The Instruction Set

of the

TANGO Controller

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1. Table of Contents

2. Introduction

All instructions and parameters which are sent to the controller, as well as all feedbacks of the controller, are transferred as a sequence of ASCII characters. The connection may be controlled manually at any time with a terminal program (e.g. HyperTerminal). The use of ASCII string communication simplifies error tracing, if the instructions are given over a customized program. Commands from the PC to the controller are marked with either an exclamation mark '!', if they transmit parameters to the controller or with a preceding question mark '?', if data is requested from the controller. The controller accepts lower case and upper case ASCII characters as well. All floating point decimal numbers contain a point and no comma between pre and postpositions.

Examples:
!cal command the controller to do a calibration
?status ask for the status of the controller

Hints:
In some cases, like single character instructions, it is not neccessary to use the leading indicator '!' or '?'. Other instructions, e.g. for moving the axes, require the delivery of parameters following the instruction. Blanks must be inserted between the command text, its parameters and for separation of the parameters. Example: "moa 45 13 20[CR]" means move x, y and z to the positions 45, 13 and 20. Each instruction must be terminated with a carriage return [CR], which is represented as follows in the ASCII character set:

Symbol	decimal value	hexadecimal value	binary value
CR	13	0xD	00001101

Move commands are executed as a vector move, so they complete at the same time. To move axes independently, with their individual velocities, they may be started by separate single axis commands. Please refer to the "move" command descriptions.

Many parameters can be stored permanently in the Tango Controller, so they are available from each consecutive power on. When stored once, this reduces initilaization overhead of the application software. Refer to the "save" command for further information. Parameters that are saved can be identified by a 'Y' in the Save column of the brief instruction description.

Please do not send more than 255 characters at once to the Tango Controller, as the input buffer will overflow. To avoid this it is recommended to request the "?err" state each time after setting a parameter and wait for a value to be returned. Another solution is to activate the "!cts" handshake (available in Desktop RS232 or USB versions). This will automatically halt the PC transmission for as long as the input buffer is full. The PC COM port then must be opened with hardware handshake on, too. Please refer to the "!cts" command description.

Important: Security speed limitation!
The Tango controllers have a built in security function, which reduces the maximum travel velocity to a secure 10mm/s for as long as no initial cal/rm move is executed. This is to preserve the microscope stage from damage that could be caused by moving fast into its end positions. After calibrating the axis into its endswitches (cal and/or rm if switches are mounted and enabled) the travel velocity is no longer limited.
If it is not wanted or impossible to do a calibration/range measure move on each power on, the speed limit may be increased to up to 100mm/s at own risk. Please refer to the "**secvel**" command for further information.

3. Hint for controller initialization

Please make sure that first of all the following parameters have to be set:

- The axis units (here called "**dim**")
- If the controller firmware version is 1.32 or above: the **extmode**
- The axis **pitch** and - if used - also the **gear**, which are always in [mm] independend of dim

Using *dim=9* and *extmode=1* will turn all (even the vel and joyvel) units to stage related [mm] and [mm/s]. Extmode=1 also offers bugfixes, more features and flexibility. But ithas a slightly different behavior. Please refer to the **Extended Mode** description in this document.

4. Brief Description of the Tango Instruction Set

Controller Informations					
Instruction		**Example**	**Save**	**Brief description**	**Page**
(?)	version	version	fix	Read detailed firmware and controller version	14
(?)	det	det	fix	Read detailed configuration information	15
?	readsn	?readsn	fix	Read the controller serial number	15
(?)	ver	ver	fix	Read default version number	16
(?)	iver	iver	fix	Read further version number information	16
(?)	uptime	uptime	-	Read how long the controller is running	16
(?)	temp	temp	-	Read case temperature (available with encoder option)	16

Communication Interface Settings					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	baud	!baud 9600	Y	Set RS232 baud rate to 9600 Bd (default=57600)	17
? !	cts	!cts 1	Y	Switch on CTS hardware handshake	17

System Instructions					
Instruction		**Example**	**Save**	**Brief description**	**Page**
(!)	save	save	-	Save parameters to controller nonvolatile memory	18
(!)	restore	restore	-	Reload controller parameters from saved values	18
(!)	reset	reset	-	Reset controller (forces restart, similar to cycle power)	18
!	pa	!pa 1	-	Enable power amplifiers (disable = 0), see ‘axis’ cmd. too	19
? !	ipreter	!ipreter 1	Y	Select standard LSTEP command set	19

Operating Modes					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	extmode	!extmode 1	-	Enable extended controller behavior	20
? !	scanmode	!scanmode 1	-	Set controller positioning behavior to scanmode	21
? !	scanvel	!scanvel 20 20	-	Set scanmode vector velocity to 20mm/s for X and Y	21

Controller States and Error Messages					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	autostatus	!autostatus 0	-	Select autostatus response type 0 (=disabled), range: [04]	22
(?)	statusaxis	statusaxis	-	Read axis state [@,M,J,C,S,A,D,]	22
(?)	status	status	-	Read controller error state	23
(?)	err	err	-	Read error number	23
(?)	help	help	-	Read error number with additional text description	23
(?)	service	service	-	Returns a detailed parameter and state list, for debugging	24
(?)	pci	pci	-	Returns 1 if controller is plugged in a PCI slot (desktop=0)	24
!?	lock	!lock 2 1	Y	Set write protection for parameter 2 (here: motor current)	24
(?)	isvel	?isvel x	-	Query actual velocity of the X axis	25
?	maxpos	?maxpos x	-	Query maximal available position range for X axis	25

General Adjustments					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	dim	!dim 1 1 1	Y	Set position units of X Y Z to µm	26
? !	pitch	!pitch 1 1 1	Y	Set spindle pitch of X Y Z to 1 [mm/revolution]	26
? !	gear	!gear 1 1 1	Y	Set gear factor of X Y Z to 1	27
? !	motorsteps	!motorsteps x 200	Y	Set X axis motor has 200s steps per revolution	27
? !	accel	!accel 0.1 0.1 0.1	Y	Set acceleration of X Y Z to 0.1m/s²	28

General Adjustments

Instruction		Example	Save	Brief description	Page
? !	accelfunc	!accelfunc 1 1 0	Y	Set acceleration function X and Y to sin², Z to linear	28
? !	stopaccel	!stopaccel 2 2	Y	Set X and Y deceleration during stop condition to 2m/s²	29
? !	vel	!vel 10 10 10	Y	Adjust speed of X Y Z to 10 [revolutions/s]	29
? !	velfac	!velfac 1 1 1	Y	Set velocity reduction factor for X Y Z to 1 (= no reduction), range is [0.01-1]	30
? !	secvel	!secvel x 20	Y	Set secure speed limit X to 20mm/s (unit is always mm/s)	30
?	maxcur	?maxcur	fix	Show the maximum possible motor currents of all axes	30
? !	cur	!cur 0.5 0.6 1	Y	Set motor current in Ampere: X=0.5 Y=0.6 and Z=1 A	31
? !	reduction	!reduction 0.5 0.5 0.5	Y	Select 50% motor current reduction for X Y Z	31
? !	curdelay	!curdelay 1000	Y	Delay X axis motor current reduction by 1000 [ms]	32
? !	axis	!axis 1 0 -1	Y	Enable X, disable Y and switch off Z axis	32
? !	axisdir	!axisdir 0 1 0	Y	Reverse rotating direction of Y motor (caution!)	33
? !	motortable	!motortable x 2	Y	Select custom motor correction table type 2 for X axis	33
? !	usteps	!usteps 50000	Y	Set microstepping resolution to 50000/rev for all axes	34
? !	resolution	!resolution 6	Y	Set pos query return string resolution to 6 decimal places	34
? !	backlash	!backlash 12.3 0 0	Y	Set backlash compensation to 12.3µm in X and 0 in Y & Z	34
!?	lockaxis	!lockaxis 0 0 0 0	Y	Remove lock protection from all axes (lock has no effect)	35
?	lockstate	?lockstate x	-	Query extended locked parameters, including internal limitations currently applied to X axis	35
? !	stout	!stout 2	Y	Make Status LED state available at AUX-I/O Pin VR_OUT	35

Limit Switch Instructions (Hardware and Software)

Instruction		Example	Save	Brief description	Page
? !	lim	!lim 0 10 0 10 0 10	-	Set lower position limit to 0 and upper limit to 10 (assume unit is [mm] if dim was set to 2) for X Y Z	36
? !	limctr	!limctr x 1	-	Enable hardware limit switches for X axis, default = 1	36
? !	nosetlimit	!nosetlimit 1 1 1 1	Y	Disable setting/overwriting of software limits during cal and rm for all axes (here: X Y Z A), default = 0	37
? !	swtyp	!swtyp 1 0 1 !swtyp y 0 0 0	Y	Set limit switch type for all axes to NPN (pull-up) Set limit switch type for Y to PNP (pull-down)	37
? !	swpol	!swpol 1 0 1 !swpol z 1 0 1	Y	Set polarity of limit switches for all axes to active high (=1) Set polarity of limit switches for Z to active high	38
? !	swact	!swact 1 0 1 !swact y 1 0 0	Y	Enable cal and rm limit switches for all axes Enable cal limit switch for Y, disable ref and rm	38
? !	swdir	!swdir x 1	Y	Swap reference- and endswitch assignment for X axis	39
?	readsw	?readsw	-	Read states of all limit switches (1=active and actuated)	39
(?)	swin	swin	-	Read TTL signal level of all limit switch inputs (1=high)	40
(?)	statuslimit	statuslimit	-	Read current limit status „A“ = calibration done „D“ = rm done „L“ = limit switch modified by software „ “ = not yet modified	41

Calibration and Range Measure Instructions

Instruction		Example	Save	Brief description	Page
(!)	cal	cal	-	Perform a calibration move for all enabled axes, see ‘axis’	42
(!)	rm	rm x	-	Perform a range measure move in X	42
? !	calmode	!calmode 2 2	Y	Set calibration/closed loop behavior X, Y to type 2	43
? !	caltimeout	!caltimeout 60 60 10	Y	Set calibration timeout for X and Y to 1 minute, Z to 10s	43
? !	caliboffset	!caliboffset 1 1 1	Y	Set the cal zero-point 1mm aside lower limit switch (dim 2)	44
? !	rmoffset	!rmoffset 1 1 1	Y	Set rm end-position 1mm aside upper limit switch (dim 2)	44

Calibration and Range Measure Instructions

Instruction		Example	Save	Brief description	Page
? !	caldir	!caldir z 1	Y	Calibrate the Z-axis in positive direction	44
? !	calbspeed	!calbspeed 20	Y	Set the speed for move out of 'cal' and 'rm' limit switches for all axes to 0.2 [revolutions/s], range is [1...100]	45
? !	calrefspeed	!calrefspeed 10	Y	Set the speed for calibrating to the encoder reference for all axes to 0.1 [revolutions/s], range is [1...100]	45
? !	calpos	calpos	-	Read back the encoder position where the calibration switch was released	45
? !	refdir	?refdir y	-	Read the direction for encoder reference search in Y axis	46
? !	calvel	!calvel x 10 0.5	Y	**Only if extmode = 1:** Set calibration velocities in X	46
? !	rmvel	!rmvel x 10 0.5	Y	**Only if extmode = 1:** Set range measure velocities in X	46
? !	autopitch	!autopitch x 1	Y	Measure pitch after cal move of X axis	47

Move Instructions

Instruction		Example	Save	Brief description	Page
(!)	moa	moa 10 10 10 moa y 20	-	Move X Y Z absolute to positions 10 10 10 Move Y axis to position 20 (unit depends on dim seting)	48
(!)	mor	mor 4 4 4 mor y -10.5	-	Move X Y Z relative by 4 (unit depends on dim seting) Move Y axis relative 10.5 backwards	48
(!)	m	m	-	Move relative again (use same parameters as defined by last '!mor' or '!distance' instruction)	49
? !	distance	!distance 1 1 1	-	Set distance for X Y Z 'm'-move (start with 'm' or '!m')	49
(!)	moc	moc x	-	Move X to center position between lower and upper limit switch, or between lower and upper software limits	49
(!)	go	go x 12.5	-	Move X to pos. 12.5, overwritable, for tracking applications	50
? !	speed	!speed 5 5 5 !speed y 0	-	Digital joystick: move X Y Z axis with 5 [revolutions/s] Stop the Y axis speed move	50
(!)	a	a	-	Abort move (Stop)	51
? !	delay	!delay 1000	Y	Delay all consecutive moves by 1000 ms	51
? !	pause	!pause 10	Y	Delay "position reached" autostatus response by 10 ms	51
? !	pos	!pos 0 0 0 !pos z 1.2	-	Set current X Y Z position to 0 Set current Z position to 1.2	52
(!)	zero	!zero z	-	Set Z position and internal counter to 0 (e.g. filter wheel application)	53
(!)	clearpos	!clearpos z	-	Set Z position and internal counter to 0 (e.g. filter wheel application), not executable with measuring system	53

HDI: Joystick, Tackball and Handwheel Instructions

Instruction		Example	Save	Brief description	Page
? !	joy	!joy 0 !joy 2	Y	Switch joystick on(=2) or off(=0)	54
? !	joydir	!joydir 1 1 1	Y	Set motor direction for joystick operation (Z reversed)	54
? !	joywindow	!joywindow 14	Y	Set idle window of the joystick center position, where a joystick deflection has no effect [0..100]	55
? !	joyvel	!joyvel z 1.5	Y	**Only if extmode = 1:** Set joystick velocity for Z to 1.5	55
? (!)	joyspeed	joyspeed 2 25	Y	Set joystick speed for speed button 2 "medium" to 25 rev/s	55
? !	keymode	!keymode 2	Y	Select joystick key mode 2 = high speed preselection	56
? !	keyspeed	!keyspeed x 5 20	Y	Set keymode joystick speed X low=5mm/s, high=20mm/s	56
? (!)	joycurve	!joycurve z 1	Y	Set joystick characteristic for Z ot linear	57
(?)	key	key	-	Read state of all joystick buttons (0=released, 1=pressed)	57
(?)	keyl	keyl	-	Read and clear latched state of all joystick buttons	57
? !	hwfactor	!hwfactor x 1	Y	One handwheel revolution in X is 1mm stage travel	58
? !	hwfactorb	!hwfactorb x 14	Y	One handwheel revolution in X is 14mm stage travel	58

HDI: Joystick, Tackball and Handwheel Instructions

Instruction		Example	Save	Brief description	Page
? !	hwfilter	!hwfilter 0	Y	Switch off handwheel noise reduction	58
? !	tbfactor	!tbfactor 1 1	Y	Set trackball transmission factor in X and Y to default	59
(?)	zwheel	?zwheel	-	Returns 1 if HDI device has a Z-Wheel attached	60
? (!)	zwtravel	!zwtravel 1 0.25	Y	Set default Z-Wheel travel to 2.5 mm/rev	60
? !	tvrjoy	!tvrjoy z	Y	Assign AUX-IO pulse&direction joystick to Z axis	61
? !	tvrjoyf	!tvrjoyf 1	Y	Set tvrjoy transmission factor to 1	61
(?)	hdi	hdi	-	Read ID number of the connected HDI device	61
! ?	hdimode	!hdimode 0 1	Y	Set hdimode bit 0 to 1 for ErgoDrive Toggle Mode	62

Digital and Analogue I/O

Instruction		Example	Save	Brief description	Page
(?)	digin	digin digin 8	-	I/O Extension board: Read all digital inputs I/O Extension board: Read digital input 8	63
? !	digout	!digout 5 1 ?digout	-	I/O Extension board: Set digital output 5 to logic level 1 I/O Extension board: Read back all digital output levels	63
(?)	adigin	adigin adigin 2	-	Read all AUX-I/O digital inputs Read logic level of AUX-I/O digital input 2 only	64
? !	adigout	!adigout 3 1 ?adigout	-	Set AUX-I/O digital output 3 to logic level 1 Read back all digital output levels	64
(?)	anain	anain c 2	-	Read input of analogue channel 2	65
? !	anaout	!anaout c 1 17.5	-	Set analogue voltage of channel 1 to 17.5 percent (1.75V)	66
? !	stoppol	!stoppol 1	Y	Set AUX-IO stop input to active high	66
!	stop	!stop 0	-	Release stop condition (in stoppol modes 4 or 5)	66
? !	shutter	!shutter 1	-	Set AUX-IO shutter out signal to TTL high	67

Encoder Instructions

Instruction		Example	Save	Brief description	Page
? !	encmask	!encmask 1 1 0	Y	Enable activation of X and Y encoders, disable Z	68
? !	enc	!enc 1 0	-	Manually activate X encoder (caution!), set Y to inactive	68
? !	encperiod	!encperiod 0.1	Y	Set signal period of X encoder to 100 µm	69
? !	encttl	!encttl x 1	Y	X encoder is TTL type (has no analogue sin/cos signal)	70
? !	encdir	!encdir y 1	(Y)	Reverse counting direction for Y encoder	69
? !	encvel	!encvel x 0.5	Y	Set auto-adjust velocity of X encoder to 0.5mm/s	69
? !	encref	!encref 0	Y	No decoding of X encoder reference signal	70
? !	encnas	!encnas 1 0 0	Y	Enable NAS error signal input encoding for X encoder only	70
(?)	encrefstatus	encrefstatus x	-	Read X encoder reference signal state (1=on reference)	71
(?)	encrefstatusl	encrefstatusl x	-	Read latched X encoder reference signal state	71
(?)	encnasstatus	encnasstatus x	-	Read X encoder NAS signal state (1=NAS error)	71
? !	encerr	!encerr 0	-	Clear encoder error state for X axis (? response is 0 or e)	72
? !	encamp	?encamp x	-	Read X encoder signal amplitude in percent	72
? !	encpos	!encpos 1	-	?pos insruction returns for X the encoder position, if enc=1	72
(?)	hwcount	hwcount	-	Read all encoder positions (TTL counter, no interpolation)	73
(!)	clearhwcount	clearhwcount x	-	Set X axis hwcount to zero	73

