for stall detection
- coolStep feature for reduced power consumption and heat dissipation

Interfaces
- Up to 8 multi-purpose inputs (+24V compatible, incl. 2 dedicated analog inputs)
- Up to 8 multi-purpose outputs (Open-drain, incl. 2 outputs for currents up to 1A)
- Inputs for 3 incremental encoders (differential and TTL / open-drain)
- S/D in for all three axes (as alternative to on-board motion controller)
- RS485 communication interface (9pin D-SUB male)
- CAN 2.0B communication interface (9pin D-SUB male)
- USB 2.0 full-speed (12Mbit/s) communication interface (mini-USB connector)

Software
- TMCL remote (direct mode) and standalone operation
- Memory for up to 1024 TMCL commands
- Fully supported by TMCL-IDE (PC based integrated development environment)

Electrical data
- Supply voltage: +10V… +48V DC
- Motor current: up to 2.8A RMS (programmable) per axis

Safety features
- Integrated protection: overtemperature/undervoltage

Mechanical data
- Board size: 130mm x 100mm, height 30mm max.
- 4 mounting holes for M3 screws

Please see separate TMCM-3110 TMCL Firmware Manual for additional information

TRINAMICS UNIQUE FEATURES – EASY TO USE WITH TMCL

stallGuard2™   stallGuard2 is a high-precision sensorless load measurement using the back EMF on the coils. It can be used for stall detection as well as other uses at loads below those which stall the motor. The stallGuard2 measurement value changes linearly over a wide range of load, velocity, and current settings. At maximum motor load, the value goes to zero or near to zero. This is the most energy-efficient point of operation for the motor.
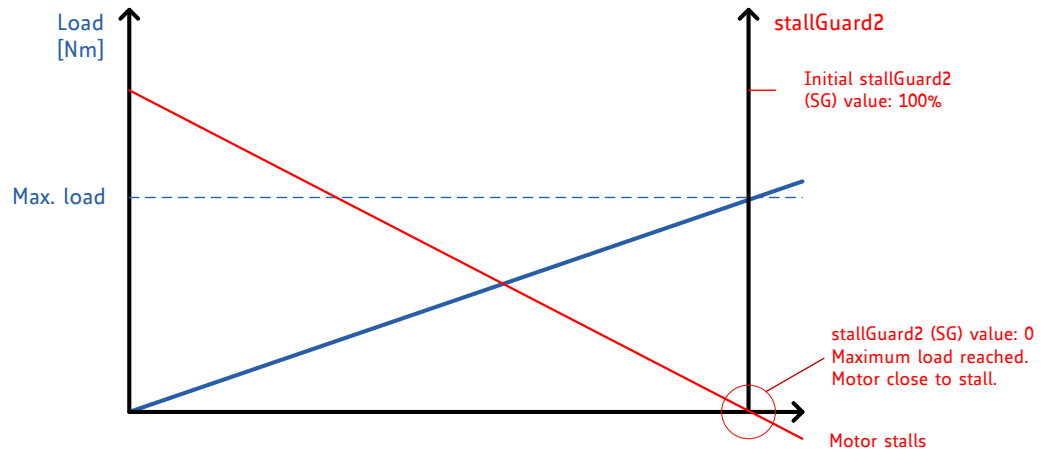
Figure 1.1 stallGuard2 load measurement SG as a function of load

coolStep™   coolStep is a load-adaptive automatic current scaling based on the load measurement via stallGuard2 adapting the required current to the load. Energy consumption can be reduced by as much as 75%. coolStep allows substantial energy savings, especially for motors which see varying loads or operate at a high duty cycle. Because a stepper motor application needs to work with a torque reserve of 30% to 50%, even a constant-load application allows significant energy savings because coolStep automatically enables torque reserve when required. Reducing power consumption keeps the system cooler, increases motor life, and allows reducing cost.

Figure 1.2 Energy efficiency example with coolStep

2 Order Codes

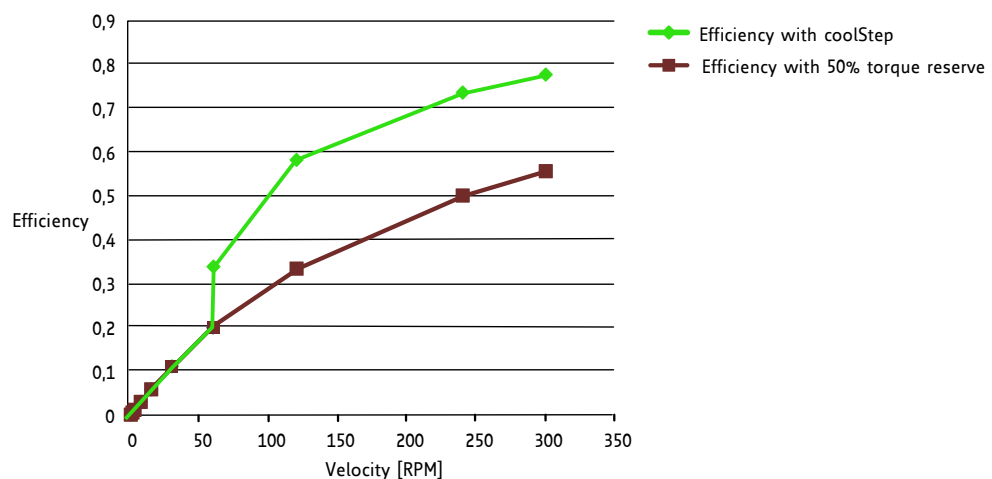| Order code	Description	Size [mm³]
TMCM-3110-*option*	3-axes bipolar stepper motor controller/driver module with encoder interface	130 x 100 x 30

Table 2.1 TMCM-3110 order codes

The following options are available:

Firmware option	Description	Order code example:
-TMCL	Module pre-programmed with TMCL firmware	TMCM-3110-*TMCL*
-CANopen	Module pre-programmed with CANopen firmware	TMCM-3110-*CANopen*

Table 2.2 TMCM-3110 firmware options

A cable loom set is available for this module:

Order code	Description
TMCM-3110-CABLE	Cable loom for TMCM-3110. Contains (see chapter 3.2, also): - 1x cable loom for power connector - 3x cable loom for reference switch connectors 0-2 - 3x cable loom for motor connectors 0-2 - 2x cable loom for I/O connectors 0+1 - 3x cable loom for encoder connectors 0-2 - 1x cable loom for S/D connector - 1x USB type A connector to mini-USB type B connector cable

Table 2.4 Cable loom order code

3 Mechanical and Electrical Interfacing

3.1 Dimensions

The board with the controller/driver electronics has an overall size of 130mm x 100mm. It has four mounting holes for M3 screws (3.2mm diameter). Maximum board height (without mating connectors and cable looms) is about 30mm (approx. 26mm above printed circuit board level).
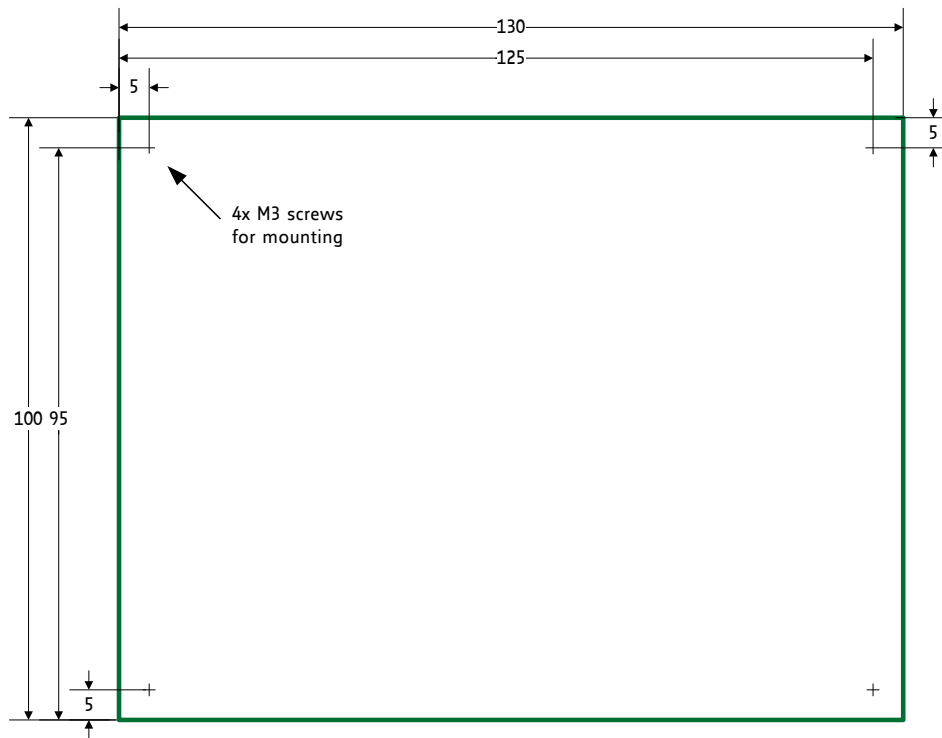

Figure 3.1 Board dimensions and position of mounting holes (all values in mm).

