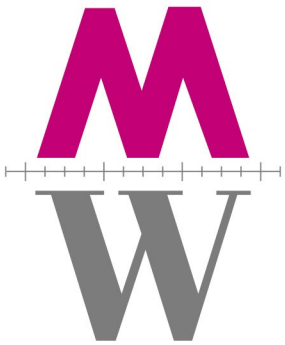
The Instruction Set

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 the PC requests data from the controller. The controller does not distinguish between upper and lower case ASCII characters. 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. These are transferred following the instruction. Blanks must be inserted between the command text, its parameters and to separate each parameter. Example: "moa 45 13 20[CR]" means proceed x, y and z to the positions 45, 13 and 20. Each instruction must be terminated with a carriage return [CR]. This indication 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 own velocities, they may be started by separate single axis commands. Please refer to the "move" command description.

Many parameters can be stored permanently in the Tango Controller, so they are available after 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 inbetween 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 controller has a built in security function, which reduces the maximum travel velocity to 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
(?)	hdi	hdi	-	Read ID number of the connected HDI device	17

Communication Interface Settings					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	baud	!baud 9600	Y	Set RS232 baud rate to 9600 Bd (default=57600)	18
? !	cts	!cts 1	Y	Switch on CTS hardware handshake	18

System Instructions					
Instruction		**Example**	**Save**	**Brief description**	**Page**
(!)	save	save	-	Save parameters to controller nonvolatile memory	19
(!)	restore	restore	-	Reload controller parameters from saved values	19
(!)	reset	reset	-	Reset controller (forces restart, similar to cycle power)	19
!	pa	!pa 1	-	Enable power amplifiers (disable = 0), see ‘axis’ cmd. too	20
? !	ipreter	!ipreter 1	Y	Select standard LSTEP command set	20

Controller States and Error Messages					
Instruction		**Example**	**Save**	**Brief description**	**Page**
? !	autostatus	!autostatus 0	-	Select autostatus response type 0 (=disabled), range: [04]	21
(?)	statusaxis	statusaxis	-	Read axis state [@,M,J,C,S,A,D,]	21
(?)	status	status	-	Read controller error state	22
(?)	err	err	-	Read error number	22
(?)	help	help	-	Read error number with additional text description	22
(?)	service	service	-	Returns a detailed parameter and state list, for debugging	23
(?)	pci	pci	-	Returns 1 if controller is plugged in a PCI slot (desktop=0)	23
!?	lock	!lock 2 1	Y	Set write protection for parameter 2 (here: motor current)	24
!?	lockaxis	!lockaxis 0 0 0 0	Y	Remove lock protection from all axes (lock has no effect)	24
?	lockstate	?lockstate x	-	Query extended locked parameters, including internal limitations currently applied to 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	27
? !	vel	!vel 10 10 10	Y	Adjust speed of X Y Z to 10 [revolutions/s]	28
? !	velfac	!velfac 1 1 1	Y	Set velocity reduction factor for X Y Z to 1 (= no reduction), range is [0.01-1]	28
? !	secvel	!secvel x 20	Y	Set secure speed limit X to 20mm/s (unit is always mm/s)	28
?	maxcur	?maxcur	fix	Show the maximum possible motor currents of all axes	29

General Adjustments

Instruction		Example	Save	Brief description	Page
? !	cur	!cur 0.5 0.6 1	Y	Set motor current in Ampere: X=0.5 Y=0.6 and Z=1 A	29
? !	reduction	!reduction 0.5 0.5 0.5	Y	Select 50% motor current reduction for X Y Z	29
? !	curdelay	!curdelay 1000	Y	Delay X axis motor current reduction by 1000 [ms]	30
? !	axis	!axis 1 0 -1	Y	Enable X, disable Y and switch off Z axis	30
? !	axisdir	!axisdir 0 1 0	Y	Reverse rotating direction of Y motor (caution!)	31
? !	stopaccel	!stopaccel 2 2	Y	Set X and Y deceleration during stop condition to 2m/s²	31
? !	motortable	!motortable x 2	Y	Select custom motor correction table type 2 for X axis	32
? !	usteps	!usteps 50000	Y	Set microstepping resolution to 50000/rev for all axes	32
? !	resolution	!resolution 6	Y	Set pos query return string resolution to 6 decimal places	32