MR Encoder Instructions

Instruction		Example	Save	Brief description	Page
? !	mra	?mra x	-	Read amplitude correction factor (sin/cos ratio) of X	74
? !	mro	?mro	-	Read offset correction value for all encoders	74
? !	mrp	!mrp x 0 0 0 0	-	Reset MR-signal peak-to-peak measurement result of X	75
?	mrt	?mrt z 2	-	List two measurement results of the Z input signals	75

Closed Loop Instructions					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	ctr	!ctr 1 1 1	Y	Set closed loop circuit X Y Z to “active until reached” mode	76
? !	ctrf	!ctrf 2.0	Y	Closed loop factor for X axis is set to 2.0	77
? !	ctrff	!ctrf 2 3.5	Y	Closed loop factors for X axis are set to 2 and 3.5	77
? !	ctrc	!ctrc 3	Y	Closed loop control is called every 3 millisecond	78
? !	ctrd	!ctrd 100	Y	Closed loop in target window for 100 milliseconds	78
? !	ctrt	!ctrt 200	Y	Closed loop control timeout after 200 milliseconds	78
? !	twi	!twi 0.01 0.01 0.01	Y	Set target window for X Y Z to 10µm (assume dim=2)	79
?	ctrstatus	?ctrstatus 1	-	Get Closed Loop active state of all axes	79
?	ctrdiff	?ctrdiff	-	Get Closed Loop position difference of all axes	80

Trigger Signal Configuration[1]					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	trig	!trig 1	-	Enable trigger functionality (should be the last command)	81
? !	triga	!triga x	-	Trigger function is related to X axis	81
? !	trigm	!trigm 0	-	Select trigger mode 0	82
(!)	trigger	trigger	-	Manually set trigger output (available in trigm 102, 103)	83
? !	trigs	!trigs 40	-	Set trigger output signal length to 40 microseconds	83
? !	trigd	!trigd 10	-	Set trigger distance to 10 (mm if dim=2)	83
? !	trigf	!trigf 1000	-	Generate periodic trigger pulses with 1kHz	84
? !	trigcount	?trigcount	-	Read number of generated trigger events	84

Snapshot Signal Configuration1					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	sns	!sns 1	1	Enable snapshot functionality (should be last command)	85
? !	snsl	!snsl 0	Y	Set snapshot input signal to active low	85
? !	snsf	!snsf 10	Y	Set snapshot signal debounce filter to 10 milliseconds	86
? !	snsm	!snsm 0	Y	Set snapshot mode to 0(=capture, 1=move)	86
? !	snsc	?snsc	-	Read number of snapshot events (=array fill size)	86
? !	snsp	?snsp x	-	Read last captured X position	88
? !	snsa	?snsa 1	-	Read first position entry of snapshot array (all axes)	88
(!)	snse	snse 2	-	Generate SnapShot event F2	89
? !	prehome	!prehome 10 20 1	-	Set prehome positions X Y Z to 10 20 1 (unit depends on dim seting)	90
? !	home	!home 5 5 0	-	Set home positions X Y Z to 5 5 0 (unit depends on dim seting)	90

[1] Function has to be enabled by factory, it is not available per default.

5. Instruction Syntax Description

Most instructions work in both directions (reading and writing). (?)! means the instruction accepts write and read. The controller identifies a read command by the preceded '?', or '!' for writing parameters.

Some examples for legal instruction syntax:
(?)!Command parameter1 parameter2 parameter3 parameter4
(?)!Command parameter1 parameter2
(?)!Command axis parameter
(?)!Command

6. Error Numbers and their possible Root Cause

0	no error
1	no valid axis name
2	no executable instruction
3	too many characters in command line
4	invalid instruction
5	number is not inside allowed range
6	wrong number of parameters
7	either ! or ? is missing
8	no TVR possible, while axis active
9	no ON or OFF of axis possible, while TVR active
10	function not configured
11	no move instruction possible, while joystick enabled
12	limit switch active
13	function not executable, because encoder detected
21	multiple axis moves are forbidden (e.g. during initialization)
22	automatic or manual move is not allowed (e.g. door open or initialization)
27	emergency STOP is active
29	servo amplifier are disabled (switched OFF)
30	safety circuit out of order
70	wrong CPLD data
71	ETS error
72	parameter is write protected (check lock bits)

7. Controller Informations

You may read the firmware version by sending the instruction 'version' to the controller. The instruction 'det' gives you further details of which options are enabled. Each controller has its own unique serial number readable with the instruction 'readsn'.

7.1. version (Read detailed Version information)

Syntax: ?version or version
Parameter: none or 1

Description: This instruction delivers detailed information about the firmware version.

Sending the version instruction with parameter 1 returns the tango firmware version number only.

Example:
```
?version
TANGO-DT-S, Version 1.37, Aug 12 2008 , 16:39:01

?version 1
1.37
```

Response syntax: Character string including controller type, firmware version and build date separated by a comma:

TANGO	Fixed string identifying the Tango controller
-DT	Desktop version
-PCI	PCI card version
-S	Tango short card version (PCI-S, DT-S)
Version 1.37	Firmware version number
Aug 12 2008	Firmware build date
16:39:01	Firmware build time

7.2. det (Read detailed Configuration)

Syntax: ?det or det
Parameter: none
Description: This instruction delivers detailed information about the current controller configuration.
Response: The controller returns a decimal integer number. Its hexadecimal value represents the configuration, like following table shows:

```
0x0    1  1Vssencoder is configured
0x0    2  MRencoder is configured
0x0    4  TTLencoder is configured
0x0   3   this is the number of configured axes (e.g. 3)
0x0  1    Display is configured
0x0  2    Speedpoti is configured
0x0  4    Hand wheel is configured
0x0  8    Snapshot is configured
0x0 1     TVRin is configured
0x0 2     Trigger out is configured
0x0 8     TVRout is configured
0x1      16 digital I/O are configured
0x2      32 digital I/O are configured
0x4      Trackball is configured
0x8      ETS available
```

The current configuration results as a logical 'or' of these bits.

Example: Assume ?det delivers the response 81697 which is 13F21 hexadecimal. This number means in detail, that the controller is configured for:

```
1 => 16 digital I/O
3 => TVRin and Trigger out
F => Display, Speedpoti, Hand wheel and Snapshot
2 => 2 axis
1 => 1Vss encoder
```

7.3. readsn (Read Serial Number)

Syntax: ?readsn or readsn
Parameter: none

Description: The instruction ?readsn delivers the current serial number.

Example: ?readsn

Response: The controller transmits its unique serial number as ASCII characters like YYWWNNXXX.

```
YY   year of manufacturing
DD   week of manufacturing
NN   available axes (in hardware)
XXX  Index number
```

7.4. ver (Read default Version Number)

```
Syntax:           ?ver or ver
Parameter:        none

Description:      This instruction reads back the default firmware version info.
                  The first number is the number of configured axes. The second
                  number is the maximum possible motor current in ampere.
      For Tango firmware version information please use "version".

Example:          ?ver
Response syntax:  Vers:LSnm.xx.xxx
                  (in some cases Vers:ESnm.xx.xxx)

                  "Vers:LS"   Fixed character string
                  n           Number of configured axes: 1, 2, 3, or 4
                  m           Maximum Current: 1=1.25A, 2=2.5A, 3=3.75A
                  x           Fixed numbers
```

7.5. iver (Read internal Version Number)

```
Syntax:           ?iver or iver
Parameter:        none

Description:      This instruction reads the internal version information
                  string. Mostly unused.
                  Please use the "version" command to read the Tango firmware
                  version.

Response syntax:  14 characters,    e.g. T[DD].[WW].[YY]-[NNNN]
                                    [DD] = Day of Week, [WW] = Week, [YY] = Year
                                    [NNNN] = Number

Example of ?iver response: T04.35.020004
```

7.6. uptime (Read Controller Up Time)

```
Syntax:           ?uptime or uptime
Parameter:        none

Description:      This instruction reads how long the controller
                  is running since power on or reset.

Response:         Time in seconds.

Example:          uptime
```

7.7. temp (Read Case Temperature)

```
Syntax:           ?temp or temp
Parameter:        none

Description:      This instruction reads the temperature inside the controller.
                  Only available with the encoder interface.

Response:         Temperature in [°C] with one decimal place.

Example of temp response: 28.9
```

8. Communication Interface Settings

8.1. baud (Baud Rate)

Syntax:	!baud or ?baud
Parameter:	9600, 19200, 38400, 57600 or 115200
Description:	This instruction sets or reads the serial communication transfer rate (baudrate). After sending this command first make sure the controlling device (e.g. a PC) has the same setting again. Then a save command may be sent to permanantly store the new baudrate. For PCI bus communication this instruction has no effect.
Response:	Current baud rate.
Examples:	
!baud 57600	The baud rate is set to 57600 [Bd].
?baud	query controller for current baud rate

8.2. cts (Enable/Disable RS232 Hardware Handshake)

Syntax:	?cts or !cts
Parameter:	0 or 1
Description:	Writing a 1 enables additional hardware handshake of the RS232 or USB interface. A 0 disables this function. For PCI bus communication this instruction has no effect. Please note that the PC COM port has to be opened in hardware handshake mode, too.
Response:	Current state of CTS (0=disabled or 1=enabled)
Examples:	
?cts	query controller for current state of CTS
!cts 0	disable CTS handshake
!cts 1	enable CTS handshake

9. System Instructions

The controller provides two different instruction sets.
> The default instruction set as described in this manual.
> The second optional instruction set is a subset of the Venus command set. The following instruction let you select your required instruction set (if the option is installed).

9.1. save (Save Parameters)

Syntax: !save or save
Parameter: none

Description: The instruction !save stores your favorite parameter settings (like spindle pitch) in a permanent and safe data area. These parameters will be taken by the controller after each consecutive reset or power on as default values. Executing a save comand always returns the "OK..." string when writing is completed.

Response: The save instruction returns the response string "OK..."

Example:
save => The currently used controller parameters are saved as default.

9.2. restore (Restore Saved Parameters)

Syntax: !restore or restore
Parameter: none

Description: The controller reloads the saved parameters from its nonvolatile memory. The current controller parameters get overwritten by the saved defaults. Refer to the "save" instruction. Similar to a software "reset", but without affecting the hardware.

Response: none
Example: restore

9.3. reset (Force a Software Reset)

There are two possibilities to reset the controller:
. The power on reset
. The Software Reset

Syntax: !reset or reset
Parameter: none

Description: The controller is forced to perform a software reset. It is a restart similar to power on. Rebooting from reset will take more than 1 second, where the controller is not responding. There is no reply to a software reset. So for knowing if the controller is rebooted and ready, it may be neccessary to poll data until it responds again.

Response: none
Example: reset

9.4. pa (Enable or Disable the Power Amplifiers)

```
Syntax:           !poweramplifier or !pa
Parameter:        0 or 1

Description:      This instruction switches all motor amplifiers on(=1) or
                  off(=0). If switched off, no motor current is flowing.
                  To switch off axes individually, please use the 'axis'
                  command.

Response:         none

Example:          !pa 1       Switch on all amplifiers.
```

9.5. ipreter (Select Instruction Set)

```
Syntax:           !ipreter or ?ipreter
Parameter:        1, 2, 3, 4 or 5

Description:      0 => Prohibited. Register command set is no longer provided.

                  1 => Default instruction set (Native, LSTEP), as described
                       in this manual.

                  2 => VENUS-1 and VENUS-2

                  3 => LUDL MAC5000

                  4 => Do not use for Firmware <= 1.45!
                       From Firmware 1.46: ASI MS-2000

                  5 => Prior ProScanII

                  To return from the VENUS instruction set (2), please enter the
                  string "1 setipreter" and press enter (or send an ASCII [CR]).
                  For other instruction sets please refer to the corresponding
                  instruction set description.

Response:         1, 2, 3, 4 or 5

Example:
!ipreter 2 => The controller switches to the VENUS instruction set.
?ipreter   => Responds the currently selected interpreter.
```

10. Operating Modes

10.1. Extended Mode

Activating Extended Mode will change some of the controllers behavior. Also there are new instructions for calibrate and range measure velocities.
Note: When initializing the controller, the desired Extended Mode should be set directly after setting **dim** and before setting gear, pitch, vel etc.

Calibration in extmode = 0:

!vel --> The velocity for moving towards an endswitch has to be set everytime before starting a **cal** / **rm** move.
!calbspeed --> There is only one velocity for all axes to travel out of the endswitch. The unit is 1/100 rev/s.

Calibration in extmode = 1:

!vel has no influence to the cal / rm move, same to **calbspeed.**
Now the calibrate (**cal**) and range measure (**rm**) velocities can be assigned once and will be used for all time.
!calvel --> Set velocities for moving towards and out of the cal endswitch (E0)
!rmvel --> Set velocities for moving towards and out of the rm endswitch (EE)

Additional differences when in extmode = 1:

All the parameters stored in revolutions/s (e.g. vel) are recalculated if the pitch or gear values have changed. So the stage velocities will remain the same even when pitch or gear changed.

joyvel --> The joystick velocity can (and has to be) set independently from **vel** by the **joyvel** instruction.

The **?lim** command, when requested without an axis specifier, now returns all limits in a correctly formatted way.

10.1.1 extmode (Switch to Extended Mode)

Syntax: !extmode or ?extmode
Parameter: 0 or 1

Description: This instruction switches the Tango controller into extended mode. This mode offers improved behavior and some more sophisticated commands then the standard interpreter. For further information please refer to the **Extended Mode** Chapter 10.1.

0 = default, compatible interpreter mode
1 = extended interpreter mode.

Response: currently used extmode.

Examples:
!extmode 1 Set controller into extended mode.
?extmode Query extended mode.

10.2. Scan Mode

In Scan Mode the controller executes move instructions with a vector velocity.

10.2.1 scanmode (Switch to Scan Mode)

Syntax: !scanmode or ?scanmode
Parameter: 0, 1 or 2

Description: This instruction switches the Tango controller into scan mode. In this mode the vector velocity for automatic moves (moa, mor) is constant and can be set by 'scanvel'.

0 = normal operation (no scan mode)
1 = scan mode 1
2 = scan mode 2

Scan mode 1:
All axes have the same scanvel velocity. Individual 'vel' settings are ignored. If started individually (e.g. "!moa z 10") the axis will also travel at scanvel.

Scan mode 2:
When the automatic move is started as a vector or without an axis character (e.g. "moa 10 5", "moa 10") the axis/axes travel at scanvel.
If started individulally (with specified axis, "moa z -10") the axis specific 'vel' velocity is used.

Response: Scanmode (automatic move mode) as integer.

Examples:
!scanmode 1 Set controller into scanmode 1.
?scanmode Query controller scanmode.

10.2.2 scanvel (Scanmode Vector Velocity)

Syntax: !scanvel or ?scanvel
Parameter: 0.000001 to 1000 [mm/s]

Description: This instruction sets or reads the scanmode vector velocity in millimeter per second.
As this is a vector mode there is only one velocity parameter.
Please also refer to the 'scanmode' instruction.

Response: Currently selected velocity in [mm/s]

Examples:
!scanvel 10 Set scanmode vector velocity to 10mm/s
?scanvel Query scan mode velocity.

11. Controller States and Error Messages

11.1. autostatus (Set Autostatus to required behavior)

```
Syntax:          !autostatus or ?autostatus
Parameter:       0, 1, 2, 3 or 4

Description:
0 =>  Sending of any automatic state messages is switched OFF, except 'save'.
1 =>  After each automatic move the message 'position reached' (this is the
      character '@' for each configured axis) is automatically transmitted by
      the controller. It is the default configuration after power on.
2 =>  The controller transmits the message 'position reached' plus other status
      messages.
3 =>  Instead of 'position reached' string a simple <CR> is transmitted (=fast).
4 =>  Echoes all input instructions including parameters.

Autostaus can not be saved. After power on or reset it is always set to 1.

Example: Assume there are three axes configured and autostatus is set to 1.
         After completion of a move (moa, mor, m, a) the controller will return
         a "@@@-." which means position reached.

!autostatus 0     Switch off autostatus (now the position reached info has to be
                  polled by using the "statusaxis" instruction).
?autostatus       Reads back the selected autostatus value.
```

11.2. statusaxis (Query State of Axis)

```
Syntax:          ?statusaxis or statusaxis
Parameter:       none

Description:     Statusaxis responds the state of each axis.
                 Similar to the 'autostatus 1' response of move commands,
                 but with an additional '-' after the dot.
                 It can be used for polling axes in 'autostatus 0' mode, where
                 no automatic response is generated.
                 Every response except of 'M' means the axis has stopped for
                 some reason and may be ready for a new move command.

Response:        6 ASCII characters: [STATUS X][STATUS Y][STATUS Z][STATUS A].-

      @ => Axis is not moving and ready
      M => Axis is moving
      J => Axis is controlled manually (by joystick)
      C => Axis is in closed loop
      S => Limit switches are triggered and prevent further automatic move
      A => ok response after cal instruction
      D => ok response after rm instruction
      E => not o.k. response after cal or rm, if an error occurred during cal
           instruction (e.g. a limitswitch is not working properly)
      U => manual adjustment (e.g. 1st setup)
      T => Timeout (refer to 'caltimeout' instruction)
       => Axis is not enabled

Example:    Assume ?statusaxis delivers the response @@@-.-
            This means three axes are enabled and ready to move.
```

11.3. status (Query the Controller Error State)

Syntax: ?status or status
Parameter: none

Description: The ?status instruction responds with the current state of the controller. Which is either 'OK...' or an 'ERR' with error number. Also see 'err' instruction.

Response: OK... or ERR with error number

Example: ?status => ERR 4
?status => OK...

11.4. err (Query Error Number)

Syntax: ?err or err, !err
Parameter: none

Description: The instructions err or ?err return the controller error state or 0, if no error occurred. The error state wil be updated or re-set by the next instruction. Additionaly the error state may be cleared to zero by sending !err.

