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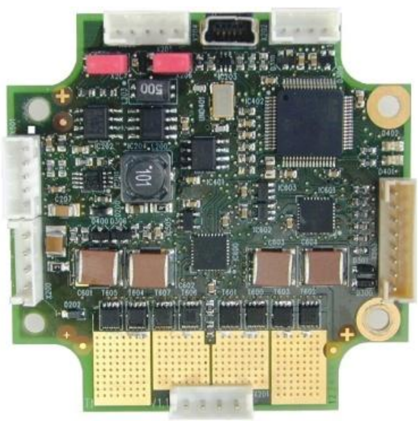
Firmware Version V1.27

TMCL™ FIRMWARE MANUAL



TMCM-1160

1-Axis Stepper
Controller / Driver
2.8 A / 48 V
USB, RS485, and CAN
Step/Dir Interface
sensOstep™ Encoder

UNIQUE FEATURES:

stallGuard2™

TRINAMIC Motion Control GmbH & Co. KG
Hamburg, Germany

www.trinamic.com

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1 Features

The TMCM-1160 is a single axis controller/driver module for 2-phase bipolar stepper motors with state of the art feature set. It is highly integrated, offers a convenient handling and can be used in many decentralized applications. The module can be mounted on the back of NEMA 23 (57mm flange size) or NEMA 24 (60mm flange size) stepper motors and has been designed for coil currents up to 2.8 A RMS and 24 or 48 V DC supply voltage. 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

Encoder

- sensOstep magnetic encoder (1024 increments per rotation) e.g. for step-loss detection under all operating conditions and positioning supervision
- Interface for connection of external incremental a/b/n encoder

Interfaces

- RS485 interface
- CAN (2.0B up to 1Mbit/s) interface
- USB full speed (12Mbit/s) interface
- Step/Direction interface (optically isolated)
- 3 inputs for stop switches and home switch (+24V compatible) with programmable pull-up
- 2 general purpose inputs (+24V compatible) and 2 general purpose outputs (open collector)
- Incremental a/b/n encoder interface (TTL and open-collector signals supported directly)

Safety features

- Shutdown input – driver will be disabled in hardware as long as this pin is left open or shorted to ground
- Separate supply voltage inputs for driver and digital logic – driver supply voltage may be switched off externally while supply for digital logic and therefore digital logic remains active

Software

- TMCL: standalone operation or remote controlled operation,
  program memory (non volatile) for up to 2048 TMCL commands, and
  PC-based application development software TMCL-IDE available for free.

Electrical and mechanical data

- Supply voltage: common supply voltages +12 V DC / +24 V DC / +48 V DC supported (+9 V… +51 V DC)
- Motor current: up to 2.8 A RMS (programmable)

Refer to separate Hardware Manual, too.

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.

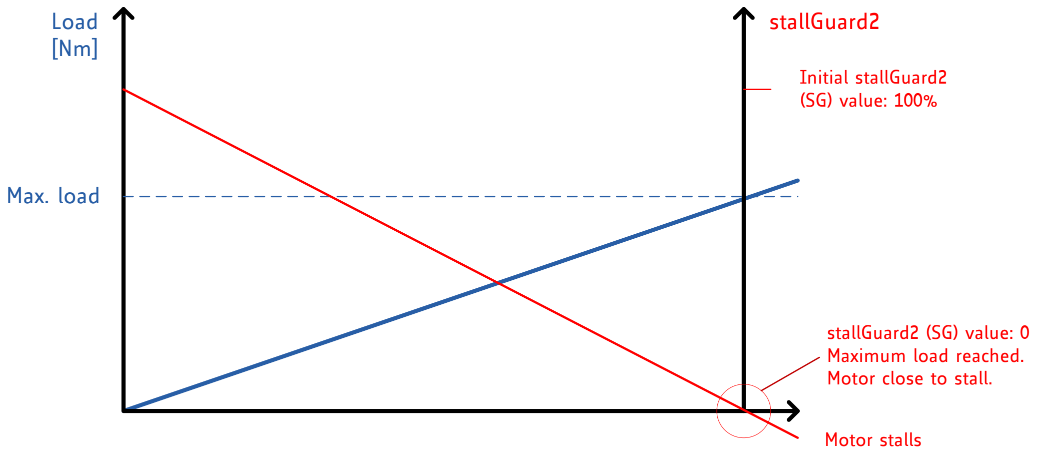

Load [Nm]
stallGuard2
Initial stallGuard2 (SG) value: 100%
Max. load
stallGuard2 (SG) value: 0 Maximum load reached. Motor close to stall.
Motor stalls

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.