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	33
? !	limctr	!limctr x 1	-	Enable hardware limit switches for X axis, default = 1	33
? !	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	34
? !	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)	34
? !	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	35
? !	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	35
? !	swdir	!swdir x 1	Y	Swap reference- and endswitch assignment for X axis	36
?	readsw	?readsw	-	Read states of all limit switches (1=active and actuated)	36
(?)	swin	swin	-	Read TTL signal level of all limit switch inputs (1=high)	37
(?)	statuslimit	statuslimit	-	Read current limit status „A“ = calibration done „D“ = rm done „L“ = limit switch modified by software „ “ = not yet modified	38

Calibration and Range Measure Instructions

Instruction		Example	Save	Brief description	Page
(!)	cal	cal	-	Perform a calibration move for all enabled axes, see ‘axis’	39
(!)	rm	rm x	-	Perform a range measure move in X	39
? !	caltimeout	!caltimeout 60 60 10	Y	Set calibration timeout for X and Y to 1 minute, Z to 10s	40
? !	calmode	!calmode 2 2	Y	Set calibration/closed loop behavior X, Y to type 2	68
? !	caliboffset	!caliboffset 1 1 1	Y	Set the cal zero-point 1mm aside lower limit switch (dim 2)	40
? !	rmoffset	!rmoffset 1 1 1	Y	Set rm end-position 1mm aside upper limit switch (dim 2)	40
? !	caldir	!caldir z 1	Y	Calibrate the Z-axis in positive direction	41
? !	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]	41
? !	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]	41
? !	calpos	calpos	-	Read back the encoder position where the calibration switch was released	42
? !	refdir	?refdir y	-	Read the direction for encoder reference search in Y axis	42
? !	calvel	!calvel x 10 0.5	Y	**Only if extmode = 1:** Set calibration velocities in X	43
? !	rmvel	!rmvel x 10 0.5	Y	**Only if extmode = 1:** Set range measure velocities in X	43
? !	autopitch	!autopitch x 1	Y	Measure pitch after cal move of X axis	43

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)	44
(!)	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	44
(!)	m	m	-	Move relative again (use same parameters as defined by last '!mor' or '!distance' instruction)	45
? !	distance	!distance 1 1 1	-	Set distance for X Y Z 'm'-move (start with 'm' or '!m')	45
(!)	moc	moc x	-	Move X to center position between lower and upper limit switch, or between lower and upper software limits	45
? !	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	46
(!)	a	a	-	Abort move (Stop)	46
? !	delay	!delay 1000	Y	Delay all consecutive moves by 1000 ms	46
? !	pause	!pause 10	Y	Delay "position reached" autostatus response by 10 ms	47
? !	pos	!pos 0 0 0 !pos z 1.2	-	Set current X Y Z position to 0 Set current Z position to 1.2	47
(!)	zero	!zero z	-	Set Z position and internal counter to 0 (e.g. filter wheel application)	47

