# The Instruction Set of the TANGO Controller

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# 2. Introduction

**Communication interface:**
All TANGO controllers appear as a serial COM port, independent of the controller type (RS232C, USB, PCI, PCI-E). The default setting to open any TANGO COM Port is 57600,8,2,N. Most USB and PCI TANGOs transform this to much higher baudrates.

**Axes:**
TANGO controllers are available with up to 4 axes. The axis specifiers used in the TANGO instruction set are the ASCII characters x, y, z, and a. Axes can be addressed individually by using the axis specifier or combined if no axis is specified in the instruction.

**Instruction syntax:**
The instructions and parameters are sent as ASCII strings with a terminating carriage return [CR], which is 0x0d hex. Characters should be lower case, but upper and camel-case are also accepted. The parameters are separated by a space character. This provides easy access to all functions by using a simple terminal program such as HyperTerminal. A typical instruction syntax is as follows:

***[!,?][instruction][SP][optional axis] [parameter1][SP][parameter2] [etc…] [CR]***

***[!,?]*** Read/write specifier, required by most instructions **:
**!** (exclamation mark) = to write parameter, execute an instruction etc.
**?** (question mark) = to read data (returns settings, or status, etc.)

| | |
|---|---|
| ***[instruction]*** | Is the instruction word itself. |
| ***[SP]*** | Space (ASCII 0x20 hex) as separation. |
| ***[optional axis]*** | Axis character x, y, z or a if only one axis must be addressed. |
| ***[parameter]*** | Usually integer or floating point numbers, floating point uses decimal point, no comma. |
| ***[CR]*** | Termination (ASCII 0x0d hex), causes instruction execution. |

A read instruction may return more than one parameter. In many cases the number of returned parameters depends on the amount of available axes:
***[axis X] [if available: axis Y] [if available: axis Z] [if available: axis A]***

For some instructions that return fractional numbers (e.g. ?pitch, ?gear, ?vel, ?encperiod and more) the number of returned fractional digits can be specified in order to increase resolution when reading back the value. For '?pos' and similar position returning functions (e.g. 'lim'), the number of fractional digits can be set by the '**resolution**' parameter. Replies are terminated by ***[CR]***.

**Syntax examples:**

| | |
|---|---|
| !vel 10 1.5 | set velocities for the first two axes |
| !cal | perform a calibration move to lower limit with all active axes |
| !moa y 10.1 | move y axis to absolute position 10.1 |
| ?pos | returns position of all axes (e.g. 0.0000 0.0000 0.0000) |
| ?vel x | returns velocity setting of X axis only (e.g. 10.000) |

**Moves:**
Move instructions are executed as a vector move (except when in **ScanMode**). If several axes are started with one instruction they will reach their destinations at the same time. This means that - depending on velocity, acceleration and travel distance – one leading axis travels at its full velocity while the others follow synchronously. To move axes independently with their individual velocities, they have to be started separately by single axis instructions. Or **scanmode 3** can be set. Please refer to the '**move**' instruction descriptions.

**Settings:**
Most settings can be stored permanently in the TANGO controller, so they are available from power on. When stored once, this reduces initialization overhead of the application software. Refer to the **'save'** instruction for further information. Parameters that are saved can be identified by a 'Y' in the Save column of the **brief instruction set description** later in this document.

**Character limits:**
To prevent the input buffer from overflow, please do not send more than 255 characters at once.
Such may happen when sending the setup sequence to the TANGO controller. A good practice is to request the **'?err'** state after each setup instruction. This will return the information if the parameters were accepted or not while preventing overflow.
Another solution is to activate the **'!cts'** handshake (available only with Desktop RS232C and some 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, as well. Please refer to the **'!cts'** instruction description.

**Important: Secure speed limitation**
The TANGO controllers have a built in safety function, which reduces the maximum travel velocity to a secure 10mm/s for as long as no initial **'cal'** and **'rm'** moves have been executed. This is to prevent the driven axis 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 perform calibration and range measure after each power on:

A) The secure speed limit may be increased to up to 100mm/s at own risk. Please refer to the **'secvel'** instruction for further information.
B) The **!rm** can be skipped by instead using !**vrm** (please read remarks).
C) Non existent limit switches can be deactivated (by **swact**) and then do not require a **!rm**. In such case secvel will be released after **!cal**.

**Important: Measuring units**
The measuring unit is set by the **'dim'** instruction, where dim 2 [which is mm] is the default setting.
In all dim settings except of dim 9, the velocity (vel) is in motor revolutions per second. Only dim 9 provides the millimeter unit for most parameters[1], positions and velocities.

**Extended mode:**
In addition to the improvements when using dim 9 units, there is an option to enable extended mode behavior. It enables more functionality, like separate calibration, rm and joystick velocities, which else are the same as the axis velocity (vel). Please refer to the **'extmode'** instruction for further details.

**Remarks:**

** [!,?] Read/write specifier:
Even if not required (optional) with some instructions (e.g. moa, mor, m, go, etc.), the response in **autostatus mode 2** depends on the exclamation mark. If this special autostatus mode is required, it must be taken care of whether or not the [!] is used. Refer to **autostatus** for further information.

[1] Only **calbspeed** and **calrefspeed** are always in 1/100 revolutions/sec, even in dim mode 9

# 3. Remarks concerning the controller initialization

The TANGO controller must be configured to meet the hardware requirements.
The configuration can be stored permanently with the **save** instruction.
It is recommended to save and reboot the controller after changing the setup parameters (e.g. !**usteps**, !**pitch**, !**gear**) to ensure all changes will be applied.

- The axis units: !**dim**
- The !**extmode** (0 or 1)
- The axis !**pitch** (always in [mm], independent of **dim**)

**Dim 9 and Extmode:**

Using *dim=9* and *extmode=1* instead of dim=2 will turn all units (also vel and joyvel) to [mm] and [mm/s]. Extmode=1 offers bugfixes, more features (e.g. separate joyvel) and flexibility. But it has a slightly different behavior. Please refer to the **Extended Mode** description in this document.