Response: Error number as decimal value
(refer to Chapter 6. "Error Numbers")

Example: err => 0
!err (clear error state if no permanent error)

11.5. help (Query Error Number with Description String)

Syntax: ?help or help
Parameter: none or requested error number

Description: The instruction help returns a text string. It contains the error state with appended error description. The error state is not cleared to zero. Please also refer to the 'err' instruction.

When called without a parameter:
It returns the controller's error state with description

When called with a parameter (error number):
It returns this error number with the corresponding comment

Response: Error number as decimal value, error description as ASCII text

Example: help => ERROR 0,no error
(controller state, assumed to be ok here)

help 29 => ERROR 29,servo amplifier off

11.6. service (Print Service Information to Terminal)

```
Syntax:          ?service or service
Parameter:       none

Description:     The instruction service returns a multi-line parameter and
                 state list of the controller. It may be used for debugging or
                 in case of service requests. Either a terminal program or
                 SwitchBoard version 1.19 and above can be used.

Response:   Many lines of text including e.g. serial number, parameters, states
                 etc.

Example:         service
```

11.7. pci (Is PCI Bus)

```
Syntax:          ?pci or pci
Parameter:       none

Description:     The instruction pci returns:

      0 = Controller is a desktop version
      1 = Controller is a PCI card and plugged in a PCI slot

Response:        0 or 1

Example:         pci => 0
```

11.8. lock (Select Parameters to Lock)

```
Syntax:          ?lock or !lock
Parameter:       0 bis 15, 0 oder 1

Description:     Write protection for parameter. The lock bits must be applied
                 to one or more axes by the lockaxis command. Else they have no
                 effect.

Response:        Lock bit state or entire lock bit field
                  0: Pitch
                  1: Gear
                  2: Cur
                  3: MotorSteps
                  4: SwPol
                  5: SwTyp
                  6: SwDir
                  7: EncTTL
                  8: EncPeriod
                  9: AxisDir
                 10: MotorTable
                 11: BackLash

Example:         !lock 111  => Set lock bits 0 1 and 2, leave others unaffected
                 !lock 2 0  => Clear lock condition for parameter 2 (=current)
                 !lock 0 1  => Set lock bit for parameter 0 (pitch)
                 ?lock      => Query lock bit field (e.g. "0000000000000000")
                 ?lock 5    => Query lock bit 5 state
```

11.9. isvel (Query Actual Velocities)

Syntax: ?isvel or isvel
Parameter: x,y,z,a or none

Description: Read the actual velocitie(s) with which the axis is currently traveling. Unlike **'?vel'** or **'?speed'** this instruction returns the current real speed of the axes.

Response: Actual motor velocity in [mm/s]

Example: ?isvel => Query actual velocity of all axes
?isvel y => Query actual velocity of the X axis

11.10. maxpos (Maximum Position)

Syntax: ?maxpos
Parameter: none

Description: Query the maximum position value which the controller can accept due to internal limitations. It depends on e.g. the selected pitch, gear or motorsteps.

Response: Theoretical maximum position value of the axes (unit depends on dim setting)

Example:
?maxpos x => 2600.0000 (X axis accepts position values in the range of ±2600mm, assuming dim = 2)

12. General Adjustments

With the following instructions the parameters of the controller are widely scalable to the given mechanic construction and to customer requirements. The controller is adaptable to the requested requirements.

12.1. dim (Unit for Positions)

Syntax: !dim or ?dim
Parameter: x, y, z or a
0 to 9

Description: The dim instruction sets the unit (or "dimension") of all input and output parameters related to length, e.g. position or move commands.

The provided units for length (parameters for dim) are:
0 => Micro steps
1 => µm
2 => mm (Tango default)
3 => 360°
4 => revolutions
5 => cm
6 => m
7 => inch
8 => mil
9 => mm (difference to mode 2: all velocity instructions in mm/s)

Examples:
!dim 4 1 the selected dimension for X is [revolutions] and for Y is [µm].
!dim z 2 the selected dimension for Z is [mm]
?dim responds the dimensions for all axes.
?dim a responds the dimension of the a-axis.
dim 2 2 2 2 set dimension for all axes to [mm]

Response: Current settings

Hint: For dimensions 3 (=360°) and 4 (=revolutions) it is recommended to set the **spindle pitch** to 1mm.

12.2. pitch (Spindle Pitch)

Syntax: !pitch or ?pitch
Parameter: x, y, z or a
0.0001 to 68

Description: This instruction sends the spindle pitch (given by mechanic components) to the controller. It will be taken for all further calculations.

Response: current spindle pitch

Examples:
!pitch 4.0 1.0 set spindle pitch X=4[mm] and Y=1[mm]
!pitch z 2.0 set spindle pitch Z=2[mm]
?pitch query all axes for their spindle pitch
?pitch a query spindle pitch for a-axis

12.3. gear (Gear Ratio)

Syntax: !gear or ?gear
Parameter: x, y, z or a
0.001 to 1000

Description: This instruction transmits the gear ratio to and from the controller. The ratio is 1, if the motor is directly mounted on the spindle.

Response: current gear ratio

Examples:

!gear 10	set gear ratio X=1/10
!gear 4.0 1.0	set gear ratio X=1/4 and Y=1/1
!gear z 10.0	set gear ratio Z=1/10
?gear	query all axes for their gear ratio
?gear a	query A-axis for its gear ratio

12.4. motorsteps (Motor Steps Per Revolution)

Syntax: !motorsteps or ?motorsteps
Parameter: x, y, z or a
[multiples of 4]

Description: This instruction sets or reads back the steps per revolution of the attached motor. Commonly the most motors have 200 steps per revolution (which is 1.8° full step). Other motors may have 400 or 500 steps per revolution. The motor steps paramerer must be a multiple of 4.

Response: Currently used motorsteps

Examples:

!motorsteps 200 200 400	set motor steps for X and Y to 200 and Z to 400
!motorsteps x 500	set motor steps for X to 500
?motorsteps	query all axes for their motorsteps
?motorsteps a	query A-axis for its motorsteps

12.5. accel (Acceleration)

```
Syntax:           !accel or ?accel
Parameter:        none, x, y, z or a
                  0.0001 to 20 [m/s²]

Description:      This instruction sets or reads the maximum acceleration which
                  is used for all moves, the speed instruction and HDI devices.

Remarks:    In case of a stop event, 'stopaccel' is used instead.

Response:         Currently used acceleration in m/s²

Examples:
!accel 0.5        set acceleration X=0.5[m/s²]. Other axes are not affected.
!accel 1 0.55     set acceleration X=1.0[m/s²] and Y=0.55[m/s²]
!accel z 0.2      set acceleration Z=0.2[m/s²]. Other axes are not affected.
?accel            query all axes for their current acceleration.
?accel z          query Z axis for its acceleration.

Additional information:

The standard ?vel query returns numbers with a resolution 0f 0.01 m/s², but the
instruction accepts higher resolutions.
In case of Firmware 1.46 or higher: In order to read out more decimal places it
is possible to add the requested decimal places to the query (valid is 0 to 6).
Examples:
?accel 6          => 0.123456 0.123456 0.123456
?accel y 4        => 0.1235 0.1235
```

12.6. accelfunc (Acceleration Ramp Function)

```
Syntax:           !accelfunc or ?accelfunc
Parameter:        none, x, y, z or a
                  0, 1 or 2

Description:      Select the acceleration ramp type for automatic moves (e.g. m,
                  moa, mor, cal, rm).

      0 = Linear acceleration/deceleration ramp
      1 = sin² acceleration/deceleration ramp
      2 = reserved, currently same as 1: sin²

Response:         Currently used acceleration function

Examples:
!accelfunc 1      set accel function X to sin². Other axes are not affected.
!accelfunc x 1    set accel function X to sin². Other axes are not affected.
!accelfunc 1 1 0  set accel function in X and Y to sin², Z to linear.
?accelfunc        query all axes for their current acceleration ramp functions.
?accelfunc z      query Z axis for its acceleration ramp function.
```

12.7. stopaccel (Emergency Stop Deceleration)

Syntax: !stopaccel or ?stopaccel
Parameter: x, y , z or a
0.01 to 200 m/s²

Description: This instruction sets the deceleration for emergency stop conditions. It will be used by abort commands or when detecting an unexpected limit switch (e.g. no cal/rm move was performed).

Response: Currently used deceleration for stop

Examples:

!stopaccel 1 1 2	Set the stop deceleration for X and Y to 1 and Z to 2 [m/s²]
!stopaccel x 1.5	Set the X stop deceleration to 1.5[m/s²]
?stopaccel	Returns the currently used stop deceleration for all axes

12.8. vel (Velocity)

Syntax: !vel or ?vel
Parameter: x, y, z or a
0.000001 to 200 [rev/s] or [mm/s] if dim = 9

Description: Velocity in motor revolutions per second, which is used for all consecutive automatic moves.

Remarks: If **extmode**=0 (default), the vel is also used for the HDI (joystick) velocity.

Response: Currently selected velocity

Examples:

!vel 10	set velocity X=10[revolution/s]. Other axis are not affected.
!vel 1.0 15	set velocity X=1[revolution/s] and Y=15[revolution/s].
!vel z 0.1	set velocity Z=0.1[revolution/s].
?vel	query all axes for their velocities.
?vel x	query x axis for its velocity.

Additional information:

The standard ?vel query returns numbers with a resolution 0f 0.001 rev/s, but the instruction accepts higher resolutions.
In order to read out more decimal places it is possible to add the requested decimal places to the query (valid is 0 to 16).
Examples:

?vel 6	=> 0.123456 0.123456 0.123456
?vel y 4	=> 0.1235 0.1235

If a higher resolution or slower velocity is needed, the **'velfac'** instruction can be used in addition.

12.9. velfac (Velocity Factor)

```
Syntax:          !velfac or ?velfac
Parameter:       x, y, z or a
                 0.01 to 1.00

Description:     This instruction sets or reads the velocity factor, which is
                 used for all consecutive automatic moves. It is internally
                 multiplied to the velocity (vel).

Response:        Currently used velocity factor [0.01 to 1.00]

Examples:
?velfac z        query X axis for its current velocity factor.
!velfac x 0.1    set velocity X to 1/10 of current velocity.
?velfac          query all axes for their current velocity factors.
```

12.10. secvel (Secure Velocity)

```
Syntax:          !secvel or ?secvel
Parameter:       none, x, y, z or a
                 1 to 100 [mm/s]

Description:     The security speed limitation is used as long as the axis is
                 not calibrated and range measured ("cal", "rm"). The velocity
                 unit is always mm/s and does not depend on the "dim" state. It
                 prevents the microscope stage from mechanical damage as long
                 as the controller does not know the mechanical limits. It may
                 also be used as a workaround, if running a cal/rm is not
                 wanted.

Response:        Currently used secure velocity [1 to 100 mm/s]

Examples:
!secvel 100 100 100 => Set maximum possible velocity of X Y Z
!secvel y 14.5      => Set maximum possible velocity of Y to 14.5 mm/s
```

12.11. maxcur (Query Maximum Motor Current)

```
Syntax:          ?maxcur
Parameter:       none, x, y, z or a

Description:     This instruction reads the maximum possible motor current.

Response:        maximum motor current in Ampere [A]

Examples:
?maxcur y        query Y axis for its maximum motor current
?maxcur          query all axes for their maximum motor currents
```

12.12. cur (Motor Current)

Syntax: !cur or ?cur
Parameter: x, y, z or a
0.1 to [maximum current]

Description: This instruction sets or reads the motor current. The maximum current is limited by hardware and may be cheched by the "**maxcur**" instruction.

Response: Motor current in Ampere

Examples:
!cur 1.0 set X motor current to 1[A]
!cur 1.0 2 set motor current for X=1[A] and Y=2[A]. Other axes are not affected.
!cur z 0.3 set Z motor current to 0.3[A].
?cur query all axes for their motor currents.
?cur x query X for its motor current.

12.13. reduction (Motor Current Reduction Factor)

Syntax: !reduction or ?reduction
Parameter: x, y, z or a
0 to 1.0

Description: This instruction sets or reads the current reduction factor. When the axis is idle (stopped), the motor current is reduced by this factor. The floating point values from 0 to 1 represent a current of 0 to 100% of the selected motor current (**cur**). A value of 1 disables the reduction.
Motor current reduction can be used to keep the motor temperature low, but as a side effect it may add noise, decrease performance and position accuracy.
A delayed current reduction can be achieved by the "**curdelay**" instruction.

Response: Reduction factor(s) [0.00 to 1.00]

Examples:
!reduction .1 .7 Set idle currents X=0.1*cur[A] and Y=0.7*cur[A]
!reduction z 0.5 Set Z idle current to 0.5*cur[A]
?reduction Query all axes for their current reduction factors.
?reduction x Query X for its reduction factor.

12.14. curdelay (Delay for Current Reduction)

```
Syntax:           !curdelay or ?curdelay
Parameter:        x, y, z or a
                  0 to 10000 [ms]

Description:      At the end of each move the axis enters the idle state. If the
                  motor current reduction factor is set to a value less than 1.0
                  this reduction will take effect after the curdelay time.

Response:         Selected delay of current reduction in [ms]

Examples:
!curdelay 100 300 set delay for motor current reduction X=100[ms] and Y=300[ms]
!curdelay z 450   set delay for motor current reduction Z=450[ms]
?curdelay         query all axes for their motor current reduction delay.
?curdelay x       query X-axis for its motor current reduction delay.
```

12.15. axis (Enable, Disable, Switch Off Axis)

```
Syntax:           !axis or ?axis
Parameter:        x, y, z or a
                  -1, 0, 1

Description:      This instruction enables, disables, switches off axes. Or
                  reads its current state. A disabled axis still powers the
                  motor with its current, while a switched off axis loses its
                  torque.

Response:         Current axis state (1=enabled, 0=disabled, -1=power stage off)

Examples:
!axis 1 1 1 1     enable all axes.
?axis x           query X-axis for its state.
!axis 1 0 1 0     disable Y and A axis while X and Z are enabled.
!axis y -1        switch off Y axis: power stage Y off.
?axis             query all axes for their state.
```

12.16. axisdir (Axis Direction)

Syntax: !axisdir or ?axisdir
Parameter: x, y, z or a
0 or 1

Description: This command reverses the specified axes. The meaning of the limit switches (E0 and EE) is also automatically exchanged against each other:
The E0 and EE switches are treated as virtual switches, E0 is the switch in negative direction, EE in positive. The hardware is reassigned to the opposite switch. Also for: swact, swpol, swtyp, readsw. Exception: The 'swin' function is not affected.
Please make sure to first set the desired axis direction before setting the end switch types, polarity etc.!
It is not recommended to change direction during operation!

0 = Normal direrction, CAl switch => E0, RM switch => EE
1 = Reversed direrction, CAl switch => EE, RM switch => E0

Hint: If you need to change the assignment of E0 and EE

Response: Current axis direction is 0=not changed or 1=changed

Examples:
!axisdir 0 1 0 1 Axis directions of Y and A are reversed.
?axisdir x Query X for its current axis direction.

12.17. motortable (Motor Correction Table)

Syntax: !motortable or ?motortable
Parameter: x, y, z or a
0 or number specified by factory

Description: This instruction adds a motor correction. The motor has to be measured for the specific application by factory. There a table number will be assigned and the customer may activate it by setting the corresponding motortable number. Using a wrong motortable will lead to increased noise and position error.