Joystick, Tackball and Handwheel Instructions

Instruction		Example	Save	Brief description	Page
? !	joy	!joy 0 !joy 2	Y	Switch joystick on(=2) or off(=0)	48
? !	joydir	!joydir 1 1 1	Y	Set motor direction for joystick operation (Z reversed)	48
? !	joywindow	!joywindow 14	Y	Set idle window of the joystick center position, where a joystick deflection has no effect [0..100]	49
? !	joyvel	!joyvel z 1.5	Y	**Only if extmode = 1:** Set joystick velocity for Z to 1.5	49
? (!)	joyspeed	joyspeed 2 25	Y	Set joystick speed for speed button 2 "medium" to 25 rev/s	49
? !	keymode	!keymode 2	Y	Select joystick key mode 2 = high speed preselection	50
? !	keyspeed	!keyspeed x 5 20	Y	Set keymode joystick speed X low=5mm/s, high=20mm/s	50
? (!)	joycurve	!joycurve z 1	Y	Set joystick characteristic for Z ot linear	51
(?)	key	key	-	Read state of all joystick buttons (0=released, 1=pressed)	51
(?)	keyl	keyl	-	Read and clear latched state of all joystick buttons	51
? !	hwfactor	!hwfactor x 100	Y	One handwheel revolution in X is 100mm stage travel	52
? !	hwfilter	!hwfilter 0	Y	Switch off handwheel noise reduction	52
? !	tbfactor	!tbfactor 1 1	Y	Set trackball transmission factor in X and Y to default	52
? !	tvrjoy	!tvrjoy z	Y	Assign AUX-IO pulse&direction joystick to Z axis	53
? !	tvrjoyf	!tvrjoyf 1	Y	Set tvrjoy transmission factor to 1	53

Digital and Analogue I/O

Instruction		Example	Save	Brief description	Page
(?)	digin	digin digin 8	-	Read all digital inputs Read digital input 8	54
? !	digout	!digout 5 1 ?digout	-	Set digital output 5 to logic level 1 Read back all digital output levels	54
(?)	anain	anain c 2	-	Read input of analogue channel 2	55
? !	anaout	!anaout c 1 17.5	-	Set analogue voltage of channel 1 to 17.5 percent (1.75V)	56
? !	stoppol	!stoppol 1	Y	Set AUX-IO stop input to active high	56
!	stop	!stop 0	-	Release stop condition (in stoppol modes 4 or 5)	56
? !	shutter	!shutter 1	-	Set AUX-IO shutter out signal to TTL high	57

Encoder Instructions

Instruction		Example	Save	Brief description	Page
? !	encmask	!encmask 1 1 0	Y	Enable activation of X and Y encoders, disable Z	58
? !	enc	!enc 1 0	-	Manually activate X encoder (caution!), set Y to inactive	58
? !	encperiod	!encperiod 0.1	Y	Set signal period of X encoder to 100 µm	59
? !	encttl	!encttl x 1	Y	X encoder is TTL type (has no analogue sin/cos signal)	60
? !	encdir	!encdir y 1	(Y)	Reverse counting direction for Y encoder	59
? !	encvel	!encvel x 0.5	Y	Set auto-adjust velocity of X encoder to 0.5mm/s	59
? !	encref	!encref 0	Y	No decoding of X encoder reference signal	60
? !	encnas	!encnas 1 0 0	Y	Enable NAS error signal input encoding for X encoder only	60
(?)	encnasstatus	encnasstatus x	-	Read X encoder NAS signal state (1=NAS error)	61
? !	encerr	!encerr 0	-	Clear encoder error state for X axis (? response is 0 or e)	61
? !	encamp	?encamp x	-	Read X encoder signal amplitude in percent	61
? !	encpos	!encpos 1	-	?pos insruction returns for X the encoder position, if enc=1	62
(?)	hwcount	hwcount	-	Read all encoder positions (TTL counter, no interpolation)	62
(!)	clearhwcount	clearhwcount x	-	Set X axis hwcount to zero	62

MR Encoder Instructions

Instruction		Example	Save	Brief description	Page
? !	mra	?mra x	-	Read amplitude correction factor (sin/cos ratio) of X	63
? !	mro	?mro	-	Read offset correction value for all encoders	63
? !	mrp	!mrp x 0 0 0 0	-	Reset MR-signal peak-to-peak measurement result of X	64
?	mrt	?mrt z 2	-	List two measurement results of the Z input signals	64

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	65
? !	ctrf	!ctrf 2.0	Y	Closed loop factor for X axis is set to 2.0	66
? !	ctrff	!ctrf 2 3.5	Y	Closed loop factors for X axis are set to 2 and 3.5	66
? !	ctrc	!ctrc 3	Y	Closed loop control is called every 3 millisecond	67
? !	ctrd	!ctrd 100	Y	Closed loop in target window for 100 milliseconds	67
? !	ctrt	!ctrt 200	Y	Closed loop control timeout after 200 milliseconds	67
? !	twi	!twi 0.01 0.01 0.01	Y	Set target window for X Y Z to 10µm (assume dim=2)	68
? !	calmode	!calmode 2 2	Y	Set calibration/closed loop behavior X, Y to type 2	68

