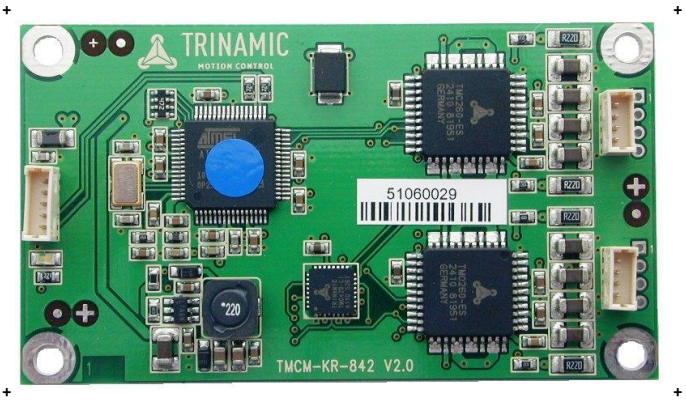
V 1.0

FIRMWARE MANUAL



TMCM-KR-842

2-axes bipolar stepper
controller / driver
0.5A RMS / +24V
RS232_TTL_3V3 interface

coolStep™

TRINAMIC Motion Control GmbH & Co. KG
Hamburg, Germany

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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.

Information given in this data sheet is believed to be accurate and reliable. However neither responsibility is assumed for the consequences of its use nor for any infringement of patents or other rights of third parties, which may result from its use.

Specifications are subject to change without notice.

2 Features

The TMCM-KR-842 is the gripper board for the KUKA youBot arm placed inside the gripper at the upper end of the arm. The main purpose of this board is controlling the two linear stepper motors (connected separately to the board) inside the gripper. These motors move the two gripper fingers.

Board version 2.0 has been designed as dual axes stepper motor controller / driver for stepper motors with up to 750mA peak / 530mA RMS current.

Applications
- KUKA youBot

Electrical data
- Supply voltage: +24VDC nom. (+9V... +28.5V DC)

Architecture
- AT91SAM7S64 processor for motion control
- TMC429 stepper motor controller for up to 3 axes
- 2x TMC260 advanced single axis stepper motor driver with integrated MOSFETs

Interfaces
- 1x 5pin power supply and serial communication interface connector
- 2x 4pin stepper motor connector

Software
- Custom software for control of two stepper motors

Please refer to separate Hardware Manual for further information.

3 Overview

As with most TRINAMIC modules the software running on the microprocessor of the TMCM-KR-842 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 shipped with most of TRINAMIC modules with regard to protocol and commands. Corresponding, this module is based on the TMC429 stepper motor controller and the TMC260 power driver and supports the standard TMCL™ with a special range of values.

The TMC260 is a new energy efficient high current high precision micro stepping driver IC for bipolar stepper motors and offers TRINAMICs patented coolStep™ feature with its special commands.

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

4 TMCL™ communication structure

The main purpose of the TMCM-KR-842 is controlling the two linear stepper motors (connected separately to the board) inside the gripper. The TMCM-KR-842 supports TMCL™ direct mode.

The module is associated with the TMCM-KR-841, which is an EtherCAT™ slave device inside the KUKA youBot arm. This module forwards mailbox commands not addressing the TMCM-KR-841 (module address not zero). The reply from TMCM-KR-842 is send to the connected TMCM-KR-841, wrapped into the mailbox answer command, and send to the EtherCAT™ master. The whole communication follows a strict master-slave-relationship.

4.1 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.