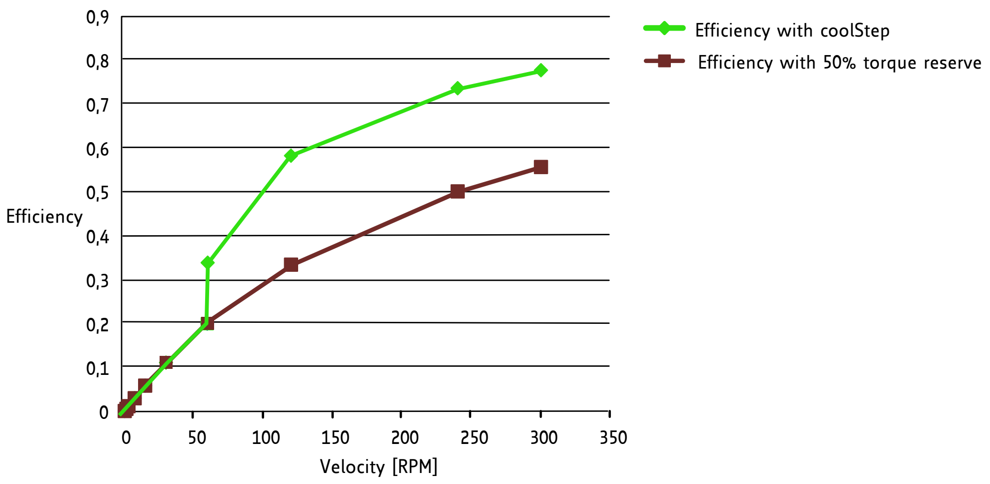


Figure 1.2 Energy efficiency example with coolStep

2 Putting the Module into Operation

Here you can find basic information for putting your TMCM-1160 into operation. If you are already common with TRINAMICs modules you may skip this chapter.

The things you need:

- TMCM-1160
- Interface (RS485/CAN/USB) suitable to your module with cables
- Nominal supply voltage +24V DC (12 V DC / 48 V DC) for your module
- TMCL-IDE program and PC
- Stepper motor

PRECAUTIONS
Do not connect or disconnect the TMCM-1160 while powered!
Do not connect or disconnect the motor while powered!
Do not exceed the maximum power supply voltage of 51 V DC!
Note, that the module is not protected against reverse polarity!
START WITH POWER SUPPLY OFF!

2.1 Basic Set-Up

The following paragraph will guide you through the steps of connecting the unit and making first movements with the motor.

CONNECTING THE MODULE

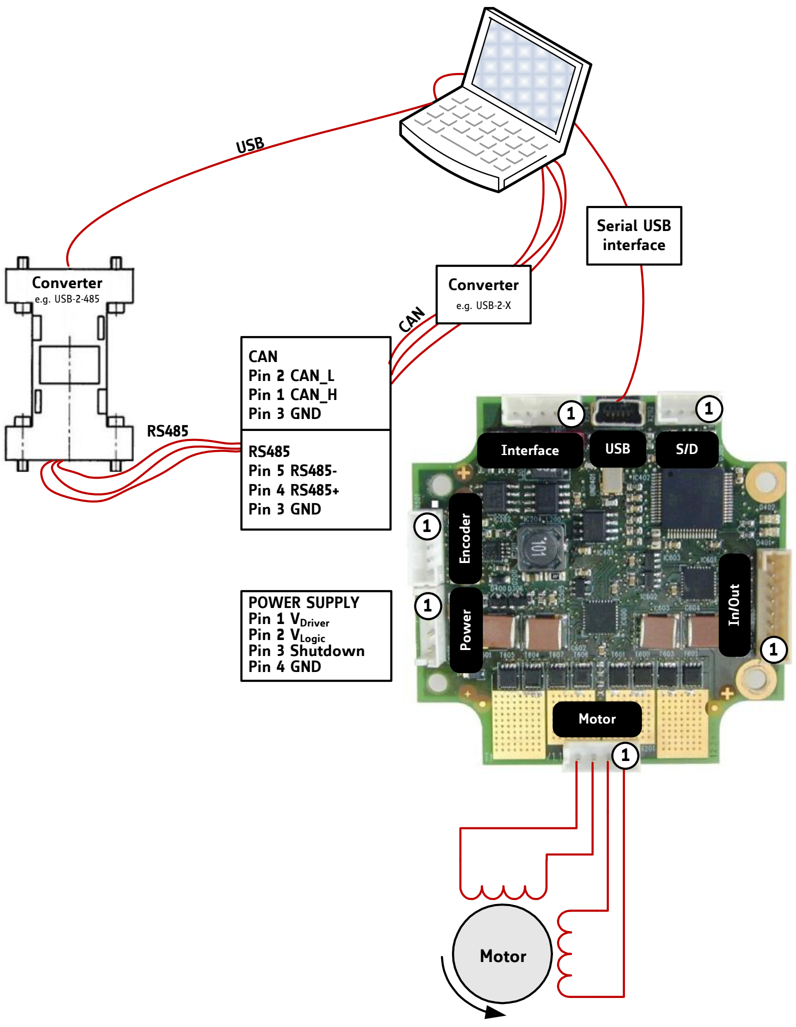


Figure 2.1: Starting up

1. Connect power supply

Note:
- In order to enable motor driver stage connect /SHUTDOWN (pin 3) to power supply!
- In case separate power supplies for driver and logic are not used pin 2 (logic supply) and pin 3 (/SHUTDOWN input) of the power connector may be connected together in order to enable driver stage.

Please refer to the TMCM-1160 Hardware Manual for further information about the power supply!

Pin	Label	Description
1	$+V_{Driver}$	Module + driver stage power supply input
2	$+V_{Logic}$	(Optional) separate digital logic power supply input
3	/SHUTDOWN	Shutdown input. Connect this input to $+V_{Driver}$ or $+V_{Logic}$ in order to activate driver stage. Leaving this input open or connecting it to ground will disable driver stage
4	GND	Module ground (power supply and signal ground)

2. Choose your interface

a) Connect CAN or RS485

CAN interface will be de-activated in case USB is connected due to internal sharing of hardware resources.

Pin	Label	Description
1	CAN_H	CAN bus signal (dominant high)
2	CAN_L	CAN bus signal (dominant low)
3	GND	Module ground (system and signal ground)
4	RS485+	RS485 bus signal (non inverted)
5	RS485-	RS485 bus signal (inverted)

b) Connect USB interface (as alternative to CAN and RS485; use a normal USB cable)

Download and install the file *TMCM-1160.inf* (www.trinamic.com).

