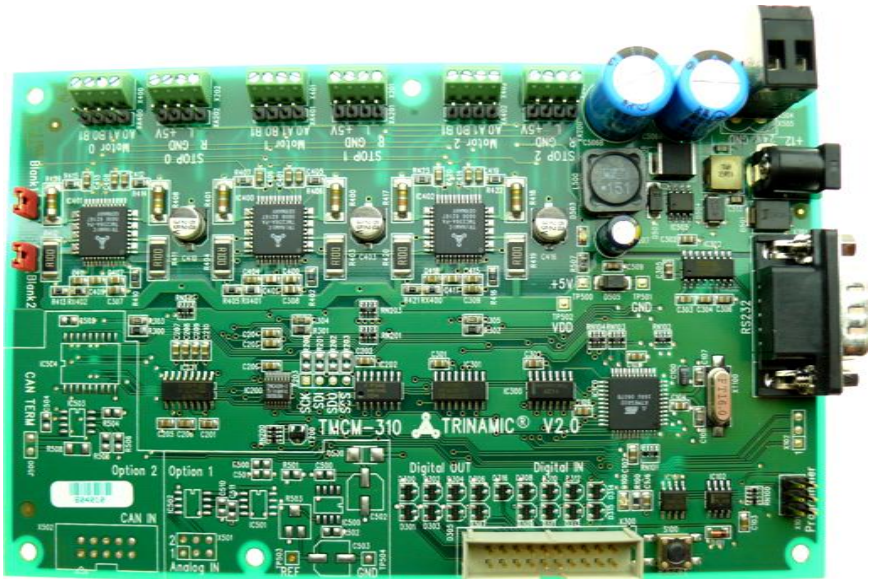
TMCM-310



TMCL™ Firmware Manual

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TRINAMIC
MOTION CONTROL

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1 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.

2 Features

The TMCM-310 is a triple axis 2-phase stepper motor controller and driver module. It provides a complete single board motion control solution at low cost. Using the integrated additional I/Os it even can do complete system control applications. The motors and switches can be connected easily with screw terminals. The connection of the multipurpose I/Os can be done via a dual-in-line pin connector. The TMCM-310 comes with the PC based software developer environment TMCL-IDE for the TRINAMIC Motion Control Language (TMCL™). Using predefined TMCL™ high level commands like *move to position* or *constant rotation* rapid and fast development of motion control applications guaranteed. The TMCM-310 can be controlled via the RS232 or the CAN interface. Communication traffic is very low since all time critical operations, e.g. ramp calculation are performed on board. A user TMCL™ program can be stored in the onboard EEPROM for stand-alone operation. The firmware of the module can be updated via the serial interface. With the optional stallGuard™ feature it is possible to detect overload and stall of the motor.

Applications
- Controller/driver board for control of up to 3 Axis
- Versatile possibilities of applications in stand alone or pc controlled mode

Motor type
- Coil current from 300mA to 1.1A RMS (1.5A peak)
- 8V to 34V nominal supply voltage

Highlights
- Automatic ramp generation in hardware
- stallGuard™ option for sensorless motor stall detection
- Full step frequencies up to 20kHz
- Fully protected drive
- On the fly alteration of motion parameters (e.g. position, velocity, acceleration)
- Local reference move using sensorless stallGuard™ feature or reference switch
- Coil current adjustable by software
- Up to 16 times microstepping
- Many adjustment possibilities make this module the solution for a great field of demands

Interfaces
- RS232
- CAN optional

Software
- Stand-alone operation using TMCL™ or remote controlled operation
- TMCL™ program storage: 16 Kbyte EEPROM (2048 TMCL™ commands)
- PC-based application development software TMCL-IDE included

Other
- Pluggable/screw terminal connectors
- RoHS compliant
- Size: 165 x 100 x 25 mm^3

3 Order codes

Order code	Description	Dimensions [mm³]
TMCM-310	3-axis controller/driver, RS232	165 x 100 x 25
TMCM-310-CAN	3-axis controller/driver, RS232, CAN	165 x 100 x 25
TMCM-310/SG	3-axis controller/driver, StallGuard, RS232	165 x 100 x 25
TMCM-310/SG-CAN	3-axis controller/driver, StallGuard, RS232, CAN	165 x 100 x 25
Related products:		
QSH4218-35-10-027	QMot stepper motor 42mm, 1A, 0.27Nm	42.3 x 42.3 x 33,5
QSH4218-41-10-035	QMot stepper motor 42mm, 1A, 0.35Nm	42.3 x 42.3 x 38
QSH4218-51-10-049	QMot stepper motor 42mm, 1A, 0.49Nm	42.3 x 42.3 x 47

4 Overview

As with most TRINAMIC modules the software running on the microprocessor of the TMCM-310 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 – normally – 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 firmware shipped with this module is related to the standard TMCL™ firmware [TMCL] shipped with most of TRINAMIC modules with regard to protocol and commands. Corresponding, the module is based on the TMC428-I stepper motor controller and the TMC236 or TMC246 power driver (with stallGuard™ option) and supports the standard TMCL™ with a special range of values.

All commands and parameters available with this unit are explained on the following pages.

5 Putting the TMCM-310 into operation

Here you can find basic information for putting your module into operation. The text contains two simple examples (with and without encoder) for a TMCL™ program and a short description of operating the module in direct mode.

The things you need:

- TMCM-310
- Interface (RS232 or CAN) suitable to your TMCM-310 version with cables
- Nominal supply voltage +24V DC (+8...+34V DC) for your module
- Up to three stepper motors which fit to your module, for example QSH-4218
- TMCL-IDE program and PC

Precautions:

- Do not mix up connections or short-circuit pins.
- Avoid bounding I/O wires with motor power wires as this may cause noise picked up from the motor supply.
- Do not exceed the maximum power supply of 34V DC.
- ***Do not connect or disconnect the motor while powered!***
- ***Start with power supply OFF!***

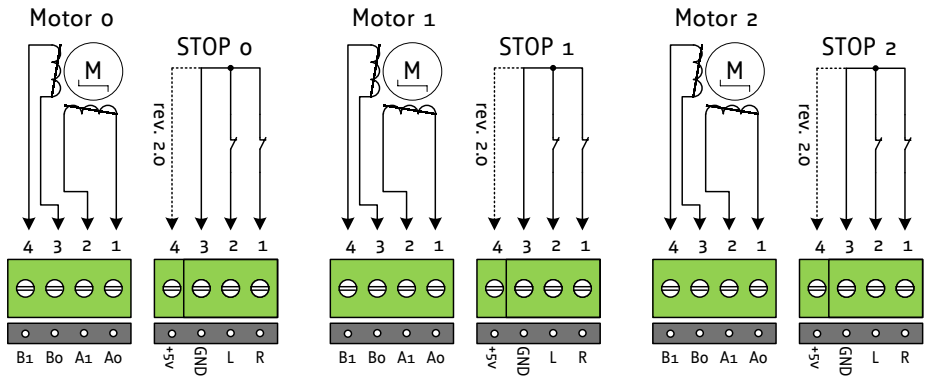
5.1 Starting up

1. Connect the motors

The TMCM-310 controls up to three 2-phase stepper motors. The screw terminals for the motors are marked on the board with *Motor 0*, *Motor 1* and *Motor 2* (2.54mm pitch connectors). Additionally there are electrically identical 4-pin connectors (2.54mm pitch) for motor and stop switches. Connect one coil of the motor to the terminals marked with *A0* and *A1* and the other coil to the terminals marked with *B0* and *B1*. If a stepper motor should run in the wrong direction just change the polarity of one (not both) of its coils.

Before connecting a motor please make sure which cable belongs to which coil. Wrong connections may lead to damage of the driver chips or the motor.

Pinning for motors 0, 1, and 2 plus stop-switches 0, 1, and 2:



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

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

   Pinning for RS232, CAN, null modem cable, and modem:

Pin	RS232	CAN	Host (female)	Null modem (female)	Modem (male)
1			1	4	1
2	RxD	CAN_L	2	3	2
3	TxD	GND	3	2	3
4			4	1	4
5	GND		5	5	5
6		GND optional	6	6	6
7		CAN_H	7	8	7
8			8	7	8
9			9	9	9
10	Not available				

3. **Connect the power supply:**
   There are two possibilities for connecting the power supply:
   - The power supply can either be connected to the X504/X505 TRINAMIC standard 5.08mm power plug
   - or to the power socket X503 (industry standard power socket with 2.0mm pin diameter). Both connections are electrically identical.

Plug X504/X505	Socket X503	Function
VS	Pin	+8…34V DC power supply (V2.0)
GND	Ring	Ground

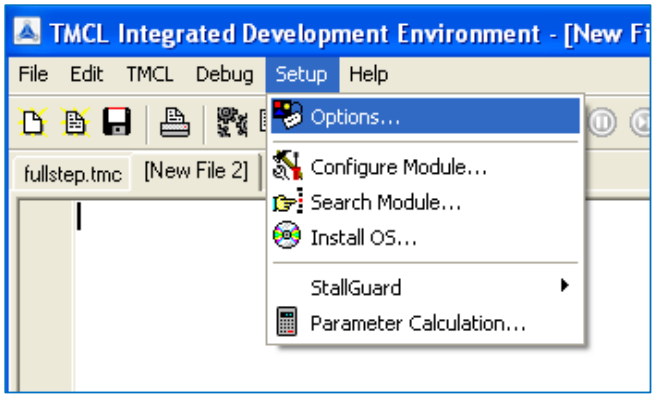
   Attention: Do not exceed the maximum power supply of 34V DC (V2.0)!

4. **Switch on the power supply**
   The green power LED (D503) lights steadily now. This indicates that the on-board +5V supply is available.

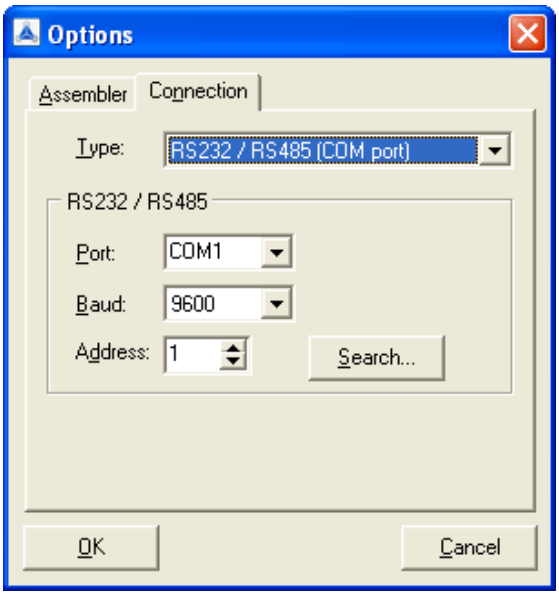
   If this does not occur, switch power OFF and check your connections as well as the power supply.

5. **Start the TMCL-IDE software development environment**
   The TMCL-IDE is available on the TechLibCD and 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 below (baud rate 9600 for RS232). Click *OK*.

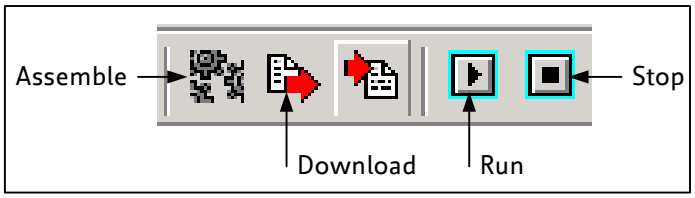


5.2 Testing with a simple TMCL™ program

Open the file test2.tmc. The following source code appears on the screen:

A description for the TMCL™ commands can be found in Appendix A.

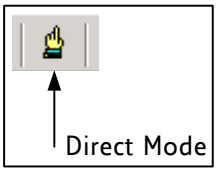
```
//A simple example for using TMCL™ and TMCL-IDE

        ROL 0, 500                  //Rotate motor 0 with speed 500
        WAIT TICKS, 0, 500
        MST 0
        ROR 1, 250                  //Rotate motor 1 with 250
        WAIT TICKS, 0, 500
        MST 1

        SAP 4, 2, 500               //Set max. Velocity
        SAP 5, 2, 50                //Set max. Acceleration
Loop:   MVP ABS, 2, 10000           //Move to Position 10000
        WAIT POS, 2, 0              //Wait until position reached
        MVP ABS, 2, -10000          //Move to Position -10000
        WAIT POS, 2, 0              //Wait until position reached
        JA Loop                     //Infinite Loop
```



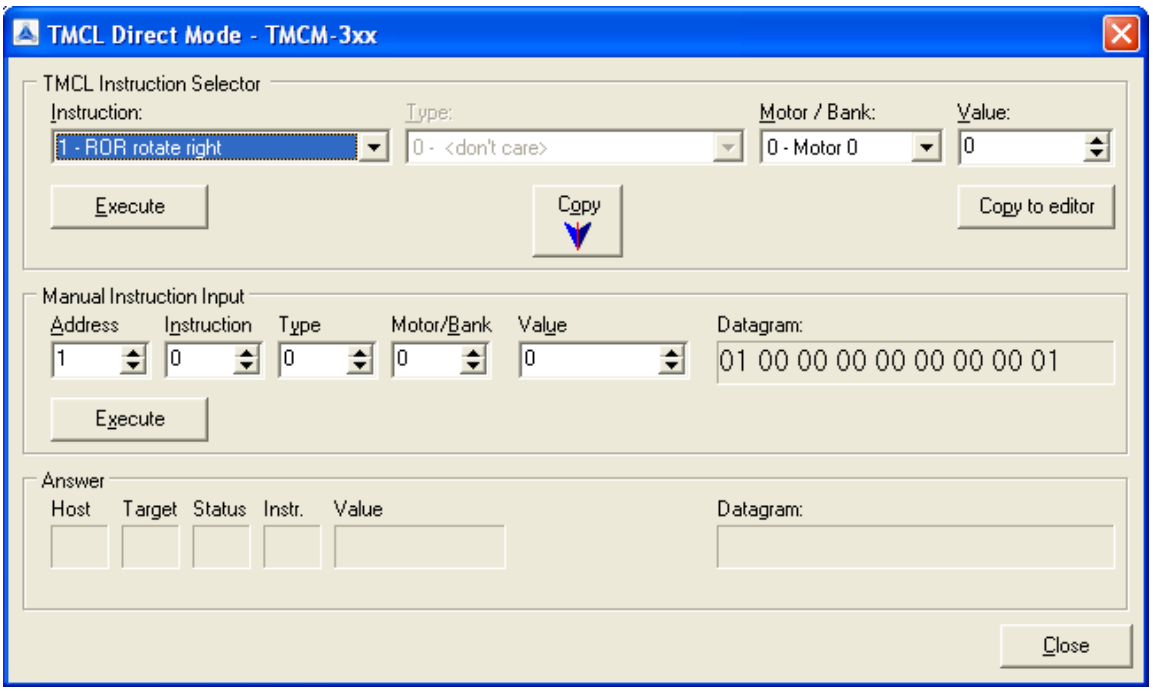
7. Click on Icon ***Assemble*** to convert the TMCL™ into machine code.
8. Then download the program to the TMCM-310 module via the icon ***Download***.
9. Press icon ***Run***. The desired program will be executed.
10. Click ***Stop*** button to stop the program.