0 = No correction

Response: Currently used motortable(s)

Examples:
!motortable 1 1 2 0 Select motortable 1 for X and Y, 2 for Z and no for A
!motortable x 0 Disable correction in x
?motortable Returns the currently used tables for all axes

12.18. usteps (Microstep Resolution)

```
Syntax:           !usteps or ?usteps
Parameter:        360 ... 819200

Description:      This instruction sets the microstep resolution of one motor
                  revolution. Only one resolution for all axes. It is used when
                  dimension Micro steps (dim 0) is selected.

Response:         Currently used microstepping resolution

Examples:
!usteps 40000     Set microstep resolution to 40000/revolution
?usteps           Query microstep resolution
```

12.19. resolution (Position Number Format)

```
Syntax:           !resolution or ?resolution
Parameter:        0 ... 6

Description:      This instruction sets the number of decimal places for "?pos"
                  instructions in dim modes 2 and 9.
      One value applies to all axes, default = 4 (100nm resolution).

Response:         Currently responded decimal places for the pos instruction.

Examples:
!resolution 6     Set position string resolution to 6 decimal places (0.000000)
? resolution      Query decimal places
```

12.20. backlash (Mechanical Backlash Compensation)

```
Syntax:           !backlash or ?backlash
Parameter:        x, y, z, a or none
                  -100.0 ... 100.0 [µm]

Description:      This instruction compensates mechanical backlash
                  separately for each axis. Unit is µm, independent from dim.

      0 = Backlash compensation off

Response:         Currently used backlash in µm

Examples:
!backlash 12.7 21.3 0   Set backlash for X to 12.7µm, Y=21.3µm and Z= none.
!backlash x 0           No backlash compensation for X
!backlash x 5           Compensate a backlash in X is of 5µm
?backlash               Returns the currently used backlash for all axes
```

12.21. lockaxis (Apply the Parameter Lock to Axes)

```
Syntax:          ?lockaxis or !lockaxis
Parameter:       x,y,z,a or none

Description:     Apply the lock to an axis. If the lock instruction is set to
                 all zero, there is no effect and vice versa.

Response:        Axes to which the lock bits are currently applied.

Example:         !lockaxis y 1  => Apply lock bits to Y axis
                 !lockaxis 1 1  => Apply lock bits to X and Y axis
                 ?lockaxis x    => Query if lock bits are applied to the X axis
                 ?lockaxis      => Query all axes (returns e.g. "1 1 0 0");
```

12.22. lockstate (Query all internal Lock States)

```
Syntax:          ?lockstate
Parameter:       x,y,z,a or none

Description:     Set/read lock bits corresponding to the parameter listed below
                  0: Pitch
                  1: Gear
                  2: Cur
                  3: MotorSteps
                  4: SwPol
                  5: SwTyp
                  6: SwDir
                  7: EncTTL
                  8: EncPeriod
                  9: AxisDir
                 10: MotorTable
                 11: BackLash

Response:        Lock state as 16bits ASCII string ('0' and '1', LSB first)

Example:         ?lockstate     => Query lock state of all axes
                 ?lockstate x   => Lock state of X axis e.g. "1100000000000000"
```

12.23. stout (Select Status Signal Output)

```
Syntax:          !stout or ?stout
Parameter:       0,1,2,3,4

Description:     Makes the state of the Status LED available to
      the AUX-I/O connector:

      0 = Just Status LED, no AUX-I/O used (Standard)
                 ~~1 = AUX-I/O Pin 5 (TAKT_OUT)~~ may not be available!
                 2 = AUX-I/O Pin 6 (VR_OUT)
                 3 = AUX-I/O Pin 7 (SHUTTER_OUT)
                 4 = AUX-I/O Pin 8 (TRIGGER_OUT)

Response:        Actual status output mode

Example:         !stout 0 => Only use Status LED
                 ?stout   => Query actual Status output mode (0,1,2,3 or 4)
```

13. Limit Switch Instructions (Hardware and Software)

13.1. lim (Software Limits)

```
Syntax:           !lim or ?lim
Parameter:        x, y, z or a
                  + maximum position range

Description:      This instruction sets the maximum allowed positioning range.
                  The upper and lower software limits shall be send together in
                  a single !lim instruction. Remember: The unit (dimension) of
                  the transmitted numbers depends on the value of instruction
                  dim.

Hint: In Extended Mode (extmode = 1) the ?lim command returns the limits as a
                  correctly formatted string)

Response:         Currently used software limits

Examples:
!lim 1000 1000 2000 2000      set the software limits for X and Y.
!lim z -500 1700              set the software limits for Z.
?lim y                        query Y-axis for its limits.
?lim                          query all axes for their limits, only recommended
                              in extmode=1
?lim response example for 3 axes in
--> extmode=0: -1000 1000,[CR]-1000 1000, -1000 100[CR]
--> extmode=1: -1000 1000 -1000 1000 -1000 100[CR]
```

13.2. limctr (Enable or Disable Limit Control)

```
Syntax:           !limctr or ?limctr
Parameter:        x, y, z or a
                  0 or 1

Description:      This instruction enables or disables the limit control or
                  shows the current state of limit control. Attention, be
                  careful: If limit controls are disabled, the controller
                  doesn't care about limits. In this case the controller may
                  damage system components. Limit control is enabled by default
                  from power on.

Response:         Limit control state (0 = not active, 1 = active)

Example:
!limctr y 0       disable Y limit control, Y axis limit switches are ignored
!limctr 1 1 1     enable X,Y and Z limit control
!limctr z 1       enable Z limit control
?limctr a         query A-axis for its status of limit control
?limctr           query all axes for their status of limit control
```

13.3. nosetlimit (Do not set limits by cal/rm)

```
Syntax:           !nosetlimit or ?nosetlimit
Parameter:        x, y, z or a
                  0 or 1

Description:      This command enables or disables the setting of software limit
                  switches during calibration and range measure. The default is
                  nosetlimit=0 which means that the software limits are set by
                  the cal/rm moves to these min/max positions.

Response:         0 = set software limits to !cal and !rm positions
                  1 = do not change software limits after !cal and/or !rm

Examples:
!nosetlimit 1 1   X and Y axis do not take software limits after !cal and !rm
!nosetlimit y 1   Y axis is does not set software limits of !cal and !rm move
?nosetlimit       query all axes for their nosetlimit state
?nosetlimit a     query A axis for its nosetlimit state
```

13.4. swtyp (Type of Limit Switch)

```
Syntax:           !swtyp or ?swtyp
Parameter:        x, y, z or a
                  0 or 1

Description:      Set/read the type of the limit switches.
                  The sequence is E0 REF EE for all axes.
                  The REF switch currently not used by the Tango controller.
      Important: When using no axis parameter (x,y,z or a), the 3 values will be
                  used for all axes! To set individual axes, please do this
                  separately, use the axis parameter x,y,z or a.
      Please note that the E0 and EE switch are reassigned by the 'axisdir'
                  command.

      0 = PNP, which adds a pull-down resistor to the switch input
                  1 = NPN, which adds a pull-up resistor (default)

Response:         Currently selected type

Examples:
!swtyp 1 0 1      Set all limit switches to NPN type
!swtyp z 0 0 1    Set Z axis limit switches E0=PNP, REF=don't care, EE=NPN
?swtyp y          Query Y axis for its switch type
```

13.5. swpol (Polarity of Limit Switch)

```
Syntax:           !swpol or ?swpol
Parameter:        x, y, z or a
                  0 or 1

Description:      Set/read the polarity of the limit switches.
                  The sequence is E0 REF EE for all axes.
                  The REF switch currently not used by the Tango controller.
      Important: When using no axis parameter (x,y,z or a), the 3 values will be
                  used for all axes! To set individual axes, please do this
                  separately, use the axis parameter x,y,z or a.
      Please note that the E0 and EE switch are reassigned by the 'axisdir'
                  command.

                  0 = switch has active low signal
                  1 = switch has active high signal

Response:         Polarity of the limit switches

Examples:
!swpol y 1 1 1    set polarity of Y limit switches (E0 REF EE) to positive edge.
!swpol 1 0 1      set polarity of limit switches (E0 REF EE) for all axes.
!swpol z 0 0 0    set polarity of Y limit switches (E0 REF EE) to negative edge.
?swpol a          query limit switch polarity of the A axis
```

13.6. swact (enable or disable limit switches)

```
Syntax:           !swact or ?swact
Parameter:        x, y, z or a
                  0 or 1

Description:      This instruction enables or disables the limit switches.
                  The sequence is always:

                  E0 REF EE

                  0 = switch is inactive (actuation state is ignored)
                  1 = switch is active

                  The REF switch is not used by the Tango controller.
                  Disabling limit switches may damage the hardware.
      When using no axis parameter, the 3 values will be used for all axes! To
                  set individual axes please do this separately, use the axis
                  parameter x, y, z or a.
      If a switch is set to inactive, it is not neccessary to cal or rm this
                  switch to abolish the secvel speed limitation.
      Inactive switches always return a non actuated state when using the '?
                  readsw' command. But the 'swin' command still returns the
                  switches TTL logic level state.
                  Please note that the E0 and EE switch are reassigned by the
                  'axisdir' command.

Response:         Current state, if limit switches are enabled or disabled

Examples:
!swact 1 0 1      Enable cal and rm limit switches for all axes (REF disabled)
!swact z 1 0 1    Set Z limit switches E0=enabled REF=disabled EE=enabled
?swact a          Query A-axis, if limit switches are enabled or disabled
```

13.7. swdir (swap assignment of cal and rm switch)

```
Syntax:           !swdir or ?swdir
Parameter:        x, y, z or a
                  0 or 1

Description:      This command swaps the cal(E0) and rm(EE) switch assignment.

                  0 = switches are not swapped
                  1 = switches are swapped

      In addition to the axisdir command, which swaps motor direction and
                  endswitch assignment, this command only swaps the switches.
                  E0<->EE.
      Caution: swdir should only be used to compensate different wiring of the
                  stage endswitches. Swapping the switches to
                  the wrong assignment may result in microscope stage damage!


Response:         Current state of endswith assignment(s)

Examples:
!swdir 1 1 0      Swap E0<->EE switch assignment in X and Y, not in Z
!swdir x 1        Swap E0<->EE switch assignment in X (E0 switch is now EE etc.)
?swdir            Query all axes for their switch assignment
?swdir z          Query Z-axis, if its limit switches are swapped
```

13.8. readsw (Read Status of Limit Switches)

```
Syntax:           ?readsw
Parameter:        none

Description:      This instruction reads the limit switch state of all axes.
                  The response is a string of 12 characters, either 0 or 1.

                  0 = limit switch is currently not actuated or disabled
                  1 = limit switch is currently actuated (axis is in switch)

                  In opposite to the "swin" command, readsw returns the
                  active/inactive state and not the signal level of the switch.
                  Also the readsw exchanges E0 and EE switches when axisdir is
                  changed.
                  Please note that the switch state is only valid when the
                  swtyp, swpol parameters are set correctly and the switch is
                  activated by swact.

                  Sequence of the 12 characters is:
                  Axis:    X   Y   Z   A   X    Y    Z    A    X   Y   Z   A
                  Switch: [E0][E0][E0][E0][Ref][Ref][Ref][Ref][EE][EE][EE][EE]

                  E0  = lower limit switch (!cal command)
                  Ref = Reference switch
                  EE  = upper limit switch (!rm command)

Response:         Actuation state of limit switches, 0 if disabled

Examples:   ?readsw => 000000000000
                  (query all limit switch actuation states)
```

13.9. swin (Read Limit Switch Input Level)

```
Syntax:          ?swin or swin
Parameter:       none or 0...7

Description:     This instruction reads the limit switch signal directly.
                 The response is a string of 8 characters, either 0 or 1.

                 0 = limit switch input signal is TTL low
                 1 = limit switch input signal is TTL high

                 In opposite to the "readsw" command, swin reflects the TTL
                 input levels. Also disabled switches are represented with
                 their current TTL input signal level. Swin is not affected by
                 the axisdir command (does not exchange E0 and EE switches).
                 The Ref signals are not used.

                 Sequence of the 8 characters is:
                 Axis:    X       Y       Z       A
                 Switch: [E0][EE][E0][EE][E0][EE][E0][EE]
                 Index :  0   1   2   3   4   5   6   7
                 E0  = lower limit switch (!cal)
                 EE  = upper limit switch (!rm)

Response:        Switch input signal TTL levelstate of limit switches

Examples:        swin   => 11111111 (query all 8 limit switch signal levels)
                 swin 1 => 1        (query EE of X Axis signal level)
```

13.10. statuslimit (Limit Status)

```
Syntax:          ?statuslimit or statuslimit
Parameter:       none

Description:     The instruction statuslimit responds a string with 16
                 characters. They represent the state of the software limits.

            They are arranged in 3 groups:
             0 -  3: Group 1 => cal state of axis 0-3 (x,y,z,a)
             4 -  7: Group 2 => rm  state of axis 0-3 (x,y,z,a)
             8 - 11: Group 3 => lower software limit state of axis 0-3 (x,y,z,a)
            12 - 15: Group 4 => upper software limit state of axis 0-3 (x,y,z,a)

            The characters may have one of four values:
            - => the software limit has not yet been modified since power on
            A => axis is already calibrated (!cal)
            D => axis is already range measured (!rm)
            L => software limit has been modified by (!lim)

Example:    Assume ?statuslimit returns the string "AA-A---D-LL-L--L"

                 This means in detail:

                 [ 0]  A -> X-axis is calibrated
                 [ 1]  A -> Y-axis is calibrated
                 [ 2]  - -> Z-axis is not calibrated
                 [ 3]  A -> A-axis is calibrated
                 [ 4]  - -> X-axis is not range measured
                 [ 5]  - -> Y-axis is not range measured
                 [ 6]  - -> Z-axis is not range measured
                 [ 7]  D -> A-axis is range measured
                 [ 8]  - -> X-axis lower software limit is not modified
                 [ 9]  L -> Y-axis lower software limit is modified
                 [10]  L -> Z-axis lower software limit is modified
                 [11]  - -> A-axis lower software limit is not modified
                 [12]  L -> X-axis upper software limit is modified
                 [13]  - -> Y-axis upper software limit is not modified
                 [14]  - -> Z-axis upper software limit is not modified
                 [15]  L -> A-axis upper software limit is modified
```

14. Calibration and Range Measure Instructions

After each power on or '!reset' of the controller the operator may execute a calibration (instruction !cal) followed by a range measure (instruction !rm), if the system is equipped with the corresponding limit switches.
This also disables the travel speed limit set by 'secvel'. So the controller is able to smoothly stop the axes automatically before they crash into the microscope stage hardware limits.
The cal/rm instructions set the limits close to the limit switch positions. An additional position offset for the these limits may be specified with the instructions !caliboffset and !rmoffset.
Long axes and/or slow velocities may exceed the default calibration timeout of 40 seconds. Therefore the timeout can be set to the desired value by **caltimeout**.
Please also refer to the optional **extmode** enhancements and **calmode** options for calibration.

14.1. cal (Command a Calibration)

Syntax: !cal or cal
Parameter: x, y, z or a

Description: This instruction moves either the specified or all currently enabled axes in negative direction towards lower positions, until the limitswitch E0 is detected. Depending on extmode it then moves with !calbspeed out of the switch. If caloffset=0, the axis will stop moving as soon as the limitswitch E0 is released. If caliboffset>0, the axis will continue moving to this distance. In both cases the reached position will be set to 0 and, if nosetlimit=1 used as lower software limit.

Response: each commanded (and enabled) axis answers either
'A' after a successful calibration or
'E' if an error occurred (cal was unsuccessful).

Examples:
!cal execute a calibration for all enabled axes
cal y execute a calibration for Y axis only (if Y is enabled)

14.2. rm (Command a Range Measure)

Syntax: !rm or rm
Parameter: x, y, z or a

Description: This instruction moves either the specified or all currently enabled axes in positive direction towards higher positions, until the limitswitch EE is detected. Depending on extmode it then moves with !calbspeed out of the switch. If rmoffset=0, the axis will stop moving as soon as the limitswitch EE is released. If rmoffset>0, the axis will continue moving to this distance. If nosetlimit=1, the reached position will be used as upper software limit.

Response: each commanded (and enabled) axis responds either
'D' after a successful range measure or
'E' if an error occurred (rm was unsuccessful).

Examples:
!rm execute a range measure for all enabled axes
rm x execute a range measure for X axis only (if enabled)

14.3. calmode (Closed Loop/Calibration Behavior)

```
Syntax:           !calmode or ?calmode
Parameter:        x, y, z, or a
                  0, 1 or 2

Description:      This instruction reads or sets the closed loop behavior on
                  power-up and also affects the calibration behavior:

                  0 = Cal instruction sets the zero position (default setting)
                      Closed loop enabled after cal move

                  1 = the power-up position remains the zero position even after
                      calibration
                      Closed loop is enabled from power-up

                  2 = Cal instruction sets the zero position
                      Closed loop is enabled from power-up

Remarks:    For activating the closed loop, the 'encmask' of the
                  corresponding axes must be set to one. If encmask is not set
                  or no encoder is present, the calmode only affects the axis
                  zero position behavior.

Response:         Calmode behavior.

Examples:
!calmode 0 0 0    Calmode behavior of axes X,Y,Z set to normal operation
!calmode 2 2      Axes X and Y enter closed loop after controller power-up
?calmode y        Query Y-axis for its calmode
```

14.4. caltimeout (Calibration Timeout)

```
Syntax:           !caltimeout or ? caltimeout
Parameter:        x, y, z or a
                  maximum time 1 to 120 (seconds as integer, no floating point)

Description:      This instruction specifies the timeout for calibration (cal)
                  and range measure (rm) moves. It may be set for each axis
                  individually.

Response:         Calibration timeout in seconds

Examples:
!caltimeout x 40  set the calibration timeout in X to 40 seconds
?caltimeout       query all axes for their timeout
```

14.5. caliboffset (Calibration Offset)

```
Syntax:           !caliboffset or ?caliboffset
Parameter:        x, y, z or a
                  Position

Description:      This instruction specifies an extra offset position above the
                  limitswitch E0 (towards higher positions) where to zero the
                  axis and take this position as lower software limit.
                  The unit depends on the current value of instruction dim.
                  Allowed range is 0 to 30mm equivalent.

Response:         Current calibration offset

Examples:
?caliboffset y          query the Y-axis for its current calibration offset
!caliboffset 1 1 1      set the calibration offset to 1 for X,Y and Z.
```

14.6. rmoffset (Range Measure Position Offset)

```
Syntax:           !rmoffset or ?rmoffset
Parameter:        x, y, z or a
                  Position

Description:      This instruction specifies an extra offset position below the
                  limitswitch EE (towards lower positions) where to take the
                  upper software limit.
                  The unit depends on the current value of instruction dim.
                  Allowed range is 0 to 30mm equivalent.

Response:         current calibration offset

Examples:
?rmoffset z       query the Z-axis for its current range measure offset
!rmoffset 1 1 1   set the range measure offset to 1 for X,Y and Z.
```

14.7. caldir (Calibration Direction)

```
Syntax:           !caldir or ?caldir
Parameter:        x, y, z or a
                  0 or 1

Description:      This instruction set the calibration direction to either
                  positive or negative positions. Default is negative direction.
                  If set to positive(=1), the upper software limit is set. This
                  instruction is not possible for systems with encoders.

Response:         0 = cal move to negative direction
                  1 = cal move to positive direction

Examples:
!caldir y 1       set Y axis calibration direction to positive
!caldir 0 0 1     set Z axis calibration direction to negative
?caldir           query all axes for their current calibration directions
```

14.8. calbspeed (Calibration Speed for Retraction)

Syntax: !calbspeed or ?calbspeed
Parameter: range 1 to 100 [*0.01 revolution/s]

Description: **This instruction is not used in extmode 1.**
Set or read the cal,rm calibration speed which is taken for traveling out of the limit switches E0 and EE. There is only one value for all axes.

Hint: Please refer to the **calvel**, **rmvel** instructions for improved **extmode 1** behavior.

Response: Currently used calibration speed

Examples:
!calbspeed 15 set the retraction speed to 0.15 [revolutions/s] for all axes.
?calbspeed query the controller for current retraction speed.