Brief Description of the TANGO Instruction Set

## Controller Informations

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| (?) | version | version | - | Read detailed firmware and controller version | 19 |
| (?) | det | det | - | Read the controller configuration | 20 |
| (?) | detext | detext | - | Read the controller configuration and descriptive text list | 20 |
| (?) | readsn | readsn | - | Read the controller serial number | 21 |
| (?) | ver | ver | - | Read default version number | 21 |
| (?) | iver | iver | - | Read further version number information | 21 |
| (?) | uptime | uptime | - | Read how long the controller is running | 22 |
| (?) | temp | temp | - | Read case temperature (avail. depends on controller type) | 22 |
| ? | maxaxis | ?maxaxis | - | Read number of available axes | 23 |
| ? | maxcur | ?maxcur | - | Show the maximum possible motor currents of all axes | 23 |
| ? | etspresent | ?etspresent | - | Check availability of ETS | 24 |
| ? | stagesn | ?stagesn | - | Read the axis serial numbers from ETS | 25 |
| ? | maxpos | ?maxpos x | - | Read maximum available position range for X axis | 26 |
| ? | lockpos | ?lockpos | - | Read the microscope stage transport lock (screw) position | 26 |

## Communication Interface Settings

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | baud | !baud 115200 | Y | Set RS232 baud rate (here to 115200Bd, default is 57600) | 27 |
| ? ! | cts | !cts 1 | Y | Enable CTS hardware handshake | 27 |

## System Instructions

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| (!) | save | save | - | Save parameters to controller nonvolatile memory | 28 |
| (!) | restore | restore | - | Reload saved controller parameters from n.v. memory | 28 |
| (!) | reset | reset | - | Reset controller (forces restart, similar to cycle power) | 29 |
| ? ! | pa | !pa 1 | - | Power amplifiers ON (OFF=0), also refer to ‘axis’ instr. | 30 |
| ? ! | ipreter | !ipreter 2 | Y | Select optional Venus instruction set | 31 |

## Operating Modes

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | autostatus | !autostatus 0 | - | Select autostatus response type 0 (=disabled), range: [0-4] | 32 |
| ? ! | extmode | !extmode 1 | Y | Enable extended controller behavior | 33 |
| ? ! | scanmode | !scanmode 1 | Y | Set positioning behavior to scanmode | 35 |
| ? ! | scanvel | !scanvel 0.5 | Y | Set scanmode vector velocity to 0.5 mm/s | 36 |
| ? ! | modulomode | !modulomode a 1 | Y | Set positioning behavior of A axis to turntable mode 1 | 37 |
| ? ! | configdisplay | !configdisplay 1 | Y | Enable PROFILER SCD CL position display on RS232 | 38 |

## Controller States and Error Messages

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| (?) | statusaxis | statusaxis | - | Read axis state [@,M,J,C,S,A,D,-] | 39 |
| (?) | calst | calst z | - | Read calibration state of the Z axis | 40 |
| (?) | corrst | corrst x | - | Read state of position correction | 40 |
| (?) | status | status | - | Read controller error state | 41 |
| (?) | err | err | - | Read error number | 41 |
| (?) | help | help | - | Read error number with additional descriptive text | 42 |
| (?) | service | service | - | Returns a detailed parameter and state list, for debugging | 43 |
| (?) | pci | pci | - | Returns 1 if controller is plugged in a PCI slot (desktop=0) | 43 |
| (?) | isvel | ?isvel x | - | Read actual velocity of the X axis | 43 |
| (?) | iscur | ?iscur x | - | Read the momentarily applied motor current of the X axis | 44 |

## General Adjustments

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | dim | !dim 1 1 1 | Y | Set position measuring units of X Y Z to µm | 45 |
| ? ! | pitch | !pitch 1 1 1 | Y | Set spindle pitch of X Y Z to 1 [mm/revolution] | 46 |
| ? ! | gear | !gear 1 1 1 | Y | Set gear factor of X Y Z to 1 | 46 |
| ? ! | motorsteps | !motorsteps x 200 | Y | Set motor step type of X to 200 [steps/rev] for a 1.8° motor | 47 |
| ? ! | accel | !accel 0.1 0.1 0.1 | Y | Set acceleration of X Y Z to 0.1m/s² | 48 |
| ? ! | accelfunc | !accelfunc 1 1 0 | Y | Set acceleration function X and Y to s-curve, Z to linear | 49 |
| ? ! | stopaccel | !stopaccel 2 2 | Y | Set stop deceleration for X and Y to 2m/s² | 50 |
| ? ! | vel | !vel 10 10 10 | Y | Set axis velocity of X Y Z to 10 | 51 |
| ? ! | velfac | !velfac 1 1 1 | Y | Set velocity reduction factor for X Y Z to 1<br>(= no reduction), range is [0.01-1], use not recommended | 52 |
| ? ! | secvel | !secvel x 20 | Y | Set secure speed limit X to 20mm/s (unit is always mm/s) | 53 |
| ? ! | cur | !cur 0.5 0.6 1 | Y | Set motor current in Ampere: X=0.5 Y=0.6 and Z=1 A | 54 |
| ? ! | reduction | !reduction 0.5 0.5 0.5 | Y | Set idle motor current reduction for X Y Z to 50% | 55 |
| ? ! | curdelay | !curdelay 1000 1000 | Y | Set idle motor current reduction delay for X,Y to 1000 [ms] | 56 |
| ? ! | ecomove | !ecomove 30 30 0 | Y | Set motor move eco-level of X and Y to 30% less current | 56 |
| ? ! | axis | !axis 1 0 -1 | Y | Enable X, disable Y and switch off Z axis | 57 |
| ? ! | axisdir | !axisdir 0 1 0 | Y | Reverse rotating direction of Y motor (caution!) | 57 |
| ? ! | motortable | !motortable x 2 | Y | Select custom motor correction table to type 2 for X axis | 58 |
| ? ! | usteps | !usteps 50000 | Y | Set dim 0 microsteps per rev to 50000 (applies to all axes) | 58 |
| ? ! | resolution | !resolution 6 | Y | Set ?pos position resolution to 6 fract.digits (0.000001mm) | 59 |
| ? ! | backlash | !backlash 12.3 0 0 | Y | Set backlash compensation to 12.3µm in X and 0 in Y & Z | 59 |
| ? ! | lock | !lock 2 1 | Y | Set write protection for parameter 2 (here: motor current) | 60 |
| ? ! | lockaxis | !lockaxis 0 0 0 0 | Y | Remove lock protection from all axes (lock has no effect) | 60 |
| ? | lockstate | ?lockstate x | - | Read extended locked parameters, including internal limitations currently applied to X axis | 61 |
| ? ! | stout | !stout 2 | Y | Make Status-LED state available at AUX I/O Pin VR_OUT | 61 |
| ? ! | noled | !noled 1 | Y | Switch Status-LED permanently off | 62 |
| ? ! | updelay | !updelay -5000 | Y | Wait to a maximum of 5 seconds for valid external power | 62 |

## Limit Switch Instructions (Hardware and Software)

| Instruction | | Example | Save | Example 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 | 63 |
| ? ! | clim | !clim 50 70 10 | - | Set circular limit at center X=50, Y=70 with radius 10 | 64 |
| ? ! | limctr | !limctr x 0 | - | Disable axis limits for X axis, default = 1 | 65 |
| ? ! | 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 | 65 |
| ? ! | swtyp | !swtyp 1 0 1<br>!swtyp y 0 0 0 | Y | Set limit switch type for all axes to NPN (pull-up resistor)<br>Set limit switch type for Y to PNP (pull-down resistor) | 66 |
| ? ! | swpol | !swpol 1 0 1<br>!swpol z 1 0 1 | Y | Set limit switch polarity E0, EE for all axes (to active high)<br>Set limit switch polarity E0, EE for Z (1=to active high) | 67 |
| ? ! | swact | !swact 1 0 1<br>!swact y 1 0 0 | Y | Enable cal and rm limit switches for all axes<br>Enable cal limit switch for Y, disable ref and rm | 68 |
| ? ! | swdir | !swdir x 1 | Y | Swap CAL and RM endswitch assignment of X axis | 69 |
| ? | readsw | ?readsw | - | Read states of all limit switches (1=active and actuated) | 70 |
| (?) | swin | swin | - | Read TTL signal level of all limit switch inputs (1=high) | 70 |
| (?) | statuslimit | statuslimit | - | Read momentary limit status<br>„A“ = calibration done<br>„D“ = rm done<br>„L“ = limit switch modified by software<br>„-“ = not yet modified | 71 |