3.2 Considerations for Mounting

The TMCM-3110 has four metal plated mounting holes. These mounting holes are connected to the system and signal ground (which is the same as the power supply ground). In order to minimize distortion of signals and radiation of HF signals (improve EMC compatibility) especially in sensitive and/or noisy environments it is important to ensure a solid ground connection within the system. Thus, it is recommended to connect all four mounting holes in addition to the supply ground connection to system power supply ground.

Nevertheless, this might not always be an option: for instance, the metal system chassis or TMCM-3110 mounting plate is already connected to earth and a direct connection between supply ground (secondary side) and mains supply earth (primary side) is not desired. In such a case, TRINAMIC recommends to use plastic (e.g. made of nylon) spacers or distance bolts.

3.3 Connectors

The TMCM-3110 has 16 connectors altogether. There are three separate connectors for each motor, three for corresponding reference switches, and three for encoder inputs. Further, the board has two I/O connectors, one S/D IN connector, one power connector and three connectors for communication (mini-USB, RS485, and CAN).
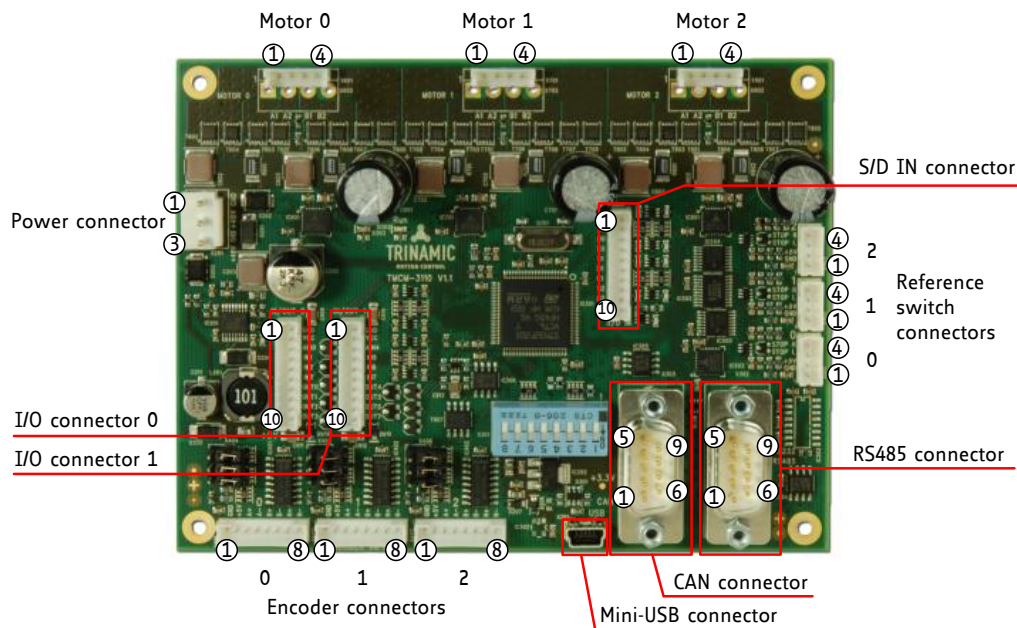

Figure 3.2 TMCM-3110 connectors

CONNECTOR TYPES AND MATING CONNECTOR TYPES

Label	Connector type	Mating connector type
Power connector	JST B3P-VH (JST VH series, 3pins, 3.96mm pitch)	Connector housing: JST VHR-3N Contacts: JST SVH-21T-P1.1 Wire: 0.83mm², AWG 18
Motor connectors	JST B4B-EH-A (JST EH series, 4pins, 2.5mm pitch)	Connector housing: JST EHR-4 Contacts: JST SEH-001T-P0.6 Wire: 0.33mm², AWG 22
Reference Switch connectors	JST B4B-PH-K-S (JST PH series, 4pins, 2mm pitch)	Connector housing: JST PHR-4 Contacts: JST SPH-002T-P0.5S Wire: 0.22mm², AWG 24
I/O connectors 0 + 1	JST B10B-PH-K-S (JST PH series, 10pins, 2mm pitch)	Connector housing: JST PHR-10 Contacts: JST SPH-002T-P0.5S Wire: 0.22mm², AWG 24
S/D IN connector	JST B10B-PH-K-S (JST PH series, 10pins, 2mm pitch)	Connector housing: JST PHR-10 Contacts: JST SPH-002T-P0.5S Wire: 0.22mm², AWG 24
USB connector	Molex 500075-1517 Mini USB Type B vertical receptacle	Any standard mini-USB plug
RS485 connector	Tyco electronics 3-1634218-2 D-SUB socket with 4-40 female screwlocks	Any standard D-SUB female 9-pin
CAN connector	Tyco electronics 3-1634218-2 D-SUB socket with 4-40 female screwlocks	Any standard D-SUB female 9-pin
Encoder connectors	JST B8B-PH-K-S (JST PH series, 8 pins, 2mm pitch)	Connector housing: JST PHR-8 Contacts: JST SPH-002T-P0.5S Wire: 0.22mm², AWG 24

Table 3.1 Connectors and mating connectors, contacts and applicable wire

3.3.1 Power Connector

The module offers a single power connector with the option for separate supply for driver electronics and digital controller part. A single supply voltage is sufficient. All further voltages required, e.g., for the digital components are generated on-board.

	Pin	Label	Direction	Description
	1	GND	Power (GND)	Common system supply and signal ground
	2	V_{DRIVER}	Power (supply input)	Stepper driver supply voltage. Without this voltage, the stepper driver part and therefore any motor connected will not be energized.
	3	$V_{DIGITAL}$	Power (supply input)	Supply voltage for everything else apart from the stepper motor driver ICs. An on-board voltage regulator will generate the necessary voltages for the digital circuits from this supply. This pin can be left unconnected. In this case a diode between V_{DRIVER} and $V_{DIGITAL}$ will ensure the supply of the digital parts. *Note:* *It is expected that $V_{DIGITAL}$ and V_{DRIVER} are connected to the same power supply output when both pins are used. Otherwise ensure that $V_{DIGITAL}$ is always equal or higher than V_{DRIVER} when connected (due to the diode).*

Table 3.2 Power connector

3.3.2 Motor Connector 0, 1, 2

For each stepper motor axis a separate connector is used.
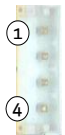
	Pin	Label	Description
	1	OA1	Motor coil A
	2	OA2	Motor coil A-
	3	OB1	Motor coil B
	4	OB2	Motor coil B-

Table 3.3 Motor connectors 0, 1, 2

TMCM-3110	QSH5718 motor		
Motor connector pin	Cable colour	Coil	Description
1	Black	A	Motor coil A pin 1
2	Green	A-	Motor coil A pin 2
3	Red	B	Motor coil B pin 1
4	Blue	B-	Motor coil B pin 2

Figure 3.3 Example: how to connect a QSH5718 stepper motor

3.3.3 S/D IN Connector

The module offers one common connector for external Step/Direction input for all three axes. This way, an external motion controller instead of the on-board one might be used together with the three on-board stepper motor driver stages.
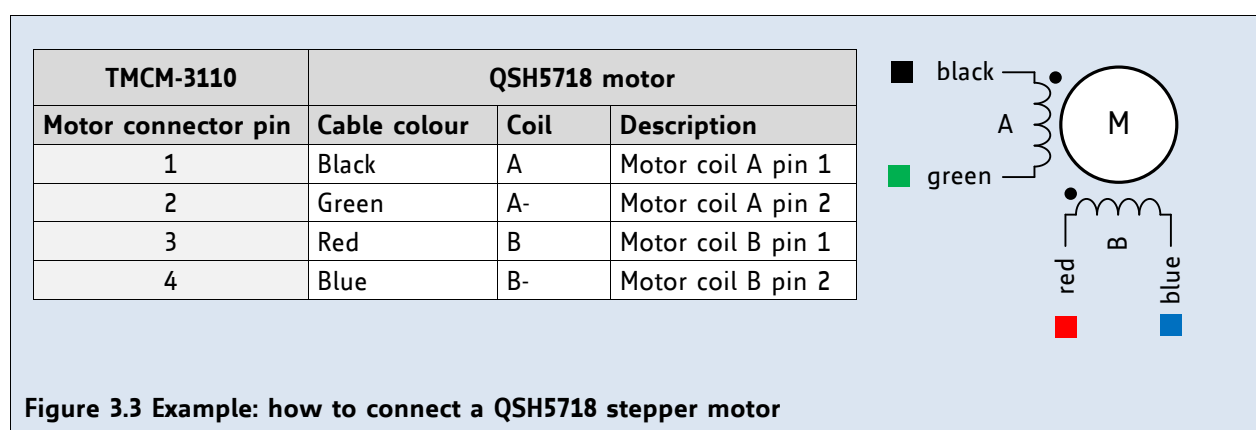
Pin	Label	Direction	Description
1	GND	Power (GND)	GND
2	S_0	Input	Step signal input for motor 0 (+24V compatible)
3	D_0	Input	Direction signal input for motor 0 (+24V compatible)
4	E_0	Input	Enable signal input for motor 0 (+24V compatible)
5	S_1	Input	Step signal input for motor 1 (+24V compatible)
6	D_1	Input	Direction signal input for motor 1 (+24V compatible)
7	E_1	Input	Enable signal input for motor 1 (+24V compatible)
8	S_2	Input	Step signal input for motor 2 (+24V compatible)
9	D_2	Input	Direction signal input for motor 2 (+24V compatible)
10	E_2	Input	Enable signal input for motor 2 (+24V compatible)