5.3 Operating the module in direct mode

1. Start TMCL™ ***Direct Mode***.



2. If the communication is established the TMCM-310 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.



Examples:

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

Please use the TMCL-IDE axis parameter calculation tool for getting best values.

6 TMCL™ and TMCL-IDE

The TMCM-310 module supports TMCL™ direct mode (binary commands or ASCII interface) and stand-alone TMCL™ program execution. You can store up to 2048 TMCL™ instructions on it.

In direct mode the TMCL™ communication over RS232 and CAN 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 module. The TMCL™ interpreter on it 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 RS232/CAN to the bus master. The master should not transfer the next command till then. 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-310 to form programs that run stand-alone 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.
- The mnemonic format is used for easy usage of the commands when developing stand-alone TMCL™ applications with 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.

6.1 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 RS232 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 takes place 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 RS232 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 the CAN bus, just leave out the first byte (module address) and the last byte (checksum).

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
```

6.2 Reply format

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

The reply format for RS232 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, the first byte (reply address) and the last byte (checksum) are left out.
- Do not send the next command before you have received the reply!

6.2.1 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

6.3 Stand-alone applications

The module is equipped with an EEPROM for storing TMCL™ applications. You can use the TMCL-IDE for developing stand-alone TMCL™ applications. You can load your program down into the EEPROM and then they will run on the module. The TMCL-IDE contains an *editor* and a 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.

6.4 TMCL™ command overview

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

6.4.1 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 stand-alone 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

6.4.2 Parameter commands

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

6.4.3 I/O port commands

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

Mnemonic	Command number	Meaning
SIO	14	Set output
GIO	15	Get input
SAC	29	Access to external SPI device

6.4.4 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 stand-alone mode only.***

Mnemonic	Command number	Meaning
JA	22	Jump always
JC	21	Jump conditional
COMP	20	Compare accumulator with constant value
CLE	36	Clear error flags
CSUB	23	Call subroutine
RSUB	24	Return from subroutine
WAIT	27	Wait for a specified event
STOP	28	End of a TMCL™ program

6.4.5 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

For calculating purposes there is an accumulator (or accu or A register) and an X register. When executed in a TMCL™ program (in stand-alone 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 (stand-alone mode), a host can still send commands like GAP, GGP or GIO 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.

6.5 TMCL™ List of commands

The following TMCL™ commands are currently supported:

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>	Restore global parameter (TMCL™ user variables 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
WAIT	27	<condition>, <motor number>, <ticks>	Wait with further program execution
STOP	28		Stop program execution
SAC	29	<bus number>, <number of bites>, <send data>	SPI bus access
SCO	30	<coordinate number>, <motor number>, <position>	Set coordinate

Command	Number	Parameter	Description
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>	Accumulator to global parameter

TMCL™ control commands:

Instruction	Description	Type	Mot/Bank	Value
128 – stop application	a running TMCL™ standalone application is stopped	(don't care)	(don't care)	(don't care)
129 – run application	TMCL™ execution is started (or continued)	0 - run from current address 1 - run from specified address	(don't care)	(don't care) starting address
130 – step application	only the next command of a TMCL™ application is executed	(don't care)	(don't care)	(don't care)
131 – reset application	the program counter is set to zero, and the standalone application is stopped (when running or stepped)	(don't care)	(don't care)	(don't care)
132 – start download mode	target command execution is stopped and all following commands are transferred to the TMCL™ memory	(don't care)	(don't care)	starting address of the application
133 – quit download mode	target command execution is resumed	(don't care)	(don't care)	(don't care)
134 – read TMCL™ memory	the specified program memory location is read	(don't care)	(don't care)	<memory address>
135 – get application status	one of these values is returned: 0 – stop 1 – run 2 – step 3 – reset	(don't care)	(don't care)	(don't care)
136 – get firmware version	return the module type and firmware revision either as a string or in binary format	0 – string 1 – binary	(don't care)	(don't care)
137 – restore factory settings	reset all settings stored in the EEPROM to their factory defaults This command does not send back a reply.	(don't care)	(don't care)	must be 1234
138 – reserved				
139 – enter ASCII mode	Enter ASCII command line (see chapter 6.6)	(don't care)	(don't care)	(don't care)

6.6 The ASCII interface

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

- ***The ASCII command line interface is entered by sending the binary command 139 (enter ASCII mode).***
- Afterwards the commands are entered as in the TMCL-IDE. Please note that only those commands, which can be used in direct mode, also can be entered in ASCII mode.
- ***For leaving the ASCII mode and re-enter the binary mode enter the command BIN.***

6.6.1 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.

Here are some examples for valid command lines:

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

These command lines would 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.

6.6.2 Format of a reply

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

6.6.3 Commands that can be used in ASCII mode

The following commands can be used in ASCII mode: ROL, ROR, MST, MVP, SAP, GAP, STAP, RSAP, SGP, GGP, STGP, RSGP, RFS, SIO, GIO, SAC, SCO, GCO, CCO, UF0, UF1, UF2, UF3, UF4, UF5, UF6, and UF7.

There are also special commands that 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.

6.6.4 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 8.1). 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.

6.7 Commands

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

6.7.1 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 TMC428-I stepper motor controller and the TMC236/TMC246 power driver. This makes possible choosing a velocity between 0 and 2047.

Related commands: ROL, MST, SAP, GAP

Mnemonic: ROR <motor number>, <velocity>

Binary representation:

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

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:
Rotate right, motor #2, velocity = 350
Mnemonic: ROR 2, 350

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$01	$00	$02	$00	$00	$01	$5e	$62

6.7.2 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 TMC428-I stepper motor controller and the TMC236/TMC246 power driver. This makes possible choosing a velocity between 0 and 2047.

Related commands: ROR, MST, SAP, GAP

Mnemonic: ROL <motor number>, <velocity>

Binary representation:

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

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Rotate left, motor #1, velocity = 1200
Mnemonic: ROL 1, 1200

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$02	$00	$01	$00	$00	$04	$b0	$b8

6.7.3 MST (motor stop)

With this command the motor will be instructed to stop with deceleration ramp (soft stop). For information about hard stops refer to chapter 9 (hints and tips) please.

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

Related commands: ROL, ROR, SAP, GAP

Mnemonic: MST <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
3	(don't care)	<motor number>	(don't care)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Stop motor #1
Mnemonic: MST 1

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$03	$00	$01	$00	$00	$00	$00	$05

6.7.4 MVP (move to position)

With this command the motor will be instructed to move to a specified relative or absolute position or a pre-programmed coordinate. It will use the acceleration/deceleration ramp and the positioning speed programmed into the unit. This command is non-blocking – that is, a reply will be sent immediately after command interpretation and initialization of the motion controller. Further commands may follow without waiting for the motor reaching its end position. The maximum velocity and acceleration are defined by axis parameters #4 and #5.

Three operation types are available:

- Moving to an absolute position in the range from - 8388608 to +8388607 (-2^{23} to$+2^{23}-1$).
- Starting a relative movement by means of an offset to the actual position. In this case, the new resulting position value must not exceed the above mentioned limits, too.
- Moving the motor to a (previously stored) coordinate (refer to SCO for details). When moving more than one axis the module will try to interpolate: The velocities will be calculated so that all motors reach their target positions at the same time. It is important that the maximum accelerations (axis parameter #5) and the ramp and pulse dividers (axis parameters #153 and #154) of all axes are set to the same values as otherwise interpolation will not work correctly.

Please note, that the distance between the actual position and the new one should not be more than 8388607 microsteps. Otherwise the motor will run in the wrong direction for taking a shorter way. If the value is exactly 8388608 the motor maybe stops.

Internal function: A new position value is transferred to the axis parameter #2 *target position*.

Related commands: SAP, GAP, SCO, CCO, GCO, and MST

Mnemonic: MVP <ABS|REL|COORD>, <motor number>, <position|offset|coordinate number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
4	0 ABS – absolute	<motor number>	<position>
	1 REL – relative	<motor number>	<offset>
	2 COORD – coordinate	0 motor 0 1 motor 1 2 motor 2 3 (not allowed) 4 motors 0 and 1 5 motors 1 and 2 6 motors 0 and 2 7 motors 0,1,2	<coordinate number (0…20)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example MVP ABS:

Move motor #1 to (absolute) position 90000
Mnemonic: MVP ABS, 1, 9000

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$04	$00	$01	$00	$01	$5f	$90	$f6

Example MVP REL:

Move motor #0 from current position 1000 steps backward (move relative –1000)
Mnemonic: MVP REL, 0, -1000

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$04	$01	$00	$ff	$ff	$fc	$18	$18

Examples MVP COORD:

Move motor #2 to previously stored coordinate #8
Mnemonic: MVP COORD, 2, 8
Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$04	$02	$02	$00	$00	$00	$08	$11

It is possible to use stall detection. Please see section 9.2 for details.

When moving to a coordinate, the coordinate has to be set properly in advance with the help of the SCO command (see 6.7.25).

6.7.5 SAP (set axis parameter)

With this command most of the motion control parameters of the module can be specified. The settings will be stored in SRAM and therefore are volatile. That is, information will be lost after power off. ***Please use command STAP (store axis parameter) in order to store any setting permanently.***

Internal function: The parameter format is converted ignoring leading zeros (or ones for negative values). The parameter is transferred to the correct position in the appropriate device.

Related commands: GAP, STAP, RSAP, AAP

Mnemonic: SAP <parameter number>, <motor number>, <value>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
5	<parameter number>	<motor number>	<value>

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

List of parameters, which can be used for SAP:

Please note, that for the binary representation <parameter number> has to be filled with the* number *and the <value> has to be filled with a value from* range*.

Number	Axis Parameter	Description	Range [Unit]
0	target (next) position	The desired position in position mode (see ramp mode, no. 138).	± 2^{23} [µsteps]
1	actual position	The current position of the motor. Should only be overwritten for reference point setting.	± 2^{23} [µsteps]
2	target (next) speed	The desired speed in velocity mode (see ramp mode, no. 138). In position mode, this parameter is set by hardware: to the maximum speed during acceleration, and to zero during deceleration and rest.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
3	actual speed	The current rotation speed.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
4	maximum positioning speed	Should not exceed the physically highest possible value. Adjust the pulse divisor (no. 154), if the speed value is very low (<50) or above the upper limit. See TMC 428 datasheet for calculation of physical units.	0...2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
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 428 datasheet for calculation of physical units.	0... 2047*
6	absolute max. current	The most important motor setting, since too high values might cause motor damage! The maximum value is 1500 (which mean 100% of the maximum current of the module).	0... 1500 [mA]

Number	Axis Parameter	Description	Range [Unit]
7	standby current	The current limit two seconds after the motor has stopped.	0… 1500 [mA]
12	right limit switch disable	If set, deactivates the stop function of the right switch	0/1
13	left limit switch disable	Deactivates the stop function of the left switch resp. reference switch if set.	0/1
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. Do not change!	0…2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
138	ramp mode	Automatically set when using ROR, ROL, MST and MVP. 0: position mode. Steps are generated, when the parameters actual position and target position differ. Trapezoidal speed ramps are provided. 2: velocity mode. The motor will run continuously and the speed will be changed with constant (maximum) acceleration, if the parameter *target speed* is changed. For special purposes, the soft mode (value 1) with exponential decrease of speed can be selected.	0/1/2
140	microstep resolution	0 – full step*) 1 – half step*) 2 – 4 microsteps 3 – 8 microsteps 4 – 16 microsteps 5 – 32 microsteps**) 6 – 64 microsteps**) Note that modifying this parameter will affect the rotation speed in the same relation: *) The full-step setting and the half-step setting are not optimized for use without an adapted microstepping table. These settings just step through the microstep table in steps of 64 respectively 32. To get real full stepping use axis parameter 211 or load an adapted microstepping table. **) If the module is specified for 16 microsteps only, switching to 32 or 64 microsteps brings an enhancement in resolution and smoothness. The position counter will use the full resolution, but, however, the motor will resolve a maximum of 24 different microsteps only for the 32 or 64 microstep units.	0…6
149	soft stop flag	If cleared, the motor will stop immediately (disregarding motor limits), when the reference or limit switch is hit.	0/1
153	ramp divisor	The exponent of the scaling factor for the ramp generator- should be de/incremented carefully (in steps of one).	0…13
154	pulse divisor	The exponent of the scaling factor for the pulse (step) generator – should be de/incremented carefully (in steps of one).	0…13

Number	Axis Parameter	Description	Range [Unit]
193	referencing mode	1 – Only the left reference switch is searched. 2 – The right switch is searched and afterwards the left switch is searched. 3 – Three-switch-mode: the right switch is searched first and afterwards the reference switch will be searched. Please see chapter 6.7.13 for details on reference search.	1/2/3
194	referencing search speed	For the reference search this value specifies the search speed as a fraction of the maximum velocity: 0 – full speed 1 – half of the maximum speed 2 – a quarter of the maximum speed 3 – 1/8 of the maximum speed (etc.)	0…8
195	referencing switch speed	Similar to parameter no. 194, the speed for the switching point calibration can be selected.	0..8
203	mixed decay threshold	If the actual velocity is above this threshold, mixed decay will be used. This can also be set to -1 which turns on mixed decay permanently also in the rising part of the microstep wave. This can be used to fix microstep errors.	0..2048 or -1 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.	0…65535 0 = never [msec]
205	stall detection threshold	Stall detection threshold. Set it to 0 for no stall detection or to a value between 1 (low threshold) and 7 (high threshold). The motor will be stopped if the load value exceeds the stall detection threshold. Switch off mixed decay to get usable results.	0…7
211	fullstep threshold	When exceeding this speed the driver will switch to real full step mode. To disable this feature set this parameter to zero or to a value greater than 2047. Setting a full step threshold allows higher motor torque of the motor at higher velocity. When experimenting with this in a given application, try to reduce the motor current in order to be able to reach a higher motor velocity!	0…2048 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
214	power down delay	Standstill period before the current is changed down to standby current. The standard value is 200 (value equates 2000msec).	1… 65535 [10msec]

Please use the TMCL-IDE axis parameter calculation tool for getting best values.

Example:

Set the absolute maximum current of motor #1 to 200mA
Mnemonic: SAP 6, 1, 200

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$05	$06	$01	$00	$00	$00	$c8	$d5

6.7.6 GAP (get axis parameter)

Most parameters of the TMCM-310 can be adjusted individually for the axis. With this parameter they can be read out. In stand-alone mode the requested value is also transferred to the accumulator register for further processing purposes (such as conditioned jumps). In direct mode the value read is only output in the *value* field of the reply (without affecting the accumulator).

Internal function: The parameter is read out of the correct position in the appropriate device. The parameter format is converted adding leading zeros (or ones for negative values).

Related commands: SAP, STAP, AAP, RSAP

Mnemonic: GAP <parameter number>, <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
6	<parameter number>	<motor number>	(don't care)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

List of parameters, which can be used for GAP:

Number	Axis Parameter	Description	Range [Unit]
0	target (next) position	The desired position in position mode (see ramp mode, no. 138).	$\pm 2^{23}$ [µsteps]
1	actual position	The current position of the motor. Should only be overwritten for reference point setting.	$\pm 2^{23}$ [µsteps]
2	target (next) speed	The desired speed in velocity mode (see ramp mode, no. 138). In position mode, this parameter is set by hardware: to the maximum speed during acceleration, and to zero during deceleration and rest.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
3	actual speed	The current rotation speed.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
4	maximum positioning speed	Should not exceed the physically highest possible value. Adjust the pulse divisor (no. 154), if the speed value is very low (<50) or above the upper limit. See TMC 428 datasheet for calculation of physical units.	0...2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
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 428 datasheet for calculation of physical units.	0... 2047*
6	absolute max. current	The most important motor setting, since too high values might cause motor damage! The maximum value is 1500 (which mean 100% of the maximum current of the module).	0... 1500 [mA]
7	standby current	The current limit two seconds after the motor has stopped.	0... 1500 [mA]
8	target pos. reached	Indicates that the actual position equals the target position.	0/1

Number	Axis Parameter	Description	Range [Unit]
9	ref. switch status	The logical state of the reference (left) switch. See the TMC 428 data sheet for the different switch modes. The default has two switch modes: the left switch as the reference switch, the right switch as a limit (stop) switch.	0/1
10	right limit switch status	The logical state of the (right) limit switch.	0/1
11	left limit switch status	The logical state of the left limit switch (in three switch mode)	0/1
12	right limit switch disable	If set, deactivates the stop function of the right switch	0/1
13	left limit switch disable	Deactivates the stop function of the left switch resp. reference switch if set.	0/1
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. Do not change!	0…2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
135	actual acceleration	The current acceleration (read only).	0… 2047*
138	ramp mode	Automatically set when using ROR, ROL, MST and MVP. 0: position mode. Steps are generated, when the parameters actual position and target position differ. Trapezoidal speed ramps are provided. 2: velocity mode. The motor will run continuously and the speed will be changed with constant (maximum) acceleration, if the parameter *target speed* is changed. For special purposes, the soft mode (value 1) with exponential decrease of speed can be selected.	0/1/2
140	microstep resolution	0 – full step*) 1 – half step*) 2 – 4 microsteps 3 – 8 microsteps 4 – 16 microsteps 5 – 32 microsteps**) 6 – 64 microsteps**) Note that modifying this parameter will affect the rotation speed in the same relation: *) The full-step setting and the half-step setting are not optimized for use without an adapted microstepping table. These settings just step through the microstep table in steps of 64 respectively 32. To get real full stepping use axis parameter 211 or load an adapted microstepping table. **) If the module is specified for 16 microsteps only, switching to 32 or 64 microsteps brings an enhancement in resolution and smoothness. The position counter will use the full resolution, but, however, the motor will resolve a maximum of 24 different microsteps only for the 32 or 64 microstep units.	0…6

Number	Axis Parameter	Description	Range [Unit]
149	soft stop flag	If cleared, the motor will stop immediately (disregarding motor limits), when the reference or limit switch is hit.	0/1
153	ramp divisor	The exponent of the scaling factor for the ramp generator- should be de/incremented carefully (in steps of one).	0…13
154	pulse divisor	The exponent of the scaling factor for the pulse (step) generator – should be de/incremented carefully (in steps of one).	0…13
193	referencing mode	1 – Only the left reference switch is searched. 2 – The right switch is searched and afterwards the left switch is searched. 3 – Three-switch-mode: the right switch is searched first and afterwards the reference switch will be searched. Please see chapter 6.7.13 for details on reference search.	1/2/3
194	referencing search speed	For the reference search this value specifies the search speed as a fraction of the maximum velocity: 0 – full speed 1 – half of the maximum speed 2 – a quarter of the maximum speed 3 – 1/8 of the maximum speed (etc.)	0…8
195	referencing switch speed	Similar to parameter no. 194, the speed for the switching point calibration can be selected.	0..8
196	distance end switches	This parameter provides the distance between the end switches after executing the RFS command (mode 2 or 3).	0…8388307
203	mixed decay threshold	If the actual velocity is above this threshold, mixed decay will be used. This can also be set to -1 which turns on mixed decay permanently also in the rising part of the microstep wave. This can be used to fix microstep errors.	0..2048 or -1 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.	0…65535 0 = never [msec]
205	stall detection threshold	Stall detection threshold. Set it to 0 for no stall detection or to a value between 1 (low threshold) and 7 (high threshold). The motor will be stopped if the load value exceeds the stall detection threshold. Switch off mixed decay to get usable results.	0…7
206	actual load value	Readout of the actual load value used for stall detection.	0…7
208	driver error flags	TMC236 error flags.	

Number	Axis Parameter	Description	Range [Unit]
211	fullstep threshold	When exceeding this speed the driver will switch to real full step mode. To disable this feature set this parameter to zero or to a value greater than 2047. Setting a full step threshold allows higher motor torque of the motor at higher velocity. When experimenting with this in a given application, try to reduce the motor current in order to be able to reach a higher motor velocity!	0..2048 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$
214	power down delay	Standstill period before the current is changed down to standby current. The standard value is 200 (value equates 2000msec).	1... 65535 [10msec]

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

Example:

Get the actual position of motor #2

Mnemonic: GAP 2, 1

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$06	$01	$02	$00	$00	$00	$00	$0a

Reply:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Host-address	Target-address	Status	Instruction	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$02	$01	$64	$06	$00	$00	$02	$c7	$36

⇨ **status=no error, position=711**

6.7.7 STAP (store axis parameter)

An axis parameter previously set with a *Set Axis Parameter command (SAP)* will be stored permanent. Most parameters are automatically restored after power up (refer to axis parameter list in chapter 7).

Internal function: An axis parameter value stored in SRAM will be transferred to EEPROM and loaded from EEPORM after next power up.

Related commands: SAP, RSAP, GAP, AAP

Mnemonic: STAP <parameter number>, <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
7	<parameter number>	<motor number>	(don't care)*

The value operand of this function has no effect. Instead, the currently used value (e.g. selected by SAP) is saved.

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Parameter ranges:

Parameter number	Motor number	Value
s. chapter 7	0	s. chapter 7

List of parameters, which can be used for STAP:

Number	Axis Parameter	Description
4	maximum positioning speed	Should not exceed the physically highest possible value. Adjust the pulse divisor (no. 154), if the speed value is very low (<50) or above the upper limit. See TMC 428 datasheet for calculation of physical units.
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 428 datasheet for calculation of physical units.
6	absolute max. current	The most important motor setting, since too high values might cause motor damage! The maximum value is 1500 (which mean 100% of the maximum current of the module).
7	standby current	The current limit two seconds after the motor has stopped.
12	right limit switch disable	If set, deactivates the stop function of the right switch
13	left limit switch disable	Deactivates the stop function of the left switch resp. reference switch if set.
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. Do not change!

Number	Axis Parameter	Description
138	ramp mode	Automatically set when using ROR, ROL, MST and MVP. 0: position mode. Steps are generated, when the parameters actual position and target position differ. Trapezoidal speed ramps are provided. 2: velocity mode. The motor will run continuously and the speed will be changed with constant (maximum) acceleration, if the parameter *target speed* is changed. For special purposes, the soft mode (value 1) with exponential decrease of speed can be selected.
140	microstep resolution	0 – full step*) 1 – half step*) 2 – 4 microsteps 3 – 8 microsteps 4 – 16 microsteps 5 – 32 microsteps**) 6 – 64 microsteps**) Note that modifying this parameter will affect the rotation speed in the same relation: *) The full-step setting and the half-step setting are not optimized for use without an adapted microstepping table. These settings just step through the microstep table in steps of 64 respectively 32. To get real full stepping use axis parameter 211 or load an adapted microstepping table. **) If the module is specified for 16 microsteps only, switching to 32 or 64 microsteps brings an enhancement in resolution and smoothness. The position counter will use the full resolution, but, however, the motor will resolve a maximum of 24 different microsteps only for the 32 or 64 microstep units.
149	soft stop flag	If cleared, the motor will stop immediately (disregarding motor limits), when the reference or limit switch is hit.
153	ramp divisor	The exponent of the scaling factor for the ramp generator- should be de/incremented carefully (in steps of one).