14.9. calrefspeed (Reference Signal Calibration Speed)

Syntax: !calrefspeed or ?calrefspeed
Parameter: range 1 100 [*0.01 revolution/s]

Description: This instruction transmits the reference calibration speed. This speed is taken for systems with encoders, when searching the reference on the scale. The default is 32. There is only one value for all axes. The value is not stored with !save instruction.

Response: Currently used calrefspeed [in 1/100 rev/s]

Examples:
!calrefspeed 5 set the retraction speed to 0.05 [revolutions/s] for all axes.

14.10. calpos (Calibration Position)

Syntax: !calpos or ?calpos
Parameter: x, y, z or a
position value

Description: This instruction is used for systems with encoders only. During calibration the encoder signal period is stored as soon as the E0 limit switch is left and may be queried later on with ?calpos.
This position may also be set to an other value. The value depends on the unit set by "dim". Allowed range is 0 to 30mm equivalent.

Response: within range of one encoder signal period

Examples:
?calpos y query Y-axis for its calibration position
!calpos 0 0 0 set calibration position to zero (X,Y and Z)
?calpos query all axes for their read calibration position

14.11. refdir (Direction for Searching Reference Signal)

Syntax: !refdir or ?refdir
Parameter: x, y, z or a
0 or 1

Description: This instruction is intended for systems with encoders and transmits the current or requested direction for searching the reference point on the scale. The default is 0 for minus direction.

Response: 0 = search in negative direction
1 = search in positive direction

Examples:
!refdir y 1 set the Y-axis reference search to positive direction
?refdir query all axes for their reference search directions

14.12. calvel (Calibration Velocities for CAL Instruction)

Syntax: !calvel or ?calvel
Parameter: none, x, y, z or a
two velocities > 0.0 [revolution/s] or [mm/s] if dim=9

Description: **This instruction is accessible in extmode 1 only.**
As a superset of the regular calbspeed command in combination with the vel command it now sets the two calibration velocities for the **cal** instruction (towards and out of cal endswitch). Out speed should be set slow for high accuracy.

Response: Two velocities (towards and out of endswitch) per axis

Examples:
!calvel x 10 0.5 Cal in X moves towards endswitch with velocity 10 [rev/s] or [mm/s], depending on dim and out of the endswitch with velocity 0.5
?calvel query all axes for their cal velocities
?calvel y query Y-axis for its cal velocities

14.13. rmvel (Range Measure Velocities for RM Instruction)

Syntax: !rmvel or ?rmvel
Parameter: x, y, z or a
two velocities > 0.0 [revolution/s] or [mm/s] if dim=9

Description: **This instruction is accessible in extmode 1 only.**
As a superset of the regular calbspeed command in combination with the vel command it now sets the two range measure velocities for the **rm** instruction (towards and out of rm endswitch). Out speed should be set slow for high accuracy.

Response: Two velocities (towards and out of endswitch) per axis

Examples:
!rmvel x 10 0.5 Rm in X moves towards endswitch with velocity 10 [rev/s] or [mm/s], depending on dim and out of the endswitch with velocity 0.5
?rmvel query all axes for their rm velocities
?rmvel y query Y-axis for its rm velocities

14.14. autopitch (Measure Pitch after CAL Instruction)

```
Syntax:           !autopitch or ?autopitch
Parameter:        x, y, z or a
                  0 or 1

Description:      Measures and sets the spindle pitch each time when executing a
                  cal instruction.
Hint:             Only works if encoders are present.
                  Not neccessary for spindles.

Response:         Autopitch enabled (1) or disabled (0, default)

Examples:
!autopitch 1 1 0  Measure and readjust pitch after each cal instruction X and Y
?autopitch x      query X-axis for its autopitch setting
```

15. Move Instructions

All move instructions include an automatic linear interpolation. Axis, which are started together reach their destination at the same time (vector move). Nevertheless, the accelerations and velocities of each axis are not hurt. The user can also start the axis independently from each other. In this case each axis drives which its own maximum parameters and the axes do not reach the destination at the same time.
E.g. !moa 10 10 followed by !moa z 1 makes X and Y move as a vector and Z independently.

15.1. moa (Move Absolute)

Syntax: !moa or moa
Parameter: none or x, y, z, a
position values within ±maxpos

Description: This instruction moves one or more axes to a requested destination. The unit of the input numbers depends on instruction dim.

Response: Each commanded (and enabled) axis responses either '@' after successfully completing the move, or 'E' if an error occurred.
The response depends on the autostatus setting which is assumed to be 1.

Examples:
moa x 10.2 the X-axis is moved to position 10.2 ([mm] assume dim=2)
moa 10 0 20 the axes X,Y,Z are moved to the given position
moa y 34.5 the Y-axis is moved to position 34.5 ([mm] assume dim=2)

15.2. mor (Move Relative)

Syntax: !mor or mor
Parameter: none or x, y, z, a

Description: This instruction moves one or more axes relative to the current position. The unit of the input numbers depends on instruction dim.

Response: Each commanded (and enabled) axis responses either '@' after successfully completing the move, or 'E' if an error occurred.
The response depends on the autostatus setting which is assumed to be 1.

Examples:
mor x 12.3 the X-axis is moved by 12.3 ([µm] assume dim=1)
!mor 1 1 the X and Y-axis are moved by 1 ([mm] assume dim=2)

!mor a 298 the A-axis is moved by 298 (unit depends on dim)
!mor -10 0 0 -10 the X and A-axis are moved by -10 (unit depends on dim)

15.3. m (Move Relative Shortcut)

```
Syntax:           !m or m
Parameter:        none

Description:      The instruction is a shortcut (abbreviation) of mor. It is
                  useful to speed up communication especially for consecutive
                  identical vectors. The vector is taken from the preceding !mor
                  or !distance instruction. The instruction will move enabled
                  axes if their distance is not zero.

Response:         Depends on state of autostatus, recommended is mode 3.

This is one example of consecutive moves:
!moa 1 2 3 4      will position to 1 2 3 4
!mor 1 1 1 1      will move to 2 3 4 5
m                 will move to 3 4 5 6
!distance 0 2 0 0
m                 will move to 3 6 5 6
```

15.4. distance (Distance for m)

```
Syntax:           !distance or ?distance
Parameter:        x, y, z or a
                  Distance (+-2600mm max.)

Description:      This instruction transmits the travel distance for !m
                  instructions. The unit depends on the selected dimension
                  (refer to "dim" instruction).
                  Hint: The distance value is also set by executing a !mor
                  command.

Response:         Currently used value for distance (unit depends on 'dim')

Examples:
?distance         query current distance values for all axes
?distance z       query Z-axis for its distance value
!distance 10 20   set X and Y distance
!distance 1 2 3   set X,Y and Z distance
!distance y 20    set Y distance. Other axes keep their distance value.
```

15.5. moc (Move to Center)

```
Syntax:           !moc or moc
Parameter:        x, y, z or a

Description:      This instruction centers all enabled axis to the midpoint
                  between lower and upper software limits. The recommended
                  precondition is to first execute the instructions !cal and !
                  rm.

Response:         each successful centered axis responds with ,@'.

Examples:
moc               moves all axes to their centers
moc z             the Z-axis is centered, with no move of other axis
```

15.6. go (Go To Position)

Syntax: !go or go
Parameter: none or x, y, z, a
position values within ±maxpos

Description: Used for position tracking applications.
Similar to the 'moa' instruction 'go' executes a move of one or more axes to an absolute position.

The differences to move instructions are:

- Go can be overwritten anytime, also when moving, by another go position (without the need to abort it first)
- Go does not generate a complete message
- Go is no vector move, each axis is started at its own velocity **'vel'**
- No autostatus reply on completion (**'statusaxis'** polling neccessary)

The unit of the input numbers depends on instruction dim.

Remarks: In order to check for a completed go move, please poll the **'statusaxis'** state, which should not be 'M' then.

Response: None.

Examples:

```
go x 10.2          the X-axis moves to position 10.2 ([mm] assume dim=2)
go 10.7 14  the axes X,Y   move to the given position
go 10.1 -0.5 0     the axes X,Y,Z move to the given position
```

15.7. speed (Speed Move)

Syntax: !speed or ?speed
Parameter: x, y, z or a
+ 100

Description: This instruction moves one or more axes with requested speed, and not to a specified position. The command may be stopped by setting speed back to zero.
As this is a "digital Joystick" function, this command only affects axes with Joystick enabled.

Response: current value for speed [revolutions/s]

Examples:

```
!speed 33 0.01     set speed for X= 33[revolutions/s] and Y= 0.01[revolutions/s]
!speed 0           set speed for X-axis to 0[revolutions/s] (stop X axis)
!speed 10          set speed for X-axis to 10[revolutions/s]
!speed y 0.001     set speed for Y-axis
?speed             query all axes for their current speed
?speed z           query Z-axis for current speed
```

15.8. a (Abort the Current Move)

```
Syntax:          !a or a
Parameter:       none

Description:     This instruction stops all axes and sets them into position
                 reached state.
                 You may also send a "Ctrl+C" (hex 0x03) command instead.

Response:        Each configured axis responds an ,@'.

Example:         a
```

15.9. delay (Set the Delay Time for Consecutive Moves)

```
Syntax:          ?delay or !delay
Parameter:       0 to 10000 [ms]

Description:     This instruction will insert a delay time between the
                 reception and execution of move commands (delayed start).
                 There is only one value for all axes.

Response:        Delay time in [ms]

Examples:
!delay 500       Set the delay time to 0.5 seconds
?delay           Query the current delay time
```

15.10. pause (Set the Pause after Position Reached)

```
Syntax:          ?pause or !pause
Parameter:       0 to 10000 [ms]

Description:     Complementary to "delay", this instruction adds a pause time
                 after the axes have reached their target positions. In
                 autostatus 1 mode the "@@@-." response is delayed by this
                 time. It may be used to insert an automatic settling time
                 after a move command.

Response:        Pause time currently used, in [ms]

Examples:
!pause 10        Delay the autostatus response by 10 milliseconds
?pause           Query the current pause time
```

15.11. pos (Read or Set Position)

```
Syntax:           !pos or ?pos
Parameter:        x, y, z or a
                  Position (+- 2600mm max.)

Description:      This instruction either reads or sets the current position.
                  The used position unit depends on the selected dimension
                  (refer to "dim" instruction).
      If an encoder and the 'encpos' is enabled, it returns the encoder position
                  of the axis.

Response:         Axis position(s) (depends on dim, and enc/encpos state)

Examples:
?pos              Query all axes for their positions
!pos100 200       Set positions of X=100 and Y=200 (unit depends on dim)
!pos 0.1          Set the position X=0.1 (unit depends on dim)
!pos y 2000       Set the position Y=2000 (unit depends on dim)
?pos z            Query Z-axis for its position
```

15.12. zero (Set Internal Position to Zero)

Syntax: !zero or zero
Parameter: x, y, z, a (or none)

Description: Unlike the command "!pos 0" this "!zero" instruction resets the internal position counter to zero.
It has to be used in applications where axes exceed the position limits, e.g. filter wheels (in such case a "!pos 0" instruction is not sufficient).
The zero instruction should be executed after completing one or several complete revolutions, before reaching the software limits. So the reference point remains at the same position.

Response: none.

Examples:
!zero Set all internal positions to zero
!zero z Set Z axis position to zero

15.13. clearpos (Set Internal Position to Zero)

Syntax: !clearpos or clearpos
Parameter: x, y, z, a (or none)

Description: For compatibility with LStep controllers.
Functionality is almost the same as with the 'zero' instruction.
The only difference is that the clearpos instruction is not executed when in closed loop.

Response: none.

Examples:
!clearpos Set all internal positions to zero
!clearpos x Set X axis position to zero

16. HDI: Joystick, Tackball and Handwheel Instructions

The hdi device velocities are limited by the **'secvel'** velocity as long as no cal/rm instruction has been executed. If an axis provides limit switches, it will stop when the corresponding switch, or a software settable limit, is reached.
The human device interface (HDI) tolerates hot plugging of the devices: It is possible to safely unplug, plug and change the input devices during operation of the controller.

16.1. joy (Generally Enable/Disable/Set Joystick Mode)

```
Syntax:           !joy or ?joy
Parameter:        0, 1, 2, 3, 4 or 5

Description:
!joy 0            disable the HDI device (joystick,trackball etc.)
!joy 2            enables the HDI device with position counting (=default)
                  Using other values than 0 or 2 is not recommended.

Response:         HDI (e.g. joystick, trackball, etc.) mode

Examples:
!joy 2            set HDI mode 2 (HDI on, device e.g. joystick can be used)
?joy              query the HDI mode
```

16.2. joydir (Joystick Direction or Assign Joystick)

```
Syntax:           !joydir or ?joydir
Parameter:        none or x, y, z, a
                  and 0, 1, 2, -1, -2

Description:      In addition to the 'joy' instruction, this instruction is used
                  to enable/disable single HDI axes (e.g. of a joystick,
                  trackball, ErgoDrive etc.) and set their counting directions.
      The parameter functions are as follows:
      0  = Disable the HDI axis (e.g. joystick deflection is ignored)
                  1  = Enable the HDI axis, no motor current reduction
      2  = Enable the HDI axis, with current reduction support
                      (default)
                  -1 = Same as 1, direction reversed
                  -2 = Same as 2, direction reversed

Remarks:    Please make sure that the joystick function is globally
                  enabled by the 'joy' instruction.

                  When using a 4 axis controller with a 3 axis HDI device, the
                  3rd axis must be assigned to axis 3(=default setting), 4 or
                  both (3 and 4) by enabling/disabling their joydir!

Response:         HDI directions of the axes or specified axis

Examples:
!joydir 1         enable HDI X-axis, reversed, without current reduction.
!joydir z 0       disable HDI Z-axis.
?joydir           query all axes for their HDI direction settings.
!joydir 2 2 0 2   set positive direction, allow current reduction, assign the
                  joysticks 3rd axis to the controller A axis instead of Z.
```

16.3. joywindow (Joystick Window)

Syntax: !joywindow or ?joywindow
Parameter: 0 to 100

Description: This instruction sets the with of middle range, where joystick deflection has no effect to motor movement.
Please note that there is only one value for all axes!
This value should not be reduced, as this may result in slow unwanted moving of axes even when the joystick is apparently not deflected. Increasing the value will result in a loss of speed resolution.

Response: joywindow value

Examples:
?joywindow query for joystick window
!joywindow 14 set joystick window to 14

16.4. joyvel (Joystick Velocity)

Syntax: !joyvel or ?joyvel
Parameter: x, y, z or a
0.0001 to 100 [revolutions/s] or [mm/s] for dim = 9

Description: **This instruction is accessible in extmode 1 only!**
In extmode=1 this instruction must be used to set the joystick velocities. If so, the vel command has no influence to the joystick velocity. In normal mode (extmode=0) the joystick velocities are derived from the axis vel settings.

Response: Currently used joystick velocities

Examples:
!joyvel 12.5 20 0.4 Set joystick velocities for 3 axes
!joyspeed z 1 Set joystick velocities for z to 1 [rev/s], (e.g. dim=2)
or [mm/s] if dim=9
?joyvel x Query X-axis for its joystick velocity

16.5. joyspeed (Joystick Speed Presets for BPZ Device)

Syntax: !joyspeed or ?joyspeed
Parameter: 1, 2 or 3 and
0.0001 to 100 [revolutions/s]

Description: Only used by a customer designed external device (called BPZ), this instruction sets the joystick speeds for the three speed buttons (Slow, Medium, Fast). Unit is in motor revolutions per second (like 'vel' instruction). While the velocity applies to all axes, each speed button has to be set individually:
1 = Slow Button speed, one parameter for all axes
2 = Medium Button speed, one parameter for all axes
3 = Fast Button speed, one parameter for all axes

Response: Speed currently assigned to the specified button

Examples:
?joyspeed 1 Query for "Slow" joystick button speed
!joyspeed 3 30 Set "fast" joystick button speed to 30 [revolutions/s]

16.6. keymode (Joystick Key Mode)

```
Syntax:           !keymode or ?keymode
Parameter:        0, 1 or 2

Description:      Assign keyspeed values to the Joystick buttons. The Joystick
                  can be used with two different velocity settings slow/fast.
      'vel' or 'joyvel' instructions have no effect in keymode 1, 2.
      Also refer to 'keyspeed'.
      Please note that other special functions which require Joystick buttons
                  (e.g. some snapshot modes) should not be used at the same time
                  as keymode.

      Pressing F1 selects the fast keyspeed values of X and Y axis,
      while    F4 selects the slow keyspeed values of X and Y axis.

      Pressing F2 selects the fast keyspeed value of the Z axis,
      while    F3 selects the slow keyspeed value of the Z axis.

                  0 = Normal key functions
                  1 = X/Y and Z Joystick velocity, initial value: slow [F4,F3]
                  2 = X/Y and Z Joystick velocity, initial value: fast [F2,F1]

Response:         keymode as decimal number

Examples:
!keymode 1        slow preset keymode
?keymode          => 0 (assumed keymode is disabled)
```

16.7. keyspeed (Joystick Key Speed Presets)

```
Syntax:           !keyspeed or ?keyspeed
Parameter:        x, y, z or a
                  0.0000025 to 100 [mm/s]

Description:      Two Joystick velocities can be set for each axis individually.
                  The first parameter is the slow value and the second parameter
                  is the fast. Unit is always mm/s, independent from 'dim'.
      In keymode 1 or 2 the X and Y values (slow/fast) are assigned to F4 and
                  F1, while the Z values are assigned to F3/F2.
      Please also refer to 'keymode'.

Response:         Two floating point values per axis (slow fast)
                  single axis  : => [slow] [fast]
                  multiple axes: => [slow_x] [fast_x] [slow_y] [fast_y] ...

Examples:
?keyspeed x       => 1 10 (Query for X Joystick button velocities)
?keyspeed         => 1 10 1 10 0.1 1 (Query 3 axis controller)
!keyspeed z 0.1 1 (Set fast Joystick button speed to 0.1 and fast to 1 [mm/s])
!keyspeed 5 20 2 10 0.2 2 (Set 3 axes at once)
```