Table 3.4 S/D IN connector

3.3.4 Reference Switch Connector 0, 1, 2

For each stepper motor axis a separate reference/limit switch input connector is available.

Pin	Label	Direction	Description
1	GND	Power (GND)	Signal and system ground
2	+5V	Power (Supply output)	+5V output for external circuit
3	REF_L	Input	Input for reference / limit switch left, integrated pull-up to +5V
4	REF_R	Input	Input for reference / limit switch right, integrated pull-up to +5V

Table 3.5 Reference switch connectors 0, 1, 2

3.3.5 I/O Connectors 0, 1

The module offers two I/O connectors. The number and type of inputs, outputs and supply is the same for both connectors. Therefore, if only half of the inputs / outputs etc. is required it will be sufficient to use just one of the two connectors and reduce/simplify cabling.

I/O CONNECTOR 0

	Pin	Label	Direction	Description
	1	GND	Power (GND)	GND
	2	$V_{DIGITAL}$	Power (supply output)	Connected to $V_{DIGITAL}$ of Power connector
	3	AIN_0	Input	Dedicated analog input, input voltage range: 0… +10V, resolution: 12bit (0… 4095)
	4	IN_1	Input	Digital input (+24V compatible) Home switch input for motor 0
	5	IN_2	Input	Digital input (+24V compatible) Home switch input for motor 1
	6	IN_3	Input	Digital input (+24V compatible) Home switch input for motor 2
	7	OUT_0	Output	Open-drain output (max. 100mA) Integrated freewheeling diode
	8	OUT_1	Output	Open-drain output (max. 100mA) Integrated freewheeling diode to $V_{digital}$
	9	OUT_2	Output	Open-drain output (max. 100mA) Integrated freewheeling diode to $V_{digital}$
	10	OUT_3	Output	Open-drain output (max. 1A) Integrated freewheeling diode to $V_{digital}$

Table 3.6 I/O connector 0

I/O CONNECTOR 1

	Pin	Label	Direction	Description
	1	GND	Power (GND)	GND
	2	$V_{DIGITAL}$	Power (supply output)	Connected to $V_{DIGITAL}$ of Power connector
	3	AIN_4	Input	Dedicated analog input, input voltage range: 0… +10V, resolution: 12bit (0… 4095)
	4	IN_5	Input	Digital input (+24V compatible)
	5	IN_6	Input	Digital input (+24V compatible)
	6	IN_7	Input	Digital input (+24V compatible)
	7	OUT_4	Output	Open-drain output (max. 100mA) Integrated freewheeling diode
	8	OUT_5	Output	Open-drain output (max. 100mA) Integrated freewheeling diode to $V_{digital}$
	9	OUT_6	Output	Open-drain output (max. 100mA) Integrated freewheeling diode to $V_{digital}$
	10	OUT_7	Output	Open-drain output (max. 1A) Integrated freewheeling diode to $V_{digital}$

Table 3.7 I/O connector 1

3.3.6 Encoder Connector 0, 1, 2

For each stepper motor axis a separate encoder input connector is available. Encoders with incremental output signals – either differential (RS422 signals) or single ended (TTL or open collector signals) – with or without zero/index channel are supported. For encoders with +5V supply the required +5V output is also available via this connector (max. 100mA per connector).

	Pin	Label	Direction	Description
	1	GND	Power (GND)	Signal and system ground
	2	+5V	Power (supply output)	+5V output for external circuit (max. 100mA)
	3	A+	Input	Encoder channel A+ input (differential, non-inverting)
	4	A-	Input	Encoder channel A- input (differential, inverting)
	5	B+	Input	Encoder channel B+ input (differential, non-inverting)
	6	B-	Input	Encoder channel B- input (differential, inverting)
	7	N+	Input	Encoder zero / index channel input (differential, non-inverting)
	8	N-	Input	Encoder zero / index channel input (differential, inverting)

Table 3.8 Encoder connector 0, 1, 2

DIFFERENTIAL ENCODER SIGNALS

For differential encoder signals connect all differential signals (A+ and A-, B+ and B- and opt. N+ and N-) to the respective connector input pins. Usually, onboard line termination should be also installed for differential signals (close all three jumpers for 120R line termination of the respective differential encoder input):

Place jumpers for proper temrination
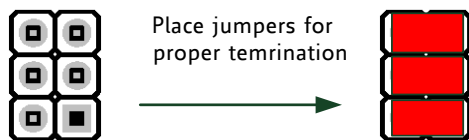
Please refer to encoder manufacturer data sheet for correct interface settings, also.

Figure 3.4 Encoder input termination

SINGLE ENDED ENCODERS

For single ended encoders (TTL or open collector signals) connect the encoder signals A, B and optional N to the positive/non-inverting differential inputs of the encoder connector A+ / B+ / N+.

The following connections should be made:

Encoder signals	Encoder connectors 0, 1, 2		
	Pin	Label	Description
A	3	A+	Encoder channel A+ input (differential, non-inverting)
B	5	B+	Encoder channel B+ input (differential, non-inverting)
N/I (optional)	7	N+	Encoder zero / index channel input (differential, non-inverting)

Table 3.9 Encoder signals for single ended encoders

Pins A-, B-, N- of the encoder connector may be left unconnected.

3.3.7 CAN Connector

A CAN 2.0B interface is available via a standard 9-pin male D-SUB connector. Only three pins of this connector are used. The pin assignment of these three pins is according to CiA Draft Recommendation Part 1: cabling and connector pin assignment.
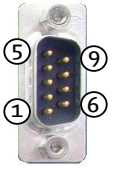
Pin	Label	Direction	Description
1			
2	CAN_L	Bi-directional	Differential CAN bus signal (inverting)
3	GND	Power (GND)	Signal and system ground
4			
5			
6			
7	CAN_H	Bi-directional	Differential CAN bus signal (non-inverting)
8			
9			

Table 3.10 CAN connector

3.3.8 RS485 Connector

An RS485 interface is available via a 9-pin male D-SUB connector.
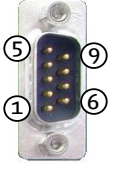
Pin	Label	Direction	Description
1			
2	RS485-	Bi-directional	Differential RS485 bus signal (inverting)
3	GND	Power (GND)	Signal and system ground
4			
5			
6			
7	RS485+	Bi-directional	Differential RS485 bus signal (non-inverting)
8			
9			

Table 3.11 RS485 connector

3.3.9 USB Connector

A USB interface is available via a Mini-USB connector. This module supports USB 2.0 Full-Speed (12Mbit/s) connections.

Attention
On-board digital core logic (mainly processor and EEPROM) will be powered via USB in case no other supply is connected. Use this to set parameters and download TMCL programs or perform firmware updates with the module connected via USB only or inside the machine while the machine is powered off.

Pin	Label	Direction	Description
1	VBUS	Power (+5V input)	+5V supply from Host
2	D-	Bi-directional	USB Data -
3	D+	Bi-directional	USB Data +
4	ID		Connected to signal and system ground
5	GND	Power (GND)	Signal and System ground

Table 3.12 USB connector

3.4 Power Supply

For proper operation care has to be taken with regard to power supply concept and design. The board offers around 1400uF / 63V electrolytic buffer capacitors and additionally around 28uF / 63V ceramic capacitors for supply voltage filtering.