Pin	Label	Description
1	VBUS	+5V power
2	D-	Data –
3	D+	Data +
4	ID	Not connected
5	GND	Module ground

3. **Connect In/Out connector (optional)**
   If you like to work with the GPIOs or switches, use the In/Out connector.

Pin	Label	Description
1	OUT_0	General purpose output, open drain (max. 1A) Integrated freewheeling diode connected to +VLogic
2	OUT_1	General purpose output, open drain (max. 1A) Integrated freewheeling diode connected to +VLogic
3	IN_0	General purpose input (analog and digital), +24V compatible Resolution when used as analog input: 12bit (0..4095)
4	IN_1	General purpose input (analog and digital), +24V compatible Resolution when used as analog input: 12bit (0..4095)
5	STOP_L	Left stop switch input (digital input), +24V compatible, programmable internal pull-up to +5V
6	STOP_R	Right stop switch input (digital input), +24V compatible, programmable internal pull-up to +5V
7	HOME	Home switch input (digital input), +24V compatible, programmable internal pull-up to +5V
8	GND	Module ground (system and signal ground)

4. **Connect the encoder (optional)**
   If you like to work with encoder, use the encoder connector.

Pin	Label	Description
1	GND	Module ground (system and signal ground)
2	+5V	+5V supply output for external encoder circuit (100 mA max.)
3	ENC_A	Encoder a channel input (internal pull-up)
4	ENC_B	Encoder b channel input (internal pull-up)
5	ENC_N	Optional encoder n / index channel input (internal pull-up)

5. **Connect the motor**

Pin	Label	Description
1	OA1	Motor coil A
2	OA2	Motor coil A
3	OB1	Motor coil B
4	OB2	Motor coil B

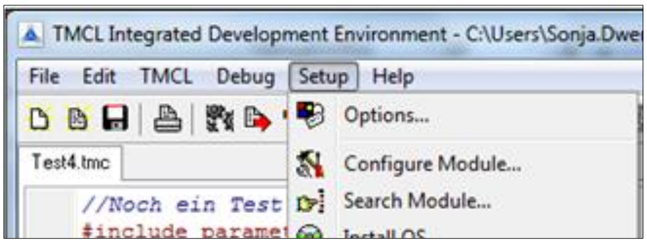
6. **Switch ON the power supply**
   Turn power ON. The green LED for power lights up and the motor is powered but in standstill now.

   If this does not occur, switch power OFF and check your connections as well as the power supply!

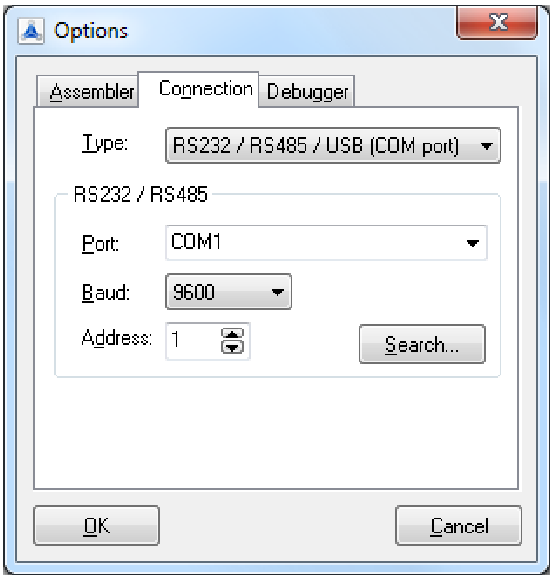
2.1.1 Start the TMCL-IDE Software Development Environment

The TMCL-IDE is available on www.trinamic.com.

Installing the TMCL-IDE:
Make sure the COM port you intend to use is not blocked by another program.
Open TMCL-IDE by clicking ***TMCL.exe***.
Choose ***Setup*** and ***Options*** and thereafter the ***Connection tab***.
Choose ***COM port*** and ***type*** with the parameters shown in



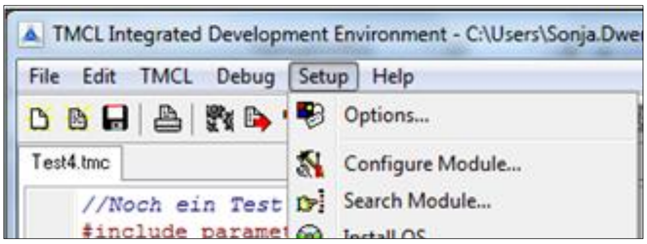
```
//Noch ein Test
#include paramet
```



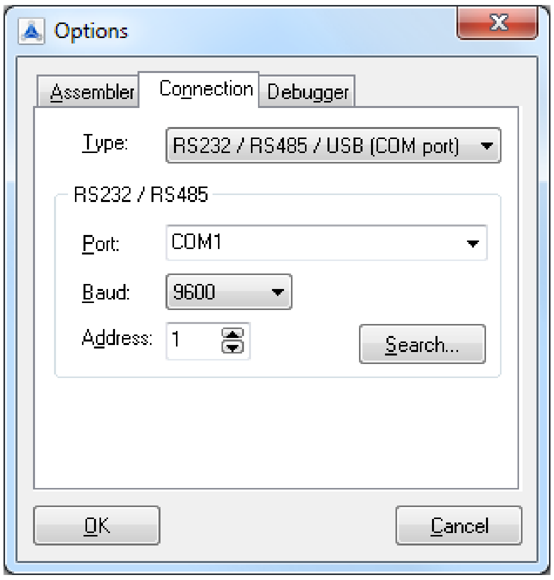
Type: RS232 / RS485 / USB (COM port)
Port: COM1
Baud: 9600
Address: 1

Figure 2.2 (baud rate 9600). Click ***OK***.