## Calibration and Range Measure Instructions

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| (!) | cal | cal | - | Perform a calibration move for all enabled axes, see 'axis' | 72 |
| (!) | rm | rm x | - | Perform a range measure move in X | 73 |
| (!) | vrm | vrm 75 50 | - | Virtual range measure for a 75x50 microscope stage | 74 |
| ? ! | calmode | !calmode 2 2 | Y | Set calibration/closed loop behavior X, Y to mode 2 | 77 |
| ? ! | calrequired | !calrequired z 1 | Y | Z axis does not move until !cal is executed | 77 |
| ? ! | caltimeout | !caltimeout 60 60 10 | Y | Set calibration timeout for X and Y to 1 minute, Z to 10s | 77 |
| ? ! | caliboffset | !caliboffset 1 1 1 | Y | Set the cal zero-point 1mm aside lower limit switch (dim 2) | 78 |
| ? ! | rmoffset | !rmoffset 1 1 1 | Y | Set rm end-position 1mm aside upper limit switch (dim 2) | 78 |
| ? ! | caldir | !caldir z 1 | Y | Dummy function, please use axisdir instruction | 78 |
| ? ! | 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] | 79 |
| ? ! | 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] | 79 |
| ? ! | encrefvel | !encrefvel 5 5 5 | Y | Set the speed for calibrating to the encoder reference for axes X,Y,Z to 5 [rev/s] if dim=2, [mm/s] if dim=9 | 80 |
| ? ! | calpos | calpos | - | Read back the encoder position where the calibration switch was released | 81 |
| ? | calzeropos | ?calzeropos | - | Read the “zero” position after cal (for calmode 1) | 81 |
| ? ! | calvel | !calvel x 10 0.5 | Y | **Only if extmode = 1:** Set calibration velocities in X | 82 |
| ? ! | rmvel | !rmvel x 10 0.5 | Y | **Only if extmode = 1:** Set range measure velocities in X | 83 |
| ? ! | autopitch | !autopitch x 1 | Y | Measure pitch after cal move of X axis | 83 |
| ? ! | refdir | ?refdir y | Y | (dummy) Read the direction for Y-axis REF switch search | 84 |

## Move Instructions

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| (!) | moa | moa 10 10 10<br>moa y 20 | - | Move X Y Z absolute to positions 10 10 10<br>Move Y axis to position 20 (unit depends on dim setting) | 86 |
| (!) | mor | mor 4 4 4<br>mor y -10.5 | - | Move X Y Z relative by 4 (unit depends on dim setting)<br>Move Y axis relative 10.5 backwards | 86 |
| (!) | m | m | - | Move relative again (use same parameters as defined by last ‘!mor’ or ‘!distance’ instruction) | 87 |
| ? ! | distance | !distance 1 1 1 | - | Set distance for X Y Z ‘m’-move (start with ‘m’ or ‘!m’) | 87 |
| (!) | moc | moc x | - | Move X to center position between lower and upper limit switch, or between lower and upper software limits | 88 |
| (!) | mol | mol | - | Move all axes to their transportlock positions (fix. screw) | 88 |
| (!) | go | go x 12.5 | - | Move X to pos. 12.5, overwritable, for tracking applications | 89 |
| ? ! | speed | !speed 5 5 5<br>!speed y 0 | - | Let X Y Z axis travel at 5 [revolutions/s]<br>Stop the Y axis speed move | 90 |
| (!) | a | a | - | Abort move (Stop) | 91 |
| ? ! | delay | !delay 1000 | Y | Delay the start of move instructions by 1000 ms | 92 |
| ? ! | pause | !pause 10 | Y | Delay “position reached” autostatus response by 10 ms | 92 |
| ? ! | pos | !pos 0 0 1.5<br>?pos z | - | Set current X Y positions to 0 and Z position to 1.5<br>Read current Z position | 93 |
| (!) | posclr | !posclr x | - | Reset the position offset that was manipulated by !pos | 93 |
| (!) | zero | !zero z | - | Set Z position and internal counter to 0 (e.g. filter wheel application) | 94 |
| (!) | clearpos | !clearpos z | - | Set Z position and internal counter to 0 (e.g. filter wheel application), not executable with measuring system | 94 |

## HDI Instructions (Joystick, Trackball, ERGODRIVE)

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | joy | !joy 0<br>!joy 2 | Y | Switch joystick ON=2 or OFF**=0<br>(**Switching off may cause an autostatus response) | 95 |

## HDI Instructions (Joystick, Trackball, ERGODRIVE)

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | joydir | !joydir 2 -2 0 | Y | Set HDI axis mode to X=ON, Y=Reversed, Z=OFF | 96 |
| ? ! | joychangeaxis | !joychangeaxis 1 | Y | Change Joystick X and Y axis (X→Y, Y→X) | 96 |
| ? ! | joywindow | !joywindow 14 | Y | Set idle window of the joystick center position, where a joystick deflection has no effect [0..100] | 96 |
| ? ! | joyvel | !joyvel z 1.5 | Y | **Only if extmode = 1:** Set joystick velocity for Z to 1.5 | 97 |
| ?(!) | joyspeed | joyspeed 2 25 | Y | Set joystick speed for speed button 2 “medium” to 25 rev/s | 97 |
| ? ! | keymode | !keymode 2 | Y | Select joystick key mode 2 = high speed preselection | 98 |
| ? ! | keyspeed | !keyspeed x 5 20 | Y | Set keymode joystick speed X low=5mm/s, high=20mm/s | 99 |
| ?(!) | joycurve | !joycurve z 1 | Y | Set joystick characteristic for Z ot linear | 99 |
| (?) | key | key | - | Read state of all joystick buttons (0=released, 1=pressed) | 100 |
| (?) | keyl | keyl | - | Read and clear latched state of all joystick buttons | 100 |
| ? ! | hwfactor | !hwfactor x 1 | Y | One coaxial drive knob revolution in X is 1mm axis travel | 101 |
| ? ! | hwfactorb | !hwfactorb x 14 | Y | One coaxial drive knob revolution in X is 14mm axis travel | 101 |
| ? ! | hwfilter | !hwfilter 0 | Y | Deactivate coaxial drive noise reduction | 101 |
| ? ! | tbfactor | !tbfactor 1 1 | Y | Set trackball transmission factor in X and Y to default | 102 |
| (?) | zwheel | ?zwheel | - | Returns 1 if HDI device has a multi-function wheel | 103 |
| ?(!) | zwtravel | !zwtravel 1 0.25 | Y | Set default multi-function wheel travel to 2.5 mm/rev | 103 |
| ? ! | zwaxis | !zwaxis a | Y | Assign multi-function wheel to A-axis | 104 |
| ? ! | zwfactor | !zwfactor 1 | Y | Set multi-function wheel factor to 1:1 (default) | 104 |
| (?)! | zwpos | zwpos | - | Read independent multi-function wheel position counter | 104 |
| ? ! | tvrjoy | !tvrjoy z | Y | Assign AUX I/O pulse&direction device to Z axis | 105 |
| ? ! | tvrjoyf | !tvrjoyf 1 | Y | Set tvrjoy transmission factor to 1 | 105 |
| (?) | hdi | hdi | - | Read ID number of the connected HDI device | 106 |
| ! ? | hdimode | !hdimode 0 1 | Y | Set hdimode bit 0 to 1 for ERGODRIVE Toggle Mode | 107 |
| ! ? | configaxsel | !configaxsel 1 | Y | Toggle joystick Z-axis between axes Z and A by F4 key | 108 |