It is important that the power supply voltage (V_{DRIVER} and $V_{DIGITAL}$) is kept below the upper limit of 52.8V DC (48V + 10%). Otherwise the on-board electronics will seriously be damaged! Especially, when the selected operating voltage is near the upper limit, a regulated power supply is highly recommended.
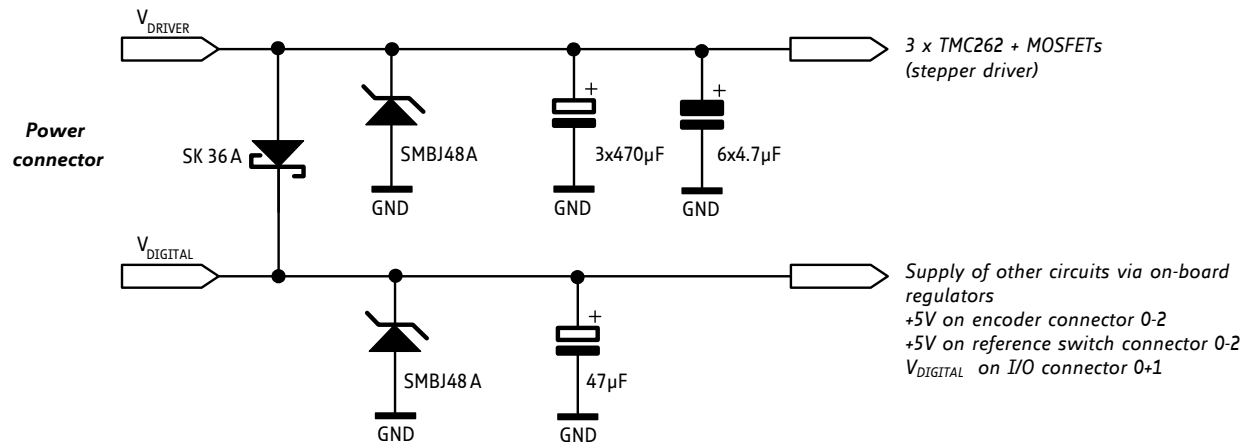

Figure 3.5 TMCM-3110 power supply concept

CAUTION!

⚠	**Add external power supply capacitors!** The module contains a number of capacitors for power supply filtering. Nevertheless, depending on operation and selected motors the resulting capacity might be not large enough for proper supply buffering. Rule of thumb: buffer capacity should be around 1000µF per 1A power supply current located not far away from the module between power supply wires. Please note: upper supply voltage limit must not be exceeded – not even for a short period of time! In this context it should be taken into account that the module will transfer energy from the motor back into the supply rail when the motor is working as generator e.g. during de-acceleration or brake conditions. In case the power supply capacitors are not sufficient for limiting power supply rising, additional measures have to be considered (e.g. suppressor diodes, brake resistor).
⚠	**Do not connect or disconnect motor during operation!** Motor cable and motor inductivity might lead to voltage spikes when the motor is disconnected / connected while energized. These voltage spikes might exceed voltage limits of the driver MOSFETs and might permanently damage them. Therefore, always disconnect power supply before connecting / disconnecting the motor.

3.5 Communication

3.5.1 RS485

For remote control and communication with a host system the TMCM-3110 provides a two wire RS485 bus interface. To select a modules' address, the TMCM-3110 is equipped with dip switches with digits from 1 to 8. Anyhow, the switches use the binary digit system. Thus, node addresses from 1 to 255 can be set.

THERE ARE TWO POSSIBILITIES FOR THE ADDRESS SETTING

- *All DIP switches off*: RS485 address is taken from the on-board non-volatile memory (EEPROM). Factory default value for the module address is 1.
- *At least one DIP switch on*: the 8 DIP switches define the RS485 address. The address is specified as binary 8bit value – DIP switches 1… 8 specify bit 1… 8 of the address
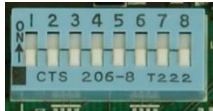

Figure 3.6 Dip switch for address selection

> *Note*
> - Per default, all dip switches are off and the module address taken from the EEPROM is 1. Per default, the host address is 2.
> - Do not use equal addresses for the host and the TMCM-3110!

For remote control and communication with a host system the TMCM-3110 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.
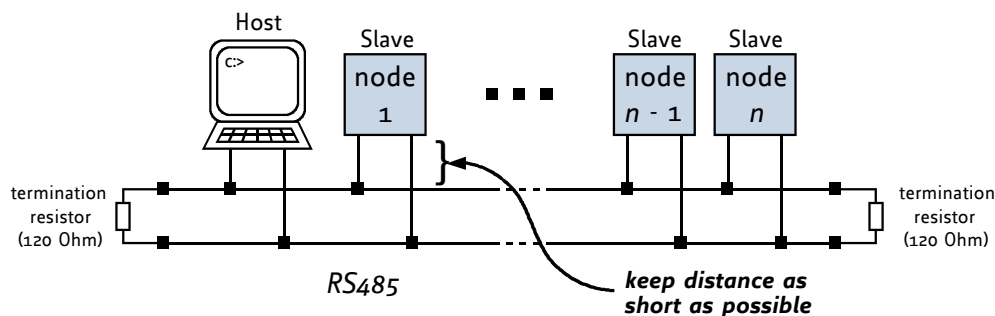

Figure 3.3: Bus structure

2. *BUS TERMINATION*:
   Especially for longer busses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-3110 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-3110 (SN65HVD1781D) has a significantly reduced bus load and allows a maximum of 255 units to be connected to a single RS485 bus using 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-3110 is 1Mbit/s. Factory default is 9600 bit/s. *Please see separate TMCM-6110 TMCL firmware manual for information regarding other possible communication speeds.*

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):
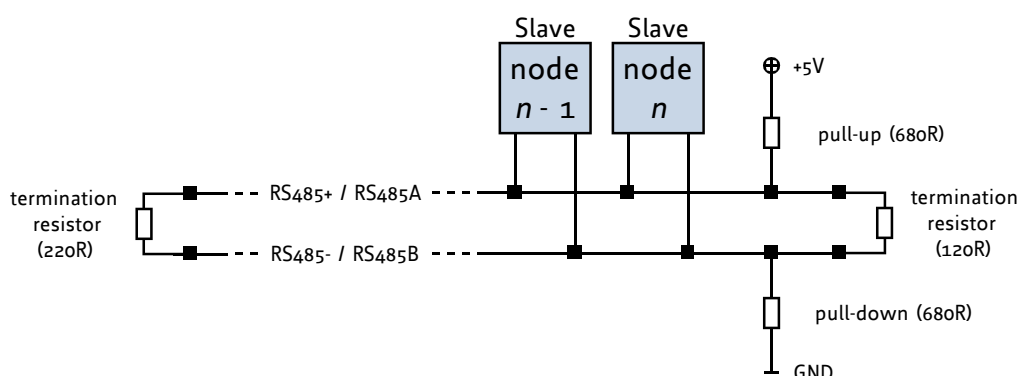
Figure 3.4: **Bus lines with resistor (Bias) network on one side, only**

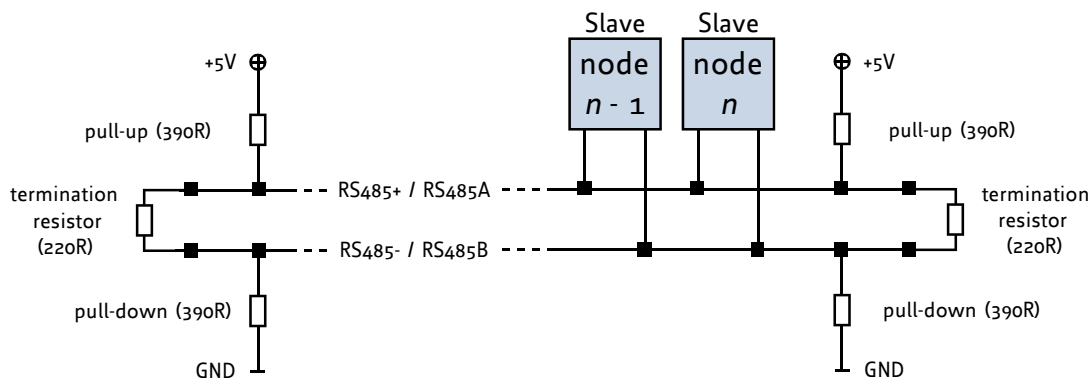Or add resistor (Bias) network at **both** ends of the bus (like Profibus™ termination):

Figure 3.5: **Bus lines with resistor (Bias) network at both ends**

3.5.2 CAN

For remote control and communication with a host system the TMCM-3110 provides a CAN bus interface. To select a modules' address, the TMCM-3110 is equipped with dip switches with digits from 1 to 8. Anyhow, the switches use the binary digit system. Thus, node addresses from 1 to 255 can be set.