Trigger Signal Configuration[1]

Instruction		Example	Save	Brief description	Page
? !	trig	!trig 1	-	Enable trigger functionality (should be the last command)	69
? !	triga	!triga x	-	Trigger function is related to X axis	69
? !	trigm	!trigm 0	-	Select trigger mode 0	70
(!)	trigger	trigger	-	Manually set trigger output (available in trigm 102, 103)	71
? !	trigs	!trigs 40	-	Set trigger output signal length to 40 microseconds	71
? !	trigd	!trigd 10	-	Set trigger distance to 10 (mm if dim=2)	71
? !	trigf	!trigf 1000	-	Generate periodic trigger pulses with 1kHz	72
? !	trigcount	?trigcount	-	Read number of generated trigger events	72

Snapshot Signal Configuration1

Instruction		Example	Save	Brief description	Page
? !	sns	!sns 1	-	Enable snapshot functionality (should be last command)	73
? !	snsl	!snsl 0	-	Set snapshot input signal to active low	73
? !	snsf	!snsf 10	-	Set snapshot signal glitch filter to 10 milliseconds	74
? !	snsm	!snsm 0	-	Set snapshot mode to 0(=capture, 1=move)	74
? !	snsc	?snsc	-	Read number of snapshot events (=array fill size)	74
? !	snsp	?snsp x	-	Read last captured X position	75
? !	snsa	?snsa 1	-	Read first position entry of snapshot array (all axes)	75
? !	prehome	!prehome 10 20 1	-	Set prehome positions X Y Z to 10 20 1 (unit depends on dim seting)	76
? !	home	!home 5 5 0	-	Set home positions X Y Z to 5 5 0 (unit depends on dim seting)	76

Operating Modes

Instruction		Example	Save	Brief description	Page
? !	extmode	!extmode 1	-	Enable extended controller behavior	77
? !	scanmode	!scanmode 1	-	Set controller positioning behavior to scanmode	78
? !	scanvel	!scanvel 20 20	-	Set scanmode vector velocity to 20mm/s for X and Y	78

[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

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

Example: ?version
TANGO-DT-S, Version 1.24, Jun 20 2007 , 11:19:32
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 1.24	Firmware version number
Jun 20 2007	Firmware build date
11:19:32	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:  'T''day of week''.''week''.''year''-''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
```

7.8. 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)
```

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:        0, 1 or 2

Description:      0 => Prohibited. Register command set is no longer provided.
                  1 => Default instruction set (LSTEP), as described in this
                       manual.
                  2 => Optional instruction set (VENUS-1).

                  To return from the VENUS instruction set (2), please enter the
                  string "1 setipreter" and press enter (or send an ASCII [CR]).

Response:         0, 1 or 2 (here certainly 1 only)

Example:
!ipreter 1 => The controller uses the LSTEP interpreter.
?ipreter   => Responds the currently selected interpreter.
```

10. Controller States and Error Messages

10.1. 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.
```

10.2. 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.
```

10.3. 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...

10.4. 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)

10.5. 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

10.6. 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

10.7. 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

10.8. 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

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
```

10.9. 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");
```

10.10.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

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”
```

11. 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.

11.1. 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) you should use a spindle pitch of 1mm to prevent rounding error.