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

Checksum calculation

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
```

4.2 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

Do not send the next command before you have received the reply!

4.2.1 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
1	Wrong checksum
2	Invalid command
3	Wrong type
4	Invalid value
6	Command not available

5 TMCL™ command overview

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

5.1.1 Motion commands

These commands control the motion of the motor.

Mnemonic	Command number	Meaning
ROL	2	Rotate left
ROR	1	Rotate right
MVP	4	Move to position
MST	3	Motor stop

5.1.2 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.

Mnemonic	Command number	Meaning
SAP	5	Set axis parameter
GAP	6	Get axis parameter

5.1.3 TMCL™ control command

Instruction	Description	Type	Mot/Bank	Value
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)

5.2 Commands

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

5.2.1 ROR (rotate right)

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

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

The module is based on the TMC429 stepper motor controller and the TMC260 power driver. This makes possible choosing a velocity between 0 and 2047.

Related commands: ROL, MST, SAP, GAP

Mnemonic: ROR <motor>, <velocity>

Binary representation:

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

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

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

5.2.2 ROL (rotate left)

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

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

The module is based on the TMC429 stepper motor controller and the TMC260 power driver. This makes possible choosing a velocity between 0 and 2047.

Related commands: ROR, MST, SAP, GAP

Mnemonic: ROL <motor>, <velocity>

Binary representation:

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

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Rotate left motor #0, velocity = 1200
Mnemonic: ROL 0, 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	$00	$00	$00	$04	$b0	$b8

5.2.3 MST (motor stop)

With this command the motor will be instructed to stop. Please note: depending on motor speed a hard stop might lead to step losses.

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

Related commands: ROL, ROR, SAP, GAP

Mnemonic: MST <motor>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
3	(don't care)	<motor> 0, 1	(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

5.2.4 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.

Two 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.

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, MST

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

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
4	0 ABS – absolute	<motor> 0, 1	<position>
	1 REL – relative	<motor> 0, 1	<offset>

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

Example:

Move motor #0 to (absolute) position 90000
Mnemonic: MVP ABS, 0, 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	$00	$00	$01	$5f	$90	$f6

Example:

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

5.2.5 SAP (set axis parameter)

With this command most of the motion control parameters of the module can be specified.

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

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

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
5	<parameter number>	<motor> 0, 1	<value>

Reply in direct mode:

STATUS	VALUE
100 – OK	(don't care)

List of parameters, which can be used for SAP:

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.	$\pm 2^{23}$ [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 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$
3	actual speed	The current rotation speed.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$
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.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$
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	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$
6	absolute max. current (CS / Current Scale)	The most important motor setting, since too high values might cause motor damage! The maximum value is 255. This value means 100% of the maximum current of the module. The current adjustment is within the range 0… 255 and can be adjusted in 32 steps (0… 255 divided by eight; e.g. step 0 = 0… 7, step 1 = 8… 15 and so on).	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$