THERE ARE TWO POSSIBILITIES FOR THE ADDRESS SETTING

- *All DIP switches off*: CAN address is taken from the on-board non-volatile memory (EEPROM). Factory default value for the module address is 1.
- *At least one DIP switch on*: the 8 DIP switches define the CAN address. The address is specified as binary 8bit value – DIP switches 1… 8 specify bit 1… 8 of the address.
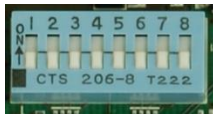

Figure 3.7 Dip switch for address selection

> *Note*
> - Per default, all dip switches are off and the module address taken from the EEPROM is 1. Per default, the host address is 2.
> - Do not use equal addresses for the host and the TMCM-3110!

For proper operation the following items should be taken into account when setting up a CAN network:

6. *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.
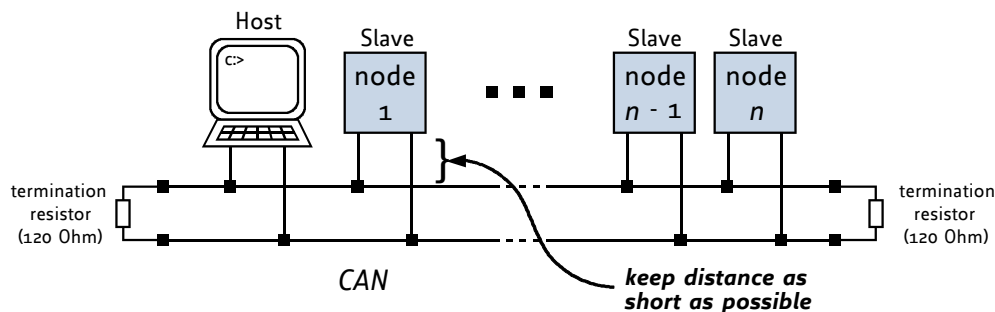
Figure 3.8 CAN bus structure

7. *BUS TERMINATION*:
   Especially for longer busses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-3110 does not integrate any termination resistor. Therefore, 120Ω termination resistors at both ends of the bus have to be added externally.

8. *NUMBER OF NODES*:
   The bus transceiver used on the TMCM-3110 units (TJA1050T) supports at least 110 nodes under optimum conditions. Practically achievable number of nodes per CAN bus highly depends on bus length (longer bus -> less nodes) and communication speed (higher speed -> less nodes).

3.5.3 USB

For remote control and communication with a host system the TMCM-3110 provides a USB 2.0 full-speed (12Mbit/s) interface (mini-USB connector). As soon as a USB-Host is connected the module will accept commands via USB. The CAN interface will be de-activated then.

The TMCM-3110 supports both, *USB self powered operation* (when an external power is supplied via the power supply connector) and *USB bus powered operation*, (no external power supply via power supply connector).

USB BUS POWERED OPERATION MODE

On-board digital core logic will be powered via USB in case no other supply is connected (USB bus powered operation). The digital core logic comprehends the microcontroller itself and also the EEPROM. The *USB bus powered operation mode* has been implemented to enable configuration, parameter settings, read-outs, firmware updates, etc. by just connecting an USB cable between module and host PC. No additional cabling or external devices (e.g. power supply) are required.

Please note that the module might draw current from the USB +5V bus supply even in USB self powered operation depending on the voltage level of this supply.

Motor movements are not possible in this operation mode. Therefore, connect the power connector and change to USB self powered operation mode.

3.6 Inputs and Outputs

3.6.1 Reference Switch Inputs

The three reference switch connectors – one for each stepper motor axis – offer two reference switch inputs each, REF_L and REF_R. Both inputs have the same input circuit with voltage resistor dividers, limiting diodes against over- and under-voltage and programmable 2k2 pull-ups to +5V. The programmable pull-ups can be switched on or off together for all three axes.
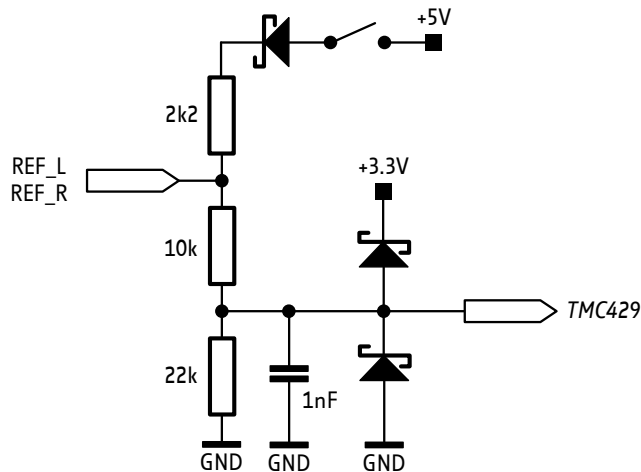

Figure 3.9 Reference switch input circuit (simplified diagram)

With TMCL firmware commands GAP 10, 0 and GAP 11, 0 can be used to read out the status of the reference switch inputs. See *TMCL Firmware Manual* chapter 5 about *Axis parameters* and *Reference search* for more details.

3.6.2 General Purpose Inputs

The TMCM-3110 offers two I/O connectors with 8 inputs altogether including two dedicated analog inputs. All inputs offer the same basic input protection circuit. The dedicated analog inputs have different input voltage dividers in order to support a full scale input voltage range of 0…+10V. The other digital inputs have been designed in order to be able to accept +5V and +24V signal levels.
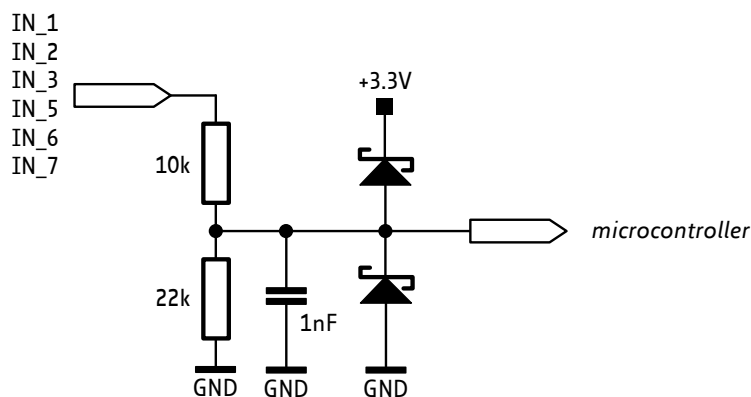

Figure 3.10 General purpose digital input circuit

With TMCL firmware command GIO <n>, 0 can be used to read out the status of the digital input <n>. See *TMCL Firmware Manual* command GIO for more details.
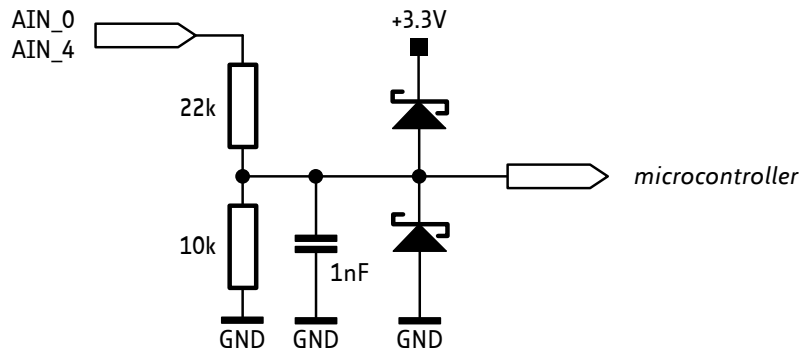
Figure 3.11 General purpose analog input circuit

With TMCL firmware command GIO `<n>, 1` can be used to read out the analog / digital converted value of the analog input *<n>*. See *TMCL Firmware Manual* command GIO for more details.

The function of the inputs might differ depending on firmware version.

3.6.3 General Purpose Outputs

The TMCM-3110 offers two I/O connectors with 8 outputs altogether. All 16 outputs are open-drain outputs and a freewheeling diode (to V_{DIGTAL}) is already integrated.

Note
- Two outputs offer more powerful MOSFET driver transistors supporting currents up to 1A. All other outputs have been designed for currents up to 100mA.
- If $V_{DIGITAL}$ connection of the I/O connectors is used for supply of substantial current to any external circuit, please make sure to connect V_{DIGTAL} in addition to V_{DRIVER} of the power supply connector.
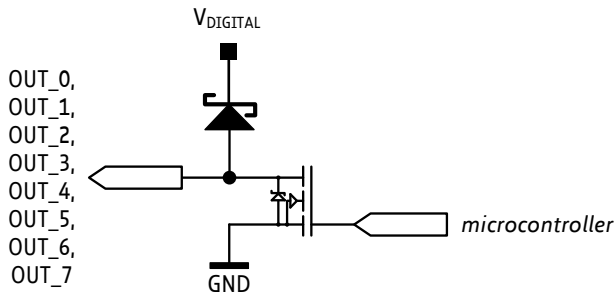
Figure 3.12 General purpose output (open-drain with freewheeling diode)

With TMCL firmware command SIO `<n>, 2, 1` can be used to set / pull-down the output *<n>*. See *TMCL Firmware Manual* command SIO for more details.