11.2. 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

11.3. 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
```

11.4. 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
```

11.5. accel (Acceleration)

```
Syntax:           !accel or ?accel
Parameter:        x, y, z or a
                  0.01 to 20.00 [m/s²]

Description:      This instruction transmits the maximum acceleration, which is
                  currently used or shall be used for calculation of all
                  consecutive moves.

Response:         current acceleration in m/s²

Examples:
!accel 1.00       set acceleration X=1.0[m/s²]. Other axis are not affected.
!accel 1.00 1.50  set acceleration X=1.0[m/s²] and X=1.5[m/s²]
!accel z 0.2      set acceleration Z=200[mm/s²]. Other axis are not affected.
?accel            query all axes for their current acceleration.
?accel z          query Z axis for its acceleration.
```

11.6. vel (Velocity)

```
Syntax:          !vel or ?vel
Parameter:       x, y, z or a
                 0.0000025 to 100 [rev/s] or [mm/s] if dim = 9

Description:     This instruction transfers the velocity in motor revolutions
                 per second, which is currently used or shall be used for
                 calculation of all consecutive automatic moves.

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 maximum velocity for automatic point to point moves has a resolution of 0.0001[revolution/s]. A query has a resolution of 0.001[revolution/s]. Nevertheless the internal representation and calculation is done with the higher resolution of the commanded number. If you need the higher accuracy also for queries, we recommend to use the command velfac in addition.

11.7. velfac (Velocity Factor)

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

Description:     This instruction transfers the velocity factor, which is
                 currently used or shall be used for calculation of 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.
```

11.8. secvel (Secure Velocity)

```
Syntax:          !secvel or ?secvel
Parameter:       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
```

11.9. maxcur (Query Maximum Motor Current)

```
Syntax:           ?maxcur
Parameter:        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
```

11.10.cur (Motor Current)

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

Description:      This instruction transfers the current used or required motor
                  current. The maximum current is limited by hardware and may be
                  cheched by the "maxcur" command.

Response:         Selected 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.
```

11.11.reduction (Motor Current Reduction Factor)

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

Description:      This instruction transfers the current reduction factor. When
                  the axis is idle, the motor current is reduced by this factor.
                  A value of 1 disables the reduction, so even when the axis is
                  stopped the motor current remains the same.
                  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.
                  Please note that when setting the reduction back to 1, this
                  will first take effect after the next move.
                  Please also refer to the "curdelay" command.

Response:         Selected reduction(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.
```

11.12.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.
```

11.13.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.
```

11.14.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.

11.15.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

11.16.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
```

11.17.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
```

11.18.resolution (Position String Decimal Places)

```
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 5     Set position string resolution to 6 decimal places (0.000000)
? resolution      Query decimal places
```

12. Limit Switch Instructions (Hardware and Software)

12.1. 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]
```

12.2. 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
```

12.3. 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
```

12.4. 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
```

12.5. 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
```

12.6. 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
```

12.7. 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

12.8. 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 => query all limit switch actuation states

12.9. swin (Read Limit Switch Input Level)

Syntax: ?swin or swin
Parameter: none

Description: This instruction reads the limit switch signal directly.
The response is a string of 12 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 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)
Ref = Reference switch (!ref)
EE = upper limit switch (!rm)

Response: Switch input signal TTL levelstate of limit switches

Examples: swin => query all limit switch signal levels

12.10.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 "AAA-DLLLL"

                  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
```

13. Calibration and Range Measure Instructions

After each power on or '!reset' of the controller the operator may run 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.
These instructions set the limits very close to the limit switches. An additional offset for the these limits may be specified with the instructions ! caliboffset and !rmoffset. Depending on the end switch version (e.g. light barrier), adding a position offset of 1 up to 10 millimeter may lead to a more stable !cal / !rm result.
Long axes 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 for calibration.

13.1. 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)

13.2. 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)

13.3. 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
```

13.4. 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.
```

13.5. 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.
```

13.6. 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

13.7. 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/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.

13.8. 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.

13.9. 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

13.10.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

13.11.calvel (Calibration Velocities for CAL Instruction)

Syntax: !calvel or ?calvel
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.**
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

13.12.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.**
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

13.13.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

14. Move Instructions

All move instructions include an automatic linear interpolation. Axis, which are started together are reaching the destination at the same time. Nevertheless, user requested parameters, as specified for a single axis, are always calculated and the parameter given rules are not hurt. The user is free to also start the axis independent from each other. In this case each axis drives which its own maximum parameters and the axis do not reach the destination at the same time.