7	standby current	The current limit two seconds after the motor has stopped.	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. *Do not change!*	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$

Number	Axis Parameter	Description	Range [Unit]
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 7 128 microsteps 8 256 microsteps	0… 8
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
160	step interpolation enable	Step interpolation is supported with a 16 microstep setting only. In this setting, each step impulse at the input causes the execution of 16 times 1/256 microsteps. This way, a smooth motor movement like in 256 microstep resolution is achieved. 0 – step interpolation off 1 – step interpolation on	0/1
161	double step enable	Every edge of the cycle releases a step/microstep. *It does not make sense to activate this parameter for internal use.* Double step enable can be used with Step/Dir interface. 0 – double step off 1 – double step on	0/1
162	chopper blank time	Selects the comparator *blank time*. This time needs to safely cover the switching event and the duration of the ringing on the sense resistor. For low current drivers, a setting of 1 or 2 is good.	0… 3
163	chopper mode	Selection of the chopper mode: 0 – spread cycle 1 – classic const. off time	0/1
164	chopper hysteresis decrement	Hysteresis decrement setting. This setting determines the slope of the hysteresis during on time and during fast decay time. 0 – fast decrement 3 – very slow decrement	0… 3

Number	Axis Parameter	Description	Range [Unit]
165	chopper hysteresis end	Hysteresis end setting. Sets the hysteresis end value after a number of decrements. Decrement interval time is controlled by axis parameter 164. -3… -1 negative hysteresis end setting 0 zero hysteresis end setting 1… 12 positive hysteresis end setting	-3… 12
166	chopper hysteresis start	Hysteresis start setting. Please remark, that this value is an offset to the hysteresis end value.	0… 8
167	chopper off time	The off time setting controls the minimum chopper frequency. An off time within the range of 5µs to 20µs will fit. Off time setting for constant t_{OFF} chopper: N_{CLK}= 12 + 32*t_{OFF} (Minimum is 64 clocks) *Setting this parameter to zero completely disables all driver transistors and the motor can free-wheel.*	0 / 2… 15
168	smartEnergy current minimum (SEIMIN)	Sets the lower motor current limit for coolStep™ operation by scaling the CS (Current Scale, see axis parameter 6) value. minimum motor current: 0 – 1/2 of CS 1 – 1/4 of CS	0/1
169	smartEnergy current down step	Sets the number of stallGuard2™ readings above the upper threshold necessary for each current decrement of the motor current. Number of stallGuard2™ measurements per decrement: Scaling: 0… 3: 32, 8, 2, 1 0: slow decrement 3: fast decrement	0… 3
170	smartEnergy hysteresis	Sets the distance between the lower and the upper threshold for stallGuard2™ reading. Above the upper threshold the motor current becomes decreased. Hysteresis: (smartEnergy hysteresis value + 1) * 32 Upper stallGuard2™ threshold: (smartEnergy hysteresis start + smartEnergy hysteresis + 1) * 32	0… 15
171	smartEnergy current up step	Sets the current increment step. The current becomes incremented for each measured stallGuard2™ value below the lower threshold (see smartEnergy hysteresis start). current increment step size: Scaling: 0… 3: 1, 2, 4, 8 0: slow increment 3: fast increment / fast reaction to rising load	1… 3
172	smartEnergy hysteresis start	The lower threshold for the stallGuard2™ value (see smart Energy current up step).	0… 15

Number	Axis Parameter	Description	Range [Unit]
173	stallGuard2™ filter enable	Enables the stallGuard2™ filter for more precision of the measurement. If set, reduces the measurement frequency to one measurement per four fullsteps. *In most cases it is expedient to set the filtered mode before using coolStep™.* *Use the standard mode for step loss detection.* 0 – standard mode 1 – filtered mode	0/1
174	stallGuard2™ threshold	This signed value controls stallGuard2™ *threshold* level for stall output and sets the optimum measurement range for readout. A lower value gives a higher sensitivity. Zero is the starting value. A higher value makes stallGuard2™ less sensitive and requires more torque to indicate a stall. 0 | Indifferent value 1… 63 | less sensitivity -1… -64 | higher sensitivity	-64… 63
175	slope control high side	Determines the slope of the motor driver outputs. *Set to 2 or 3 for this module or rather use the default value.* 0: lowest slope 3: fastest slope	0… 3