3.6.4 Encoder Inputs

The TMCM-3110 offers three connectors for incremental a/b/n encoders. Encoders with or without index/ null/zero channel are supported. Differential signals, push-pull (TTL) or open-collector are accepted. For differential signals on-board termination resistors can be activated via jumpers.

Encoder input circuit for each encoder channel:
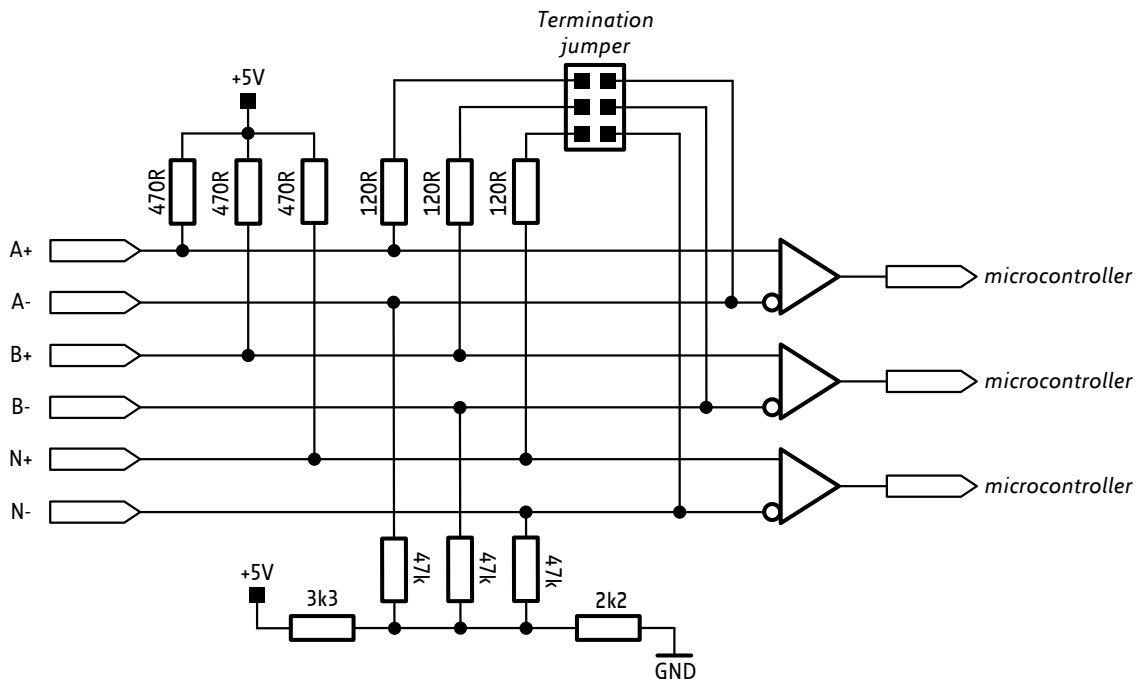
Figure 3.13 Encoder input circuit

The termination jumpers – three jumpers per encoder input channel – are located close to the encoder connector:
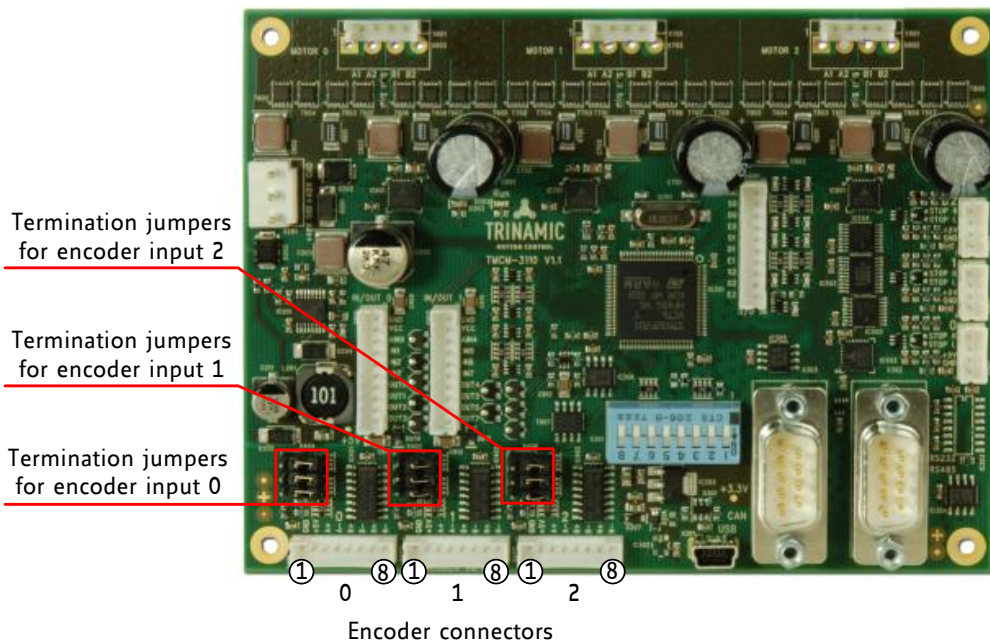
Figure 3.14 Termination jumper for differential encoder signals (jumper shown open / no termination)

For activation of line termination for differential encoder signals, jumpers have to be closed (see chapter 3.3.6).

3.6.5 Step/Dir Inputs

The TMCM-3110 offers an external Step/Dir IN connector. This way, an external motion controller can be used to directly control the three on-board stepper drivers via Step/Direction instead of the on-board motion controller.

The external Step/Dir inputs offer input protection and accept +5V up to +24V compatible input signals. An on-board multiplexer allows selection of the external Step/Dir input via software.

Figure 3.15 Step/Dir In connector input circuit

4 Motor driver current

The on-board stepper motor driver operates current controlled. The driver current may be programmed in software for motor coil currents up-to 2.8A RMS with 32 effective scaling steps in hardware (CS in table below).

Explanation of different columns in table below:

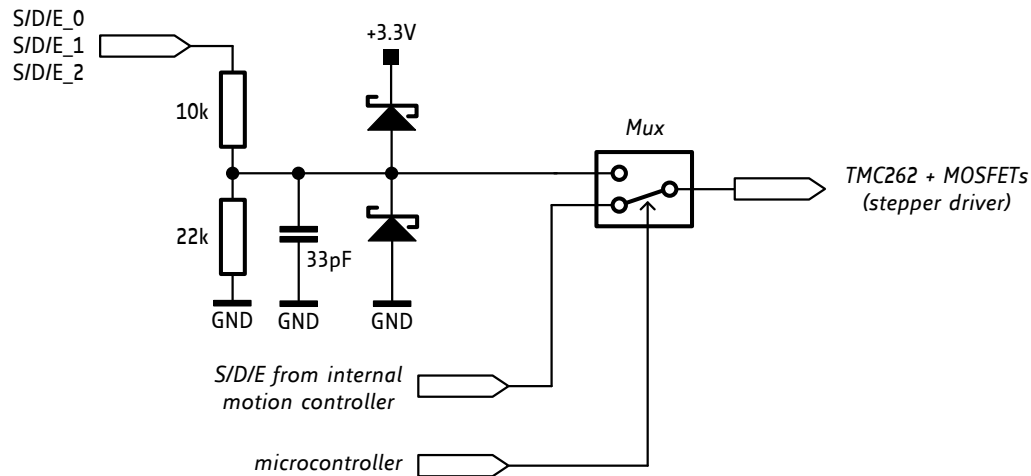|	

Motor current setting in software (TMCL)	These are the values for TMCL axis parameter 6 (motor run current) and 7 (motor standby current). They are used to set the run / standby current using the following TMCL commands:
	
	`SAP 6, 0, <value> // set run current`
	
	`SAP 7, 0, <value> // set standby current`
	
	(read-out value with `GAP` instead of `SAP`. Please see separate TMCM-3110 firmware manual for further information)

Motor current I_{RMS} [A]	Resulting motor current based on motor current setting

Motor current setting in software (TMCL)	Current scaling step (CS)	Motor current I_{COIL_PEAK} [A]	Motor current I_{COIL_RMS} [A]
0..7	0	0.132	0.093
8..15	1	0.264	0.187
16..23	2	0.397	0.280
24..31	3	0.529	0.374
32..39	4	0.661	0.467
40..47	5	0.793	0.561
48..55	6	0.925	0.654
56..63	7	1.058	0.748
64..71	8	1.190	0.841
72..79	9	1.322	0.935
80..87	10	1.454	1.028
88..95	11	1.587	1.122
96..103	12	1.719	1.215
104..111	13	1.851	1.309
112..119	14	1.983	1.402
120..127	15	2.115	1.496
128..135	16	2.248	1.589
136..143	17	2.380	1.683
144..151	18	2.512	1.776
152..159	19	2.644	1.870
160..167	20	2.776	1.963
168..175	21	2.909	2.057
176..183	22	3.041	2.150
184..191	23	3.173	2.244
192..199	24	3.305	2.337
200..207	25	3.438	2.431
208..215	26	3.570	2.524
216..223	27	3.702	2.618
224..231	28	3.834	2.711
232..239	29	3.966	2.805
240..247	30	4.099	2.898
248..255	31	4.231	2.992

In addition to the settings in the table the motor current may be switched off completely (free-wheeling) using axis parameter 204 (see TMCM-3110 firmware manual).