## Digital and Analogue I/O

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| (?) | digin | digin<br>digin 8 | - | I/O1 Extension module: Read all digital inputs<br>I/O1 Extension module: Read digital input 8 | 111 |
| ? ! | digout | !digout 5 1<br>?digout | - | I/O1 Extension module: Set digital output 5 to logic level 1<br>I/O1 Extension module: Read back all digital output levels | 111 |
| ? ! | diginpol | !diginpol 5 1 | Y | I/O1 Extension module: Invert input 5 signal | 112 |
| ? ! | digintyp | !digintyp 111111 | Y | I/O1 Extension module: Apply pull-up resistor to all inputs | 112 |
| ? ! | digoutpreset | !digoutpreset 3 1 | Y | I/O1 Extension module: Preset state of output 3 to high | 113 |
| (?) | edigin | edigin<br>edigin 8 | - | Multi I/O Extension: Read all digital inputs<br>Multi I/O Extension: Read digital input 8 | 114 |
| ? ! | edigout | !edigout 5 1<br>?edigout | - | Multi I/O Extension: Set digital output 5 to logic level 1<br>Multi I/O Extension: Read back all digital output levels | 114 |
| ? ! | ediginpol | !ediginpol 5 1 | Y | Multi I/O Extension: Invert input 5 signal | 115 |
| ? ! | edigintyp | !edigintyp 111111 | Y | Multi I/O Extension: Apply pull-up resistor to input 0-5 | 115 |
| ? ! | edigoutpreset | !edigoutpreset 3 1 | Y | Multi I/O Extension: Preset state of output 3 to high | 116 |
| ? ! | edigrly | !edigrly 1 | - | Multi I/O Extension: Switch optional relay on | 116 |
| (?) | adigin | adigin<br>adigin 2 | - | Read all AUX I/O digital inputs<br>Read logic level of AUX I/O digital input 2 only | 117 |
| ! ? | adigintyp | !adigintyp 1111 | | TANGO 3 mini: Apply pull-up resistors to all adigin inputs | 117 |
| ! ? | adiginfunc | !adiginfunc 2 0 0 1 | | TANGO 3 mini: Set adigin0 = snapshot and adigin3 = stop | 118 |
| ? ! | adigout | !adigout 3 1<br>?adigout | - | Set AUX I/O digital output 3 to high (logic level 1)<br>Read back all digital output levels | 119 |
| (?) | anain | anain c 2 | - | Read input of analogue channel 2 | 120 |
| ? ! | anaout | !anaout c 1 17.5 | - | Set analogue voltage of channel 1 to 17.5 percent (1.75V) | 121 |
| ? ! | anamode | !anamode 0 | (N) | Set analogue output mode to default behavior | 122 |

## Digital and Analogue I/O

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | stoppol | !stoppol 1 | Y | Set AUX I/O stop input to active high | 123 |
| ! | stop | !stop 0 | - | Release stop condition (in latched stoppol modes 4 or 5) | 124 |
| ? ! | shutter | !shutter 1 | - | Set AUX I/O shutter out signal to TTL high | 124 |
| (!) | flash | flash 0.1 | - | Send a 100µs high pulse to AUX I/O TAKT_OUT (LED) | 125 |
| ? ! | tvr | !tvr z 5 | Y | Enable AUX I/O TVR pulse and direction for Z axis | 125 |
| ? ! | brake | !brake 0 0 1 | Y | Enable Brake for Z axis on I/O extension output pin OUT0 | 126 |
| (!) | brakepos | brakepos z | - | Move to initial motor pole position to avoid jump | 127 |
| ? ! | drop | !drop 5 | - | Liquid Dispenser: generate 5 drops or dispense for 5 sec. | 128 |
| ? ! | pump | !pump 1 | - | Liquid Dispenser: Switch on air pressure pump manually | 129 |
| ? ! | vbus | !vbus 1 | - | TANGO mini3: Switch on +24V of AUX mini port | 130 |
| ? ! | configvbus | !configvbus 1 | Y | TANGO mini3: Set +24V of AUX mini to always on | 130 |

## Encoder Instructions

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | encmask | !encmask 1 1 0 | Y | Enable the activation of X and Y encoders, disable Z | 131 |
| ? ! | enc | !enc 1 0 | - | Manually activate X encoder (caution!), set Y to inactive | 132 |
| ? ! | encperiod | !encperiod 0.1 | Y | Set signal period of X encoder to 100 µm | 133 |
| ? ! | enctype | !enctype x 1 | Y | Set encoder type of X to TTL (no analogue sin/cos signal) | 135 |
| ? ! | encttl | !encttl x 1 | Y | Set encoder type of X to TTL (no analogue sin/cos signal) | 136 |
| ? ! | encdir | !encdir y 1 | (Y) | Reverse counting direction for Y encoder (caution!) | 133 |
| ? ! | encvel | !encvel x 0.5 | Y | Set auto-adjust velocity of X encoder to 0.5mm/s | 134 |
| ? ! | encref | !encref 1 1 0 | Y | Enable encoder reference signal for X and Y, disable for Z | 136 |
| ? ! | encnas | !encnas 1 0 0 | Y | Enable NAS error signal input encoding for X encoder only | 137 |
| (?) | encrefstatus | encrefstatus x | - | Read X encoder reference signal state (1=on reference) | 137 |
| (?) | encrefstatusl | encrefstatusl x | - | Read latched X encoder reference signal state | 137 |
| (?) | encnasstatus | encnasstatus x | - | Read X encoder NAS signal state (1=NAS error) | 138 |
| ? ! | encerr | !encerr 0 | - | Clear encoder error state for X axis (? response is 0 or e) | 138 |
| ? ! | encamp | ?encamp x | - | Read X encoder signal amplitude in percent | 138 |
| ? ! | encpos | !encpos 1 | - | ?pos insruction returns for the encoder positions, if enc=1 | 139 |
| ? ! | configencpos | !configencpos 0 0 1 | Y | Preset value for encpos at power up (default=0) | 140 |
| (?) | encsync | encsync -1 | - | Read the state of the encoder signal synchronization | 141 |
| (?) | hwcount | hwcount | - | Read all encoder positions (TTL counter, non-interpolated) | 141 |
| (!) | clearhwcount | clearhwcount x | - | Set hwcount encoder position counter to zero, here: X axis | 141 |