14.1. moa (Move Absolute)

Syntax:	!moa or moa
Parameter:	x, y, z or a
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 answers either '@' after an successful move or 'E' if an error occurred.

Examples:

moa x 10.2	the X-axis is moved to position 10.2 ([mm] assume dim=2)
moa 10 0 20	the axis 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)

14.2. mor (Move Relative)

Syntax:	!mor or mor
Parameter:	x, y, z or 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 answers either '@' after an successful move or 'E' if an error occurred.

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)

14.3. 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.

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
```

14.4. 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:         current value for distance (unit depends on dim instruction)

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.
```

14.5. 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
```

14.6. 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
```

14.7. 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
```

14.8. 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
```

14.9. 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
```

14.10.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
```

14.11.zero (Set Internal Position to Zero)

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

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 (a "!pos 0" instruction is
                  not sufficient here).
                  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. Joystick, Tackball and Handwheel Instructions

All manual moves with human input devices, like joystick and trackball, are limited by the limit switches automatically. You are allowed to unplug, plug and exchange these input devices, while the controller is switched on (hot plug). You can imagine the instruction speed as a digital, accurate joystick, nevertheless this instruction is an automatic controlled move. It is allowed to drive axis in different operation modes, e.g. to move X and Y axis with a moa instruction, while Z is controlled with speed instruction. This feature is basic and provides e.g. dynamic auto focus while moving the table.

15.1. 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:	Joystick mode
Examples:	
!joy 2	set joystick mode 2 (on)
?joy	query the mode

15.2. joydir (Joystick Direction or Assign Joystick)

Syntax:	!joydir or ?joydir
Parameter:	x, y, z, or a 0, 1, 2, -1, -2
Description:	This instruction sets the joystick/trackball direction or disables the joystick/trackball. Please note that when using a 4 axis controller with a 3 axis Joystick, its 3rd axis may be assigned to Z and/or A by enabling one or both Z, A joydirs. A value of 0 disables the joystick/trackball for this axis. A value of +-1 enables the joystick with full current. A value of +-2 enables the joystick with reduced current function support (refer to reduction/curdelay). Please make sure that the joystick function is globally enabled by the joy command.
Response:	joydir settings
Examples:	
!joydir 1	enable X-axis joystick reversed without current reduction.
?joydir	query all axes for their joystick 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.

15.3. 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

15.4. 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.**
In extmode=1 this instruction shall be used to set the joystick velocities. If so, the vel command has no influence to the joystick velocity.

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], or [mm/s] if dim=9
?joyvel x Query X-axis for its joystick velocity

15.5. 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]

15.6. 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)
```

15.7. 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)
```

15.8. 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
```

15.9. 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)
```

15.10.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)
```

15.11.hwfactor (Handwheel Transmission Factor)

```
Syntax:           !hwfactor or ?hwfactor
Parameter:        none or x, y, z, a
                  and -200 to +200

Description:      This instruction sets or reads the handwheel transmission
                  factor, which is a floating point number between -200.0 and
                  +200.0. A sign change may be used to change direction.
                  The factor represents the stage travel distance in millimeter
                  per handwheel knob revolution.
                  Please note that when a higher transmission factor is
                  selected, the step resolution becomes more coarse.

Response:         Currently used handwheel factor(s)

Examples:
!hwfactor 10 10   => One knob revolution in X or Y results in 10mm travel
!hwfactor X 100   => One knob revolution in X results in 100mm travel
?hwfactor         => Query all axes for their transmission factor
```

15.12.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 some inaccuracy between
                  automatic moves, as the noise will cause slight position
                  jitter when move commands are completed.

Response:         Current state of handwheel filter

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

15.13.tbfactor (Handwheel Transmission Factor)

```
Syntax:           !tbfactor or ?tbfactor
Parameter:        none or x, y, z, a
                  and -200 to +200

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
```

15.14.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
```

15.15.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. 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.