5 Onboard LEDs

The board offers two LEDs in order to indicate board status. The function of both LEDs is dependent on firmware version. With standard TMCL firmware the green LED should be flashing slowly during operation and the red LED should be off. Please see separate TMCM-3110 TMCL firmware manual for additional information.

If there is no valid firmware programmed into the board or during firmware update, the red and green LEDs are permanently on.
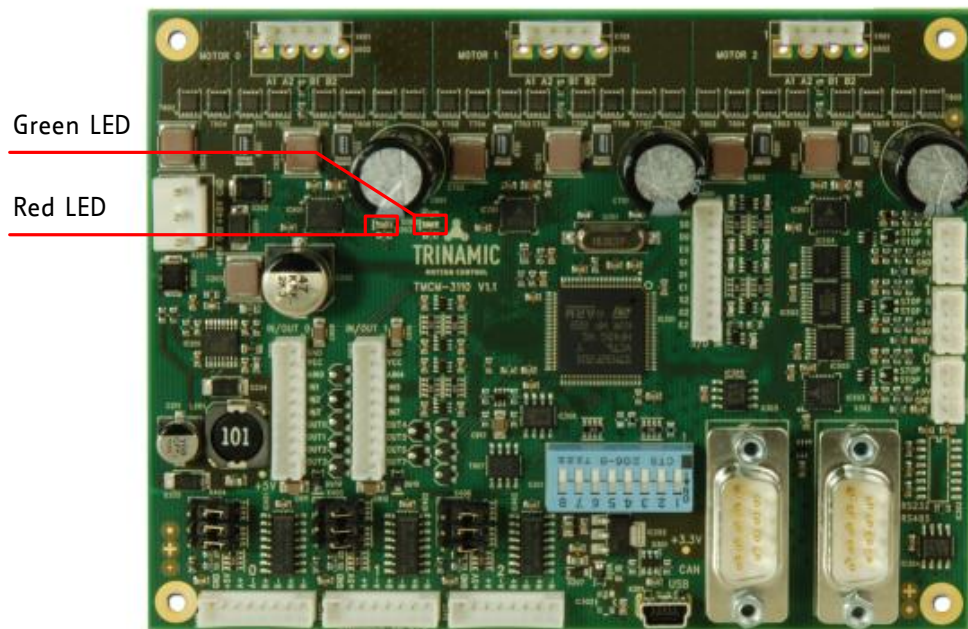
Green LED

Red LED

Figure 5.1 On-board LEDs

6   Reset to Factory Defaults

It is possible to reset the TMCM-3110 module to factory default settings without establishing a communication link. This might be helpful in case communication parameters of the preferred interface have been set to unknown values or got accidentally lost.

For this procedure two pads on the bottom side of the board have to be shortened.

PERFORM THE FOLLOWING STEPS:

1. Power supply off and USB cable disconnected.
2. Short two pads as marked in Figure 6.1.
3. Power up board (power via USB is sufficient for this purpose).
4. Wait until the on-board red and green LEDs start flashing fast (this might take a while).
5. Power-off board (disconnect USB cable).
6. Remove short between pads.
7. After switching on power-supply and connecting USB cable all permanent settings have been restored to factory defaults.
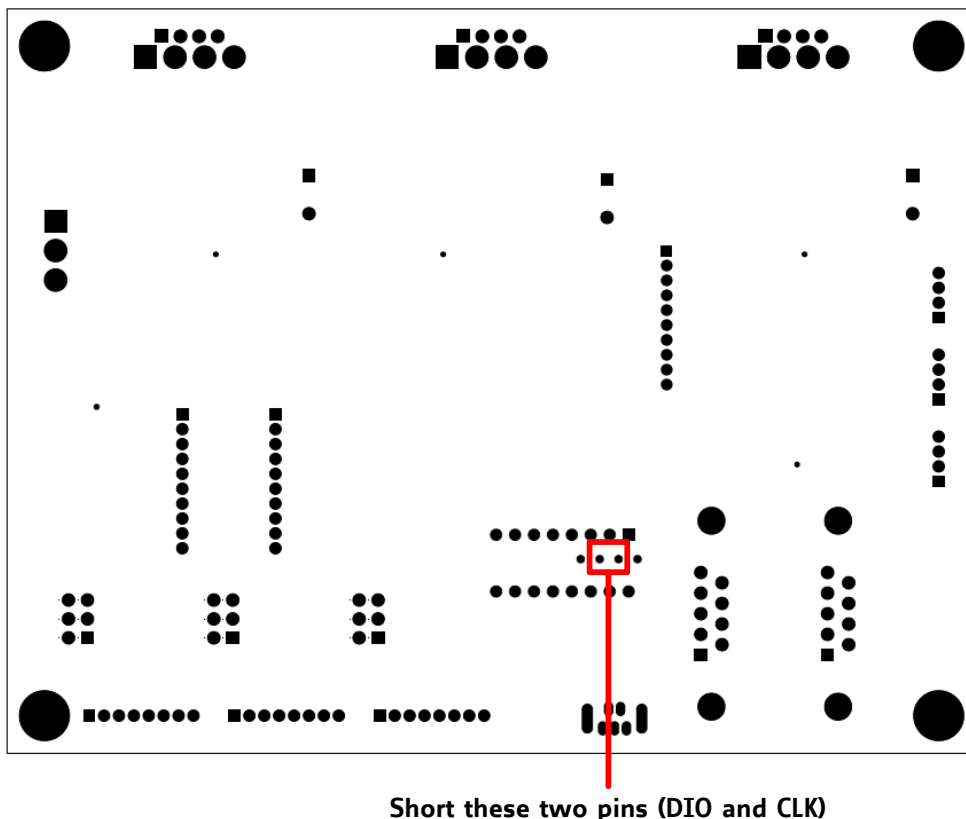

Short these two pins (DIO and CLK)

Figure 6.1 Reset pins (bottom view of module)

7 Operational Ratings

The operational ratings show the intended or the characteristic ranges and should be used as design values. *In no case shall the maximum values be exceeded.*

GENERAL OPERATIONAL RATINGS OF THE MODULE

Symbol	Parameter	Min	Typ	Max	Unit
V_{DRIVER}	Power supply voltage for driver	9	24 … 48	52.8	V
$V_{DIGITAL}$	Power supply voltage for controller (option, can be left unconnected)	V_{DRIVER}			V
V_{USB}	Power supply via USB connector		5		V
I_{USB}	Current withdrawn from USB supply when USB bus powered (no other supply connected)		130		mA
I_{+5V}	Current at +5V output for supply of external circuits (e.g. encoder, reference / limit switches) – all +5V outputs together			400	mA
I_{COIL}	Motor coil current for sine wave **peak** (chopper regulated, adjustable via software)	0		4	A
I_{MC}	Continuous motor current (**RMS**)	0		2.8	A
I_S	Power supply current		<< 3x I_{COIL}	1.4x 3x I_{COIL}	A
T_{ENV}	Environmental temperature at maximum current (all three axes, no forced cooling)	-30		+40	°C

Table 7.1 General operational ratings of the module

OPERATIONAL RATINGS OF THE REFERENCE SWITCH INPUTS

Symbol	Parameter	Min	Typ	Max	Unit
$V_{REF\_L/R}$	Input voltage for reference switch inputs REF_L / REF_R	0	0 .. 24	27	V
V_{REF_L/R_L}	Low level voltage for reference switch inputs REF_L / REF_R	0		1.4	V
V_{REF_L/R_H}	High level voltage for reference switch inputs REF_L / REF_R	3.4		27	V