176	slope control low side	Determines the slope of the motor driver outputs. *Set identical to slope control high side.*	0… 3
177	short protection disable	0: Short to GND protection is on 1: Short to GND protection is disabled *Use default value!*	0/1
178	short detection timer	0: 3.2µs 1: 1.6µs 2: 1.2µs 3: 0.8µs *Use default value!*	0..3
179	Vsense	sense resistor voltage based current scaling 0: Full scale sense resistor voltage is 1/18 VDD 1: Full scale sense resistor voltage is 1/36 VDD (refers to a current setting of 31 and DAC value 255) *Use default value. Do not change!*	0/1
181	stop on stall	Motor stop in case of stall.	0/1
182	smartEnergy threshold speed	Above this speed coolStep™ becomes enabled.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD}\ \frac{\mu\text{steps}}{\text{sec}}\right]$
183	smartEnergy slow run current	Sets the motor current which is used below the threshold speed.	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.	0… 65535 0 = never [msec]
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]

Example:

Set the absolute maximum current of motor #0 to 200mA
Mnemonic: SAP 6, 0, 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	$00	$00	$00	$00	$c8	$d5

5.2.6 GAP (get axis parameter)

Most parameters of the TMCM-KR-842 can be adjusted individually for each axis. With this parameter they can be read out in the *value* field of the reply.

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

Mnemonic: GAP <parameter number>, <motor>

Binary representation:

INSTRUCTION NO.	TYPE	MOT/BANK	VALUE
6	<parameter number>	<motor> 0, 1	(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 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\text{µsteps}}{\text{sec}}\right]$
3	actual speed	The current rotation speed.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\text{µsteps}}{\text{sec}}\right]$
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.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\text{µsteps}}{\text{sec}}\right]$
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.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\text{µsteps}}{\text{sec}}\right]$
6	absolute max. current (CS / Current Scale)	The most important motor setting, since too high values might cause motor damage! The maximum value is 255. This value means 100% of the maximum current of the module. The current adjustment is within the range 0… 255 and can be adjusted in 32 steps (0… 255 divided by eight; e.g. step 0 = 0… 7, step 1 = 8… 15 and so on).	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$
7	standby current	The current limit two seconds after the motor has stopped.	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$

Number	Axis Parameter	Description	Range [Unit]
8	target pos. reached	Indicates that the actual position equals the target position.	0/1
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. *Do not change!*	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$
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 7 128 microsteps 8 256 microsteps	0… 8
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
160	step interpolation enable	Step interpolation is supported with a 16 microstep setting only. In this setting, each step impulse at the input causes the execution of 16 times 1/256 microsteps. This way, a smooth motor movement like in 256 microstep resolution is achieved. 0 – step interpolation off 1 – step interpolation on	0/1
161	double step enable	Every edge of the cycle releases a step/microstep. *It does not make sense to activate this parameter for internal use.* Double step enable can be used with Step/Dir interface. 0 – double step off 1 – double step on	0/1
162	chopper blank time	Selects the comparator *blank time*. This time needs to safely cover the switching event and the duration of the ringing on the sense resistor. For low current drivers, a setting of 1 or 2 is good.	0… 3

Number	Axis Parameter	Description	Range [Unit]
163	chopper mode	Selection of the chopper mode: 0 – spread cycle 1 – classic const. off time	0/1
164	chopper hysteresis decrement	Hysteresis decrement setting. This setting determines the slope of the hysteresis during on time and during fast decay time. 0 – fast decrement 3 – very slow decrement	0… 3
165	chopper hysteresis end	Hysteresis end setting. Sets the hysteresis end value after a number of decrements. Decrement interval time is controlled by axis parameter 164. -3… -1 negative hysteresis end setting 0 zero hysteresis end setting 1… 12 positive hysteresis end setting	-3… 12
166	chopper hysteresis start	Hysteresis start setting. Please remark, that this value is an offset to the hysteresis end value.	0… 8