16.8. joycurve (Joystick Characteristic)

```
Syntax:          !joycurve or ?joycurve
Parameter:       x, y, z, or a
                 0, 1, 2

Description:     The speed characteristic of Joystick deflection
                 can be independendly defined for each axis.

                 0 = Logarithmic (standard)
                 1 = Linear
                 2 = Quadratic

Response:        Currently used characteristic

Examples:        !joycurve 0 0 0 => set X,Y,Z axes to logarithmic
                 !joycurve z 1   => set Z axis to linear
                 ?joycurve       => query all active axes characteristics
```

16.9. key (Read HDI Device Key State)

```
Syntax:          ?key or key
Parameter:       none or key number 1, 2, 3, 4

Description:     This instruction reads the state of up to 4 HDI device keys.

                 0 = key is currently released or not available
                 1 = key is currently pressed

Response:        1 or 4 Key states, each either 0 or 1

Examples:        key   => query all keys, returns 4 numbers, e.g. 0 0 0 0
                 key 1 => query only key 1 (e.g. F1 Joystick button)
```

16.10. keyl (Read HDI Device Latched Key State)

```
Syntax:          ?keyl or !keyl
Parameter:       none or key number 1, 2, 3, 4

Description:     This instruction reads the latched state of up to 4
                 HDI device keys and clears their latched state. The latch
                 state is cleard after reading.

                 0 = key is is/was released since last key or keyl instruction
                 1 = key is is/was pressed since last key or keyl instruction

Response:        1 or 4 Latched key states, each either 0 or 1

Examples:        key    => query all keys, returns 4 numbers, e.g. 0 0 0 0
                 key 1  => query only key 1 (e.g. F1 Joystick button)
                 !key 1 => clear latch state of key 1 (=0)
                 !key   => clear latch state of all keys (=0)
```

16.11. hwfactor (Handwheel Transmission Factor)

```
Syntax:           !hwfactor or ?hwfactor
Parameter:        none or x, y, z, a
                  and -200.0 to 200.0

Description:      The handwheel transmission factor represents the stage travel
                  distance in millimeter per handwheel knob revolution, which is
                  a floating point number between -200.0 and +200.0.
                  Negative factors reverse the travel direction.
                  Higher factors result in a more coarse resolution, as a
                  typical handwheel provides about 100000 steps per revolution.

Response:         Currently used handwheel factor(s)

Examples:
!hwfactor 14 14   => One knob revolution in X or Y results in 14mm axis travel
!hwfactor x 100   => One knob revolution in X results in 100mm travel
?hwfactor         => Query all axes for their transmission factor
```

16.12. hwfactorb (Alternate Handwheel Factor)

```
Syntax:           !hwfactorb or ?hwfactorb
Parameter:        none or x, y, z, a
                  and -200.0 to 200.0

Description:      Similar to 'hwfactor', this instruction accesses the
                  alternate parameter for the second travel distance per
                  knob revolution. As available with the ErgoDrive.
                  Negative factors reverse the travel direction.

Response:         Currently used alternate handwheel factor(s)

Examples:
!hwfactorb 26.6 26.6  => One knob revolution in X or Y results in 26.6mm travel
?hwfactorb y          => Query Y axis for its alternate transmission factor
```

16.13. hwfilter (Handwheel Noise Filter)

```
Syntax:           !hwfilter or ?hwfilter
Parameter:        0 or 1

Description:      This instruction sets or reads the handwheel noise filter
                  state.

                  1 = Noise filter is active (recommended, default)
                  0 = Noise filter is deactivated (finer step resolution)

                  The filter can only be activated/deactivated for all axes.
                  Disabling the filter may result in a finer resolution.
                  But it also may result in some inaccuracy between automatic
                  moves, as its signal noise will cause a permanent slight
                  position jitter.

Response:         Current state of handwheel filter

Examples:
!hwfilter 0       => No noise filter for handwheel, increased finer resolution
?hwfilter         => Query hwfilter state
```

16.14. tbfactor (Handwheel Transmission Factor)

```
Syntax:           !tbfactor or ?tbfactor
Parameter:        none or x, y, z, a
                  and -200.0 to 200.0

Description:      This instruction sets or reads the trackball transmission
                  factor, which is a floating point number between -200.0 and
                  +200.0. A sign change may be used to change direction.

Response:         Currently used trackball factor(s)

Examples:
!tbfactor x 100   => X axis is 10 times more sensitive than the default setting
?tbfactor         => Query all axes for their transmission factor
```

16.15. zwheel (Is Z-Wheel Available)

Syntax: ?zwheel or zwheel
Parameter: none

Description: The instruction zwheel returns:

0 = HDI device has no additional Z-Wheel
1 = HDI device has additional Z-Wheel

Response: 0 or 1

Example: ?zwheel => 0

16.16. zwtravel (Z-Wheel Travel per wheel revolution)

Syntax: !zwtravel or ?zwtravel
Parameter: 1, 2 or 3 and
- 50.0 to 50 [mm/revolution]

Description: Only used when a HDI device with Z-Wheel is connected to the controller. This instruction sets the Z travel distances for one revolution of the Z-Wheel knob.

In order to prevent mechanical damage, please make sure that the correct **'pitch'** and **'gear'** settings are made and **'save'**d. It is recommended to restart or **'reset'** the Tango controller after changing these parameters.

Please also check that **'secvel'** and **'vel'** or **'joyvel'** speed limitations do not prevent faster traveling when turning the Z-Wheel.

1 = Default (used when no HDI function key is pressed)
2 = Used while Joystick F4 button is pressed (suggested slow)
3 = used while Joystick F1 button is pressed (suggested fast)

Presets for travel distance are
1: 0.1 mm/rev
2: 0.01 mm/rev
3: 1.0 mm/rev

If neccessary, the default travel may be set to zero (0) for security reasons. So the axis will move only when a key is pressed (F1, F4).

It is also possible to set negative values for direction change. While the **'joydir'** command changes the direction in general.

Response: Stage travel distance currently assigned to the specified function

Examples:
?zwtravel 1 Query for default Z-Wheel travel distance
!zwtravel 3 2.5 Set F1 "fast" Z-Wheel travel to 2.5 [mm/revolution]

16.17. tvrjoy (Pulse and Direction Joystick Functionality)

```
Syntax:           !tvrjoy or ?tvrjoy
Parameter:        0, z, a

Description:      This instruction enables and assigns the AUX-IO pulse and
                  direction input to an axis for simple joystick functionality.
      The behavior is similar to the trackball, which is available as HDI
                  device.
                  Important: This option must not be used for absolute
                  positioning of axes by an external controller. Please use the
                  tvr functionality for this applications.

      0 = Disabled
      z = Assigned to Z-axis
      a = Assigned to A-axis

Response:         Currently assigned axis

Examples:
!tvrjoy 0         Disable AUX-IO tvr joystick function
!tvrjoy z         Assign AUX-IO tvr joystick function to Z-axis
?tvrjoy           Query assigned axis
```

16.18. tvrjoyf (Pulse and Direction Joystick Factor)

```
Syntax:           !tvrjoyf or ?tvrjoyf
Parameter:        -200 to +200

Description:      This instruction sets or reads the tvrjoy transmission factor,
                  which is a floating point number between -200.0 and +200.0. A
                  sign change may be used to change direction.

Response:         Currently used tvr factor

Examples:
!tvrjoyf 100      Axis is 10 times more sensitive than the default setting
?tvrjoyf          Query tvrjoy transmission factor
```

16.19. hdi (Read HDI ID)

```
Syntax:           ?hdi or hdi
Parameter:        none

Description:      This instruction reads the ID number of the connected hdi
                  device. A second number shows how good the hardware ID code
                  matches the theoretical ID value [in %]. This value should be
                  more than 30.

                  ID range = 0,1,2, ... 16 (=no device connected)
                  Match    = 0 (poor) ... 100 (good)

Response:         HDI ID number and the hardware coded ID match in percent.

Example of hdi response: 12 97      (hdi device 12, 97% match)
```

16.20. hdimode (HDI Mode Options)

```
Syntax:           ?hdimode or !hdimode
Parameter:  Set LSB or more bits at once:   string of 0s and 1s,
                  or single bit with two numbers: 0 to 15 and 0 or 1

Description:      This instruction gives access to extended HDI device options.
      Options may be set either by a string of levels (0s and 1s)
                  or by bit number and logic state (on/off = 1/0).
      The string is LSB first (bit 0 is the first and leftmost).

      Bit   Function

                   0:   ErgoDrive toggle mode 0=off, 1=on

                   1:   Joystick KeySpeed Toggle in KeyModes 1 and 2:
                        0=select KeySpeed velocitiy with F1 and F4,
                        1=toggle KeySpeed velocitiy by pressing F1

                   2:   - reserved -
                   3:   - reserved -
                   4:   - reserved -
                   5:   - reserved -
                   6:   - reserved -
                   7:   - reserved -
                   8:   - reserved -
                   9:   - reserved -
                  10:   - reserved -
                  11:   - reserved -
                  12:   - reserved -
                  13:   - reserved -
                  14:   - reserved -
                  15:   - reserved -


Response:         Single mode bit or all 16 mode bits as ASCII string

Examples:
!hdimode 100010   Set mode bits 0 and 4 to "on", bits 1,2,3,5 to "off". Bits
                  6...15 are left unchanged.
!hdimode 0 1      Set mode bit 0 to 1 (on) = ErgoDrive Toggle Mode selected
!hdimode 5 1      Set mode bit 5 to 1 (on)
?hdimode          query the current state of all mode bits (returns 16 digits)
?hdimode 0        query the current state of mode bit 0 (toggle mode)
```

17. Digital and Analogue I/O

The Tango provides several digital I/O, two analogue outputs (channel 0 and 1) and one analogue input. These are available on the optional auxillary I/O port. The analogue output channel 2 is reserved for special purpose. Furthermore the HDI Interface analogue inputs may be read as well, if no HDI-device is connected.

17.1. digin (Digital Input)

```
Syntax:           ?digin or digin
Parameter:        none or 0 to 15

Description:      Only available with I/O extension board.
                  This instruction queries the logic state of one or all digital
                  inputs. If no parameter is used all inputs are returned as a
                  string of 16 characters, ASCII 0 or 1, LSB (channel #0) first.

Response:         logic state of digital inputs

Examples:
?digin            query all 16 digital inputs (response e.g. 0000000000000000)
?digin 8          query digital input 8 (response e.g. 1)
```

17.2. digout (Digital Output)

```
Syntax:           !digout oder ?digout
Parameter:  Set LSB or more bits at once:   string of 0s and 1s,
                  or single bit with two numbers: 0 to 15 and 0 or 1

Description:      Only available with I/O extension board.
                  This instruction sets or reads back the logic level of the
                  optional digital outputs.
      Outputs may be set either by a string of levels (0s and 1s)
                  or by channel number and signal level.
      The string is LSB first (channel 0 is the leftmost).

Response:         current output state

Examples:
!digout 11110000  The digital outputs 0,1,2,3 are set to logic ‚1' and the
                  outputs 4,5,6,7 are set to logic ‚0'. Outputs 8...15 are
                  left unchanged.
!digout 5 1       set digital output #5 to logic 1
?digout           query the current state of all outputs
?digout 8         query the current state of output 8
!digout 7 0       set output 7 to 0
```

17.3. adigin (AUX-I/O Digital Input)

```
Syntax:           ?adigin or adigin
Parameter:        none or 0 to 3

Description:      Available with the AUX-I/O connector.
                  This instruction queries the logic state of one or all digital
                  inputs. If no parameter is used all inputs are returned as a
                  string of 4 characters, ASCII 0 or 1, LSB first:

      ~~0 = Bit 0 = AUX-I/O Pin 1 (Takt In)~~ may not be available!
                  1 = Bit 1 = AUX-I/O Pin 2 (V/R In)
                  2 = Bit 2 = AUX-I/O Pin 3 (Stop)
                  3 = Bit 3 = AUX-I/O Pin 4 (SnapShot2)

Response:         logic state of digital inputs

Examples:
?adigin           query all (4) AUX-I/O digital inputs (response e.g. 1111)
?adigin 3         query AUX-I/O digital input 3 ("SnapShot2", response e.g. 1)
```

17.4. adigout (AUX-I/O Digital Output)

```
Syntax:           !adigout oder ?adigout
Parameter:  Set LSB or more bits at once:   string of 0s and 1s,
                  or single bit with two numbers: 0 to 3 and 0 or 1

Description:      Available with the AUX-I/O connector.
                  This instruction sets or reads back the logic level of the
                  AUX-I/O digital outputs.
      Outputs may be set either by a string of levels (0s and 1s)
                  or by channel number and signal level:

      ~~0 = BIT0 = AUX-I/O Pin 5 (TAKT_OUT)~~ may not be available!
                  1 = BIT1 = AUX-I/O Pin 6 (VR_OUT)
                  2 = BIT2 = AUX-I/O Pin 7 (SHUTTER_OUT)
                  3 = BIT3 = AUX-I/O Pin 8 (TRIGGER_OUT)

      The string is LSB first (channel 0 is the leftmost).

Response:         current output state

Examples:
!adigout 1011     All digital outputs except output 1 are set to logic 1.
!adigout 10 Digital outputs 0 and 1 are set to logic 1(BIT0) and 0(BIT1),
                  outputs 2 and 3 are left unchanged.
!adigout 2 1      set digital output #2 to logic 1
?adigout          query the current state of all outputs
?adigout 3        query the current state of output 3
!adigout 1 0      set output 1 to logic 0
```

17.5. anain (Analogue Input)

Syntax: ?anain
Parameter: c (c = channel)
0 to 15 (channel number)

Description: This instruction reads the current value of one analogue input channel. The range is decimal from 0 (=0V) to 1023 (=5V).

Channel No	Connector	Pin	Signal Name
0	HDI	1	Joystick X
1	HDI	2	Joystick Y
2	HDI	3	Joystick Z
3	HDI	4	
4	HDI	5	Speedpoti
5	HDI	6	
6	HDI	7	
7	HDI	8	
8	HDI	9	
9	HDI	10	HDI-ID
10	AUX-IO	9	ANAIN0
11	internal	-	U-HIP
12	internal	-	V-MOT
13	EXT	20	X-ID0
14	EXT	18	X-ID1 / temp
15	internal	-	REF (2.5V)

Calculating the internal motor voltage:

Umot[V] = (5 / 1023) * [anain c 12] * (55.7/4.7)
More accurate:
Umot[V] = (2.5 / [anain c 15]) * [anain c 12] * (55.7/4.7)

Calculating the internal PSE voltage:

Umot[V] = (5 / 1023) * [anain c 11] * (14.7/4.7)
More accurate:
Umot[V] = (2.5 / [anain c 15]) *[anain c 11] * (14.7/4.7)

Calculating the case temperature (if available):

T[°C] = (250 / [anain c 11]) * [anain c 14]

Example:
?anain c 10 Query level of channel 10 (analogue input of AUX-IO connector)

17.6. anaout (Analogue Output)

```
Syntax:           !anaout or ?anaout
Parameter:        0 to 100 in percent  (100% = 10V)
                  c                    (c = single channel keyword)
                  0, 1 or 2            (single channel number)

Description:      This instruction sets and reads the analog output signal
                  levels in percent. There are two ways to access the values,
                  with or without the 'c' keyword (see examples below). So it is
                  possible to address a single channel by using the 'c' or
                  channel 0 or all channels by directly writing the percent
                  values. Fractional numbers may be used, too.
                  100% corresponds to 10 Volts.
```

Channel No	Connector	Pin	Signal Name
0	AUX-IO	10	ANOUT0
1	AUX-IO	11	ANOUT1
2	reserved	-	-

```
Response:         Analogue output signal level in percent

Examples:
!anaout 100 50.1  Set channel 0 = 100% (10V) and channel 1 = 50.1% (5.01V)
!anaout 75        Set channel 0 = 75% (7.5V)
!anaout c 1 25.3  Set channel 1 to 25.3% (2.53V)
?anaout           Query all channels for their output level
?anaout c 0       Query channel 0 output level
```

17.7. stoppol (Mode and Polarity of Stop Input Signal)

```
Syntax:           !stoppol or ?stoppol
Parameter:        0 (= active low), 1 (= active high)

Response:         Mode and polarity of AUX-I/O stop signal input:

                  0 = active low , Joystick not affected by stop signal
                  1 = active high, Joystick not affected by stop signal
                  2 = active low , all moves disabled as long as signal applied
                  3 = active high, all moves disabled as long as signal applied
                  4 = active low , all moves disabled until "!stop 0" command
                  5 = active high, all moves disabled until "!stop 0" command

Description:      The stop input has an internal pull-up resistor to 5V.
                  If you connect an NO (normal open) stop switch, you have to
                  select any low active mode.
                  For NC (normal close) switches please select high active.

Example:
!stoppol 1        => Set the polarity of the AUX-I/O stop input to active high.
```

17.8. stop (Release Stop Condition)

```
Syntax:           !stop 0
Parameter:        0

Response:         -
Description:      Release stop condition in active stoppol modes 4 or 5.
Example:          !stop 0
```

17.9. shutter (Shutter Out Signal of AUX-IO)

```
Syntax:           !shutter or ?shutter
Parameter:        0 (= low), 1 (= high)

Response:         Output level of shutter signal

Description:      Manually set the AUX-IO shutter out signal to the desired TTL
                  level.

Example:
!shutter 1        => Set the shutter out signal into TTL high state.
```

18. Encoder Instructions

To enable encoder functionality, first the encoder mask has to be set for the corresponding axes. After that a cal move will activate the encoders ('enc'=1), so they can be used. Manually setting the encoders 'enc' state to 1 is not recommended. This may cause trouble with when in closed loop mode, and in case of analog encoders the signal correction will be missing also.