USB interface
If the file *TMCM-1160.inf* is installed correctly, the module will be identified automatically.



```
//Noch ein Test
#include paramet
```



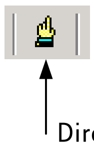
Type: RS232 / RS485 / USB (COM port)
Port: COM1
Baud: 9600
Address: 1

Figure 2.2 Setup dialogue and connection tab of the TMCL-IDE.

Please refer to the TMCL-IDE User Manual for more information (see www.TRINAMIC.com).

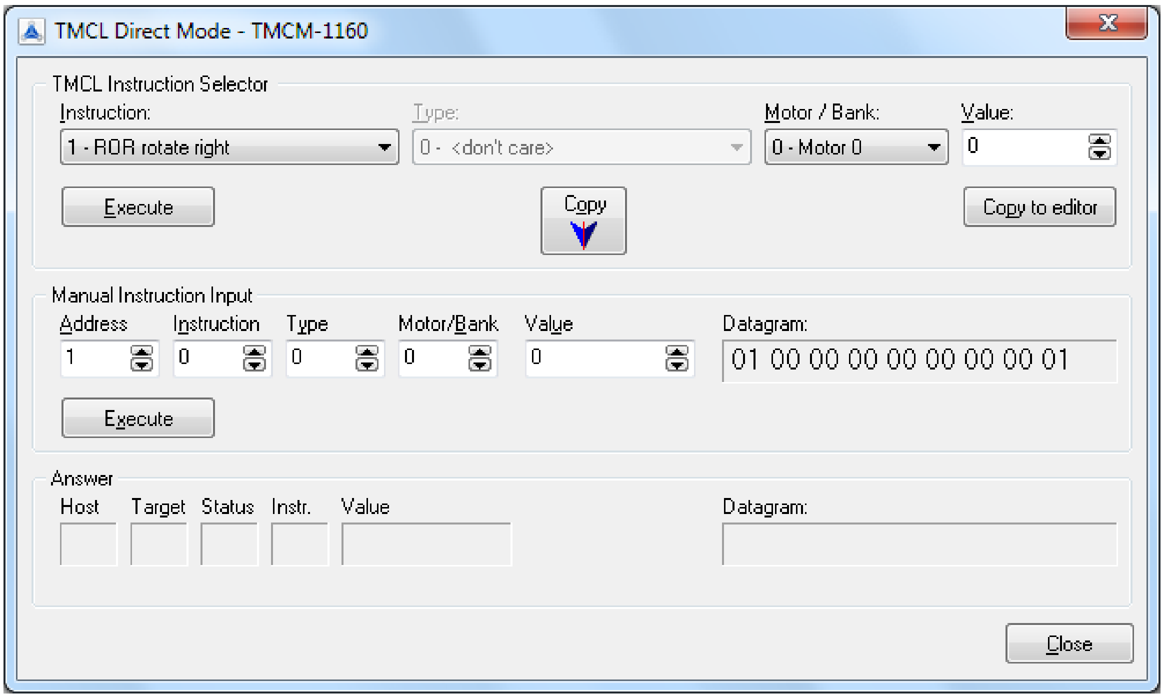
2.2 Using TMCL Direct Mode

1. Start TMCL ***Direct Mode***.



2. If the communication is established the TMCM-1160 is automatically detected.

   If the module is not detected, please check all points above (cables, interface, power supply, COM port, baud rate).



3. Issue a command by choosing ***Instruction***, ***Type*** (if necessary), ***Motor***, and ***Value*** and click ***Execute*** to send it to the module.

<u>Examples:</u>

- ROR rotate right, motor 0, value 500 -> Click *Execute*. The motor is rotating now.
- MST motor stop, motor 0 -> Click *Execute*. The motor stops now.

Top right of the *TMCL Direct Mode* window is the button *Copy to editor*. Click here to copy the chosen command and create your own TMCL program. The command will be shown immediately on the editor.

Note:
Chapter 4 of this manual (axis parameters) includes a diagram which points out the coolStep related axis parameters and their functions.

2.2.1 Important Motor Settings

There are some axis parameters which have to be adjusted right in the beginning after installing your module. Please set the upper limiting values for the speed (axis parameter 4), the acceleration (axis parameter 5), and the current (axis parameter 6). Further set the standby current (axis parameter 7) and choose your microstep resolution with axis parameter 140. Please use the *SAP* (Set Axis Parameter) command for adjusting these values. The SAP command is described in paragraph 3.6.5. You can use the TMCL-IDE direct mode for easily configuring your module.

Attention:
The most important motor setting is the *absolute maximum motor current* setting, since too high values might cause motor damage!