154	pulse divisor	The exponent of the scaling factor for the pulse (step) generator – should be de/incremented carefully (in steps of one).
193	referencing mode	1 – Only the left reference switch is searched. 2 – The right switch is searched and afterwards the left switch is searched. 3 – Three-switch-mode: the right switch is searched first and afterwards the reference switch will be searched. Please see chapter 6.7.13 for details on reference search.

Number	Axis Parameter	Description
194	referencing search speed	For the reference search this value specifies the search speed as a fraction of the maximum velocity: 0 – full speed 1 – half of the maximum speed 2 – a quarter of the maximum speed 3 – 1/8 of the maximum speed (etc.)
195	referencing switch speed	Similar to parameter no. 194, the speed for the switching point calibration can be selected.
203	mixed decay threshold	If the actual velocity is above this threshold, mixed decay will be used. This can also be set to -1 which turns on mixed decay permanently also in the rising part of the microstep wave. This can be used to fix microstep errors.
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.
205	stall detection threshold	Stall detection threshold. Set it to 0 for no stall detection or to a value between 1 (low threshold) and 7 (high threshold). The motor will be stopped if the load value exceeds the stall detection threshold. Switch off mixed decay to get usable results.
211	fullstep threshold	When exceeding this speed the driver will switch to real full step mode. To disable this feature set this parameter to zero or to a value greater than 2047. Setting a full step threshold allows higher motor torque of the motor at higher velocity. When experimenting with this in a given application, try to reduce the motor current in order to be able to reach a higher motor velocity!
214	power down delay	Standstill period before the current is changed down to standby current. The standard value is 200 (value equates 2000msec).

Example:

Store the maximum speed of motor #1
Mnemonic: STAP 4, 1

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$07	$04	$01	$00	$00	$00	$00	$0d

Note: The STAP command will not have any effect when the configuration EEPROM is locked (refer to 8.1). In direct mode, the error code 5 (configuration EEPROM locked, see also section 6.2.1) will be returned in this case.

6.7.8 RSAP (restore axis parameter)

For all configuration-related axis parameters non-volatile memory locations are provided. By default, most parameters are automatically restored after power up (refer to axis parameter list in chapter 7). A single parameter that has been changed before can be reset by this instruction also.

Internal function: The specified parameter is copied from the configuration EEPROM memory to its RAM location.

Relate commands: SAP, STAP, GAP, and AAP

Mnemonic: RSAP <parameter number>, <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
8	<parameter number>	<motor number>	(don't care)

Reply structure in direct mode:

STATUS	VALUE
100 – OK	(don't care)

List of parameters, which can be used for RSAP:

Number	Axis Parameter	Description
4	maximum positioning speed	Should not exceed the physically highest possible value. Adjust the pulse divisor (no. 154), if the speed value is very low (<50) or above the upper limit. See TMC 428 datasheet for calculation of physical units.
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 428 datasheet for calculation of physical units.
6	absolute max. current	The most important motor setting, since too high values might cause motor damage! The maximum value is 1500 (which mean 100% of the maximum current of the module).
7	standby current	The current limit two seconds after the motor has stopped.
12	right limit switch disable	If set, deactivates the stop function of the right switch
13	left limit switch disable	Deactivates the stop function of the left switch resp. reference switch if set.
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. Do not change!

Number	Axis Parameter	Description
138	ramp mode	Automatically set when using ROR, ROL, MST and MVP. 0: position mode. Steps are generated, when the parameters actual position and target position differ. Trapezoidal speed ramps are provided. 2: velocity mode. The motor will run continuously and the speed will be changed with constant (maximum) acceleration, if the parameter *target speed* is changed. For special purposes, the soft mode (value 1) with exponential decrease of speed can be selected.
140	microstep resolution	0 – full step*) 1 – half step*) 2 – 4 microsteps 3 – 8 microsteps 4 – 16 microsteps 5 – 32 microsteps**) 6 – 64 microsteps**) Note that modifying this parameter will affect the rotation speed in the same relation: *) The full-step setting and the half-step setting are not optimized for use without an adapted microstepping table. These settings just step through the microstep table in steps of 64 respectively 32. To get real full stepping use axis parameter 211 or load an adapted microstepping table. **) If the module is specified for 16 microsteps only, switching to 32 or 64 microsteps brings an enhancement in resolution and smoothness. The position counter will use the full resolution, but, however, the motor will resolve a maximum of 24 different microsteps only for the 32 or 64 microstep units.
149	soft stop flag	If cleared, the motor will stop immediately (disregarding motor limits), when the reference or limit switch is hit.
153	ramp divisor	The exponent of the scaling factor for the ramp generator- should be de/incremented carefully (in steps of one).
154	pulse divisor	The exponent of the scaling factor for the pulse (step) generator – should be de/incremented carefully (in steps of one).
193	referencing mode	1 – Only the left reference switch is searched. 2 – The right switch is searched and afterwards the left switch is searched. 3 – Three-switch-mode: the right switch is searched first and afterwards the reference switch will be searched. Please see chapter 6.7.13 for details on reference search.

Number	Axis Parameter	Description
194	referencing search speed	For the reference search this value specifies the search speed as a fraction of the maximum velocity: 0 – full speed 1 – half of the maximum speed 2 – a quarter of the maximum speed 3 – 1/8 of the maximum speed (etc.)
195	referencing switch speed	Similar to parameter no. 194, the speed for the switching point calibration can be selected.
203	mixed decay threshold	If the actual velocity is above this threshold, mixed decay will be used. This can also be set to -1 which turns on mixed decay permanently also in the rising part of the microstep wave. This can be used to fix microstep errors.
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.
205	stall detection threshold	Stall detection threshold. Set it to 0 for no stall detection or to a value between 1 (low threshold) and 7 (high threshold). The motor will be stopped if the load value exceeds the stall detection threshold. Switch off mixed decay to get usable results.
211	fullstep threshold	When exceeding this speed the driver will switch to real full step mode. To disable this feature set this parameter to zero or to a value greater than 2047. Setting a full step threshold allows higher motor torque of the motor at higher velocity. When experimenting with this in a given application, try to reduce the motor current in order to be able to reach a higher motor velocity!
214	power down delay	Standstill period before the current is changed down to standby current. The standard value is 200 (value equates 2000msec).

Example:

Restore the maximum current of motor #1
Mnemonic: RSAP 6, 1

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$08	$06	$01	$00	$00	$00	$00	$10

6.7.9 SGP (set global parameter)

With this command most of the module specific parameters not directly related to motion control can be specified and the TMCL™ user variables can be changed. Global parameters are related to the host interface, peripherals or application specific variables. The different groups of these parameters are organized in *banks* to allow a larger total number for future products. Currently, bank 0 and 1 are used for global parameters, and bank 2 is used for user variables.

All module settings will automatically be stored non-volatile (internal EEPROM of the processor). The TMCL™ user variables will not be stored in the EEPROM automatically, but this can be done by using STGP commands.

Internal function: the parameter format is converted ignoring leading zeros (or ones for negative values). The parameter is transferred to the correct position in the appropriate (on board) device.

Related commands: GGP, STGP, RSGP, AGP

Mnemonic: SGP <parameter number>, <bank number>, <value>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
9	<parameter number>	<bank number>	<value>

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Global parameters of bank 0, which can be used for SGP:

Number	Global parameter	Description			Range
64	EEPROM magic	Setting this parameter to a different value as $E4 will cause re-initialization of the axis and global parameters (to factory defaults) after the next power up. This is useful in case of miss-configuration.			0…255
65	RS232 baud rate	0	9600 baud	*Default*	0…7
		1	14400 baud		
		2	19200 baud		
		3	28800 baud		
		4	38400 baud		
		5	57600 baud		
		6	76800 baud	*Not supported by Windows!*	
		7	(115200 baud)		
66	serial address	The module (target) address for RS-232.			0…255
67	ASCII mode	Configure the TMCL™ ASCII interface: Bit 0: 0 – start up in binary (normal) mode 1 – start up in ASCII mode Bits 4 and 5: 00 – Echo back each character 01 – Echo back complete command 10 – Do not send echo, only send command reply			

Number	Global parameter	Description			Range
69	CAN bit rate	1	10kBit/s		1…7
		2	20kBit/s		
		3	50kBit/s		
		4	100kBit/s		
		5	125kBit/s		
		6	250kBit/s		
		7	500kBit/s		
		8	1000kBit/s	*Default*	
70	CAN reply ID	The CAN ID for replies from the board (default: 2)			0…7ff
71	CAN ID	The module (target) address for CAN (default: 1)			0…7ff
73	configuration EEPROM lock flag	Write: 1234 to lock the EEPROM, 4321 to unlock it. Read: 1=EEPROM locked, 0=EEPROM unlocked.			0/1
75	telegram pause time	Pause time before the reply via RS232 is sent. For RS232 set to 0. For CAN interface this parameter has no effect!			0…255
76	serial host address	Host address used in the reply telegrams sent back via RS232.			0…255
77	auto start mode	0: Do not start TMCL™ application after power up (default). 1: Start TMCL™ application automatically after power up.			0/1
80	shutdown pin functionality	Select the functionality of the SHUTDOWN pin 0 – no function 1 – high active 2 – low active			0…2
81	TMCL™ code protection	Protect a TMCL™ program against disassembling or overwriting. 0 – no protection 1 – protection against disassembling 2 – protection against overwriting 3 – protection against disassembling and overwriting ***If you switch off the protection against disassembling, the program will be erased first!*** ***Changing this value from 1 or 3 to 0 or 2, the TMCL™ program will be wiped off.***			0,1,2,3
83	CAN secondary address	Second CAN ID for the module. Switched off when set to zero.			0…7ff
132	tick timer	A 32 bit counter that gets incremented by one every millisecond. It can also be reset to any start value.			

Global parameters of bank 1, which can be used for SGP:

The global parameter bank 1 is normally not available. It may be used for customer specific extensions of the firmware. Together with user definable commands (see section 7.3) these variables form the interface between extensions of the firmware (written in C) and TMCL™ applications.

Global parameters of bank 2, which can be used for SGP:

Bank 2 contains general purpose 32 bit variables for the use in TMCL™ applications. They are located in RAM and can be stored to EEPROM. After booting, their values are automatically restored to the RAM.

Number	Global parameter	Description	Range
0	general purpose variable #0	for use in TMCL™ applications	$-2^{31}...+2^{31}$
1	general purpose variable #1	for use in TMCL™ applications	$-2^{31}...+2^{31}$
2	general purpose variable #2	for use in TMCL™ applications	$-2^{31}...+2^{31}$
3	general purpose variable #3	for use in TMCL™ applications	$-2^{31}...+2^{31}$
4	general purpose variable #4	for use in TMCL™ applications	$-2^{31}...+2^{31}$
5	general purpose variable #5	for use in TMCL™ applications	$-2^{31}...+2^{31}$
6	general purpose variable #6	for use in TMCL™ applications	$-2^{31}...+2^{31}$
7	general purpose variable #7	for use in TMCL™ applications	$-2^{31}...+2^{31}$
8	general purpose variable #8	for use in TMCL™ applications	$-2^{31}...+2^{31}$
9	general purpose variable #9	for use in TMCL™ applications	$-2^{31}...+2^{31}$
10	general purpose variable #10	for use in TMCL™ applications	$-2^{31}...+2^{31}$
11	general purpose variable #11	for use in TMCL™ applications	$-2^{31}...+2^{31}$
12	general purpose variable #12	for use in TMCL™ applications	$-2^{31}...+2^{31}$
13	general purpose variable #13	for use in TMCL™ applications	$-2^{31}...+2^{31}$
14	general purpose variable #14	for use in TMCL™ applications	$-2^{31}...+2^{31}$
15	general purpose variable #15	for use in TMCL™ applications	$-2^{31}...+2^{31}$
16	general purpose variable #16	for use in TMCL™ applications	$-2^{31}...+2^{31}$
17	general purpose variable #17	for use in TMCL™ applications	$-2^{31}...+2^{31}$
18	general purpose variable #18	for use in TMCL™ applications	$-2^{31}...+2^{31}$
19	general purpose variable #19	for use in TMCL™ applications	$-2^{31}...+2^{31}$
20...55	general purpose variables #20..#55	for use in TMCL™ applications	$-2^{31}...+2^{31}$

Example:

Set the serial address of the target device to 3
Mnemonic: SGP 66, 0, 3

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$09	$42	$00	$00	$00	$00	$03	$4f

Please refer to chapter 8 for more information about bank 0 to 2.

6.7.10 GGP (get global parameter)

All global parameters can be read with this function. Global parameters are related to the host interface, peripherals or application specific variables. The different groups of these parameters are organized in *banks* to allow a larger total number for future products. Currently, bank 0 and 1 are used for global parameters, and bank 2 is used for user variables.

Internal function: The parameter is read out of the correct position in the appropriate device. The parameter format is converted adding leading zeros (or ones for negative values).

Related commands: SGP, STGP, RSGP, AGP

Mnemonic: GGP <parameter number>, <bank number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
10	<parameter number>	<bank number>	(don't care)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Global parameters of bank 0, which can be used for GGP:

Number	Global parameter	Description			Range
64	EEPROM magic	Setting this parameter to a different value as $E4 will cause re-initialization of the axis and global parameters (to factory defaults) after the next power up. This is useful in case of miss-configuration.			0…255
65	RS232 baud rate	0	9600 baud	*Default*	0…7
		1	14400 baud		
		2	19200 baud		
		3	28800 baud		
		4	38400 baud		
		5	57600 baud		
		6	76800 baud	*Not supported by Windows!*	
		7	(115200 baud)		
66	serial address	The module (target) address for RS-232/RS-485.			0…255
67	ASCII mode	Configure the TMCL™ ASCII interface: Bit 0: 0 – start up in binary (normal) mode 1 – start up in ASCII mode Bits 4 and 5: 00 – Echo back each character 01 – Echo back complete command 10 – Do not send echo, only send command reply			
69	CAN bit rate	1	10kBit/s		1…7
		2	20kBit/s		
		3	50kBit/s		
		4	100kBit/s		
		5	125kBit/s		
		6	250kBit/s		
		7	500kBit/s		
		8	1000kBit/s	*Default*	
70	CAN reply ID	The CAN ID for replies from the board (default: 2)			0…7ff
71	CAN ID	The module (target) address for CAN (default: 1)			0…7ff

Number	Global parameter	Description	Range
73	configuration EEPROM lock flag	Write: 1234 to lock the EEPROM, 4321 to unlock it. Read: 1=EEPROM locked, 0=EEPROM unlocked.	0/1
75	telegram pause time	Pause time before the reply via RS232 is sent. For RS232 set to 0. For CAN interface this parameter has no effect!	0…255
76	serial host address	Host address used in the reply telegrams sent back via RS232.	0…255
77	auto start mode	0: Do not start TMCL™ application after power up (default). 1: Start TMCL™ application automatically after power up.	0/1
80	shutdown pin functionality	Select the functionality of the SHUTDOWN pin 0 – no function 1 – high active 2 – low active	0..2
81	TMCL™ code protection	Protect a TMCL™ program against disassembling or overwriting. 0 – no protection 1 – protection against disassembling 2 – protection against overwriting 3 – protection against disassembling and overwriting ***If you switch off the protection against disassembling, the program will be erased first! Changing this value from 1 or 3 to 0 or 2, the TMCL™ program will be wiped off.***	0,1,2,3
83	CAN secondary address	Second CAN ID for the module. Switched off when set to zero.	0..7ff
128	TMCL™ application status	0 –stop 1 – run 2 – step 3 – reset	0…3
129	download mode	0 – normal mode 1 – download mode	0/1
130	TMCL™ program counter	The index of the currently executed TMCL™ instruction.	
132	tick timer	A 32 bit counter that gets incremented by one every millisecond. It can also be reset to any start value.	
133	random number	Choose a random number. ***Read only!***	0…2147483647

Global parameters of bank 1, which can be used for GGP:

The global parameter bank 1 is normally not available. It may be used for customer specific extensions of the firmware. Together with user definable commands (see section 7.3) these variables form the interface between extensions of the firmware (written in C) and TMCL™ applications.

Global parameters of bank 2, which can be used for GGP:

Bank 2 contains general purpose 32 bit variables for the use in TMCL™ applications. They are located in RAM and can be stored to EEPROM. After booting, their values are automatically restored to the RAM.

Number	Global parameter	Description	Range
0	general purpose variable #0	for use in TMCL™ applications	$-2^{31}...+2^{31}$
1	general purpose variable #1	for use in TMCL™ applications	$-2^{31}...+2^{31}$
2	general purpose variable #2	for use in TMCL™ applications	$-2^{31}...+2^{31}$
3	general purpose variable #3	for use in TMCL™ applications	$-2^{31}...+2^{31}$
4	general purpose variable #4	for use in TMCL™ applications	$-2^{31}...+2^{31}$
5	general purpose variable #5	for use in TMCL™ applications	$-2^{31}...+2^{31}$
6	general purpose variable #6	for use in TMCL™ applications	$-2^{31}...+2^{31}$
7	general purpose variable #7	for use in TMCL™ applications	$-2^{31}...+2^{31}$
8	general purpose variable #8	for use in TMCL™ applications	$-2^{31}...+2^{31}$
9	general purpose variable #9	for use in TMCL™ applications	$-2^{31}...+2^{31}$
10	general purpose variable #10	for use in TMCL™ applications	$-2^{31}...+2^{31}$
11	general purpose variable #11	for use in TMCL™ applications	$-2^{31}...+2^{31}$
12	general purpose variable #12	for use in TMCL™ applications	$-2^{31}...+2^{31}$
13	general purpose variable #13	for use in TMCL™ applications	$-2^{31}...+2^{31}$
14	general purpose variable #14	for use in TMCL™ applications	$-2^{31}...+2^{31}$
15	general purpose variable #15	for use in TMCL™ applications	$-2^{31}...+2^{31}$
16	general purpose variable #16	for use in TMCL™ applications	$-2^{31}...+2^{31}$
17	general purpose variable #17	for use in TMCL™ applications	$-2^{31}...+2^{31}$
18	general purpose variable #18	for use in TMCL™ applications	$-2^{31}...+2^{31}$
19	general purpose variable #19	for use in TMCL™ applications	$-2^{31}...+2^{31}$
20...55	general purpose variables #20..#55	for use in TMCL™ applications	$-2^{31}...+2^{31}$

Example:

Get the serial address of the target device
Mnemonic: GGP 66, 0

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$0a	$42	$00	$00	$00	$00	$00	$4d

Reply:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Host-address	Target-address	Status	Instruction	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$02	$01	$64	$0a	$00	$00	$00	$01	$72

⇨ **Status=no error, Value=1**

Please refer to chapter 8 for more information about bank 0 to 2.

6.7.11 STGP (store global parameter)

This command is used to store TMCL™ user variables permanently in the EEPROM of the module. Some global parameters are located in RAM memory, so without storing modifications are lost at power down. This instruction enables enduring storing. Most parameters are automatically restored after power up.

Internal function: The specified parameter is copied from its RAM location to the configuration EEPROM.

Related commands: SGP, GGP, RSGP, AGP

Mnemonic: STGP <parameter number>, <bank number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
11	<parameter number>	<bank number>	(don't care)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Global parameters of bank 0, which can be used for STGP:

The global parameter bank 0 is not required for the STGP command, because these parameters are automatically stored with the SGP command in EEPROM.

Global parameters of bank 1, which can be used for STGP:

The global parameter bank 1 is normally not available, but can be used in customer specific extensions of the firmware.

Global parameters of bank 2, which can be used for STGP:

Bank 2 contains general purpose 32 bit variables for the use in TMCL™ applications. They are located in RAM and can be stored to EEPROM. After booting, their values are automatically restored to the RAM.

Number	Global parameter	Description
0	general purpose variable #0	for use in TMCL™ applications
1	general purpose variable #1	for use in TMCL™ applications
2	general purpose variable #2	for use in TMCL™ applications
3	general purpose variable #3	for use in TMCL™ applications
4	general purpose variable #4	for use in TMCL™ applications
5	general purpose variable #5	for use in TMCL™ applications
6	general purpose variable #6	for use in TMCL™ applications
7	general purpose variable #7	for use in TMCL™ applications
8	general purpose variable #8	for use in TMCL™ applications
9	general purpose variable #9	for use in TMCL™ applications
10	general purpose variable #10	for use in TMCL™ applications
11	general purpose variable #11	for use in TMCL™ applications
12	general purpose variable #12	for use in TMCL™ applications
13	general purpose variable #13	for use in TMCL™ applications
14	general purpose variable #14	for use in TMCL™ applications
15	general purpose variable #15	for use in TMCL™ applications
16	general purpose variable #16	for use in TMCL™ applications
17	general purpose variable #17	for use in TMCL™ applications
18	general purpose variable #18	for use in TMCL™ applications
19	general purpose variable #19	for use in TMCL™ applications

Number	Global parameter	Description
20…55	general purpose variables #20..#55	for use in TMCL™ applications

Example:

Store the user variable 42 in EEPROM.
STGP 42, 2

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$0b	$2a	$02	$00	$00	$00	$00	$38

Note: The STAP command will not have any effect when the configuration EEPROM is locked (refer to 8.1). In direct mode, the error code 5 (configuration EEPROM locked, see also section 6.2.1) will be returned in this case.

Please refer to chapter 8 for more information about bank 0 to 2.

6.7.12 RSGP (restore global parameter)

With this command the contents of a TMCL™ user variable can be restored from the EEPROM. For all configuration-related axis parameters, non-volatile memory locations are provided. By default, most parameters are automatically restored after power up (see global parameter list in chapter 8). A single parameter that has been changed before can be reset by this instruction.

Internal function: The specified parameter is copied from the configuration EEPROM memory to its RAM location.

Relate commands: SAP, STAP, GAP, and AAP

Mnemonic: RSAP <parameter number>, <bank number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
8	<parameter number>	<bank number>	(don't care)

Reply structure in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Global parameters of bank 0, which can be used for STGP:

The global parameter bank 0 is not required for the STGP command, because these parameters are automatically stored with the SGP command in EEPROM.

Global parameters of bank 1, which can be used for STGP:

The global parameter bank 1 is normally not available, but can be used in customer specific extensions of the firmware.

Global parameters of bank 2, which can be used for RSGP:

Bank 2 contains general purpose 32 bit variables for the use in TMCL™ applications. They are located in RAM and can be stored to EEPROM. After booting, their values are automatically restored to the RAM.

Number	Global parameter	Description
0	general purpose variable #0	for use in TMCL™ applications
1	general purpose variable #1	for use in TMCL™ applications
2	general purpose variable #2	for use in TMCL™ applications
3	general purpose variable #3	for use in TMCL™ applications
4	general purpose variable #4	for use in TMCL™ applications
5	general purpose variable #5	for use in TMCL™ applications
6	general purpose variable #6	for use in TMCL™ applications
7	general purpose variable #7	for use in TMCL™ applications
8	general purpose variable #8	for use in TMCL™ applications
9	general purpose variable #9	for use in TMCL™ applications
10	general purpose variable #10	for use in TMCL™ applications
11	general purpose variable #11	for use in TMCL™ applications
12	general purpose variable #12	for use in TMCL™ applications
13	general purpose variable #13	for use in TMCL™ applications
14	general purpose variable #14	for use in TMCL™ applications
15	general purpose variable #15	for use in TMCL™ applications
16	general purpose variable #16	for use in TMCL™ applications
17	general purpose variable #17	for use in TMCL™ applications

Number	Global parameter	Description
18	general purpose variable #18	for use in TMCL™ applications
19	general purpose variable #19	for use in TMCL™ applications
20...55	general purpose variables #20..#55	for use in TMCL™ applications

Example:

Restore the serial address of the device
Mnemonic: RSGP 66, 0

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$08	$06	$00	$00	$00	$00	$00	$10

Please refer to chapter 8 for more information about bank 0 to 2.

6.7.13 RFS (reference search)

The TMCM-310 module has a built-in reference search algorithm which can be used. The reference search algorithm provides switching point calibration and three switch modes. The status of the reference search can also be queried to see if it has already finished. (In a TMCL™ program it is better to use the WAIT command to wait for the end of a reference search.) Please see the appropriate parameters in the axis parameter table to configure the reference search algorithm to meet your needs. The reference search can be started, stopped, and the actual status of the reference search can be checked.

Internal function: The reference search is implemented as a state machine, so interaction is possible during execution.

Related commands: WAIT

Mnemonic: RFS <START|STOP|STATUS>, <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
13	0 START – start ref. search 1 STOP – abort ref. search 2 STATUS – get status	<motor number>	(don't care)

Reply in direct mode:

When using type 0 (START) or 1 (STOP):

STATUS	VALUE
100 – OK	(don't care)

When using type 2 (STATUS):

STATUS	VALUE
100 – OK	0 – no ref. search active other values – ref. search is active

Example:

Start reference search of motor #1
Mnemonic: RFS START, 1

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$0d	$00	$01	$00	$00	$00	$00	$0f

It is possible to use stall detection instead of a reference search. Please see section 9 for details.

6.7.14 SIO (set output)

This command sets the status of the general digital output either to low (0) or to high (1).

Internal function: The passed value is transferred to the specified output line.

Related commands: GIO, WAIT

Mnemonic: SIO <port number>, <bank number>, <value>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
14	<port number>	<bank number>	<value>

Reply structure:

STATUS	VALUE
100 – OK	(don't care)

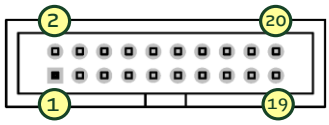
Example:

Set OUT_7 to high (bank 2, output 7; general purpose output)
Mnemonic: SIO 7, 2, 1

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$0e	$07	$02	$00	$00	$00	$01	$19

Available I/O ports:



Pin	I/O port	Command	Range
1	OUT_0	SIO 0, <bank number>, 1/0	1/0
2	OUT_1	SIO 1, <bank number>, 1/0	1/0
3	OUT_2	SIO 2, <bank number>, 1/0	1/0
4	OUT_3	SIO 3, <bank number>, 1/0	1/0
5	OUT_4	SIO 4, <bank number>, 1/0	1/0
5	OUT_5	SIO 5, <bank number>, 1/0	1/0
7	OUT_6	SIO 6, <bank number>, 1/0	1/0
8	OUT_7	SIO 7, <bank number>, 1/0	1/0

Addressing all eight output lines with one SIO command:

- Set the type parameter to 255 and the bank parameter to 2.
- The value parameter must then be set to a value between 0…255, where every bit represents one output line.
- Furthermore, the value can also be set to -1. In this special case, the contents of the lower 8 bits of the accumulator are copied to the eight output pins.

Example:

Set all output pins high.
Mnemonic: SIO 255, 2, 255

The following program will show the states of the eight input lines on the output lines:

```
Loop: GIO 255, 0
      SIO 255, 2,-1
      JA Loop
```

6.7.15 GIO (get input/output)

With this command the status of the two available general purpose inputs of the module can be read out. The function reads a digital or analogue input port. Digital lines will read 0 and 1, while the ADC channels deliver their 10 bit result in the range of 0...1023. In stand-alone mode the requested value is copied to the *accumulator* (accu) for further processing purposes such as conditioned jumps. In direct mode the value is only output in the *value* field of the reply, without affecting the accumulator. The actual status of a digital output line can also be read.

Internal function: The specified line is read.

Related commands: SIO, WAIT

Mnemonic: GIO <port number>, <bank number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
15	<port number>	<bank number>	(don't care)

Reply in direct mode:

STATUS	VALUE
100 – OK	<status of the port>

Example:

Get the analogue value of ADC channel 3
Mnemonic: GIO 3, 1

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$0f	$03	$01	$00	$00	$00	$00	$14

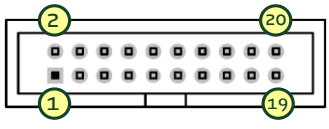
Reply:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Host-address	Target-address	Status	Instruction	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$02	$01	$64	$0f	$00	$00	$01	$fa	$72

⇨ value: 506

6.7.15.1 I/O bank 0 – digital inputs:

The ADIN lines can be read as digital or analogue inputs at the same time. The analogue values can be accessed in bank 1.



Pin	I/O port	Command	Range
11	IN_0	GIO 0, 0	I/O
12	IN_1	GIO 1, 0	I/O
13	IN_2	GIO 2, 0	I/O
14	IN_3	GIO 3, 0	I/O
15	IN_4	GIO 4, 0	I/O
16	IN_5	GIO 5, 0	I/O
17	IN_6	GIO 6, 0	I/O
18	IN_7	GIO 7, 0	I/O

Reading all eight digital inputs with one GIO command:

- Set the type parameter to 255 and the bank parameter to 0.
- In this case the status of all eight digital input lines will be read to the lower eight bits of the accumulator.

Use following program to represent the states of the eight input lines on the eight output lines:

```
Loop: GIO 255, 0
      SIO 255, 2,-1
      JA Loop
```

6.7.15.2 I/O bank 1 – analogue inputs:

The ADIN lines can be read back as digital or analogue inputs at the same time. The digital states can be accessed in bank 0.

Pin	I/O port	Command	Range
11	IN_0	GIO 0, 1	0…1023
12	IN_1	GIO 1, 1	0…1023
13	IN_2	GIO 2, 1	0…1023
14	IN_3	GIO 1, 1	0…1023
15	IN_4	GIO 3, 1	0…1023
16	IN_5	GIO 4, 1	0…1023
17	IN_6	GIO 4, 1	0…1023
18	IN_7	GIO 5, 1	0…1023

6.7.15.3 I/O bank 2 – the states of digital outputs

The states of the OUT lines (that have been set by SIO commands) can be read back using bank 2.

Pin	I/O port	Command	Range
1	OUT_0	GIO 0, 2, <n>	1/0
2	OUT_1	GIO 1, 2, <n>	1/0
3	OUT_2	GIO 2, 2, <n>	1/0
4	OUT_3	GIO 3, 2, <n>	1/0
5	OUT_4	GIO 4, 2, <n>	1/0
6	OUT_5	GIO 5, 2, <n>	1/0
7	OUT_6	GIO 6, 2, <n>	1/0
8	OUT_7	GIO 7, 2, <n>	1/0

6.7.16 CALC (calculate)

A value in the accumulator variable, previously read by a function such as GAP (get axis parameter), can be modified with this instruction. Nine different arithmetic functions can be chosen and one constant operand value must be specified. The result is written back to the accumulator, for further processing like comparisons or data transfer.

Related commands: CALCX, COMP, JC, AAP, AGP, GAP, GGP, GIO

Mnemonic: CALC <op>, <value>
where <op> is ADD, SUB, MUL, DIV, MOD, AND, OR, XOR, NOT or LOAD

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
19	0 ADD – add to accu 1 SUB – subtract from accu 2 MUL – multiply accu by 3 DIV – divide accu by 4 MOD – modulo divide by 5 AND – logical and accu with 6 OR – logical or accu with 7 XOR – logical exor accu with 8 NOT – logical invert accu 9 LOAD – load operand to accu	(don't care)	<operand>

Example:
Multiply accu by -5000
Mnemonic: CALC MUL, -5000

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$13	$02	$00	$FF	$FF	$EC	$78	$78

6.7.17 COMP (compare)

The specified number is compared to the value in the accumulator register. The result of the comparison can for example be used by the conditional jump (JC) instruction. This command is intended for use in stand-alone operation only.

The host address and the reply are only used to take the instruction to the TMCL™ program memory while the TMCL™ program loads down. It does not make sense to use this command in direct mode.

Internal function: The specified value is compared to the internal *accumulator*, which holds the value of a preceding *get* or calculate instruction (see GAP/GGP/GIO/CALC/CALCX). The internal arithmetic status flags are set according to the comparison result.

Related commands: JC (jump conditional), GAP, GGP, GIO, CALC, CALCX

Mnemonic: COMP <value>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
20	(don't care)	(don't care)	<comparison value>

Example:

Jump to the address given by the label when the position of motor #2 is greater than or equal to 1000.

```
GAP 1, 2, 0     //get axis parameter, type: no. 1 (actual position), motor: 2, value: 0 (don't care)
COMP 1000       //compare actual value to 1000
JC GE, Label    //jump, type: 5 greater/equal, the label must be defined somewhere else in the
                program
```

Binary format of the COMP 1000 command:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$14	$00	$00	$00	$00	$03	$e8	$00

6.7.18 JC (jump conditional)

The JC instruction enables a conditional jump to a fixed address in the TMCL™ program memory, if the specified condition is met. The conditions refer to the result of a preceding comparison. This function is for stand-alone operation only.

The host address and the reply are only used to take the instruction to the TMCL™ program memory while the TMCL™ program loads down. See the host-only control functions for details. It is not possible to use this command in direct mode.

Internal function: The TMCL™ program counter is set to the passed value if the arithmetic status flags are in the appropriate state(s).

Related commands: JA, COMP, WAIT, CLE

Mnemonic: JC <condition>, <label>
where <condition>=ZE|NZ|EQ|NE|GT|GE|LT|LE|ETO|EAL|EDV|EPO

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
21	0 ZE - zero 1 NZ - not zero 2 EQ - equal 3 NE - not equal 4 GT - greater 5 GE - greater/equal 6 LT - lower 7 LE - lower/equal 8 ETO - time out error 9 EAL – external alarm 12 ESD – shutdown error	(don't care)	<jump address>

Example:

Jump to address given by the label when the position of motor #2 is greater than or equal to 1000.