18.1. encmask (Encoder Mask)

Syntax: !encmask or ?encmask
Parameter: x, y, z or a,
0 or 1

Response: Encoder enable mask

Description: The instruction reads or sets the encoder globally enable mask. It is neccessary to unmask encoders (=1) as a first step in order to use them later. This instruction does not activate the encoders, it just globally enables the usage of them. Please note: Encoders get detected and finally used after a successful calibration command 'cal'. Here the signal correction data is measured, too.

Example:
!encmask 1 1 1 Globally enable encoders for X, Y and Z-axis
!encmask z 0 Globally disable encoder for Z-axis
?encmask Query encoder mask state for all axes

18.2. enc (Encoder Active)

Syntax: !enc or ?enc
Parameter: x, y, z or a
0 or 1

Response: Encoder active state

Description: This instruction may be used to determine if a 'cal' command has activated the encoders or not. In order to activate them, the encmask has to be set to 1 first. It is not recommended to activate encoders manually by setting enc to 1. Refer to the 'encmask' description for further information.

0 = Encoder is inactive (not used)
1 = Encoder is activated

Example:
?enc Globally enable encoders for X, Y and Z-axis
?enc x Globally disable encoder for Z-axis
!enc x 1 Manually activate the X-axis encoder (not recommended!)

18.3. encperiod (Encoder Signal Period)

```
Syntax:           !encperiod or ?encperiod
Parameter:        x, y, z or a
                  0.0001 to 1.000 [mm]

Response:         Encoder signal period(s)

Description:      This command reads or sets the encoder signal period. The unit
                  is always [mm].

Example:
!encperiod 0.5 0.5 0.001      Set encoder period for X and Y to 500µm, Z to 1µm
!encperiod y 0.020            Set encoder period of Y-axis to 20µm
?encperiod                    Read encoder period of all axes
?encperiod x                  Read encoder period of X-axis
```

18.4. encdir (Encoder Counting Direction)

```
Syntax:           !encdir or !encdir
Parameter:        x, y, z or a
                  0 or 1

Response:         Encoder counting direction

Description:      The encoder counting direction is set automatically by the
                  calibration 'cal' move. It is not neccessary to set the the
                  encoder direction and it must not be set when in closed loop.
      Only if the axis is not used for closed loop (e.g. only for relative
                  distance measuring) the encdir can be set manually.

                  0 = Encoder counting direction default
      1 = Encoder counting direction reversed

Example:
!encdir 1 1 1     Reverse encoder counting direction for all axes
!encdir x 1       Reverse encoder counting direction for X-axis only
?encdir           Query encoder counting direction of all axes
?encdir y         Query encoder counting direction of Y-axis only
```

18.5. encvel (Encoder Auto-Ajust Velocity)

```
Syntax:           !encvel or !encvel
Parameter:        x, y, z or a
                  0.01 ... 20.0

Response:         Encoder detect and auto-calibration velocity

Description:      The velocity for encoder auto-calibration can be set or read
                  by this command. It is recommended to keep the default
                  setting.

Example:
!encvel 0.5 0.5 0.5     Set encoder auto-adjust velocity for all axes
!encvel x 0.5           Set encoder auto-adjust velocity for X-axis only
?encvel                 Query encoder auto-adjust velocity of all axes
?encvel y               Query encoder auto-adjust velocity of Y-axis only
```

18.6. encttl (Encoder has TTL Signal)

```
Syntax:           !encttl or ?encttl
Parameter:        x, y, z or a
                  0 or 1

Response:         Currently selected encoder signal type(s)

Description:      This command reads or writes the currently selected type of
                  encoder signal processing.

                  0 = Encoder has analog sin/cos signals
      1 = Encoder has digital quadrature A/B signals (e.g. RS422)

Example:
!encttl 0 0 1     Y and Y axis encoders are analog, Z is digital A/B encoder
!encttl z 1       Set Z encoder signal processing to digital
?encttl           Query all axes for their currently used signal type
?encttl x         Query X-axis for its currently used signal type
```

18.7. encref (Use Encoder Reference Signal)

```
Syntax:           !encref or ?encref
Parameter:        x, y, z or a
                  0 or 1

Response:         Encoder reference signal used / not used

Description:      This functionality is currently not supported.

      0 = Encoder reference signal not used
      1 = Encoder reference signal used for calibration

Example:
!encref 1 1 0     Utilize encoder reference signal for X and Y-axis
!encref x 1       Utilize encoder reference signal for Y-axis
?encref           Query Encoder reference signal utilization state of all axes
?encref x         Query Encoder reference signal utilization state of X-axis
```

18.8. encnas (Use Encoder NAS Error Signal)

```
Syntax:           !encnas or ?encnas
Parameter:        x, y, z or a
                  0 or 1

Response:         Encoder NAS error signal used / not used

Description:      Before enabling this functionality please make sure that the
                  connected encoder provides a NAS error signal.
      If enabled, a encoder NAS error also generates an internal 'err' error
                  state. The NAS input signals an encoder error state by a TTL
                  low level.

      0 = NAS encoder input state is ignored (default)
      1 = NAS encoder input signal is used for extended error
                      detection

Example:
!encnas 1 1 0     Utilize encoder NAS signal for X and Y-axis
!encnas x 1       Utilize encoder NAS signal for Y-axis
?encnas           Query Encoder NAS signal utilization state of all axes
?encnas x         Query Encoder NAS signal utilization state of X-axis
```

18.9. encrefstatus (Encoder REF Signal State)

```
Syntax:           ?encrefstatus or encrefstatus
Parameter:        x, y, z, a (or none)

Response:         Encoder reference signal state

Description:      Returns the REF signal input state.

      0 = REF signal is inactive
      1 = REF signal is active (encoder is on a reference mark)

Example:
encnasstatus      Query REF signal state for all axes
encnasstatus x    Query REF signal state for X-axis only
```

18.10. encrefstatusl (Latched Encoder REF Signal State)

```
Syntax:           ?encrefstatusl or encrefstatusl
Parameter:        x, y, z, a (or none)

Response:         Latched encoder reference signal state

Description:      Returns the latched REF signal input state.
                  If the REF signal was active since last reading
                   of the encrefstatusl, a 1 is returned.

      0 = REF signal is/was inactive
      1 = REF signal is/was active (encoder is/was on a
                                              reference mark)

Example:
encnasstatus      Query latched REF signal state for all axes
encnasstatus x    Query latched REF signal state for X-axis only
```

18.11. encnasstatus (Encoder NAS Error Signal State)

```
Syntax:           ?encnasstatus or encnasstatus
Parameter:        x, y, z, a (or none)

Response:         Encoder NAS error signal state

Description:      Returns the NAS error signal input state.

      0 = NAS signal is inactive (encoder signals 'no error')
      1 = NAS signal is active (error flag is set by encoder)

Example:
encnasstatus      Query NAS signal (error) state for all axes
encnasstatus x    Query NAS signal (error) state for X-axis only
```

18.12. encerr (Encoder Error State)

```
Syntax:           !encerr or ?encerr
Parameter:        x, y, z or a
                  0

Response:         Encoder error state

Description:      This command reads or resets the encoder error state.
      On error the encoder signal is invalid and a potentially running closed
                  loop for the corresponding axis is switched off.

      0 = No error, normal function
      1 = Encoder error

Example:
!encerr 0         Reset encoder error
?encerr           Read encoder error states of all axes
?encerr x         Read encoder error states of X-axis only
```

18.13. encamp (Encoder Signal Amplitude)

```
Syntax:           ?encamp
Parameter:        x, y, z or a

Response:         Encoder signal amplitude in percent as integer

Description:      This command reads the encoder signal amplitude.
      100% represents the maximum undistorted signal amplitude.

      0 = No error, normal function
      1 = Encoder error

Example:
?encamp           Read all encoder amplitudes
?encamp x         Read X encoder amplitudey
```

18.14. encpos (Encoder Position)

```
Syntax:           !encpos or ?encpos
Parameter:        x, y, z or a
                  0 or 1

Response:         Position output type

Description:      If set to 1 and the encoder is activated (corresponding enc =
                  1), a ‘?pos’ returns the encoder position.
      Refer to the ‘pos’ and ‘enc’ commands for further information.

      0 = pos command reads the user position (default)
      1 = pos command reads the encoder position (if encoder active)
Example:
!encpos 1 1 0     a ‘pos’ command returns the encoder position for X and Y-axis
                  (if encoders are acive)
!encpos x 1       a ‘pos’ command returns the encoder position for the X -axis
                  (if encoder is acive)
?encpos           Read position output type for all axes
?encpos x         Read position output type for X-axis only
```

18.15. hwcount (Hardware Counter)

```
Syntax:           ?hwcount or hwcount
Parameter:        x, y, z or a

Response:         Hardware counter reading(s)

Description:      Hwcount returns the position(s) of the independend TTL encoder
                  counter. It is a digital counter that counts the signal slopes
                  (4 per period) and does not provide signal interpolation. So
                  one signal period corresponds to a counter reading of 4.
      See also the 'clearhwcount' command.

Example:
hwcount           Returns the counter readings of all axes
hwcount x         Returns the counter readings of X-axis only
```

18.16. clearhwcount (Clear Hardware Counter)

```
Syntax:           !clearhwcount or clearhwcount
Parameter:        x, y, z or a

Response:         Reset hardware counter reading(s)

Description:      This command resets the hardware counter(s) to zero.

Example:
clearhwcount      Reset hwcount position of all axes to zero
clearhwcount x    Reset hwcount position of X-axis to zero
```

19. MR Encoder Instructions

19.1. mra (MR Amplitude Correction Factor)

```
Syntax:           !mra or ?mra
Parameter:        x, y, z or a
                  0.8 to 1.2

Response:         Currently used correction factor(s)

Description:      This command reads or sets the cosine amplification correction
                  factor of the analogue encoder signal (here: sin/cos amplitude
                  ratio).
                  This factor is calculated automatically on each calibration
                  move 'cal' and should not be changed. If the axis is manually
                  controlled and only used for relative measurement, so that no
                  'cal' is possible, the user may determine the ratio itself and
                  then write it into mra for more accurate results. Please also
                  refer to the mro command.

Example:
?mra              Read MR signal correction factor of all axes
?mra x            Read MR signal correction factor of X-axis only
!mra x 1.0095     Amplify the X cosine signal by *1.0095 compared to the sine
```

19.2. mro (MR Offset Correction Value)

```
Syntax:           !mro or ?mro
Parameter:        x, y, z or a
                  -2048 to +2048

Response:         Currently used correction value(s)

Description:      This command reads or sets the sine and/or cosine offset
                  compensation value as 16bit signed digits.
                  This factor is calculated automatically on each calibration
                  move 'cal' and should not be changed. If the axis is manually
                  controlled and only used for relative measurement, so that no
                  'cal' is possible, the user may determine the offset itself
                  and then write it into mro for more accurate results. Please
                  also refer to the mra command.

Example:
?mro              Read MR signal offset value sine and cosine for all axes
?mro x            Read MR signal offset value sine and cosine for X-axis only
!mro 48 -100 0 0 0 0 0  Set X offset to sin=48digit, cos=-100digit, Y, Z = 0
!mro y 16 -28     Set Y offset to sin=16digit, cos=-28digit
!mro y 16         Set only sine offset of Y encoder
```

19.3. mrp (MR Signal Peak-To-Peak Measuring Result)

```
Syntax:           !mrp or ?mrp
Parameter:        x, y, z or a
                  -2048 to +2048

Response:         [sine max] [sine min] [cosine max] [cosine min] reult(s)

Description:      This command reads or sets the sine and/or cosine peak values,
                  measured since they were reset the last time.
      It is just a measurement and has no effect to the signal processing
                  itself. The returned values are signed 16bit digits.

Example:
?mrp x            Returns [x_sin max] [x_sin min] [x_cos max] [x_cos min]
?mrp              Returns the above, but for all axes (up to 16 values)
!mrp x 0 0 0 0    Reset the peak-to-peak measurement for x
!mrp x 0 0        Reset only the X sine min, max values
!mrp 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 Reset measurement for all 4 axes
```

19.4. mrt (MR Signal Level)

```
Syntax:           ?mrt
Parameter:        x, y, z or a
                  1 to 32767

Response:         [sine] [cosine] reult(s)

Description:      This command reads the corrected sine and cosine A/D converter
                  results as signed 16bit digits.
      If there is no count parameter transmitted, the command returns 10
                  measurement result lines per default.

Example:
?mrt x 1          Returns one line with [x_sin] [x_cos] signal digits
?mrt 1            Returns the above, but for all axes (up to 8 values):
                  [x_s] [x_c] [y_s] [y_c] [z_s] [z_c] if 3 axes are configured

?mrt y 2          Returns two lines with [y_sin] [y_cos] signal digits
?mrt              Returns 10 lines with all axes (up to 8 values per line)
?mrt x            Returns one line with [x_sin] [x_cos] signal digits
```

20. Closed Loop Instructions

The closed loop control positions the stage to the scale position. So the inaccuracy of the drive is compensated. The losed loop control circuit is activated by the "ctr" command. But first, in order to activate the encoders they have to be unmasked "encmask" and a calibration move "cal" has to be executed (which activates "enc" and detects the counting direction).

20.1. ctr (Control Enable)

```
Syntax:           !ctr or ?ctr
Parameter:        x, y, z or a
                  0,1,2,3,4

Description:      This instruction activates the closed loop circuit.
                  0 = Closed Loop OFF
                  1 = Closed Loop Auto OFF each time position is reached
                  2 = Closed Loop always ON (currently not supported!)
                  3 = (currently not supported!)
                  4 = (currently not supported!)

Response:         Closed loop state(s)

Examples:
!ctr 0 0 0 0      Closed loop off for all axes
!ctr x 1          Closed loop for X-axis switches off after position reached
?ctr              Query closed loop states of all axes
?ctr x            Query closed loop state of X axis
```

20.2. ctrf (Control Factor)

```
Syntax:           !ctrf or ?ctrf
Parameter:        x, y, z or a
                  0.1 to 25.0

Description:      This instruction reads or sets the closed loop factor.
                  Higher values result in more stiffness and faster settlement.
                  Above a critical value this may lead to oscillation.
                  The default factor of 2.0 mostly results in a good behavior.
                  Hint: Using the ctrff instruction instead offers more options.

Response:         Closed loop factors as integers (rounded)

Examples:
!ctrf 2 2 2       Set closed loop factor to 2 for all axes
!ctrf x 3         Set closed loop factor for X axis to 3
?ctrf             Query closed loop factors of all axes (integers)
?ctrf y           Query closed loop factor of Y axis (integer)
```

20.3. ctrff (Extended Control Factor)

```
Syntax:           !ctrff or ?ctrff
Parameter:        x, y, z or a
                  0.1 to 25.0
                  0.1 to 25.0

Description:      This instruction reads or sets 2 closed loop factors per axis.
                  Higher values result in more stiffness and faster settlement.
                  Above a critical value this may lead to oscillation.
                  The default factor of 2.0 mostly results in a good behavior.
                  Important: Can only be set per axis (with x,y,z,a parameter)!

                  Parameter1: Is used for regulation while axis is moving
                  Parameter2: Is used for regulation when axis is stopped

                  Parameter 2 cann be set to higher values than Parameter1
                  to achieve smoother axis travel while still having the
                  stiffness and faster settling times at the end of a move.
                  (E.g.: "!ctrff x 2 4".)

Response:         Closed loop factors (2 per axis)

Examples:
!ctrff 2 2 2 2    Not supported!
!ctrff x 2 4      Set closed loop factors for X axis 2(moving) and 4(reached)
?ctrff            Query closed loop factors of all axes (2 parameters per axis)
?ctrff y          Query closed loop factors of Y axis (2 parameters)
```

20.4. ctrc (Control Call)

```
Syntax:           !ctrc or ?ctrc
Parameter:        1 to 100 [ms]

Description:      This instruction reads or sets the controller call interval.
                  Unit is milliseconds. Only one parameter for all axes. The
                  default interval of 5 [ms] in most cases leads to the best
                  results. Values of less than 3 [ms] are not recommended.

Response:         Closed loop control call interval in milliseconds.

Examples:
!ctrc 5           Closed loop control is executed every 5 milliseconds
?ctrc             Query closed loop call intervall
```

20.5. ctrd (Control Target Window Delay)

```
Syntax:           !ctrd or ?ctrd
Parameter:        0 to 250 [ms]

Description:      This instruction reads or sets the control delay.
                  This is the time the closed loop has to stay inside
                  the target window "twi" until a position reached state is set.
                  Unit is milliseconds. Only one parameter for all axes.
                  Please also refer to the ctrt timeout.

Response:         Closed loop control delay in milliseconds.

Examples:
!ctrd 100         Closed loop controller must be in target window for 100 ms
?ctrd             Query closed loop target window delay
```

20.6. ctrt (Control Timeout)

```
Syntax:           !ctrt or ?ctrt
Parameter:        0 to 10000 [ms]

Description:      This instruction reads or sets the control timeout.
                  It specifies the time the closed loop tries to reach the
                  desired encoder position. If the ctrd condition could not be
                  fulfilled within this ctrt time, it will be aborted.
                  If ctrd/ctrt is used, the ctrt timeout must be set to a value
                  which is higher than the ctrd, typically 1+ seconds.
                  Unit is milliseconds. Only one parameter for all axes.

Response:         Closed loop control timeout in milliseconds.

Examples:
!ctrt 1000        Closed loop tries to reach the end position for 1 second
?ctrt             Query closed loop timeout
```

20.7. twi (Target Window)

Syntax: !twi or ?twi
Parameter: x, y, z, or a
[value corresponding 0.0001 to 1 mm] in dim units

Description: This instruction reads or sets the closed loop control target window width. While increasing this value leads to position variance, setting a too narrow window may result in oscillation and closed loop timeouts (higher ctrd,ctrt values neccessary).
The unit depends on 'dim'.

Response: Closed loop target window.