16.1. digin (Digital Input)

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

Description:      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 digital inputs
?digin 8          query digital input 8
```

16.2. digout (Digital Output)

```
Syntax:           !digout oder ?digout
Parameter:        string of 0s and 1s,
                  0 to 15, 0 or 1

Description:      This instructions sets or reads back the logic level of the
                  optional digital outputs.
                  Outputs may be set either by a string of 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'.
!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
```

16.3. 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)

16.4. 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
```

16.5. 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.
```

16.6. stop (Release Stop Condition)

```
Syntax:           !stop 0
Parameter:        0

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

16.7. 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.
```

17. 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.

17.1. 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

17.2. 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!)

17.3. 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
```

17.4. 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. These directions must not be changed
                  afterwards.
                  Only if the axis should be used for e.g. relative measurement
                  and not for closed loop, it is ok to change the direction
                  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
```

17.5. encvel (Encoder Auto-Ajust Velocity)

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

Response:         Encoder search and auto-adjust velocity

Description:      The velocity for encoder auto-adjust 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
```

17.6. 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
```

17.7. 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
```

17.8. 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
```

17.9. encnasstatus (Encoder NAS Error Signal State)

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

Response:         Encoder NAS error signal state

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 capable encoder signals: no error
                  1 = NAS capable encoder signals: error

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

17.10.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
```

17.11.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
```

17.12.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
```

17.13.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
```

17.14.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
```

18. MR Encoder Instructions

18.1. 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
```

18.2. 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
```

18.3. 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
```

18.4. 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
```

19. 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).

19.1. 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
```

19.2. 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)
```

19.3. 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)
```

19.4. 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
```

19.5. 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
```

19.6. 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
```

19.7. 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
```

19.8. 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 = Closed loop enabled by calibration move (default),
                      calibration sets the zero position
                  1 = Closed loop enabled on power-up, the power-up position
                      remains the zero position even after calibration.
                  2 = Closed loop enabled on power-up,
                      calibration sets the zero position as normal.

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
```

20. 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.

20.1. 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
```

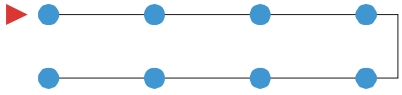
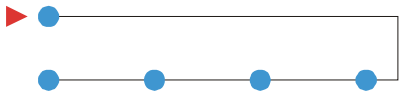
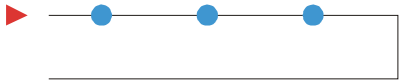
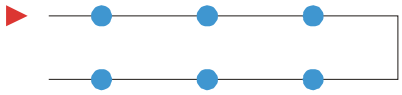
20.2. triga (Trigger Axis)

```
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
```

20.3. 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
```

20.4. 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
```

20.5. 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
```

20.6. 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
```

20.7. 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
```

20.8. 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
```

21. 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

21.1. 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

21.2. 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

21.3. 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
```

21.4. snsm (Snapshot Mode)

```
Syntax:           !snsm or ?snsm
Parameter:        0 (=capture), 1 (=move), 2 (=extended move)

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

                  0 = Capture positions with Joystick key "F2"
                  1 = 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"

                  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
```

21.5. 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
```

21.6. 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
```

21.7. 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
```

21.8. 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
```

21.9. 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
```

22. Operating Modes

22.1. 21.1 Extended Mode

Switching to extended mode will change some of the controller behavior. Also there are new instructions for calibrate and range measure velocities.
Note: Extended Mode should be initialized to the desired state directly after initializing dim (before setting gear, pitch, vel etc.).

Calibration in extmode = 0:

!vel --> Velocity to move towards the 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 --> Sets the velocity for move towards and out of the cal endswitch (E0)
!rmvel --> Sets the velocity for move 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, no matter if another pitch or gear was entered.

As with cal and rm, the joystick velocity is (and has to be) set by a special instruction, called **joyvel**.

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

22.1.1extmode (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.

0 = normal, compatible interpreter operation
1 = extended interpreter behavior mode

Response: currently used extmode.

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

22.2. Scan Mode

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

22.2.1scanmode (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.

22.2.2scanvel (Scanmode Vector Velocity)

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

Description: This instruction transfers 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.

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