167	chopper off time	The off time setting controls the minimum chopper frequency. An off time within the range of 5µs to 20µs will fit. Off time setting for constant t_{OFF} chopper: N_{CLK}= 12 + 32*t_{OFF} (Minimum is 64 clocks) *Setting this parameter to zero completely disables all driver transistors and the motor can free-wheel.*	0 / 2… 15
168	smartEnergy current minimum (SEIMIN)	Sets the lower motor current limit for coolStep™ operation by scaling the CS (Current Scale, see axis parameter 6) value. minimum motor current: 0 – 1/2 of CS 1 – 1/4 of CS	0/1
169	smartEnergy current down step	Sets the number of stallGuard2™ readings above the upper threshold necessary for each current decrement of the motor current. Number of stallGuard2™ measurements per decrement: Scaling: 0… 3: 32, 8, 2, 1 0: slow decrement 3: fast decrement	0… 3
170	smartEnergy hysteresis	Sets the distance between the lower and the upper threshold for stallGuard2™ reading. Above the upper threshold the motor current becomes decreased. Hysteresis: (smartEnergy hysteresis value + 1) * 32 Upper stallGuard2™ threshold: (smartEnergy hysteresis start + smartEnergy hysteresis + 1) * 32	0… 15

Number	Axis Parameter	Description	Range [Unit]
171	smartEnergy current up step	Sets the current increment step. The current becomes incremented for each measured stallGuard2™ value below the lower threshold (see smartEnergy hysteresis start). current increment step size: Scaling: 0… 3: 1, 2, 4, 8 0: slow increment 3: fast increment / fast reaction to rising load	1… 3
172	smartEnergy hysteresis start	The lower threshold for the stallGuard2™ value (see smart Energy current up step).	0… 15
173	stallGuard2™ filter enable	Enables the stallGuard2™ filter for more precision of the measurement. If set, reduces the measurement frequency to one measurement per four fullsteps. *In most cases it is expedient to set the filtered mode before using coolStep™.* *Use the standard mode for step loss detection.* 0 – standard mode 1 – filtered mode	0/1
174	stallGuard2™ threshold	This signed value controls stallGuard2™ *threshold* level for stall output and sets the optimum measurement range for readout. A lower value gives a higher sensitivity. Zero is the starting value. A higher value makes stallGuard2™ less sensitive and requires more torque to indicate a stall. 0 | Indifferent value 1… 63 | less sensitivity -1… -64 | higher sensitivity	-64… 63
175	slope control high side	Determines the slope of the motor driver outputs. *Set to 2 or 3 for this module or rather use the default value.* 0: lowest slope 3: fastest slope	0… 3
176	slope control low side	Determines the slope of the motor driver outputs. *Set identical to slope control high side.*	0… 3
177	short protection disable	0: Short to GND protection is on 1: Short to GND protection is disabled *Use default value!*	0/1
178	short detection timer	0: 3.2µs 1: 1.6µs 2: 1.2µs 3: 0.8µs *Use default value!*	0..3
179	Vsense	sense resistor voltage based current scaling 0: Full scale sense resistor voltage is 1/18 VDD 1: Full scale sense resistor voltage is 1/36 VDD (refers to a current setting of 31 and DAC value 255) *Use default value. Do not change!*	0/1

Number	Axis Parameter	Description	Range [Unit]
180	smartEnergy actual current	This status value provides the *actual motor current* setting as controlled by coolStep™. The value goes up to the CS value and down to the portion of CS as specified by SEIMIN. actual motor current scaling factor: 0 … 31: 1/32, 2/32, … 32/32	0… 31
181	stop on stall	Motor stop in case of stall.	0/1
182	smartEnergy threshold speed	Above this speed coolStep™ becomes enabled.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD}\ \frac{\mu\text{steps}}{\text{sec}}\right]$
183	smartEnergy slow run current	Sets the motor current which is used below the threshold speed.	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$
204	freewheeling	Time after which the power to the motor will be cut when its velocity has reached zero.	0… 65535 0 = never [msec]
206	actual load value	Readout of the actual load value with used for stall detection (stallGuard2™).	0… 1023
208	TMC260 driver error flags	Bit 0: stallGuard™ status (1: threshold reached) Bit 1: Overtemperature (1: driver is shut down due to overtemperature) Bit 2: Pre-warning overtemperature (1: Threshold is exceeded) Bit 3: Short to ground A (1: Short condition detected, driver c□rrently shut down) Bit 4: Short to ground B (1: Short condition detected, driver currently shut down) Bit 5: Open load A (1: no chopper event has happened during the last period with constant coil polarity) Bit 6: Open load B (1: no chopper event has happened during the last period with constant coil polarity) Bit 7: Stand still (1: No step impulse occurred on the step input during the last 2^20 clock cycles) *Please refer to the TMC260 Datasheet for more information.*	0/1