Examples:

!twi 0.001 0.001	Closed loop target window is 1µm (if dim=2) for X and Y-axis
!twi y 0.005	Closed loop target window is 5µm (if dim=2) for Y-axis
?twi	Query all axes for their target window
?twi z	Query Z-axis for its target window

20.8. ctrstatus (Control Status)

Syntax: ?ctrstatus
Parameter: x, y, z, a or none
optional parameter: 1

Description: This instruction returns the one of two possibel closed loop states, depending on if the optional Parameter 1 is used.

Just sending the ?ctrstatus request with or without specifying an axis returns the internal **ctr** state which is set when the closed loop gets enabled by the controller, e.g. 0, 1 or 2.
Hint: the internal ctr mode is set to the requested **ctr** mode when the closed loop is acivated. The state may be zero when the closed loop has not been activated yet by cal, calmode, encmask or ctr=0.

Sending the ?ctrstatus 1 request with or without specifying an axis returns if the closed loop momentary is active.
0 = Closed loop momentary not active
1 = Closed loop momentary active
Hint: The state may be not active when the internal cal mode is zero or e.g. during calibration, invalid encoder signal, low current **reduction** (≤ 30%) etc.

Response: Closed loop state.

Examples:

?ctrstatus	Returns the internally running ctr mode of all axes
?ctrstatus y	Returns the internally running ctr mode of the Y-axis
?ctrstatus 1	Returns the Closed Loop active state of all axes
?ctrstatus x 1	Returns the Closed Loop active state of the X-axis, e.g. "1"

20.9. ctrdiff (Control Position Difference)

Syntax:	?ctrdiff
Parameter:	x, y, z, a or none
Description:	This instruction returns the momentaryly measured closed loop position difference between the motor and encoder position (mot.pos – enc.pos). The unit depends on **dim** settings.
Response:	Momentary position difference.

Examples:

?ctrdiff	Returns the position difference of all axes
?ctrdiff y	Returns the position difference of the Y-axis e.g. "0.0015"

21. Trigger Signal Configuration

These commands read or modify the parameters for the trigger output signal. It may be used for synchronization of an external device like e.g. a video camera. The trigger output signal is available on the optional AUX-I/O connector. Access permission to the trigger functionality has to be enabled by factory. Before enabling the trigger function (by "!trig 1"), please make sure that all trigger settings have been made.

```
Example1:   !trig 0[CR]            Disable trigger
            !trigm 0[CR]           Choose trigger mode 0
            !triga x[CR]           Choose X axis as trigger source
            !trigd 0.100[CR]       Set trigger distance to 100µm (if dim = 2)
            !trigs 400[CR]         Set trigger pulse width to 0.4ms
            !trig 1[CR]            Enable trigger, set start position

Example2:   !trig 0[CR]            Disable trigger
            !trigs 120[CR]         Set trigger pulse width to 120µs
            !trigf 2500[CR]        Set pulse frequency to 2.5kHz
            !trigm 100[CR]         Choose trigger mode 100 (periodic signal)
            !trig 1[CR]            Enable trigger, set start position
```

Optional the "trigcount 0" command may be executed to reset the event counter.

21.1. trig (Trigger)

```
Syntax:           !trig or ?trig
Parameter:        0 (= disabled) or 1 (= enabled)

Description:      This instruction enables or disables the trigger circuit.
                  "!trig 1" also sets the trigger start position.

                  0 = Trigger function globally disabled
                  1 = Trigger function globally enabled

Response:         0 or 1

Examples:
!trig 0           Disable trigger circuit
?trig             Query for current state of trigger circuit
```

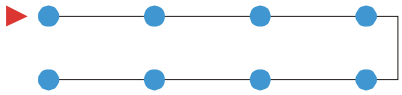
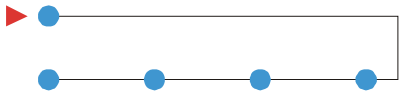
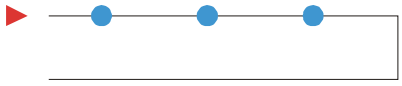
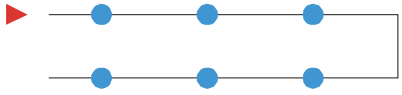
21.2. triga (Trigger Axis)

```
Syntax:           !triga or ?triga
Parameter:        x, y, z or a

Description:      This instruction selects the axis on which to trigger

Response:         x, y, z or a

Examples:
!triga x          Select X-axis as trigger source
!triga y          Select Y-axis as trigger source
?triga            Query current trigger axis
```

21.3. trigm (Trigger Mode)

Syntax: !trigm or ?trigm
Parameter: 0 to 11, 100 to 103

Description: This instruction selects the required trigger mode.

Trigger Mode	Trigger Generation	Trigger Signal	Remarks
0		High active	First pulse when move starts
1		High active	First pulse when move starts
2		High active	First pulse when move starts
3	-- See Mode 0 --	Low active	Same as 0, signal inverted
4	-- See Mode 1 --	Low active	Same as 1, signal inverted
5	-- See Mode 2 --	Low active	Same as 2, signal inverted
6		High active	Triggers shifted by trigd/2
7		High active	Triggers shifted by trigd/2
8		High active	Triggers shifted by trigd/2
9	-- See Mode 6 --	Low active	Same as 6, signal inverted
10	-- See Mode 7 --	Low active	Same as 7, signal inverted
11	-- See Mode 8 --	Low active	Same as 8, signal inverted
100	Generates periodic trigger signals with the frequency choosen by the “trigf” parameter.	High active	Does not depend on position
101	-- See Mode 100 --	Low active	Same as 100, signal inverted
102	Allows manual forced trigger signals by the “trigger” command.	High active	Does not depend on position or time
103	-- See Mode 102 --	Low active	Same as 102, signal inverted

```
Response:          Trigger mode as integer: 0 to 11, 100 to 103

Examples:          !trigm 3          Set Trigger Mode 3
                   ?trigm            Query current trigger mode
```

21.4. trigger (Force Trigger Signal)

```
Syntax:            !trigger or trigger
Parameter:         None

Description:       This instruction generates a trigger output pulse. It is
                   available in trigger modes 102 and 103. The pulse width is
                   depending on "trigs" value.

Response:          None

Examples:
trigger            Force trigger pulse now
!trigger           The same as above
```

21.5. trigs (Trigger Signal Length)

```
Syntax:            !trigs or ?trigs
Parameter:         0 to 2621400 [µs] (as multiples of 40 [µs])

Description:       This instruction is used to adjust the trigger pulse width
                   from 40 microseconds to 2.6214 seconds in increments of 40.
                   (0 = shortest trigger signal width)
      If the parameter is not a multiple of 40 ig will be rounded down to the
                   next lower multiple (e.g. 100 --> 80). When read back, the
                   corrected value is returned (here: 80).

Response:          0 to 2621400 (µs), as multiple of 40

Examples:
!trigs 40          Set Trigger pulse width to 40 µs
!trigs 2500000     Set Trigger pulse width to 2.5 s
?trigs             Query current trigger pulse width
```

21.6. trigd (Trigger Distance)

```
Syntax:            !trigd or ?trigd
Parameter:         >0 to 5000000 (unit depends on dim of the selected axis)

Description:       This instruction selects the required trigger distance. After
                   passing an interval of trigd whith the selected axis, a
                   trigger signal is generated.

Response:          Trigger distance

Examples:
!trigd 3           Set trigger distance to 3mm (if dim of selected axis is 2)
!trigd 0.010       Set trigger distance to 10µm (if dim of selected axis is 2)
?trigd             Query current trigger distance
```

21.7. trigf (Trigger Frequency)

```
Syntax:           !trigf or ?trigf
Parameter:        0.01 to 12500

Description:      This instruction generates periodic trigger pulses at the
                  desired frequency. It is available at trigger mode 100.
      Frequency resolution is 1/40µs.

Response:         Trigger frequency

Examples:
!trigf 2500       Generate periodic trigger pulses with 2.5kHz (each 0.4ms)
?trigf            Query current trigger frequency
```

21.8. trigcount (Trigger Counter)

```
Syntax:           !trigcount or ?trigcount
Parameter:        0 to 2147483647

Description:      This instruction reads or manipulates the counted trigger
                  events.

Response:         Number of executed triggers

Examples:
?trigcount        Query current trigger count
!trigcount 0      Clear trigger counter
```

22. Snapshot Signal Configuration

These commands read or modify the parameters for the snapshot input signal, which may be generated from an external device for synchronization purpose. The snapshot input signal is in the moment only available on Joystick button "F2". If snapshot is enabled, each snapshot event will store the current axis positions in an array. Access permission to the snapshot functionality has to be enabled by factory. Please globally enable the snapshot function first ("sns 1")after all snapshot settings have been made.

Example: Three snapshot positions are captured

snsc = 3
snsa =

Element Index	Position X	Position Y	Position Z	Position A
1	1.0000	1.2345	1.2345	0
2	2.0000	1.2345	1.2345	0
3	3.0000	1.2345	1.2345	0
4	*invalid*	*invalid*	*invalid*	*invalid*
5	*invalid*	*invalid*	*invalid*	*invalid*
...	...	...	...	...
200	*invalid*	*invalid*	*invalid*	*invalid*

In **snsm = 0** the next snapshot will add a new row at index 4.
Same does the **!snsp** command.
?snsp will return positions of row 3.
?snsa x 2 will return 2.0000

22.1. sns (Snapshot)

Syntax: !sns or ?sns
Parameter: 0 (=disable) or 1 (=enable)

Description: This instruction enables or disables the snapshot input.

Response: Snapshot state

Examples:
!sns 0 Disable snapshot
!sns 1 Enable snapshot
?sns Query state of snapshot circuit

22.2. snsl (Snapshot Level / Polarity)

Syntax: !snsl or ?snsl
Parameter: 0 (=active low) or 1 (active high)

Description: This instruction sets the required snapshot signal polarity.

Response: Currently used snapshot polarity

Examples:
!snsl 0 Set snapshot input to active low
!snsl 1 Set snapshot input to active high
?snsl Query current snapshot input polarity

22.3. snsf (Snapshot Filter)

```
Syntax:           !snsf or ?snsf
Parameter:        0 to 100 [ms]

Description:      This instruction reads or modifies the snapshot filter time,
                  which is used to suppress glitches or spikes on noisy signals.

Response:         Currently used snapshot filter time

Examples:
!snsf 0           Disable input filter
!snsf 10          Set snapshot filter time to 10 ms
?snsf             Query snapshot filter time
```

22.4. snsm (Snapshot Mode)

```
Syntax:           !snsm or ?snsm
Parameter:        0, 1, 2, 3, 4 or 5

Description:      This instruction reads or sets the snapshot mode (default=0).

      0 = Capture positions with Joystick key "F2"
      1 = Automatic mode: Move to Positions with Joystick key "F2"
      2 = Extended move:
          F1: Step/move through position list forward  (pointer+1)
                         (wraps around at the last element)
          F2: Step/move through position list backward (pointer-1)
                         (wraps around at the first element)
          F3: Move to start of list (first element)
          F4: Moves to "prehome" position with "vel",
              then to "home" position with "secvel"
                  3 = Dissection mode
      4 = Like mode 0, AUX-I/O SnapShot input is used instead of F2
      5 = Like mode 1, AUX-I/O SnapShot input is used instead of F2

Remarks:    Position capture and moves are always executed on all active axes.

Response:         Currently selected snapshot mode

Examples:
!snsm 0           Set snapshot mode to capture
!snsm 1     Set snapshot mode to move
!snsm 2     Set snapshot mode to extended move
?snsm             Query current snapshot mode
```

22.5. snsc (Snapshot Counter)

```
Syntax:           !snsc or ?snsc
Parameter:        --

Description:      This instruction reads the snapshot counter, which shows the
                  counted snapshots (= snapshot array entries). This instruction
                  may also be used to reset the counter to zero.

Response:         Current snapshot array entries (= number of snapshot events)

Example:
?snsc             Query the number of detected snapshots.
```

```
!snsc              Clear snapshot counter
```

22.6. snsp (Snapshot Position)

```
Syntax:           !snsp or ?snsp
Parameter:        x, y, z or a

Description:      This instruction reads or writes the snapshot position.
                  Writing positions appends them to the current position array.
                  Reading positions returns the last captured position (last
                  array element).

Remark:           The position data unit depends on selected dimension 'dim'.

Response:         Snapshot position value(s)

Examples:
!snsp 100 200     Append snapshot position for X and Y
!snsp 10 20 30    Append snapshot position for X, Y and Z axis
!snsp y 2000      Append snapshot position to Y = 2000
?snsp             Query all axes for their last captured snapshot positions
?snsp z           Query Z axis for its last captured snapshot position
```

22.7. snsa (Snapshot Array)

```
Syntax:           !snsa or ?snsa
Parameter:        x, y, z or a
                  and entry index from 1 to 200

Description:      This instruction reads or writes to the snapshot position
                  array, which may contain up to 200 elements.
      For reading, a valid element index may have a value of 1 to maximum the
                  current snapshot counter value 'snsc'.
      For writing an index of snsc+1 may be used to append a position element to
                  the array (snsc then gets updated by +1).

Remark:           The position data unit depends on selected dimension 'dim'.

Response:         Snapshot array position(s)

Examples:
?snsa 1           Query 1st snapshot entry for all axes positions
?snsa 33          Query 33rd snapshot entry for all axes positions
?snsa z 99        Query 99th snapshot entry for Z-axis position
?snsa x 199       Query 199th snapshot entry for X-axis position
!snsa 0           Clear the entire snapshot array
!snsa x 1 20.5    Set X position of first element to 20.5 (e.g. mm if dim=2)
!snsa 2 10 10 10 10     Set all axis positions of second array entry to 10
```

22.8. snse (Snapshot Event)

```
Syntax:           !snse or snse
Parameter:        1,2,3 or 4

Description:      The Snapshot event instruction can be used to execute the
                  Snapshot functions via the communication interface.
                  Instead of pressing a Joystick button or using the AUX-I/O
                  signal, these snse parameters can be sent by software:

      1 = Function normally executed by pressing Joystick F1 key
      2 = Function normally executed by pressing Joystick F2 key
                      or using the AUX-I/O SnapShot input
      3 = Function normally executed by pressing Joystick F3 key
      4 = Function normally executed by pressing Joystick F4 key

Remark:     Behavior is the same as with the function keys. It depends
                  on the snapshot mode settings and only works when Snapshot
                  is enabled.

Response:         -

Example:
snse 2            Execute F2 Snapshot event (e.g. store current position in
                  the snapshot array and snapshot position)
```

22.9. prehome (Snapshot PreHome Position)

```
Syntax:           !prehome or ?prehome
Parameter:        x, y, z or a

Description:      This instruction sets the prehome position used by the
                  snapshot extended move. The unit of the input position depends
                  on instruction dim.
      See "snsm" 2 for more details.

Response:   Position value(s)

Examples:
!prehome x 10.2   Set prehome position X-value to 10.2 (e.g. [mm] when dim=2)
!prehome 10 0 20  Set prehome position X,Y,Z
?prehome x        Read currently used prehome X-position
?prehome          Read currently used prehome positions of all axes
```

22.10. home (Snapshot Home Position)

```
Syntax:           !home or ?home
Parameter:        x, y, z or a

Description:      This instruction sets the home position used by the snapshot
                  extended move. The unit of the input position depends on
                  instruction dim.
      See "snsm" 2 for more details.

Response:   Position value(s)

Examples:
!home x 10.2      Set home position X-value to 10.2 (e.g. [mm] when dim=2)
!home 10 0 20     Set home position X,Y,Z
?home x           Read currently used home X-position
?home             Read currently used home positions of all axes
```

23. Document Revision History

No.	Revision	Date	Changes	Remarks
01	A	03. July 2007	New layout, improved and corrected descriptions, added new instructions, re-sorted instructions	Based on Tango firmware revision 1.26
02	B	09. July 2007	Added new instructions	Based on Tango firmware revision 1.26
03	prelim. C	27. July 2007	twi example corrected	Based on Tango firmware revision 1.26
04	C	03. Sept 2007	Added snapshot functions	Based on Tango firmware revision 1.26
05	D	28. Feb. 2008	Added some new instructions of firmware 1.31 and 1.32, Bugfixes in examples and descriptions.	Based on Tango firmware revision 1.32
06	prelim E	17. Jun. 2008	Added new instructions of firmware 1.34	Based on Tango firmware revision 1.34
07	E	07. July 2008	Added new instructions of firmware 1.35	Based on Tango firmware revision 1.35
08	prelim F	23. July 2008	Added encamp instruction	Based on Tango firmware revision 1.35
09	G	14. Aug. 2008	Added instructions keymode, keyspeed, extended help instruction, improved some comments	Based on Tango firmware revision 1.37
10	prelim H	29. Aug. 2008	Added Z-Wheel and extended version instructions	Based on preliminary Tango firmware revision 1.374
11	prelim H	14. Oct. 2008	added backlash instruction, extended lockstate bits	Based on preliminary Tango firmware revision 1.394
12	prelim H	07. Jan. 2009	Improved description of calmode behavior	
13	prelim H	06. Feb. 2009	zwtravel description corrected	
14	H	13. Feb. 2009	Documentation Rev. H released	Based Tango firmware revision 1.40
12	prelim I	05. May 2009	corrected ?swin- and improved ?readsw command-description, added new MW logo	
13	I	27. May 2009	updated ipreter command description	
14	prelim J	09. July 2009	iver command description	
15	J	26. Aug. 2009	Corrected description of encnasstatus, encrefstatus, encdir. Extended snsm parameter, accel parameter. Improved description of HDI instructions, vel. Added new instructions: go, adigout, adigin, snse, hwfactorb, encrefstatusl, clearpos, maxpos, stout, accelfunc, hdimode, ctrstatus, ctrdiff.	Based Tango firmware revision 1.46
16	prelim K	31. Aug. 2009	ipreter 1,2 extended up to 5.	Based Tango firmware revision 1.46
17	K	13. Nov 2009	improved extended mode and pitch description	
18	prelim L	02. Dec. 2009	resolution example corrected	