Table 7.2 Operational ratings of the reference switch inputs

OPERATIONAL RATINGS OF THE GENERAL PURPOSE I/Os

Symbol	Parameter	Min	Typ	Max	Unit
$V_{OUT\_0..7}$	Voltage at open collector output	0		$V_{DIGITAL}$	V
$I_{OUT\_0/1/2/4/5/6}$	Output sink current for OUT_0/1/2 and OUT_4/5/6			100	mA
$I_{OUT\_3/7}$	Output sink current for OUT_3 and OUT_7			1	A
$V_{IN\_1/2/3/5/6/7}$	Input voltage for general purpose digital inputs IN_1/2/3 and IN_5/6/7	0	0 .. 24	27	V
$V_{IN\_1/1/2/3/5/6/7\_L}$	Low level voltage for general purpose digital inputs IN_1/2/3 and IN_5/6/7	0		1.1	V
$V_{IN\_1/2/3/5/6/7\_H}$	High level voltage for general purpose digital inputs IN_1/2/3 and IN_5/6/7	2.9		27	V
$V_{AIN\_0/4}$	Full scale input voltage range for analog voltage inputs	0		10	V

Table 7.3 Operational ratings of the general purpose I/Os

OPERATIONAL RATINGS OF THE S/D INPUTS

Symbol	Parameter	Min	Typ	Max	Unit
$V_{S/D/E\_0/1/2}$	Input voltage for step inputs S_0/1/2, direction inputs D_0/1/2 and enable inputs E_0/1/2	0	0 .. 24	27	V
$V_{S/D/E\_0/1/2\_L}$	Low level voltage for step inputs S_0/1/2, direction inputs D_0/1/2 and enable inputs E_0/1/2	0		1.4	V
$V_{S/D/E\_0/1/2\_H}$	High level voltage for step inputs S_0/1/2, direction inputs D_0/1/2 and enable inputs E_0/1/2	3.4		27	V

Table 7.4 Operational ratings of the S/D inputs

OPERATIONAL RATINGS OF THE ENCODER INPUTS 0/1/2

Symbol	Parameter	Min	Typ	Max	Unit
$V_{A+/A-/B+/B-/N+/N-}$	Voltage at encoder signal inputs	-0.3		+5.5	V

Table 7.5 Operational ratings of the encoder inputs 0/1/2

OPERATIONAL RATINGS OF THE RS485 INTERFACE

Symbol	Parameter	Min	Typ	Max	Unit
N_{RS485}[*]	Number of nodes connected to single RS485 network			320	
$1/t_{RS485}$[*]	Maximum signaling rate			1	Mbps

Table 7.6 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	
$1/t_{CAN}$[*]	Maximum signaling rate			1	Mbps

Table 7.7 Operational ratings of the CAN interface

*) Please note: maximum signaling rate and maximum number of nodes will not be achieved at the same time (for both serial bus interfaces - RS485 and CAN). With increasing number of nodes per bus and increasing bus length the maximum data rate usually has to be reduced. Maximum number of nodes per bus and maximum signaling rate might be limited by firmware (with TMCL max. 255 nodes), also.

8 Functional Description

The TMCM-3110 is a highly integrated 3-axes controller and driver module with encoder inputs. It can be controlled via CAN, RS485 or USB serial interfaces. Communication traffic is kept low since all time critical operations, e.g. ramp calculation are performed onboard. The module is designed for both, standalone operation and direct mode. Full remote control of device with feedback is possible. The firmware of the module can be updated via any of the serial interfaces.

In Figure 8.1 the main parts of the module are shown:

- the microprocessor, which runs the TMCL or CANopen operating system
- the TMCL program memory (stores up to 2048 TMCL commands)
- 1x motion controller for three axes, which calculates ramps and speed profiles by hardware
- 3x power driver with stallGuard2 and the energy efficient coolStep feature
- 3x external MOSFET driver transistors
- RS485, CAN and USB transceivers
- on-board switching and linear voltage regulators for supply of on-board digital circuits
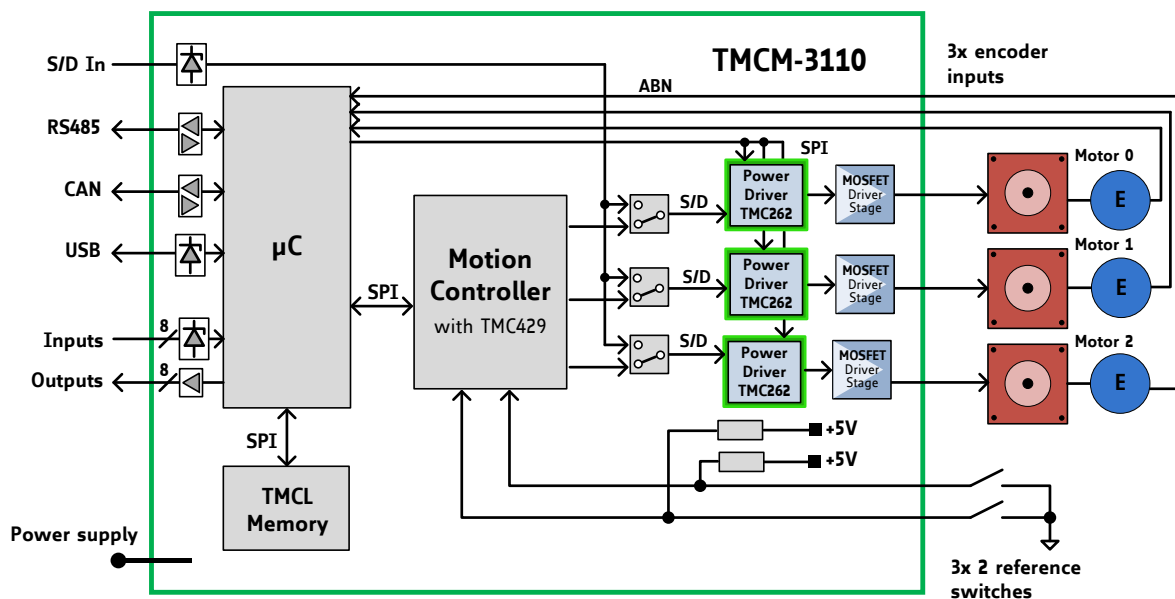- 3x encoder interface

Figure 8.1 TMCM-3110 block diagram

The TMCM-3110 comes with the PC based software development environment TMCL-IDE for the Trinamic Motion Control Language (TMCL). Using predefined TMCL high level commands as *move to position* a rapid and fast development of motion control applications is guaranteed.

Please refer to the TMCM-3110 Firmware Manual for more information about TMCL commands.

9   Operational Description

9.1   Calculation: Velocity and Acceleration vs. Microstep and Fullstep Frequency

The values of the parameters sent to the TMC429 do not have typical motor values like rotations per second as velocity. But these values can be calculated from the TMC429 parameters as shown in this section.

PARAMETERS OF TMC429

Signal	Description	Range
f_{CLK}	clock-frequency	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… 8

Table 9.1 TMC429 velocity parameters

MICROSTEP FREQUENCY

The microstep frequency of the stepper motor is calculated with

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

FULLSTEP FREQUENCY

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

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

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

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

This results in acceleration in fullsteps of:

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

EXAMPLE:

Signal	value
f$_{CLK}$	16 MHz
velocity	1000
a_max	1000
pulse_div	1
ramp_div	1
usrs	6

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

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

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

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

CALCULATION OF THE NUMBER OF ROTATIONS

A stepper motor has e.g. 72 fullsteps per rotation.

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

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

10 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.

11 Revision History

11.1 Document Revision

Version	Date	Author	Description
0.90	2012-SEP-26	GE	Preliminary version
1.00	2013-JUN-12	SD	First complete version
1.01	2013-JUL-23	SD	Minor changes
1.02	2014-DEC-11	GE	- Home switch inputs added - Table with motor current settings added (chapter 4) - Minor corrections / additions
1.03	2018-SEP-24	GE	- Operational ratings switching levels for end switches and S/D inputs corrected
1.04	2018-NOV-21	GE	- Typos corrected

Table 11.1 Document revision

11.2 Hardware Revision

Version	Date	Description
TMCM-3110_V10	2012-MAY-25	Initial version
TMCM-3110_V11	2012-AUG-17	Few corrections and enhancement: - Processor reset corrected - Encoder N-channel connected to different port-pin for better interrupt handling in software

Table 11.2 Hardware revision

12 References

[JST]   JST connector
             http://www.jst.com
[USB-2-485] USB-2-485 interface converter
             Manual available on http://www.trinamic.com
[TMC262]   TMC262 datasheet
             Manual available on http://www.trinamic.com.
[TMC429]   TMC429 datasheet
             Manual available on http://www.trinamic.com.
[TMCL-IDE]   TMCL-IDE User Manual
             Manual available on http://www.trinamic.com.

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