IMPORTANT AXIS PARAMETERS FOR MOTOR SETTING

Number	Axis Parameter	Description	Range [Unit]
4	Maximum positioning speed	Should not exceed the physically highest possible value. Adjust the pulse divisor (axis parameter 154), if the speed value is very low (<50) or above the upper limit.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{pulse\_divisor} \frac{\mu\text{steps}}{\text{sec}}\right]$
5	Maximum acceleration	The limit for acceleration (and deceleration). Changing this parameter requires re-calculation of the acceleration factor (no. 146) and the acceleration divisor (no. 137), which is done automatically. See TMC 429 datasheet for calculation of physical units.	0… 2047*¹
6	Absolute max. current (CS / Current Scale)	The maximum value is 255. This value means 100% of the maximum current of the module. The current adjustment is within the range 0… 255 and can be adjusted in 32 steps. 0… 7 | 79…87 | 160… 167 | 240… 247 8… 15 | 88… 95 | 168… 175 | 248… 255 16… 23 | 96… 103 | 176… 183 | 24… 31 | 104… 111 | 184… 191 | 32… 39 | 112… 119 | 192… 199 | 40… 47 | 120… 127 | 200… 207 | 48… 55 | 128… 135 | 208… 215 | 56… 63 | 136… 143 | 216… 223 | 64… 71 | 144… 151 | 224… 231 | 72… 79 | 152… 159 | 232… 239 | *The most important motor setting, since too high values might cause motor damage!*	0… 255 $I_{peak} =< value > \times \frac{4A}{255}$ $I_{RMS} =< value > \times \frac{2.8A}{255}$
7	Standby current	The current limit two seconds after the motor has stopped.	0… 255 $I_{peak} =< value > \times \frac{4A}{255}$ $I_{RMS} =< value > \times \frac{2.8A}{255}$
140	Microstep resolution	0 full step 1 half step 2 4 microsteps 3 8 microsteps 4 16 microsteps 5 32 microsteps 6 64 microsteps 7 128 microsteps 8 256 microsteps	0… 8

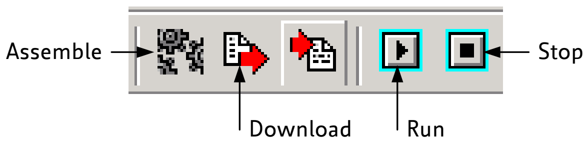
*¹ Unit of acceleration: $\frac{16MHz^2}{536870912 \cdot 2^{puls\_divisor+ramp\_divisor}} \frac{\text{microsteps}}{\text{sec}^2}$

2.3 Testing with a Simple TMCL Program

Type in the following program:

```
        ROL 0, 500                //Rotate motor 0 with speed 10000
        WAIT TICKS, 0, 500
        MST 0
        ROR 0, 500                 //Rotate motor 0 with 50000
        WAIT TICKS, 0, 500
        MST 0

        SAP 4, 0, 500              //Set max. Velocity
        SAP 5, 0, 50               //Set max. Acceleration
Loop:   MVP ABS, 0, 10000          //Move to Position 10000
        WAIT POS, 0, 0             //Wait until position reached
        MVP ABS, 0, -10000         //Move to Position -10000
        WAIT POS, 0, 0             //Wait until position reached
        JA Loop                    //Infinite Loop
```



1. Click the ***Assemble*** icon to convert the TMCL program into binary code.
2. Then download the program to the TMCM-1160 module by clicking the ***Download*** icon.
3. Click the ***Run*** icon. The desired program will be executed.
4. Click the ***Stop*** button to stop the program.

3 TMCL and the TMCL-IDE: Introduction

As with most TRINAMIC modules the software running on the microprocessor of the TMCM-1160 consists of two parts, a boot loader and the firmware itself. Whereas the boot loader is installed during production and testing at TRINAMIC and remains untouched throughout the whole lifetime, the firmware can be updated by the user. New versions can be downloaded free of charge from the TRINAMIC website (http://www.trinamic.com).

The TMCM-1160 supports TMCL direct mode (binary commands) and standalone TMCL program execution. You can store up to 2048 TMCL instructions on it. In direct mode and most cases the TMCL communication over RS485, CAN, or USB follows a strict master/slave relationship. That is, a host computer (e.g. PC/PLC) acting as the interface bus master will send a command to the TMCM-1160. The TMCL interpreter on the module will then interpret this command, do the initialization of the motion controller, read inputs and write outputs or whatever is necessary according to the specified command. As soon as this step has been done, the module will send a reply back over RS485/CAN/USB to the bus master. Only then should the master transfer the next command. Normally, the module will just switch to transmission and occupy the bus for a reply, otherwise it will stay in receive mode. It will not send any data over the interface without receiving a command first. This way, any collision on the bus will be avoided when there are more than two nodes connected to a single bus.

The Trinamic Motion Control Language [TMCL] provides a set of structured motion control commands. Every motion control command can be given by a host computer or can be stored in an EEPROM on the TMCM module to form programs that run standalone on the module. For this purpose there are not only motion control commands but also commands to control the program structure (like conditional jumps, compare and calculating).

Every command has a binary representation and a mnemonic. The binary format is used to send commands from the host to a module in direct mode, whereas the mnemonic format is used for easy usage of the commands when developing standalone TMCL applications using the TMCL-IDE (IDE means *Integrated Development Environment*).

There is also a set of configuration variables for the axis and for global parameters which allow individual configuration of nearly every function of a module. This manual gives a detailed description of all TMCL commands and their usage.

3.1 Binary Command Format

Every command has a mnemonic and a binary representation. When commands are sent from a host to a module, the binary format has to be used. Every command consists of a one-byte command field, a one-byte type field, a one-byte motor/bank field and a four-byte value field. So the binary representation of a command always has seven bytes. When a command is to be sent via RS485 or USB interface, it has to be enclosed by an address byte at the beginning and a checksum byte at the end. In this case it consists of nine bytes.

This is different when communicating is via the CAN bus. Address and checksum are included in the CAN standard and do not have to be supplied by the user.