## MR Encoder Instructions

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | mra | ?mra x | - | Read amplitude correction factor (sin/cos ratio) of X | 142 |
| ? ! | mro | ?mro | - | Read offset correction value for all encoders | 142 |
| ? ! | mrp | !mrp x 0 0 0 0 | - | Reset MR-signal peak-to-peak measurement result of X | 143 |
| ? | mrt | ?mrt z 2 | - | List two measurement results of the Z input signals | 143 |

## Closed Loop Instructions

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | ctr | !ctr 2 2 2 | Y | Set closed loop mode of X Y Z to always active (=default) | 147 |
| ? ! | ctrf | !ctrf 2.0 | Y | Closed loop factor for X axis is set to 2.0 | 148 |
| ? ! | ctrff | !ctrff 2 3.5 | Y | Closed loop factors for X axis are set to 2 and 3.5 | 148 |
| ? ! | ctrd | !ctrd 100 | Y | Closed loop in target window for 100 milliseconds | 149 |
| ? ! | ctrt | !ctrt 200 | Y | Closed loop control timeout after 200 milliseconds | 149 |
| ? ! | twi | !twi 0.01 0.01 0.01 | Y | Set target window for X Y Z to 10µm (assume dim=2) | 150 |
| ? ! | ctrc | !ctrc 3 | Y | Closed loop control is called every 3 milliseconds | 150 |
| ? ! | ctrsm | !ctrsm x 1 | Y | Set X behavior outside lock-in range to “slow closed loop” | 151 |

## Closed Loop Instructions

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | ctrs | !ctrs x 0.2 | Y | Set lock-in range for X to 0.2mm (assume dim=2) | 151 |
| ? | ctrstatus | ?ctrstatus 1 | - | Get Closed Loop active state of all axes | 152 |
| ? | ctrdiff | ?ctrdiff | - | Get Closed Loop position difference of all axes | 153 |

## Trigger Output Functionality[1]

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | trig | !trig 1 | - | Enable trigger functionality (the setup must be complete) | 154 |
| ? ! | trigm | !trigm 0 | Y | Select trigger mode 0 | 155 |
| ? ! | triga | !triga x | Y | Trigger function is related to X axis | 157 |
| ! ? | trigo | !trigo 1 | Y | Select the default trigger signal output | 157 |
| ? ! | trigs | !trigs 40 | Y | Set trigger output signal length to 40 microseconds | 158 |
| ? ! | trigd | !trigd 10 | Y | Set trigger distance to 10 (mm if dim=2) | 157 |
| ? ! | trigcomp | !trigcomp 50 | Y | Compensate a trigger signal delay of 50µs | 159 |
| ? ! | trigenc | !trigenc 1 | Y | Select encoder signal as trigger source (if available) | 160 |
| ? ! | trigf | !trigf 1000 | Y | Set periodic trigger pulse frequency to 1kHz | 160 |
| ? ! | trigbdelay | !trigbdelay 15.05 | Y | Set Precise secondary trigger out to 15.05µs delayed | 161 |
| ? ! | trigbwidth | !trigbwidth 4.35 | Y | Set Precise secondary trigger out signal length to 4.35µs | 161 |
| ? ! | trigbf | !trigbf 66000000 | Y | Set Precise secondary trigger out frequency to 66 MHz | 161 |
| ? ! | trigcount | ?trigcount | - | Read number of generated trigger events | 162 |
| (!) | trigger | trigger | - | Manually set trigger output (available in trigm 102, 103) | 162 |
| ? ! | trigr | !trigr 5 10 6 | - | Generate 6 trigger signals from 5 to 10→5,6,7,8,9,10 (mm) | 163 |
| ? ! | trigp | !trigp -1 12.5 | - | Append a position value to the trigger position list | 166 |
| ? ! | trigc | ?trigc | - | Read number of entries in trigp trigger position list | 169 |
| ? ! | trigi | ?trigi | | Read or manipulate the momentary list index of trigp, trigr | 169 |
| ? ! | trigl | !trigl 1 | Y | Set trigger signal level for !trigr and !trigp to active high | 170 |

## Snapshot - Trigger Input Functionality[1]

| Instruction | | Example | Save | Example description | Page |
|---|---|---|---|---|---|
| ? ! | sns | !sns 1 | - | Enable snapshot functionality (always 1 after power up) | 177 |
| ? ! | snsl | !snsl 0 | Y | Set snapshot input signal to active low | 177 |
| ? ! | snsf | !snsf 10 | Y | Set snapshot signal debounce filter to 10 milliseconds | 177 |
| ? ! | snsm | !snsm 0 | Y | Set snapshot mode to 0 (0=capture pos, 1=move to pos) | 178 |
| ? ! | snsc | ?snsc | - | Read number of snapshot events (=array fill size) | 181 |
| ? ! | snsi | !snsi 5 | - | Set snapshot index to 6th entry (snsa 6) | 181 |
| ? ! | snsaxis | !snsaxis 1 1 0 0 | - | X and Y axis moves wait for snapshot (in snsm mode 6) | 182 |
| ? ! | snsp | ?snsp x | - | Read last captured X position | 183 |
| ? ! | snsa | ?snsa 1 | - | Read first position entry of snapshot array (all axes) | 183 |
| (!) | snse | snse 2 | - | Generate SnapShot event F2 | 184 |
| ? ! | snsv | ?snsv 3 | - | Read captured ANIN0 voltage in mV of 3rd snapshot entry | 184 |
| ? ! | snsj | !snsj 1 0.5 0 0 | - | Set snapshot jump distances (snapshot mode snsm 9) | 185 |
| ? ! | prehome | !prehome 10 20 1 | - | Set prehome positions X Y Z to 10 20 1<br>(unit depends on dim setting) | 186 |
| ? ! | home | !home 5 5 0 | - | Set home positions X Y Z to 5 5 0<br>(unit depends on dim setting) | 186 |

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

# 4. Instruction Syntax Description

Most instructions work in both directions (reading and writing). (?)! means the instruction accepts read and write access. The controller identifies a read instruction by a proceeding '?', while '!' indicates writing to a parameter or executing an instruction. More information can be found in the **Introduction** chapter of this document.