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]

Example:

Get the actual position of motor #0

Mnemonic: GAP 0, 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	$00	$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**

5.2.7 TMCL™ control functions

This function is mentioned here only for reasons of completeness. It has no mnemonic, as it cannot be used in the TMCL™ program.

Instruction	Description	Type	Mot/Bank	Value
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)

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. KR842V20)

There is no checksum in this reply format!

- **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)

6 Axis parameters

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

Meaning of the letters in column *Access*:

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

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 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$	RW
3	actual speed	The current rotation speed.	±2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$	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.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$	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.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$	RWE
6	absolute max. current (CS / Current Scale)	The most important motor setting, since too high values might cause motor damage! The maximum value is 255. This value means 100% of the maximum current of the module. The current adjustment is within the range 0… 255 and can be adjusted in 32 steps (0… 255 divided by eight; e.g. step 0 = 0… 7, step 1 = 8… 15 and so on).	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$	RWE
7	standby current	The current limit two seconds after the motor has stopped.	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$	RWE
8	target pos. reached	Indicates that the actual position equals the target position.	0/1	R
130	minimum speed	Should always be set 1 to ensure exact reaching of the target position. Do not change!	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD} \frac{\mu\text{steps}}{\text{sec}}\right]$	RWE
135	actual acceleration	The current acceleration (read only).	0… 2047*	R

Number	Axis Parameter	Description	Range [Unit]	Acc.
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 7 128 microsteps 8 256 microsteps	0… 8	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
160	step interpolation enable	Step interpolation is supported with a 16 microstep setting only. In this setting, each step impulse at the input causes the execution of 16 times 1/256 microsteps. This way, a smooth motor movement like in 256 microstep resolution is achieved. 0 – step interpolation off 1 – step interpolation on	0/1	RW
161	double step enable	Every edge of the cycle releases a step/microstep. *It does not make sense to activate this parameter for internal use.* Double step enable can be used with Step/Dir interface. 0 – double step off 1 – double step on	0/1	RW
162	chopper blank time	Selects the comparator *blank time*. This time needs to safely cover the switching event and the duration of the ringing on the sense resistor. For low current drivers, a setting of 1 or 2 is good.	0… 3	RW
163	chopper mode	Selection of the chopper mode: 0 – spread cycle 1 – classic const. off time	0/1	RW
164	chopper hysteresis decrement	Hysteresis decrement setting. This setting determines the slope of the hysteresis during on time and during fast decay time. 0 – fast decrement 3 – very slow decrement	0… 3	RW

Number	Axis Parameter	Description	Range [Unit]	Acc.
165	chopper hysteresis end	Hysteresis end setting. Sets the hysteresis end value after a number of decrements. Decrement interval time is controlled by axis parameter 164. -3… -1: negative hysteresis end setting 0: zero hysteresis end setting 1… 12: positive hysteresis end setting	-3… 12	RW
166	chopper hysteresis start	Hysteresis start setting. Please remark, that this value is an offset to the hysteresis end value.	0… 8	RW
167	chopper off time	The off time setting controls the minimum chopper frequency. An off time within the range of 5µs to 20µs will fit. Off time setting for constant t_{OFF} chopper: N_{CLK}= 12 + 32*t_{OFF} (Minimum is 64 clocks) *Setting this parameter to zero completely disables all driver transistors and the motor can free-wheel.*	0 / 2… 15	RW