The binary command format for R485/USB is as follows:

Bytes	Meaning
1	Module address
1	Command number
1	Type number
1	Motor or Bank number
4	Value (MSB first!)
1	Checksum

- The checksum is calculated by adding up all the other bytes using an 8-bit addition.
- When using CAN bus, just leave out the first byte (module address) and the last byte (checksum).

3.1.1 Checksum Calculation

As mentioned above, the checksum is calculated by adding up all bytes (including the module address byte) using 8-bit addition. Here are two examples to show how to do this:

```
-   in C:
unsigned char i, Checksum;
unsigned char Command[9];

//Set the "Command" array to the desired command
Checksum = Command[0];
for(i=1; i<8; i++)
   Checksum+=Command[i];

Command[8]=Checksum; //insert checksum as last byte of the command
//Now, send it to the module
```

```
 -   in Delphi:
var
  i, Checksum: byte;
  Command: array[0..8] of byte;

  //Set the "Command" array to the desired command

  //Calculate the Checksum:
  Checksum:=Command[0];
  for i:=1 to 7 do Checksum:=Checksum+Command[i];
  Command[8]:=Checksum;
  //Now, send the "Command" array (9 bytes) to the module
```

3.2 Reply Format

Every time a command has been sent to a module, the module sends a reply.

The reply format for RS485/ /USB is as follows:

Bytes	Meaning
1	Reply address
1	Module address
1	Status (e.g. 100 means *no error*)
1	Command number
4	Value (MSB first!)
1	Checksum

- The checksum is also calculated by adding up all the other bytes using an 8-bit addition.
- When using CAN bus, just leave out the first byte (module address) and the last byte (checksum).
- Do not send the next command before you have received the reply!

3.2.1 Status Codes

The reply contains a status code. The status code can have one of the following values:

Code	Meaning
100	Successfully executed, no error
101	Command loaded into TMCL program EEPROM
1	Wrong checksum
2	Invalid command
3	Wrong type
4	Invalid value
5	Configuration EEPROM locked
6	Command not available

3.3 Standalone Applications

The module is equipped with a TMCL memory for storing TMCL applications. You can use TMCL-IDE for developing standalone TMCL applications. You can download a program into the EEPROM and afterwards it will run on the module. The TMCL-IDE contains an editor and the TMCL assembler where the commands can be entered using their mnemonic format. They will be assembled automatically into their binary representations. Afterwards this code can be downloaded into the module to be executed there.

3.4 TMCL Command Overview

In this section a short overview of the TMCL commands is given.

3.4.1 TMCL Commands

Command	Number	Parameter	Description
ROR	1	<motor number>, <velocity>	Rotate right with specified velocity
ROL	2	<motor number>, <velocity>	Rotate left with specified velocity
MST	3	<motor number>	Stop motor movement
MVP	4	ABS|REL|COORD, <motor number>, <position|offset>	Move to position (absolute or relative)
SAP	5	<parameter>, <motor number>, <value>	Set axis parameter (motion control specific settings)
GAP	6	<parameter>, <motor number>	Get axis parameter (read out motion control specific settings)
STAP	7	<parameter>, <motor number>	Store axis parameter permanently (non volatile)
RSAP	8	<parameter>, <motor number>	Restore axis parameter
SGP	9	<parameter>, <bank number>, value	Set global parameter (module specific settings e.g. communication settings or TMCL™ user variables)
GGP	10	<parameter>, <bank number>	Get global parameter (read out module specific settings e.g. communication settings or TMCL™ user variables)
STGP	11	<parameter>, <bank number>	Store global parameter (TMCL™ user variables only)
RSGP	12	<parameter>, <bank number>	Restore global parameter (TMCL™ user variable only)
RFS	13	START|STOP|STATUS, <motor number>	Reference search
SIO	14	<port number>, <bank number>, <value>	Set digital output to specified value
GIO	15	<port number>, <bank number>	Get value of analogue/digital input
CALC	19	<operation>, <value>	Process accumulator & value
COMP	20	<value>	Compare accumulator <-> value
JC	21	<condition>, <jump address>	Jump conditional
JA	22	<jump address>	Jump absolute
CSUB	23	<subroutine address>	Call subroutine
RSUB	24		Return from subroutine
EI	25	<interrupt number>	Enable interrupt
DI	26	<interrupt number>	Disable interrupt
WAIT	27	<condition>, <motor number>, <ticks>	Wait with further program execution
STOP	28		Stop program execution
SCO	30	<coordinate number>, <motor number>, <position>	Set coordinate
GCO	31	<coordinate number>, <motor number>	Get coordinate
CCO	32	<coordinate number>, <motor number>	Capture coordinate
CALCX	33	<operation>	Process accumulator & X-register
AAP	34	<parameter>, <motor number>	Accumulator to axis parameter
AGP	35	<parameter>, <bank number>	Accumulator to global parameter
VECT	37	<interrupt number>, <label>	Set interrupt vector
RETI	38		Return from interrupt
ACO	39	<coordinate number>, <motor number>	Accu to coordinate

3.4.2 Commands Listed According to Subject Area

3.4.2.1 Motion Commands

These commands control the motion of the motor. They are the most important commands and can be used in direct mode or in standalone mode.

Mnemonic	Command number	Meaning
ROL	2	Rotate left
ROR	1	Rotate right
MVP	4	Move to position
MST	3	Motor stop
RFS	13	Reference search
SCO	30	Store coordinate
CCO	32	Capture coordinate
GCO	31	Get coordinate

3.4.2.2 Parameter Commands

These commands are used to set, read and store axis parameters or global parameters. Axis parameters can be set independently for each axis, whereas global parameters control the behavior of the module itself. These commands can also be used in direct mode and in standalone mode.