Some examples of legal instruction syntax:
!*Instruction parameter1 parameter2 parameter3 parameter4*
!*Instruction parameter1 parameter2*
!*Instruction axis parameter*
!*Instruction*
?*Instruction axis parameter*
?*Instruction*

# 5. 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 amplifiers 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) |
| 73 | internal error, e.g. eeprom data corruption |
| 74 | closed loop switched off due to parameter change |
| 75 | could not enable axis correction, or axis correction was disabled |
| 76 | io extension error (output overload on IO1 or Multi-IO connector) |
| 77 | io extension internal communication error (internal bus error) |
| 78 | HDI input device error |
| 79 | xPos module error |
| 80 | internal error: HDI ISR not running |
| 81 | internal error: Encoder ISR not running |
| 82 | overload on motor connector +5V |
| 83 | overload on AUX I/O +5V supply |
| 84 | overload on encoder +5V supply |
| 85 | overload on AUX I/O +24V supply |
| 86 | low brake output voltage |

# 6. Controller Informations

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

## 6.1. version (Read detailed Version information)

Syntax: ?version or version
Parameter: none or 1

Description: Read the TANGO type and firmware version.

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

Response syntax: Character string including controller type, firmware version and build date separated by a comma, e.g.
*TANGO-DT-S, Version 1.57, Apr 17 2012 , 12:12:02*

| | |
|---|---|
| TANGO-DT | Desktop version, PCI card based |
| TANGO-DT-S | Desktop version, PCI-S card based |
| TANGO-DTe | Desktop version, PCI-E card based |
| TANGO-PCI | PCI card |
| TANGO-PCI-S | PCI-S card |
| TANGO-PCIe | PCI-E card (PCI Express) |
| TANGO-MINI | TANGO mini |
| TANGO-C | Motorized stage with integrated controller |
| TANGO-I | TANGO integrale |
| TANGO-MINI3 | TANGO 3 mini |
| | |
| Version 1.57 | Firmware version number |
| Apr 17 2012 | Firmware build date |
| 12:12:02 | Firmware build time |

Example:

?version ==> *TANGO-DTe, Version 1.69, Mar 6 2018 , 15:52:19*
?version 1 ==> *1.69*

## 6.2. det (Read detailed Configuration)

Syntax: ?det or det
Parameter: none

Description: Read detailed information of the controller configuration.

Response: The response is a decimal integer number. Its bit pattern represents the configuration as described below:

```
0x0 0 0 0 0 1   configured encoder interface = 1Vpp
0x0 0 0 0 0 2   configured encoder interface = MR
0x0 0 0 0 0 4   configured encoder interface = TTL
0x0 0 0 0 0 8   configured encoder interface = Universal 1V+MR
0x0 0 0 0 3 0   the number of configured axes (e.g. 3)
0x0 0 0 1 0 0   Display is configured (PROFILER SCD CL @RS232)
0x0 0 0 2 0 0   Speedpoti is configured
0x0 0 0 4 0 0   Hand wheel is configured
0x0 0 0 8 0 0   Snapshot (Trigger in) is configured
0x0 0 1 0 0 0   TVRin is configured
0x0 0 2 0 0 0   Trigger out is configured
0x0 0 8 0 0 0   TVRout is configured
0x0 1 0 0 0 0   digital extension: I/O1      (24in+8out)
0x0 2 0 0 0 0   digital extension: Multi I/O (12in+8out)
0x0 4 0 0 0 0   Trackball is configured
0x0 8 0 0 0 0   ETS is connected
0x1 0 0 0 0 0   xPos Module (3 axis extension)
```

Individual configured options can be identified by applying a logic AND mask to the returned value.
E.g. (val & 0x0800) to identify if Snapshot instructions are available/configured by factory, (val & 0x02000) for Trigger.

Example: Assume the ?det response is 81697, which is 0x13F21 hex. This number means in detail, that the controller is configured for:

```
1 => Built in digital I/O extension with 24in + 8out
3 => TVRin and Trigger out
F => Display, Speedpoti, Hand wheel and Snapshot
2 => 2 axes
1 => 1Vpp encoder
```

## 6.3. detext (Read Extended detailed Configuration)

Syntax: ?detext or detext
Parameter: none

Description: Read Detailed information of the controller configuration as multi-line readable text (description strings). Each line is terminated by a [CR].

Response: Multi line reply, containing the configuration number as hex value (bit representation as describet with 'det'), and the meaning of it as multi line text.

Example:

```
detext     =>     02832
                  = MR Encoder
                  = 3 Axes
                  = Snapshot
                  = Trigger out
```

## 6.4. readsn (Read Serial Number)

Syntax: ?readsn or readsn
Parameter: none

Description: Reads the serial number of the TANGO controller.

Response: The controller returns its unique serial number as ASCII character string. The syntax is YYWWTNXXX.

YY year of manufacturing
WW week of manufacturing
T controller type identifier
N in hardware available axes (may differ from **?maxaxis**)
XXX index number

Example: ?readsn => 140413045

## 6.5. ver (Read default Version Number)

Syntax: ?ver or ver
Parameter: none

Description: Read the default controller version info. The first digit is the number of configured axes. The second digit is the maximum possible motor current in ampere.
To read the TANGO firmware version, please use **'version'**.

Response syntax: Vers:*LSnm.xx.xxx* (in some cases "Vers:*ESnm.xx.xxx*")

"Vers:LS" Fixed character string (also "Vers:ES" possible)
n Number of configured axes: 1, 2, 3, or 4
m Maximum Motor current: 1=1.25A, 2=2.5A, 3=3.75A
x Fixed numbers

Example: ?ver => Vers:LS32.00.038 (=3 axis 2.5 A)

## 6.6. iver (Read internal Version Number)

Syntax: ?iver or iver
Parameter: none

Description: Read the internal version information string. Mostly unused.
To read the TANGO firmware version, please use **'version'**.

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

Example: ?iver => T04.35.02-0004

## 6.7. uptime (Read Controller Up Time)

```
Syntax:          ?uptime or uptime, !uptime
Parameter:       none, 1 or -2, or uptime millisecond offset as integer

Description:     Returns the power-on time of the controller
                 since it was switched on or resetted.
                 Depending on the parameter (none, -2 or 1) the readout
                 can be in seconds, in hh,mm,ss or in milliseconds.

                 The milliseconds can be manipulated.
                 It is possible to to set the milliseconds to zero
                 or a specified positive value.
                 A negative value will clear the milliseconds offset
                 and return to the true internal time.
                 The seconds and hh, mm, ss readout are not affected
                 by the millisecond manipulation. They always return
                 the true uptime.

Response:        Time in seconds
                 or in milliseconds with optional time offset
                 or in hours, minutes and seconds
                 Please refer to the examples below.

Example:         ?uptime     => 4503        (time in seconds)
                 uptime      => 4503        (same as ?uptime)

                 ?uptime -2  => 01h 15m 03s (time in hh,mm,ss)

                 ?uptime 1   => 45033821    (time in milliseconds)

                 !uptime (sets the milliseconds uptime time to zero)
                 ?uptime 1   => 2
                 !uptime 1000 (sets the ms uptime time to 1000ms)
                 ?uptime 1   => 1002
                 !uptime -1   (clear the millisecond offset)
                 ?uptime 1   => 45033826
```

## 6.8. temp (Read Case Temperature)

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

Description:     Read the ambient temperature inside the controller.
Remarks:         Not all TANGO controllers provide a temperature sensor.