168	smartEnergy current minimum (SEIMIN)	Sets the lower motor current limit for coolStep™ operation by scaling the CS (Current Scale, see axis parameter 6) value. minimum motor current: 0 – 1/2 of CS 1 – 1/4 of CS	0/1	RW
169	smartEnergy current down step	Sets the number of stallGuard2™ readings above the upper threshold necessary for each current decrement of the motor current. Number of stallGuard2™ measurements per decrement: Scaling: 0… 3: 32, 8, 2, 1 0: slow decrement 3: fast decrement	0… 3	RW
170	smartEnergy hysteresis	Sets the distance between the lower and the upper threshold for stallGuard2™ reading. Above the upper threshold the motor current becomes decreased. Hysteresis: (smartEnergy hysteresis value + 1) * 32 Upper stallGuard2™ threshold: (smartEnergy hysteresis start + smartEnergy hysteresis + 1) * 32	0… 15	RW
171	smartEnergy current up step	Sets the current increment step. The current becomes incremented for each measured stallGuard2™ value below the lower threshold (see smartEnergy hysteresis start). current increment step size: Scaling: 0… 3: 1, 2, 4, 8 0: slow increment 3: fast increment / fast reaction to rising load	1… 3	RW
172	smartEnergy hysteresis start	The lower threshold for the stallGuard2™ value (see smart Energy current up step).	0… 15	RW

Number	Axis Parameter	Description	Range [Unit]	Acc.
173	stallGuard2™ filter enable	Enables the stallGuard2™ filter for more precision of the measurement. If set, reduces the measurement frequency to one measurement per four fullsteps. *In most cases it is expedient to set the filtered mode before using coolStep™.* *Use the standard mode for step loss detection.* 0 – standard mode 1 – filtered mode	0/1	RW
174	stallGuard2™ threshold	This signed value controls stallGuard2™ *threshold* level for stall output and sets the optimum measurement range for readout. A lower value gives a higher sensitivity. Zero is the starting value. A higher value makes stallGuard2™ less sensitive and requires more torque to indicate a stall. 0 | Indifferent value 1… 63 | less sensitivity -1… -64 | higher sensitivity	-64… 63	RW
175	slope control high side	Determines the slope of the motor driver outputs. *Set to 2 or 3 for this module or rather use the default value.* 0: lowest slope 3: fastest slope	0… 3	RW
176	slope control low side	Determines the slope of the motor driver outputs. *Set identical to slope control high side.*	0… 3	RW
177	short protection disable	0: Short to GND protection is on 1: Short to GND protection is disabled *Use default value!*	0/1	RW
178	short detection timer	0: 3.2µs 1: 1.6µs 2: 1.2µs 3: 0.8µs *Use default value!*	0..3	RW
179	Vsense	sense resistor voltage based current scaling 0: Full scale sense resistor voltage is 1/18 VDD 1: Full scale sense resistor voltage is 1/36 VDD (refers to a current setting of 31 and DAC value 255) *Use default value. Do not change!*	0/1	RW
180	smartEnergy actual current	This status value provides the *actual motor current* setting as controlled by coolStep™. The value goes up to the CS value and down to the portion of CS as specified by SEIMIN. actual motor current scaling factor: 0 … 31: 1/32, 2/32, … 32/32	0… 31	RW
181	stop on stall	Motor stop in case of stall.	0/1	RW
182	smartEnergy threshold speed	Above this speed coolStep™ becomes enabled.	0… 2047 $\left[\frac{16\text{MHz}}{65536} \cdot 2^{PD}\ \frac{\mu\text{steps}}{\text{sec}}\right]$	RW
183	smartEnergy slow run current	Sets the motor current which is used below the threshold speed.	0… 255 $\left[\frac{\text{max. module current}}{255}\right]$	RW

Number	Axis Parameter	Description	Range [Unit]	Acc.
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
206	actual load value	Readout of the actual load value with used for stall detection (stallGuard2™).	0… 1023	R
208	TMC260 driver error flags	Bit 0 stallGuard™ status (1: threshold reached) Bit 1 Overtemperature (1: driver is shut down due to overtemperature) Bit 2 Pre-warning overtemperature (1: Threshold is exceeded) Bit 3 Short to ground A (1: Short condition detected, driver currently shut down) Bit 4 Short to ground B (1: Short condition detected, driver currently shut down) Bit 5 Open load A (1: no chopper event has happened during the last period with constant coil polarity) Bit 6 Open load B (1: no chopper event has happened during the last period with constant coil polarity) Bit 7 Stand still (1: No step impulse occurred on the step input during the last 2^20 clock cycles) *Please refer to the TMC260 Datasheet for more information.*	0/1	R