Mnemonic	Command number	Meaning
SAP	5	Set axis parameter
GAP	6	Get axis parameter
STAP	7	Store axis parameter into EEPROM
RSAP	8	Restore axis parameter from EEPROM
SGP	9	Set global parameter
GGP	10	Get global parameter
STGP	11	Store global parameter into EEPROM
RSGP	12	Restore global parameter from EEPROM

3.4.2.3 Control Commands

These commands are used to control the program flow (loops, conditions, jumps etc.). It does not make sense to use them in direct mode. They are intended for standalone mode only.

Mnemonic	Command number	Meaning
JA	22	Jump always
JC	21	Jump conditional
COMP	20	Compare accumulator with constant value
CSUB	23	Call subroutine
RSUB	24	Return from subroutine
WAIT	27	Wait for a specified event
STOP	28	End of a TMCL™ program

3.4.2.4 I/O Port Commands

These commands control the external I/O ports and can be used in direct mode and in standalone mode.

Mnemonic	Command number	Meaning
SIO	14	Set output
GIO	15	Get input

3.4.2.5 Calculation Commands

These commands are intended to be used for calculations within TMCL applications. Although they could also be used in direct mode it does not make much sense to do so.

Mnemonic	Command number	Meaning
CALC	19	Calculate using the accumulator and a constant value
CALCX	33	Calculate using the accumulator and the X register
AAP	34	Copy accumulator to an axis parameter
AGP	35	Copy accumulator to a global parameter
ACO	39	Copy accu to coordinate

For calculating purposes there is an accumulator (or accu or A register) and an X register. When executed in a TMCL program (in standalone mode), all TMCL commands that read a value store the result in the accumulator. The X register can be used as an additional memory when doing calculations. It can be loaded from the accumulator.

When a command that reads a value is executed in direct mode the accumulator will not be affected. This means that while a TMCL program is running on the module (standalone mode), a host can still send commands like GAP and GGP to the module (e.g. to query the actual position of the motor) without affecting the flow of the TMCL™ program running on the module.

3.4.2.6 Interrupt Commands

Due to some customer requests, interrupt processing has been introduced in the TMCL firmware for ARM based modules.

Mnemonic	Command number	Meaning
EI	25	Enable interrupt
DI	26	Disable interrupt
VECT	37	Set interrupt vector
RETI	38	Return from interrupt

3.4.2.6.1 Interrupt Types

There are many different interrupts in TMCL, like timer interrupts, stop switch interrupts, position reached interrupts, and input pin change interrupts. Each of these interrupts has its own interrupt vector. Each interrupt vector is identified by its interrupt number. Please use the TMCL included file *Interrupts.inc* for symbolic constants of the interrupt numbers.

3.4.2.6.2 Interrupt Processing

When an interrupt occurs and this interrupt is enabled and a valid interrupt vector has been defined for that interrupt, the normal TMCL program flow will be interrupted and the interrupt handling routine will be called. Before an interrupt handling routine gets called, the context of the normal program will be saved automatically (i.e. accumulator register, X register, TMCL flags).

There is no interrupt nesting, i.e. all other interrupts are disabled while an interrupt handling routine is being executed.

On return from an interrupt handling routine, the context of the normal program will automatically be restored and the execution of the normal program will be continued.

3.4.2.6.3 Interrupt Vectors

The following table shows all interrupt vectors that can be used.

Interrupt number	Interrupt type
0	Timer 0
1	Timer 1
2	Timer 2
3	(Target) position reached
15	Stall (stallGuard2)
21	Deviation
27	Stop left
28	Stop right
39	IN_0 change
40	IN_1 change
255	Global interrupts

3.4.2.6.4 Further Configuration of Interrupts

Some interrupts need further configuration (e.g. the timer interval of a timer interrupt). This can be done using SGP commands with parameter bank 3 (SGP <type>, 3, <value>). Please refer to the SGP command (paragraph 3.6.9) for further information about that.

3.4.2.6.5 Using Interrupts in TMCL

For using an interrupt proceed as follows:

- Define an interrupt handling routine using the VECT command.
- If necessary, configure the interrupt using an SGP <type>, 3, <value> command.
- Enable the interrupt using an EI <interrupt> command.
- Globally enable interrupts using an EI 255 command.
- An interrupt handling routine must always end with a RETI command

EXAMPLE FOR THE USE OF A TIMER INTERRUPT:

```
    VECT 0, Timer0Irq   //define the interrupt vector
    SGP 0, 3, 1000      //configure the interrupt: set its period to 1000ms
    EI 0                //enable this interrupt
    EI 255              //globally switch on interrupt processing

//Main program: toggles output 3, using a WAIT command for the delay
Loop:
    SIO 3, 2, 1
    WAIT TICKS, 0, 50
    SIO 3, 2, 0
    WAIT TICKS, 0, 50
    JA Loop

//Here is the interrupt handling routine
Timer0Irq:
    GIO 0, 2            //check if OUT0 is high
    JC NZ, Out0Off      //jump if not
    SIO 0, 2, 1         //switch OUT0 high
    RETI                //end of interrupt
Out0Off:
    SIO 0, 2, 0         //switch OUT0 low
    RETI                //end of interrupt
```

In the example above, the interrupt numbers are used directly. To make the program better readable use the provided include file *Interrupts.inc.* This file defines symbolic constants for all interrupt numbers which can be used in all interrupt commands. The beginning of the program above then looks like the following:

```
#include Interrupts.inc
    VECT TI_TIMER0, Timer0Irq
    SGP TI_TIMER0, 3, 1000
    EI TI_TIMER0
    EI TI_GLOBAL
```

Please also take a look at the other example programs.