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

Example:         temp        => 28.5
```

## 6.9. maxaxis (Read number of available Axes)

Syntax: ?maxaxis
Parameter: none

Description: Read the number of available (factory configured) axes.
1, 2, 3 or 4 (single axis Z controllers return a 'z').

Response: Number of available axes.

Example: ?maxaxis => 3

## 6.10. maxcur (Read Maximum Motor Current)

Syntax: ?maxcur
Parameter: x, y, z, a or none
Optional parameter 1

Description: Read the maximum possible motor current which can be set by !**cur**.

A) Maxcur called without parameter:
Maximum motor current which the power amplifier can deliver.

B) Maxcur called with parameter "1":
Motor current limitation, set by the connected axis (via ETS).

Response: maximum motor current in Ampere [A] (e.g. "1.25" or "1.00")

Examples:

| | |
|---|---|
| ?maxcur y | read maximum adjustable motorcurrent of Y axis only |
| ?maxcur | read maximum adjustable motorcurrent of all available axes (e.g. returns 1.25 1.25 1.25 1.00) |
| ?maxcur y 1 | read motor current limitation of Y axis only (e.g. set by ETS) |
| ?maxcur 1 | read motor current limitation of all axes (e.g. set by ETS) |

## 6.11. etspresent (Read ETS Detect State)

```
Syntax:          ?etspresent
Parameter:       none

Description:     Check if an ETS was detected by the TANGO (during power-up).

                 0 = No ETS found at the corresponding address
                 1 = ETS was found at the corresponding address (is available)

Remarks:         If more than one ETS is found, the first one (lowest address)
                 is treated as the 'main' ETS, the ETS with higher address only
                 for the there defined axis specific parameters (e.g. axis 3).

Response:        ASCII string of 4 characters, 0 or 1
                 [ETS ADR0][ETS ADR1][ETS ADR2][ETS ADR3]

Example:         ?etspresent  => 0000   (no ETS connected)
                 ?etspresent  => 1000   (ETS found at address 0, usual case)
                 ?etspresent  => 1010   (ETS found at address 0 and 2)
```

# 6.12. stagesn (Read Connected Devices Serial Number)

Syntax: ?stagesn
Parameter: none or -1,0,1,2,3

Description: Read the device serial number from the ETS.
If the motor axis provides an ETS identification circuit, the serial number of the axis or connected unit (e.g. a microscope stage) is returned.

Call parameter options:

- None: 4 serial numbers are returned, one for each possible ETS address (0,1,2,3)
- -1 : 1 Serial number is returned, of the main ETS (usually also the only connected ETS, recommendet instruction)
- 0~3 : Addresses an individual ETS, usually only ETS#0 is available (which also responds to the -1 parameter)

Response: ASCII string(s) of 8 or 9 characters.
The syntax is YYMMDDXXX or "---------" if no ETS available.

YY year of manufacturing
MM month of manufacturing
DD day of manufacturing
XX(X) index number

Example: One ETS connected to the XY stage (at ETS address 0)

```
?stagesn     => 140328015 --------- --------- ---------
?stagesn -1  => 140328015      (The ETS at address 0 is the "first" ETS)
?stagesn 0   => 140328015      (The ETS at address 0)
?stagesn 1   => ---------
```

One ETS connected to the Z axis (here at ETS address 3)

```
?stagesn     => --------- --------- --------- 140328015
?stagesn -1  => 140328015      (The ETS at address 3 is the "first" ETS)
?stagesn 0   => ---------
?stagesn 1   => ---------
?stagesn 2   => ---------
?stagesn 3   => 140328015      (The ETS at address 3)
```

Two ETS connected to the XY stage and the Z axis (here ETS addresses 0 and 1)

```
?stagesn     => 151125014 160714003 --------- ---------
?stagesn -1  => 151125014      (The ETS at address 0 is the "first" ETS)
?stagesn 0   => 151125014      (The ETS at address 0 is the "first" ETS)
?stagesn 1   => 160714003      (The ETS at address 1)
?stagesn 2   => ---------
```

## 6.13. maxpos (Maximum Position)

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

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

Response:         Maximum position value of the axes
                  (unit depends on 'dim' setting)

Example:
?maxpos     => 2600.0000 2600.0000 2600.0000
?maxpos x   => 2600.0000 (X axis accepts positions from -2600mm to +2600mm)
```

## 6.14. lockpos (TransportLock Position)

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

Description:      Read the factory set transportlock position, where the axis
                  must be positioned to for the fixation screw/transportation.
                  A value of zero indicates the position is not available.