```
GAP 1, 2, 0      //get axis parameter, type: no. 1 (actual position), motor: 2, value: 0 (don't care)
COMP 1000        //compare actual value to 1000
JC GE, Label     //jump, type: 5 greater/equal
...
...
Label: ROL 0, 1000
```

Binary format of "JC GE, Label" when Label is at address 10:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$15	$05	$00	$00	$00	$00	$0a	$25

6.7.19 JA (jump always)

Jump to a fixed address in the TMCL™ program memory. This command is intended for stand-alone operation only.

The host address and the reply are only used to take the instruction to the TMCL™ program memory while the TMCL™ program loads down. This command cannot be used in direct mode.

Internal function: The TMCL™ program counter is set to the passed value.

Related commands: JC, WAIT, CSUB

Mnemonic: JA <Label>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
22	(don't care)	(don't care)	<jump address>

Example: An infinite loop in TMCL™

```
Loop:  MVP ABS, 0, 10000
       WAIT POS, 0, 0
       MVP ABS, 0, 0
       WAIT POS, 0, 0
       JA Loop          //Jump to the label "Loop"
```

Binary format of "JA Loop" assuming that the label "Loop" is at address 20:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$16	$00	$00	$00	$00	$00	$14	$2b

6.7.20 CSUB (call subroutine)

This function calls a subroutine in the TMCL™ program memory. It is intended for stand-alone operation only.

The host address and the reply are only used to take the instruction to the TMCL™ program memory while the TMCL™ program loads down. This command cannot be used in direct mode.

Internal function: The actual TMCL™ program counter value is saved to an internal stack, afterwards overwritten with the passed value. The number of entries in the internal stack is limited to 8. This also limits nesting of subroutine calls to 8. The command will be ignored if there is no more stack space left.

Related commands: RSUB, JA

Mnemonic: CSUB <Label>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
23	(don't care)	(don't care)	<subroutine address>

Example: Call a subroutine

```
Loop:  MVP ABS, 0, 10000
       CSUB SubW      //Save program counter and jump to label "SubW"
       MVP ABS, 0, 0
       JA Loop

SubW:  WAIT POS, 0, 0
       WAIT TICKS, 0, 50
       RSUB           //Continue with the command following the CSUB command
```

Binary format of the "CSUB SubW" command assuming that the label "SubW" is at address 100:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$17	$00	$00	$00	$00	$00	$64	$7C

6.7.21 RSUB (return from subroutine)

Return from a subroutine to the command after the CSUB command. This command is intended for use in stand-alone mode only.

The host address and the reply are only used to take the instruction to the TMCL™ program memory while the TMCL™ program loads down. This command cannot be used in direct mode.

Internal function: The TMCL™ program counter is set to the last value of the stack. The command will be ignored if the stack is empty.

Related command: CSUB

Mnemonic: RSUB

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
24	(don't care)	(don't care)	(don't care)

Example: Please have a look at the CSUB example below.

Binary format of RSUB:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$18	$00	$00	$00	$00	$00	$00	$19

6.7.22 WAIT (wait for an event to occur)

This instruction interrupts the execution of the TMCL™ program until the specified condition is met. This command is intended for stand-alone operation only.

The host address and the reply are only used to take the instruction to the TMCL™ program memory while the TMCL™ program loads down. This command is not to be used in direct mode.

There are five different wait conditions that can be used:

- TICKS: Wait until the number of timer ticks specified by the <ticks> parameter has been reached.
- POS: Wait until the target position of the motor specified by the <motor> parameter has been reached. An optional timeout value (0 for no timeout) must be specified by the <ticks> parameter.
- REFSW: Wait until the reference switch of the motor specified by the <motor> parameter has been triggered. An optional timeout value (0 for no timeout) must be specified by the <ticks> parameter.
- LIMSW: Wait until a limit switch of the motor specified by the <motor> parameter has been triggered. An optional timeout value (0 for no timeout) must be specified by the <ticks> parameter.
- RFS: Wait until the reference search of the motor specified by the <motor> field has been reached. An optional timeout value (0 for no timeout) must be specified by the <ticks> parameter.

The timeout flag (ETO) will be set after a timeout limit has been reached. You can then use a JC ETO command to check for such errors or clear the error using the CLE command.

Internal function: The TMCL™ program counter is held until the specified condition is met.

Related commands: JC, CLE

Mnemonic: WAIT <condition>, <motor number>, <ticks>
where <condition> is TICKS|POS|REFSW|LIMSW|RFS

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
27	0 TICKS - timer ticks*[1]	(don't care)	<no. of ticks*>
	1 POS - target position reached	<motor number> 0…2	<no. of ticks* for timeout>, 0 for no timeout
	2 REFSW – reference switch	<motor number> 0…2	<no. of ticks* for timeout>, 0 for no timeout
	3 LIMSW – limit switch	<motor number> 0…2	<no. of ticks* for timeout>, 0 for no timeout
	4 RFS – reference search completed	<motor number> 0…2	<no. of ticks* for timeout>, 0 for no timeout

***[1] one tick is 10msec (in standard firmware)**

Example:

Wait for motor #1 to reach its target position, without timeout
Mnemonic: WAIT POS, 1, 0

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$1b	$01	$01	$00	$00	$00	$00	$1e

6.7.23 STOP (stop TMCL™ program execution)

This function stops executing a TMCL™ program. The host address and the reply are only used to transfer the instruction to the TMCL™ program memory.

Every stand-alone TMCL™ program needs the STOP command at its end. It is not to be used in direct mode.

Internal function: TMCL™ instruction fetching is stopped.

Related commands: none
Mnemonic: STOP

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
28	(don't care)	(don't care)	(don't care)

Example:

Mnemonic: STOP

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$1C	$00	$00	$00	$00	$00	$00	$1D

6.7.24 SAC – SPI Bus Access

Description: Allows access to external SPI devices connected to the SPI bus of the module.

This command has been extended so that not only direct values but also the contents of the accumulator register can be sent. In stand-alone mode the received data is also stored in the accumulator. The module has three chip select outputs (SPI_SEL0, SPI_SEL1, and SPI_SEL2). The *type* parameter (bus number) determines the chip select output that is to be used. The *motor/bank* parameter determines the number of bytes to be sent (1, 2, 3, or 4). The *value* parameter contains the data to be sent. When bit 7 of the bus number is set, this value is ignored and the contents of the accumulator are sent instead.

Please note that in the TMCL-IDE always all three values have to be specified (when sending the contents of the accumulator the value parameter is a dummy parameter).

Related commands: SIO, GIO

Mnemonic: SAC <bus number>, <number of bytes>, <send data>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
29	<bus number>	<number of bytes>	<send data>

Reply in direct mode:

STATUS	VALUE
100 – Success	<received data>

The bus numbers are as follows:

Bus number	Chip select output
0	SPI_SEL0, output direct value
1	Do not use
2	SPI_SEL1, output direct value
3	SPI_SEL2, output direct value
128	SPI_SEL0, output contents of accumulator
129	Do not use
130	SPI_SLE1, output contents of accumulator
131	SPI_SEL2, output contents of accumulator

Please note the gap in the bus numbers; do not use 1 or 129!

6.7.25 SCO (set coordinate)

Up to 20 position values (coordinates) can be stored for every axis for use with the MVP COORD command. This command sets a coordinate to a specified value.

Please note that the coordinate number 0 is always stored in RAM only. All others are also stored in the EEPROM.

Internal function: The passed value is stored in the internal position array.

Related commands: GCO, CCO, MVP

Mnemonic: SCO <coordinate number>, <motor number>, <position>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
30	<coordinate number> (0…20)	<motor number>	<position> (-2^{23}… $+2^{23}$)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Set coordinate #1 of motor #2 to 1000
Mnemonic: SCO 1, 2, 1000

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$1e	$01	$02	$00	$00	$03	$e8	$0d

6.7.26 GCO (get coordinate)

This command makes possible to read out a previously stored coordinate. In stand-alone mode the requested value is copied to the accumulator register for further processing purposes such as conditioned jumps. In direct mode, the value is only output in the value field of the reply, without affecting the accumulator.

Please note that the coordinate number 0 is always stored in RAM only. All others are also stored in the EEPROM.

Internal function: The desired value is read out of the internal coordinate array, copied to the accumulator register and -in direct mode- returned in the *value* field of the reply.

Related commands: SCO, CCO, MVP

Mnemonic: GCO <coordinate number>, <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
31	<coordinate number> (0…20)	<motor number>	(don't care)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Get value coordinate 1 of motor #2
Mnemonic: GCO 1, 2

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$1f	$01	$02	$00	$00	$00	$00	$23

Reply:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Target-address	Status	Instruction	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$02	$01	$64	$0a	$00	$00	$00	$00	$86

⇨ **Value: 0**

6.7.27 CCO (capture coordinate)

The actual position of the axis is copied to the selected coordinate variable.

Please note that the coordinate number 0 is always stored in RAM only. All others are also stored in the EEPROM.

Internal function: The selected (24 bit) position values are written to the 20 by 3 bytes wide coordinate array.

Related commands: SCO, GCO, MVP

Mnemonic: CCO <coordinate number>, <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
32	<coordinate number> (0…20)	<motor number> (0..2) 7*	(don't care)

*** Choose 7 if you want to save the positions of all connected axes. Now the bits 0…2 of the <motor number> parameter define the motors you want to work with. Each of these bits stands for one motor.**

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Store current position of all axes to coordinate 3
Mnemonic: CCO 3, 7

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$20	$03	$07	$00	$00	$00	$00	$2b

6.7.28 CALCX (calculate using the X register)

This instruction is very similar to CALC, but the second operand comes from the X register. The X register can be loaded with the LOAD or the SWAP type of this instruction. The result is written back to the accumulator for further processing like comparisons or data transfer.

Related commands: CALC, COMP, JC, AAP, AGP

Mnemonic: CALCX <operation>
with <operation>=ADD|SUB|MUL|DIV|MOD|AND|OR|XOR|NOT|LOAD|SWAP

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
33	0 ADD – add X register to accu 1 SUB – subtract X register from accu 2 MUL – multiply accu by X register 3 DIV – divide accu by X-register 4 MOD – modulo divide accu by x-register 5 AND – logical and accu with X-register 6 OR – logical or accu with X-register 7 XOR – logical exor accu with X-register 8 NOT – logical invert X-register 9 LOAD – load accu to X-register 10 SWAP – swap accu with X-register	(don't care)	(don't care)

Example:
Multiply accu by X-register
Mnemonic: CALCX MUL
Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$21	$02	$00	$00	$00	$00	$00	$24

6.7.29 AAP (accumulator to axis parameter)

The content of the accumulator register is transferred to the specified axis parameter. For practical usage, the accumulator has to be loaded e.g. by a preceding GAP instruction. The accumulator may have been modified by the CALC or CALCX (calculate) instruction.

Related commands: AGP, SAP, GAP, SGP, GGP, GIO, GCO, CALC, CALCX

Mnemonic: AAP <parameter number>, <motor number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
34	<parameter number>	<motor number>	<don't care>

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

List of parameters, which can be used for AAP:

Number	Axis Parameter	Description
0	target (next) position	The desired position in position mode (see ramp mode, no. 138).
1	actual position	The current position of the motor. Should only be overwritten for reference point setting.
2	target (next) speed	The desired speed in velocity mode (see ramp mode, no. 138). In position mode, this parameter is set by hardware: to the maximum speed during acceleration, and to zero during deceleration and rest.
3	actual speed	The current rotation speed.
4	maximum positioning speed	Should not exceed the physically highest possible value. Adjust the pulse divisor (no. 154), if the speed value is very low (<50) or above the upper limit. See TMC 428 datasheet for calculation of physical units.
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 428 datasheet for calculation of physical units.
6	absolute max. current	The most important motor setting, since too high values might cause motor damage! The maximum value is 1500 (which mean 100% of the maximum current of the module).
7	standby current	The current limit two seconds after the motor has stopped.
12	right limit switch disable	If set, deactivates the stop function of the right switch
13	left limit switch disable	Deactivates the stop function of the left switch resp. reference switch if set.
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. Do not change!

Number	Axis Parameter	Description
138	ramp mode	Automatically set when using ROR, ROL, MST and MVP. 0: position mode. Steps are generated, when the parameters actual position and target position differ. Trapezoidal speed ramps are provided. 2: velocity mode. The motor will run continuously and the speed will be changed with constant (maximum) acceleration, if the parameter *target speed* is changed. For special purposes, the soft mode (value 1) with exponential decrease of speed can be selected.
140	microstep resolution	0 – full step*) 1 – half step*) 2 – 4 microsteps 3 – 8 microsteps 4 – 16 microsteps 5 – 32 microsteps**) 6 – 64 microsteps**) Note that modifying this parameter will affect the rotation speed in the same relation: *) The full-step setting and the half-step setting are not optimized for use without an adapted microstepping table. These settings just step through the microstep table in steps of 64 respectively 32. To get real full stepping use axis parameter 211 or load an adapted microstepping table. **) If the module is specified for 16 microsteps only, switching to 32 or 64 microsteps brings an enhancement in resolution and smoothness. The position counter will use the full resolution, but, however, the motor will resolve a maximum of 24 different microsteps only for the 32 or 64 microstep units.
149	soft stop flag	If cleared, the motor will stop immediately (disregarding motor limits), when the reference or limit switch is hit.
153	ramp divisor	The exponent of the scaling factor for the ramp generator- should be de/incremented carefully (in steps of one).
154	pulse divisor	The exponent of the scaling factor for the pulse (step) generator – should be de/incremented carefully (in steps of one).
193	referencing mode	1 – Only the left reference switch is searched. 2 – The right switch is searched and afterwards the left switch is searched. 3 – Three-switch-mode: the right switch is searched first and afterwards the reference switch will be searched. Please see chapter 6.7.13 for details on reference search.

Number	Axis Parameter	Description
194	referencing search speed	For the reference search this value specifies the search speed as a fraction of the maximum velocity: 0 – full speed 1 – half of the maximum speed 2 – a quarter of the maximum speed 3 – 1/8 of the maximum speed (etc.)
195	referencing switch speed	Similar to parameter no. 194, the speed for the switching point calibration can be selected.
203	mixed decay threshold	If the actual velocity is above this threshold, mixed decay will be used. This can also be set to -1 which turns on mixed decay permanently also in the rising part of the microstep wave. This can be used to fix microstep errors.
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.
205	stall detection threshold	Stall detection threshold. Set it to 0 for no stall detection or to a value between 1 (low threshold) and 7 (high threshold). The motor will be stopped if the load value exceeds the stall detection threshold. Switch off mixed decay to get usable results.
211	fullstep threshold	When exceeding this speed the driver will switch to real full step mode. To disable this feature set this parameter to zero or to a value greater than 2047. Setting a full step threshold allows higher motor torque of the motor at higher velocity. When experimenting with this in a given application, try to reduce the motor current in order to be able to reach a higher motor velocity!
214	power down delay	Standstill period before the current is changed down to standby current. The standard value is 200 (value equates 2000msec).

Example:

Positioning motor #0 by a potentiometer connected to the analogue input #0:

```
Start:  GIO 0,1       // get value of analogue input line 0
        CALC MUL, 4   // multiply by 4
        AAP 0,0       // transfer result to target position of motor 0
        JA Start      // jump back to start
```

Binary format of the AAP 0,0 command:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$22	$00	$00	$00	$00	$00	$00	$23

6.7.30 AGP (accumulator to global parameter)

The content of the accumulator register is transferred to the specified global parameter. For practical usage, the accumulator has to be loaded e.g. by a preceding GAP instruction. The accumulator may have been modified by the CALC or CALCX (calculate) instruction. ***Note that the global parameters in bank 0 are EEPROM-only and thus should not be modified automatically by a stand-alone application.*** (See chapter 8 for a complete list of global parameters).

Related commands: AAP, SGP, GGP, SAP, GAP, GIO

Mnemonic: AGP <parameter number>, <bank number>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
35	<parameter number>	<bank number>	(don't care)

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Global parameters of bank 0, which can be used for AGP:

Number	Global parameter	Description		
64	EEPROM magic	Setting this parameter to a different value as $E4 will cause re-initialization of the axis and global parameters (to factory defaults) after the next power up. This is useful in case of miss-configuration.		
65	RS232 baud rate	0	9600 baud	*Default*
		1	14400 baud	
		2	19200 baud	
		3	28800 baud	
		4	38400 baud	
		5	57600 baud	
		6	76800 baud	*Not supported by Windows!*
		7	(115200 baud)	
66	serial address	The module (target) address for RS-232.		
67	ASCII mode	Configure the TMCL™ ASCII interface: Bit 0: 0 – start up in binary (normal) mode 1 – start up in ASCII mode Bits 4 and 5: 00 – Echo back each character 01 – Echo back complete command 10 – Do not send echo, only send command reply		
69	CAN bit rate	1	10kBit/s	
		2	20kBit/s	
		3	50kBit/s	
		4	100kBit/s	
		5	125kBit/s	
		6	250kBit/s	
		7	500kBit/s	
		8	1000kBit/s	*Default*
70	CAN reply ID	The CAN ID for replies from the board (default: 2)		
71	CAN ID	The module (target) address for CAN (default: 1)		
73	configuration EEPROM lock flag	Write: 1234 to lock the EEPROM, 4321 to unlock it. Read: 1=EEPROM locked, 0=EEPROM unlocked.		

Number	Global parameter	Description
75	telegram pause time	Pause time before the reply via RS232 is sent. For RS232 set to 0. For CAN interface this parameter has no effect!
76	serial host address	Host address used in the reply telegrams sent back via RS232.
77	auto start mode	0: Do not start TMCL™ application after power up (default). 1: Start TMCL™ application automatically after power up.
80	shutdown pin functionality	Select the functionality of the SHUTDOWN pin 0 – no function 1 – high active 2 – low active
81	TMCL™ code protection	Protect a TMCL™ program against disassembling or overwriting. 0 – no protection 1 – protection against disassembling 2 – protection against overwriting 3 – protection against disassembling and overwriting ***If you switch off the protection against disassembling, the program will be erased first! Changing this value from 1 or 3 to 0 or 2, the TMCL™ program will be wiped off.***
83	CAN secondary address	Second CAN ID for the module. Switched off when set to zero.
84	coordinate storage	0 – coordinates are stored in the RAM only (but can be copied explicitly between RAM and EEPROM) 1 – coordinates are always stored in the EEPROM only
132	tick timer	A 32 bit counter that gets incremented by one every millisecond. It can also be reset to any start value.

Global parameters of bank 1, which can be used for SGP:

The global parameter bank 1 is normally not available. It may be used for customer specific extensions of the firmware. Together with user definable commands (see section 7.3) these variables form the interface between extensions of the firmware (written in C) and TMCL™ applications.

Global parameters of bank 2, which can be used for AGP:

Bank 2 contains general purpose 32 bit variables for the use in TMCL™ applications. They are located in RAM and can be stored to EEPROM. After booting, their values are automatically restored to the RAM.

Number	Global parameter	Description	Range
0	general purpose variable #0	for use in TMCL™ applications	$-2^{31}...+2^{31}$
1	general purpose variable #1	for use in TMCL™ applications	$-2^{31}...+2^{31}$
2	general purpose variable #2	for use in TMCL™ applications	$-2^{31}...+2^{31}$
3	general purpose variable #3	for use in TMCL™ applications	$-2^{31}...+2^{31}$
4	general purpose variable #4	for use in TMCL™ applications	$-2^{31}...+2^{31}$
5	general purpose variable #5	for use in TMCL™ applications	$-2^{31}...+2^{31}$
6	general purpose variable #6	for use in TMCL™ applications	$-2^{31}...+2^{31}$
7	general purpose variable #7	for use in TMCL™ applications	$-2^{31}...+2^{31}$
8	general purpose variable #8	for use in TMCL™ applications	$-2^{31}...+2^{31}$
9	general purpose variable #9	for use in TMCL™ applications	$-2^{31}...+2^{31}$
10	general purpose variable #10	for use in TMCL™ applications	$-2^{31}...+2^{31}$
11	general purpose variable #11	for use in TMCL™ applications	$-2^{31}...+2^{31}$
12	general purpose variable #12	for use in TMCL™ applications	$-2^{31}...+2^{31}$
13	general purpose variable #13	for use in TMCL™ applications	$-2^{31}...+2^{31}$
14	general purpose variable #14	for use in TMCL™ applications	$-2^{31}...+2^{31}$
15	general purpose variable #15	for use in TMCL™ applications	$-2^{31}...+2^{31}$
16	general purpose variable #16	for use in TMCL™ applications	$-2^{31}...+2^{31}$
17	general purpose variable #17	for use in TMCL™ applications	$-2^{31}...+2^{31}$
18	general purpose variable #18	for use in TMCL™ applications	$-2^{31}...+2^{31}$
19	general purpose variable #19	for use in TMCL™ applications	$-2^{31}...+2^{31}$
20..55	general purpose variables #20..#55	for use in TMCL™ applications	$-2^{31}...+2^{31}$

Please refer to chapter 8 for more information about bank 0 to 2.

Example:

Copy accumulator to TMCL™ user variable #3
Mnemonic: AGP 3, 2

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$23	$03	$02	$00	$00	$00	$00	$29

6.7.31 CLE (clear error flags)

This command clears the internal error flags. ***It is intended for use in stand-alone mode only and must not be used in direct mode.***

The following error flags can be cleared by this command (determined by the <flag> parameter):

- ALL: clear all error flags.
- ETO: clear the timeout flag.
- EAL: clear the external alarm flag
- EDV: clear the deviation flag (modules with encoder feedback only)
- EPO: clear the position error flag (modules with encoder feedback only)

Related commands: JC

Mnemonic: CLE <flags>
where <flags>=ALL|ETO|EDV|EPO

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
36	0 – (ALL) all flags 1 – (ETO) timeout flag 2 – (EAL) alarm flag 3 – (EDV) deviation flag 4 – (EPO) position flag 5 – (ESD) shutdown flag	(don't care)	(don't care)

Example:
Reset the timeout flag
Mnemonic: CLE ETO

Binary:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Instruction Number	Type	Motor/ Bank	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$01	$24	$01	$00	$00	$00	$00	$00	$26

6.7.32 Customer specific TMCL™ command extension (UF0...UF7/user function)

The user definable functions UF0...UF7 are predefined, functions without topic for user specific purposes. Contact TRINAMIC for customer specific programming of these functions.

Internal function: Call user specific functions implemented in *C* by TRINAMIC.

Related commands: none

Mnemonic: UF0...UF7

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
64...71	(user defined)	(user defined)	(user defined)

Reply in direct mode:

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Target-address	Status	Instruction	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$02	$01	(user defined)	64...71	(user defined)	(user defined)	(user defined)	(user defined)	<checksum>

6.7.33 Request target position reached event

This command is the only exception to the TMCL™ protocol, as it sends two replies: One immediately after the command has been executed (like all other commands also), and one additional reply that will be sent when the motor has reached its target position.

This instruction can only be used in direct mode (in stand alone mode, it is covered by the WAIT command) and hence does not have a mnemonic.

Internal function: Send an additional reply when the motor has reached its target position

Mnemonic: ---

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
138	(don't care)	(don't care)	motor bit mask

The *value* field contains a bit mask where every bit stands for one motor:

bit 0 = motor 0
bit 1 = motor 1
bit 2 = motor 2

Reply in direct mode (right after execution of this command):

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Target-address	Status	Instruction	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$02	$01	100	138	$00	$00	$00	Motor bit mask	<checksum>

The additional reply will be sent when all chosen motors have reached their target positions.

Additional reply in direct mode (after motors have reached their target positions):

Byte Index	0	1	2	3	4	5	6	7	8
Function	Target-address	Target-address	Status	Instruction	Operand Byte3	Operand Byte2	Operand Byte1	Operand Byte0	Checksum
Value (hex)	$02	$01	128	138	$00	$00	$00	Motor bit mask	<checksum>

6.7.34 BIN (return to binary mode)

This command can only be used in ASCII mode. It quits the ASCII mode and returns to binary mode.

Related Commands: none

Mnemonic: BIN

Binary representation: This command does not have a binary representation as it can only be used in ASCII mode.

6.7.35 TMCL™ Control Functions

The following functions are for host control purposes only and are not allowed for stand-alone mode. In most cases, there is no need for the customer to use one of those functions (except command 139). They are mentioned here only for reasons of completeness. These commands have no mnemonics, as they cannot be used in TMCL™ programs. The Functions are to be used only by the TMCL-IDE to communicate with the module, for example to download a TMCL™ application into the module.

The only control commands that could be useful for a user host application are:

- *get firmware revision* (command 136, please note the special reply format of this command, described at the end of this section)
- *run application* (command 129)

All other functions can be achieved by using the appropriate functions of the TMCL™ IDE.

Instruction	Description	Type	Mot/Bank	Value
128 – stop application	a running TMCL™ standalone application is stopped	(don't care)	(don't care)	(don't care)
129 – run application	TMCL™ execution is started (or continued)	0 - run from current address 1 - run from specified address	(don't care)	(don't care) starting address
130 – step application	only the next command of a TMCL™ application is executed	(don't care)	(don't care)	(don't care)
131 – reset application	the program counter is set to zero, and the standalone application is stopped (when running or stepped)	(don't care)	(don't care)	(don't care)
132 – start download mode	target command execution is stopped and all following commands are transferred to the TMCL™ memory	(don't care)	(don't care)	starting address of the application
133 – quit download mode	target command execution is resumed	(don't care)	(don't care)	(don't care)
134 – read TMCL™ memory	the specified program memory location is read	(don't care)	(don't care)	<memory address>
135 – get application status	one of these values is returned: 0 – stop 1 – run 2 – step 3 – reset	(don't care)	(don't care)	(don't care)
136 – get firmware version	return the module type and firmware revision either as a string or in binary format	0 – string 1 – binary	(don't care)	(don't care)
137 – restore factory settings	reset all settings stored in the EEPROM to their factory defaults This command does not send back a reply.	(don't care)	(don't care)	must be 1234
138 – reserved				
139 – enter ASCII mode	Enter ASCII command line (see chapter 6.6)	(don't care)	(don't care)	(don't care)

Special reply format of command 136:

Type set to 0 - reply as a string:

Byte index	Contents
1	Host Address
2..9	Version string (8 characters, e.g. 140V2.50

- There is no checksum in this reply format!
- To get also the last byte when using the CAN bus interface, just send this command in an eight byte frame instead of a seven byte frame. Then, eight bytes will be sent back, so you will get all characters of the version string.

Type set to 1 - version number in binary format:

- Please use the normal reply format.
- The version number is output in the *value* field of the reply in the following way:

Byte index in value field	Contents
1	Version number, low byte
2	Version number, high byte
3	Type number, low byte (currently not used)
4	Type number, high byte (currently not used)

7 Axis parameters

The following sections describe all axis parameters that can be used with the SAP, GAP, AAP, STAP and RSAP commands.

Meaning of the letters in column *Access*:

R = readable (GAP)
W = writable (SAP)
E = automatically restored from EEPROM after reset or power-on

7.1 Axis parameters

Number	Axis Parameter	Description	Range [Unit]	Acc.
0	target (next) position	The desired position in position mode (see ramp mode, no. 138).	$\pm 2^{23}$ [µsteps]	RW
1	actual position	The current position of the motor. Should only be overwritten for reference point setting.	$\pm 2^{23}$ [µsteps]	RW
2	target (next) speed	The desired speed in velocity mode (see ramp mode, no. 138). In position mode, this parameter is set by hardware: to the maximum speed during acceleration, and to zero during deceleration and rest.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$	RW
3	actual speed	The current rotation speed.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$	RW
4	maximum positioning speed	Should not exceed the physically highest possible value. Adjust the pulse divisor (no. 154), if the speed value is very low (<50) or above the upper limit. See TMC 428 datasheet for calculation of physical units.	0...2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$	RWE
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 428 datasheet for calculation of physical units.	0... 2047*	RWE
6	absolute max. current	The most important motor setting, since too high values might cause motor damage! The maximum value is 1500 (which mean 100% of the maximum current of the module).	0... 1500 [mA]	RWE
7	standby current	The current limit two seconds after the motor has stopped.	0... 1500 [mA]	RWE
8	target pos. reached	Indicates that the actual position equals the target position.	0/1	R
9	ref. switch status	The logical state of the reference (left) switch. See the TMC 428 data sheet for the different switch modes. The default has two switch modes: the left switch as the reference switch, the right switch as a limit (stop) switch.	0/1	R
10	right limit switch status	The logical state of the (right) limit switch.	0/1	R
11	left limit switch status	The logical state of the left limit switch (in three switch mode)	0/1	R

Number	Axis Parameter	Description	Range [Unit]	Acc.
12	right limit switch disable	If set, deactivates the stop function of the right switch	0/1	RWE
13	left limit switch disable	Deactivates the stop function of the left switch resp. reference switch if set.	0/1	RWE
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. Do not change!	0…2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$	RWE
135	actual acceleration	The current acceleration (read only).	0… 2047*	R
138	ramp mode	Automatically set when using ROR, ROL, MST and MVP. 0: position mode. Steps are generated, when the parameters actual position and target position differ. Trapezoidal speed ramps are provided. 2: velocity mode. The motor will run continuously and the speed will be changed with constant (maximum) acceleration, if the parameter *target speed* is changed. For special purposes, the soft mode (value 1) with exponential decrease of speed can be selected.	0/1/2	RWE
140	microstep resolution	0 – full step*) 1 – half step*) 2 – 4 microsteps 3 – 8 microsteps 4 – 16 microsteps 5 – 32 microsteps**) 6 – 64 microsteps**) Note that modifying this parameter will affect the rotation speed in the same relation: *) The full-step setting and the half-step setting are not optimized for use without an adapted microstepping table. These settings just step through the microstep table in steps of 64 respectively 32. To get real full stepping use axis parameter 211 or load an adapted microstepping table. **) If the module is specified for 16 microsteps only, switching to 32 or 64 microsteps brings an enhancement in resolution and smoothness. The position counter will use the full resolution, but, however, the motor will resolve a maximum of 24 different microsteps only for the 32 or 64 microstep units.	0…6	RWE
149	soft stop flag	If cleared, the motor will stop immediately (disregarding motor limits), when the reference or limit switch is hit.	0/1	RWE
153	ramp divisor	The exponent of the scaling factor for the ramp generator- should be de/incremented carefully (in steps of one).	0…13	RWE
154	pulse divisor	The exponent of the scaling factor for the pulse (step) generator – should be de/incremented carefully (in steps of one).	0…13	RWE

Number	Axis Parameter	Description	Range [Unit]	Acc.
193	referencing mode	1 – Only the left reference switch is searched. 2 – The right switch is searched and afterwards the left switch is searched. 3 – Three-switch-mode: the right switch is searched first and afterwards the reference switch will be searched. Please see chapter 6.7.13 for details on reference search.	1/2/3	RWE
194	referencing search speed	For the reference search this value specifies the search speed as a fraction of the maximum velocity: 0 – full speed 1 – half of the maximum speed 2 – a quarter of the maximum speed 3 – 1/8 of the maximum speed (etc.)	0…8	RWE
195	referencing switch speed	Similar to parameter no. 194, the speed for the switching point calibration can be selected.	0..8	RWE
196	distance end switches	This parameter provides the distance between the end switches after executing the RFS command (mode 2 or 3).	0…8388307	R
203	mixed decay threshold	If the actual velocity is above this threshold, mixed decay will be used. This can also be set to -1 which turns on mixed decay permanently also in the rising part of the microstep wave. This can be used to fix microstep errors.	0..2048 or -1 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$	RWE
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.	0…65535 0 = never [msec]	RWE
205	stall detection threshold	Stall detection threshold. Set it to 0 for no stall detection or to a value between 1 (low threshold) and 7 (high threshold). The motor will be stopped if the load value exceeds the stall detection threshold. Switch off mixed decay to get usable results.	0…7	RWE
206	actual load value	Readout of the actual load value used for stall detection.	0…7	R
208	driver error flags	TMC236 error flags.		R
211	fullstep threshold	When exceeding this speed the driver will switch to real full step mode. To disable this feature set this parameter to zero or to a value greater than 2047. Setting a full step threshold allows higher motor torque of the motor at higher velocity. When experimenting with this in a given application, try to reduce the motor current in order to be able to reach a higher motor velocity!	0..2048 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{\text{PD}} \frac{\mu\text{steps}}{\text{sec}}\right]$	RWE
214	power down delay	Standstill period before the current is changed down to standby current. The standard value is 200 (value equates 2000msec).	1… 65535 [10msec]	RWE

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

Please use the TMCL-IDE axis parameter calculation tool for getting best values.

8 Global parameters

The global parameters apply for all types of TMCM modules.

They are grouped into 3 banks:

- bank 0 (global configuration of the module)
- bank 1 (normally not available; for customer specific extensions of the firmware)
- bank 2 (user TMCL™ variables)

Please use SGP and GGP commands to write and read global parameters. Further you can use the STGP command in order to store TMCL™ user variables permanently in the EEPROM of the module. With the RSGP command the contents of a user variable can be restored from the EEPROM, if this is necessary.

8.1 Bank 0

Parameters 0...38

The first parameters 0...38 are only mentioned here for completeness. They are used for the internal handling of the TMCL-IDE and serve for loading micro step and driver tables. Normally these parameters remain untouched. ***If you want to use them for loading your specific values with your PC software please contact TRINAMIC and ask how to do this. Otherwise you might cause damage on the motor driver!***

Number	Parameter
0	datagram low word (read only)
1	datagram high word (read only)
2	cover datagram position
3	cover datagram length
4	cover datagram contents
5	reference switch states (read only)
6	TMC428 SMGP register
7...22	driver chain configuration long words 0...15
23...38	microstep table long word 0...15

Parameters 64...132

Parameters with numbers from 64 on configure stuff like the serial address of the module RS232 baud rate or the CAN bit rate. Change these parameters to meet your needs. The best and easiest way to do this is to use the appropriate functions of the TMCL-IDE. The parameters with numbers between 64 and 128 are stored in EEPROM only. A SGP command on such a parameter will always store it permanently and no extra STGP command is needed.

Take care when changing these parameters, and use the appropriate functions of the TMCL-IDE to do it in an interactive way.

Meaning of the letters in column *Access*:

- R = readable (GGP)
- W = writeable (SGP)
- E = automatically restored from EEPROM after reset or power-on.

Number	Global parameter	Description	Range	Access
64	EEPROM magic	Setting this parameter to a different value as $E4 will cause re-initialization of the axis and global parameters (to factory defaults) after the next power up. This is useful in case of miss-configuration.	0...255	RWE

Number	Global parameter	Description			Range	Access
65	RS232 baud rate	0	9600 baud	*Default*	0…7	RWE
		1	14400 baud			
		2	19200 baud			
		3	28800 baud			
		4	38400 baud			
		5	57600 baud			
		6	76800 baud	*Not supported by Windows!*		
		7	(115200 baud)			
66	serial address	The module (target) address for RS-232.			0…255	RWE
67	ASCII mode	Configure the TMCL™ ASCII interface: Bit 0: 0 – start up in binary (normal) mode 1 – start up in ASCII mode Bits 4 and 5: 00 – Echo back each character 01 – Echo back complete command 10 – Do not send echo, only send command reply				RWE
69	CAN bit rate	1	10kBit/s		1…7	RWE
		2	20kBit/s			
		3	50kBit/s			
		4	100kBit/s			
		5	125kBit/s			
		6	250kBit/s			
		7	500kBit/s			
		8	1000kBit/s	*Default*		
70	CAN reply ID	The CAN ID for replies from the board (default: 2)			0..7ff	RWE
71	CAN ID	The module (target) address for CAN (default: 1)			0..7ff	RWE
73	configuration EEPROM lock flag	Write: 1234 to lock the EEPROM, 4321 to unlock it. Read: 1=EEPROM locked, 0=EEPROM unlocked.			0/1	RWE
75	telegram pause time	Pause time before the reply via RS232 is sent. For RS232 set to 0. For CAN interface this parameter has no effect!			0…255	RWE
76	serial host address	Host address used in the reply telegrams sent back via RS232.			0…255	RWE
77	auto start mode	0: Do not start TMCL™ application after power up (default). 1: Start TMCL™ application automatically after power up.			0/1	RWE
80	shutdown pin functionality	Select the functionality of the SHUTDOWN pin 0 – no function 1 – high active 2 – low active			0…2	RWE
81	TMCL™ code protection	Protect a TMCL™ program against disassembling or overwriting. 0 – no protection 1 – protection against disassembling 2 – protection against overwriting 3 – protection against disassembling and overwriting ***If you switch off the protection against disassembling, the program will be erased first! Changing this value from 1 or 3 to 0 or 2, the TMCL™ program will be wiped off.***			0,1,2,3	RWE
83	CAN secondary address	Second CAN ID for the module. Switched off when set to zero.			0…7ff	RWE
84	coordinate storage	0 – coordinates are stored in the RAM only (but can be copied explicitly between RAM and EEPROM) 1 – coordinates are always stored in the EEPROM only			0 or 1	RWE

Number	Global parameter	Description	Range	Access
128	TMCL™ application status	0 –stop 1 – run 2 – step 3 – reset	0…3	R
129	download mode	0 – normal mode 1 – download mode	0/1	R
130	TMCL™ program counter	The index of the currently executed TMCL™ instruction.		R
132	tick timer	A 32 bit counter that gets incremented by one every millisecond. It can also be reset to any start value.		RW
133	random number	Choose a random number. ***Read only!***	0…2147483647	R

8.2 Bank 1

The global parameter bank 1 is normally not available. It may be used for customer specific extensions of the firmware. Together with user definable commands (see section 7.3) these variables form the interface between extensions of the firmware (written in C) and TMCL™ applications.

8.3 Bank 2

Bank 2 contains general purpose 32 bit variables for the use in TMCL™ applications. They are located in RAM and can be stored to EEPROM. After booting, their values are automatically restored to the RAM.

Up to 56 user variables are available.

Meaning of the letters in column *Access*:

- R = readable (GGP)
- W = writeable (SGP)
- E = automatically restored from EEPROM after reset or power-on.

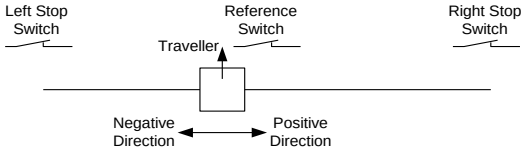
Number	Global parameter	Description	Range	Access
0	general purpose variable #0	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
1	general purpose variable #1	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
2	general purpose variable #2	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
3	general purpose variable #3	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
4	general purpose variable #4	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
5	general purpose variable #5	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
6	general purpose variable #6	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
7	general purpose variable #7	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
8	general purpose variable #8	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
9	general purpose variable #9	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
10	general purpose variable #10	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
11	general purpose variable #11	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
12	general purpose variable #12	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
13	general purpose variable #13	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
14	general purpose variable #14	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
15	general purpose variable #15	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
16	general purpose variable #16	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
17	general purpose variable #17	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
18	general purpose variable #18	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
19	general purpose variable #19	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE
20..55	general purpose variables #20..#55	for use in TMCL™ applications	$-2^{31}...+2^{31}$	RWE

9 Hints and tips

This chapter gives some hints and tips on using the functionality of TMCL, for example how to use and parameterize the built-in reference point search algorithm.

9.1 Reference search

The built-in reference search features switching point calibration and supports of one reference switch per axis. The internal operation is based on three individual state machines (one per axis) that can be started, stopped and monitored (instruction RFS, no. 13). The settings of the automatic stop functions corresponding to the switches (axis parameters 12 and 13) do not have any influence on the reference search.



Definition of the switches

- Selecting the referencing mode (axis parameter 193): in modes 1 and 2, the motor will start by moving *left* (negative position counts). In mode 3 (three-switch mode), the right stop switch is searched first to distinguish the left stop switch from the reference switch by the order of activation when moving left (reference switch and left limit switch share the same electrical function).
- Until the reference switch is found for the first time, the searching speed is identical to the maximum positioning speed (axis parameter 4), unless reduced by axis parameter 194.
- After hitting the reference switch, the motor slowly moves right until the switch is released. Finally the switch is re-entered in left direction, setting the reference point to the center of the two switching points. This low calibrating speed is a quarter of the maximum positioning speed by default (axis parameter 195).
- In Figure 9.1 the connection of the left and the right limit switch is shown. Figure 9.2 shows the connection of three switches as left and right limit switch and a reference switch for the reference point. The reference switch is connected in series with the left limit switch. The differentiation between the left limit switch and the reference switch is made through software. Switches with open contacts (normally closed) are used.
- In circular systems there are no end points and thus only one reference switch is used for finding the reference point.

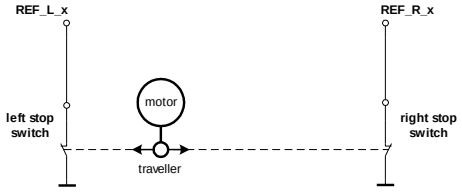


Figure 9.1: Two limit switches

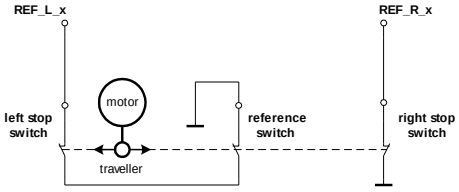


Figure 9.2: Limit switches with extra reference switch

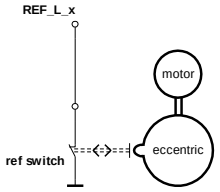


Figure 9.3: Circular system

9.2 Stall detection

The TMCM-310 is offered with the stallGuard™ option. In this case the module is equipped with three TMC246 motor driver chips, which feature load measurement that can be used for stall detection. Stall detection means that the motor will be stopped when the load gets too high. It is controlled by axis parameter #205. If this parameter is set to a value between 1 and 7 the stall detection will be activated. Setting it to 0 means that stall detection is turned off. A greater value means a higher threshold. This also depends on the motor and on the velocity. There is no stall detection while the motor is being accelerated or decelerated.

Stall detection can also be used for finding the reference point. You can do this by using the following TMCL™ code:

```
      SAP 205, 0, 5   //Turn on Stall Detection (use other threshold if needed)
      ROL 0, 500      //Let the motor run (or use ROR or other velocity)
Loop: GAP 3, 0
      COMP 0
      JC NE, Loop     //Wait until the motor has stopped
      SAP 1, 0, 0     //Set this position as the zero position
```

Do not use RFS in this case.

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

9.3 Fixing microstep errors

Due to the *zero crossing problem* of the TMC236/TMC246 stepper motor drivers, microstep errors may occur with some motors as the minimum motor current that can be reached is slightly higher than zero (depending on the inductivity, resistance and supply voltage of the motor).
This can be solved by setting the *mixed decay threshold* parameter (axis parameter number 203) to the value –1. This switches on mixed decay permanently, in every part of the microstepping waveform. Now the minimum reachable motor current is always near zero which gives better microstepping results.
A further optimization is possible by adapting the motor current shape. (For further information about TMCL-IDE please refer to the TMCL™ reference and programming manual.)

Use SAP 203, <motor number>, -1 to turn on this feature.

10 Revision history

10.1 Firmware revision

Version	Date	Author	Description
3.37	2008-OKT-11	OK	Most recent version

10.2 Document revision

Version	Date	Author	Description
1.00	2009-OKT-15	SD	Initial version
1.01	2009-OKT-27	SD	Axis parameters 194 and 195 corrected
1.02	2011-JAN-11	SD	Value range of axis parameter 6 corrected.

11 References

[TMCL] TMCL™ reference and programming manual (see http://www.trinamic.com)
[TMCM-310] TMCM-310 Hardware Manual (see http://www.trinamic.com)