3.5 The ASCII Interface

There is also an ASCII interface that can be used to communicate with the module and to send some commands as text strings.

THE FOLLOWING COMMANDS CAN BE USED IN ASCII MODE:

ROL, ROR, MST, MVP, SAP, GAP, STAP, RSAP, SGP, GGP, STGP, RSGP, RFS, SIO, GIO, SCO, GCO, CCO, UF0, UF1, UF2, UF3, UF4, UF5, UF6, and UF7.

Note:
Only direct mode commands can be entered in ASCII mode!

SPECIAL COMMANDS WHICH ARE ONLY AVAILABLE IN ASCII MODE:

- BIN: This command quits ASCII mode and returns to binary TMCL™ mode.
- RUN: This command can be used to start a TMCL™ program in memory.
- STOP: Stops a running TMCL™ application.

ENTERING AND LEAVING ASCII MODE:

1. The ASCII command line interface is entered by sending the binary command 139 (*enter ASCII mode*).
2. Afterwards the commands are entered as in the TMCL-IDE.
3. For leaving the ASCII mode and re-enter the binary mode enter the command BIN.

3.5.1 Format of the Command Line

As the first character, the address character has to be sent. The address character is *A* when the module address is 1, *B* for modules with address 2 and so on. After the address character there may be spaces (but this is not necessary). Then, send the command with its parameters. At the end of a command line a <CR> character has to be sent.

EXAMPLES FOR VALID COMMAND LINES:

```
AMVP ABS, 1, 50000
A MVP ABS, 1, 50000
AROL 2, 500
A MST 1
ABIN
```

The command lines above address the module with address 1. To address e.g. module 3, use address character C instead of A. The last command line shown above will make the module return to binary mode.

3.5.2 Format of a Reply

After executing the command the module sends back a reply in ASCII format.

The reply consists of:

- the address character of the host (host address that can be set in the module)
- the address character of the module
- the status code as a decimal number
- the return value of the command as a decimal number
- a <CR> character

So, after sending AGAP 0, 1 the reply would be BA 100 –5000 if the actual position of axis 1 is –5000, the host address is set to 2 and the module address is 1. The value 100 is the status code 100 that means command successfully executed.

3.5.3 Configuring the ASCII Interface

The module can be configured so that it starts up either in binary mode or in ASCII mode. ***Global parameter 67 is used for this purpose*** (please see also chapter 5.1).

Bit 0 determines the startup mode: if this bit is set, the module starts up in ASCII mode, else it will start up in binary mode (default).

Bit 4 and Bit 5 determine how the characters that are entered are echoed back. Normally, both bits are set to zero. In this case every character that is entered is echoed back when the module is addressed. Character can also be erased using the backspace character (press the backspace key in a terminal program).

When bit 4 is set and bit 5 is clear the characters that are entered are not echoed back immediately but the entire line will be echoed back after the <CR> character has been sent.

When bit 5 is set and bit 4 is clear there will be no echo, only the reply will be sent. This may be useful in RS485 systems.

3.6 Commands

The module specific commands are explained in more detail on the following pages. They are listed according to their command number.

3.6.1 ROR (rotate right)

With this command the motor will be instructed to rotate with a specified velocity in *right* direction (increasing the position counter).

Internal function: First, velocity mode is selected. Then, the velocity value is transferred to axis parameter #0 (*target velocity*).

The module is based on the TMC429 stepper motor controller and the TMC262 power driver. This makes possible choosing a velocity between 0 and 2047.

Related commands: ROL, MST, SAP, GAP

Mnemonic: ROR 0, <velocity>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
1	(don't care)	0*	<velocity> 0… 2047

***motor number is always 0 as only one motor is involved**

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Rotate right, velocity = 350
Mnemonic: ROR 0, 350

Binary:

Byte Index	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0
Value (hex)	$01	$01	$00	$00	$00	$00	$01	$5e

3.6.2 ROL (rotate left)

With this command the motor will be instructed to rotate with a specified velocity (opposite direction compared to ROR, decreasing the position counter).

Internal function: First, velocity mode is selected. Then, the velocity value is transferred to axis parameter #0 (*target velocity*).

The module is based on the TMC429 stepper motor controller and the TMC262 power driver. This makes possible choosing a velocity between 0 and 2047.

Related commands: ROR, MST, SAP, GAP

Mnemonic: ROL 0, <velocity>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
2	(don't care)	0*	<velocity> 0… 2047

***motor number is always 0 as only one motor is involved**

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Rotate left, velocity = 1200
Mnemonic: ROL 0, 1200

Binary:

Byte Index	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0
Value (hex)	$01	$02	$00	$00	$00	$00	$04	$b0

3.6.3 MST (motor stop)

With this command the motor will be instructed to stop with a soft stop.

Internal function: The axis parameter *target velocity* is set to zero.

Related commands: ROL, ROR, SAP, GAP

Mnemonic: MST 0

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
3	(don't care)	0*	(don't care)

***motor number is always 0 as only one motor is involved**

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Stop motor
Mnemonic: MST 0

Binary:

Byte Index	0	1	2	3	4	5	6	7
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0
Value (hex)	$01	$03	$00	$00	$00	$00	$00	$00