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

6.1 coolStep™ related parameters

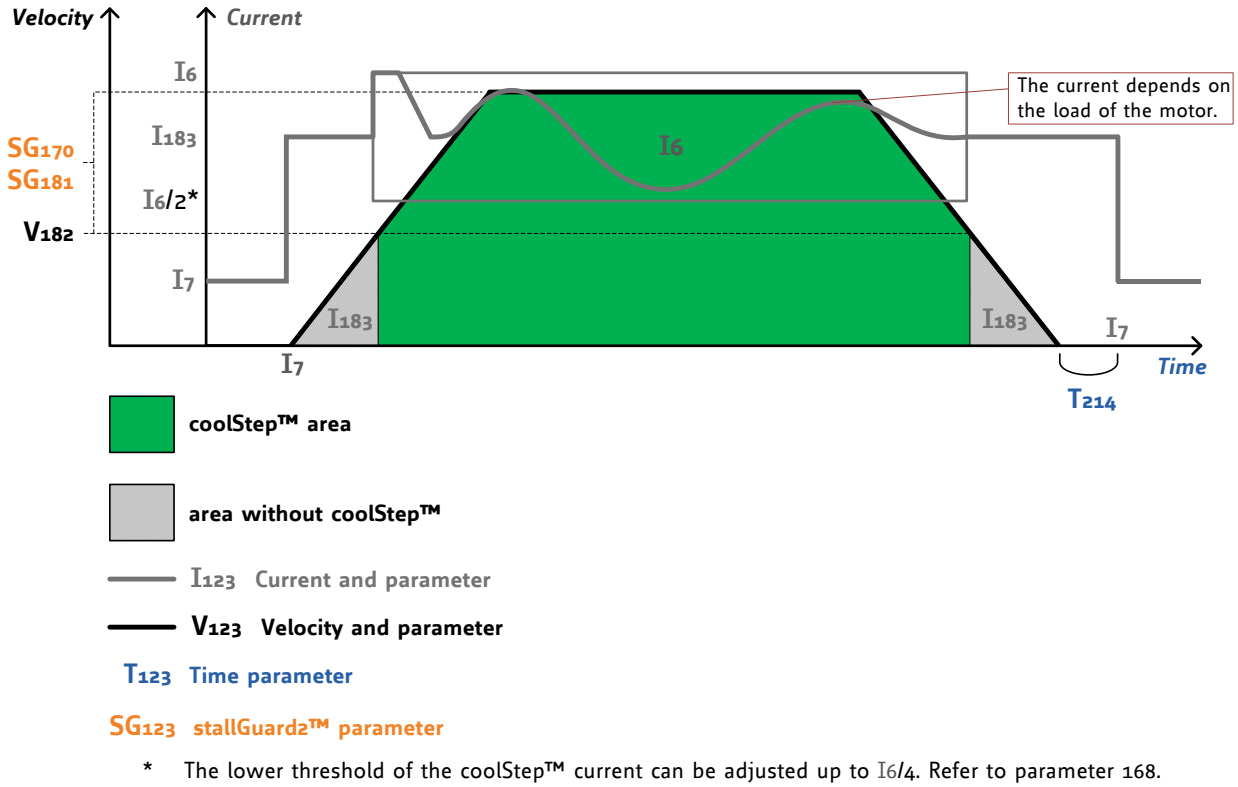
The figure below gives an overview of the coolStep™ related parameters. Please have in mind that the figure shows only one example for a drive. There are parameters which concern the configuration of the current. Other parameters are for velocity regulation and for time adjustment.

It is necessary to identify and configure the thresholds for current (I6, I7 and I183) and velocity (V182). Furthermore the stallGuard2™ feature has to be adjusted and enabled (SG170 and SG181).

The reduction or increasing of the current in the coolStep™ area (depending on the load) has to be configured with parameters I169 and I171.

In this chapter only basic axis parameters are mentioned which concern coolStep™ and stallGuard2™. The complete list of axis parameters in chapter 6 contains further parameters which offer more configuration possibilities.

coolStep™ adjustment points and thresholds



* The lower threshold of the coolStep™ current can be adjusted up to I6/4. Refer to parameter 168.

Number	Axis parameter	Description
I6	absolute max. current (CS / Current Scale)	The maximum value is 255. This value means 100% of the maximum current of the module. The current adjustment is within the range 0… 255 and can be adjusted in 32 steps (0… 255 divided by eight; e.g. step 0 = 0… 7, step 1 = 8… 15 and so on). *The most important motor setting, since too high values might cause motor damage!*
I7	standby current	The current limit two seconds after the motor has stopped.
I168	smartEnergy current minimum (SEIMIN)	Sets the lower motor current limit for coolStep™ operation by scaling the CS (Current Scale, see axis parameter 6) value. Minimum motor current: 0 – 1/2 of CS 1 – 1/4 of CS
I169	smartEnergy current down step	Sets the number of stallGuard2™ readings above the upper threshold necessary for each current decrement of the motor current. Number of stallGuard2™ measurements per decrement: Scaling: 0… 3: 32, 8, 2, 1 0: slow decrement 3: fast decrement
I171	smartEnergy current up step	Sets the current increment step. The current becomes incremented for each measured stallGuard2™ value below the lower threshold (see smartEnergy hysteresis start). current increment step size: Scaling: 0… 3: 1, 2, 4, 8 0: slow increment 3: fast increment / fast reaction to rising load
I183	smartEnergy slow run current	Sets the motor current which is used below the threshold speed. Please adjust the threshold speed with axis parameter 182.
SG170	smartEnergy hysteresis	Sets the distance between the lower and the upper threshold for stallGuard2™ reading. Above the upper threshold the motor current becomes decreased.
SG181	stop on stall	Motor stop in case of stall.
V182	smartEnergy threshold speed	Above this speed coolStep™ becomes enabled.
T214	power down delay	Standstill period before the current is changed down to standby current. The standard value is 200 (value equates 2000msec).

For further information about the coolStep™ feature please refer to the TMC260 Datasheet.

7 stallGuard2™

The module is equipped with TMC260 motor driver chip. The TMC260 features load measurement that can be used for stall detection. stallGuard2™ delivers a sensorless load measurement of the motor as well as a stall detection signal. The measured value changes linear with the load on the motor in a wide range of load, velocity and current settings. At maximum motor load the stallGuard™ value goes to zero. This corresponds to a load angle of 90° between the magnetic field of the stator and magnets in the rotor. This also is the most energy efficient point of operation for the motor.

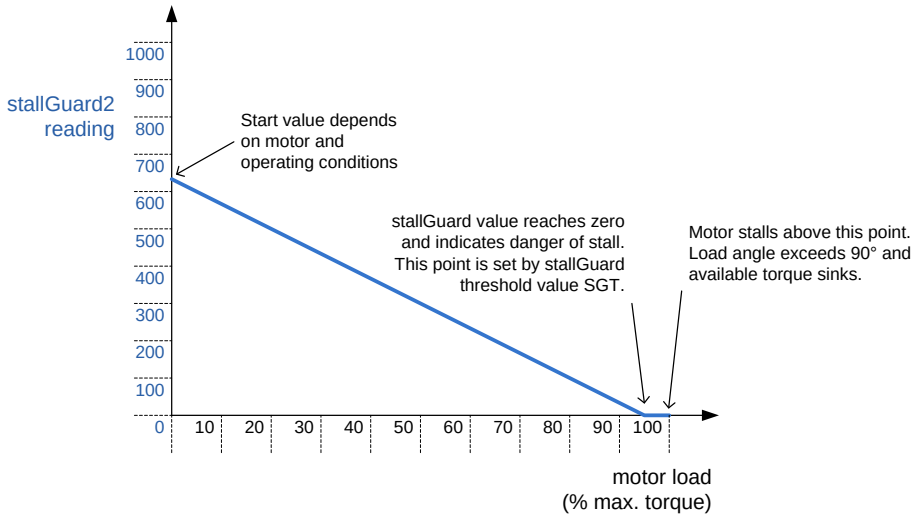


Figure 7.1: Principle function of stallGuard2

Stall detection means that the motor will be stopped when the load gets too high. It is configured by axis parameter #174.

Stall detection can also be used for finding the reference point.

Mixed decay should be switched off when stallGuard2™ operational in order to get usable results.

For further information refer to the TMC260 Datasheet please.

8 Revision history

8.1 Firmware revision

Version	Date	Description
2.00	2010-NOV-26	Version supporting all TMCL™ features

8.2 Document revision

Version	Date	Author	Description
1.00	2011-APR-21	SD	Initial version

9 References

[TMCM-KR-841] TMCM-KR-841 Firmware Manual and TMCM-KR-841 Hardware Manual
[TMC260] TMC260 Datasheet (please refer to www.trinamic.com)
[TMC429] TMC429 Datasheet (please refer to www.trinamic.com)