Remarks:          Refer to the !mol instruction

Response:         Transportlock position

Example:
?lockpos     => 50.3815 38.0018 0.0000
?lockpos y   => 38.0018 (Y axis transportlock position)
?lockpos z   =>  0.0000 (Z axis provides no transportlock position)
```

# 7. Communication Interface Settings

## 7.1. baud (Baud Rate)

Syntax: !baud or ?baud
Parameter: 1200, 2400, 4800, 9600, 19200, 38400, **57600** or 115200

Description: Set or read the baudrate of the serial COM Port interface.

It applies to devices with a true RS232 serial connection, as available with TANGO-DT, TANGO mini (RS232 and USB versions), TANGO 3 mini (RS232 only), TANGO integrale and the USB Pilot stage.

Remarks: For PCI/PCI-E card versions, TANGO-DT or TANGO 3 mini with USB interface this instruction has no effect, as communication is managed by the driver at a very high, internally fixed baudrate. In this case it does not matter which baudrate the virtual COM port is opened with, it has no effect on performance.

After sending this instruction the PC has to re-open the COM Port with the new baudrate, else no communication is possible. Then a **'!save'** instruction may be sent to permanantly store the new baudrate in the controller.

The default baudrate to connect a TANGO is 57600.

Response: Current baud rate of the controller

Examples:

| | |
|---|---|
| !baud 57600 | Set the baud rate to 57600 [Bd] |
| ?baud | Read currently set baud rate |

## 7.2. cts (Enable/Disable RS232 Hardware Handshake)

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

Description: Only supported by TANGO PCI-S/DT-S and PCI-E/DT-E controllers. Enable or disable RTS/CTS hardware.

0 = no handshake (default)
1 = RTS/CTS handshake

Remarks: The COM port of the PC has to be opened in the same hardware handshake mode.

Response: Currently selected cts mode

Examples:

| | |
|---|---|
| ?cts | read current handshake mode |
| !cts 0 | disable RTS/CTS handshake (default, recommended) |
| !cts 1 | enable RTS/CTS handshake |

# 8. System Instructions

## 8.1. save (Save Parameters)

Syntax: !save or save
Parameter: none

Description: The save instruction permanently stores the parameter settings (e.g. spindle pitch, motor current) in the TANGO controller. These parameters will be applied as default values after each consecutive power-on or reset. Executing a save comand always returns the "OK..." string when writing to the internal memory has completed successfully.

Remarks: When using TANGO controllers with 4 axes, a save should not be executed while the 4th axis is traveling.
When using a TANGO 3 mini, a save instruction should not be executed while any axis is traveling in closed loop. In both cases, it is preferred to save only when those axes are idle.

Response: ASCII string "OK... " or "ERR"

Example: save
==> OK... (The currently used controller parameters are saved and from now on used as defaults)

## 8.2. restore (Restore Saved Parameters)

Syntax: !restore, restore or ?restore
Parameter: none or -1

Description: Reload or reset the saved parameters.

**When called without parameter (restore, !restore, ?restore)**
The controller reloads the parameter settings from its nonvolatile memory, same as it does at power-on or reset. But restore does not affect or restart the entire hardware.

***?****restore* returns "OK..." or "ERR" (like the save instruction), Executing *restore* without a question mark does not reply. **?err** then might be sent once after the restore instruction and will reply the err response (e.g. a 0) after restore has completed.

**When called with parameter "-1" (restore -1, !restore -1)**
The saved parameters (nonvolatile memory) will be deleted and set to the firmware defaults. The parameters then have to be checked and set to the hardware requirements by the user. Else it may cause damage (due to overcurrent, wrong pitch, limit switch types etc). Software reset is performed automatically.

There is no reply to the restore -1 instruction, ?err polling may be required as described with the software **'reset'**.

Response: none, or "OK..." or "ERR" when using ?restore

Example:
```
restore          (reload the saved parameter set)
?restore         (like restore, but with "OK..."/"ERR" reply)
restore -1       (reset the saved parameters to default)
```

## 8.3. reset (Force a 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.

Remarks: Wait for reboot after Reset:
For knowing if the controller has rebooted and is ready, data may be polled until it responds again. E.g. send **'?err'** until the controller responds:
Send ?err [wait 0.5s for response]
Send ?err [wait 0.5s for response]
...
Send ?err [wait 0.5s for response]
Send ?err => 0 [Response, controller is ready]

Response: none

Example: reset

# 8.4. pa (Enable or Disable the Power Amplifiers)

Syntax: !pa or !poweramplifier
?pa or ?poweramplifier

Parameter: 0, 1, 2 or 3, the options for read are: none or -1

Description: Switch all motor amplifiers on/off or read amplifier state.

If switched off, no motor current is flowing (high impedance).

Amplifier switch off can also be caused by a short circuit, the PSE pin functionality or loss of motor supply voltage. Then an internal error (error 29) is generated and the status LED flashes. ?pa will return 0. After removing the switch-off cause, the amplifiers can be switched on again, e.g. by !pa 1.

PARAMETERS FOR THE SET INSTRUCTION (!pa)

0 : Amplifiers off
1 : Amplifiers on
2 : Special Closed Loop switch on instruction, see remarks
3 : Similar to 1, but keeps the cal and rm limits (caution!)

PARAMETERS FOR THE READ INSTRUCTION (?pa)

none = read general amplifier state: 1 = ok, 0 = error or off
-1 = read individual amplifiers : 1 = on, 0 = off

Remarks: To switch off individual axes, use the **'axis -1'** instructions.

If the amplifiers switched off due to any condition or by the "!pa 0" instruction, and the axes were in active closed loop state before, it is possible to switch them on again and reactivate the closed loop at the current axis positions by sending "!pa 2". A **cal** or **rm** sequence is not required and the momentary (measuring system) postions of the axes are applied. For axes without encoders, "!pa 2" will behave like "!pa 1". "!pa 3" is only for open loop applications and where the axis positions did not change while the amplifiers were off.

When using !pa 1 (or using !pa 2 without active closed loop), the **cal** and **rm** sequence must be executed again.

Response: amplifier state 0 = Amplifiers are off or at least one amplifier switched off (by error,PSE,!pa0)
1 = Amplifiers are on

Example:

| | | |
|---|---|---|
| !pa 0 | Switch all amplifiers off | |
| !pa 1 | Switch on all amplifiers, closed loop not recovered CAL/RM has to be repeated due to uncertain position. | |
| !pa 2 | Switch on all amplifiers, closed loop is recovered. If axes were in closed loop before they switched off, they continue at their momentary position and CAL/RM is not required. | |
| !pa 3 | Switch on all amplifiers, closed loop not recovered CAL/RM state is recovered (→ useful in open loop) | |
| ?pa | Read amplifier state | (e.g. returns 1) |
| ?pa -1 | Read amplifier state of all axes | (e.g. returns 1 1 1) |

# 8.5. ipreter (Select Instruction Set)

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

Description: Instruction set of the TANGO controller.
The TANGO controller provides 4 different instruction sets, also called "interpreter".
It is recommended to use the default interpreter 1, as it is the native language and supports the most complex instruction set available.
Other instruction sets may be used for compatibility to existing applications. They are described in separate manuals.

| INTERPRETER NR. | |
|---|---|
| 0 | Not supported! (old register instruction set) |
| 1 | TANGO instruction set (default), as described in this manual |
| 2 | VENUS-1 and VENUS-2 |
| 3 | LUDL MAC5000 |
| 4 | ASI MS-2000 (available with Firmware >= 1.46) |

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

Response: 1, 2, 3 or 4

Example:
!ipreter 2 => Switch the interpreter to the VENUS instruction set
?ipreter => Responds the currently selected interpreter

# 9. Operating Modes

## 9.1. autostatus (Set Autostatus Behavior)

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

Description: Select auto response behavior for completion of move and calibration instructions. The power-on default is mode 1. Autostaus mode cannot be saved by the **'save'** instruction. Move instructions !moa,!mor,m,!moc,!mol behave identical. Calibrate instructions are slightly different, ('A','D').

**0** : Disable automatic status replies
(Except **'!save'** instructions will still return either "OK..." or "ERR")

**1** : **Default state at power on. Recommended.**
Position reached response after an automatic move (!moa,!mor,m,!moc,!mol) as a 5 character string with e.g. '@' for each configured axis: "@@@@."
!cal returns an 'A' instead of '@' and !rm returns a 'D'.
Disabling the joystick by "!joy 0" also causes a response.
Please refer to **'statusaxis'** for further explanation of the reply.

2 : Instructions with a leading "!" are immediately acknowledged by the **status message** ("OK..." or "ERR"). Move and Cal/Rm instructions will respond additionally like in auostatus 1 (e.g. "AAA-." response).

3 : Similar to the default mode 1, but a simple <CR> (0x0d hex) is returned to indicate that the move is completed. It can be used to improve performance for higher vector throughput, but contains less information e.g. concerning possible errors.

4 : Echoes the instruction that was sent, in case of set or move instruction.

Example: !autostatus 0 disable autostatus (**'statusaxis'** must be polled to identify if the axis is traveling or stopped)
!autostatus 1 set autostatus to the default behavior
?autostatus read the currently selected autostatus

**--- autostatus 0 ---**

!moa,!mor,m,a,cal,rm ==> [returns nothing, statusaxis (sa) must be polled]

**--- autostatus 1 --- (the default mode after power on)**

!moa,!mor,m,!moc,!mol ==> [returns completion, 5 ASCII character string @@@-.]
!cal,!rm ==> [returns completion, 5 ASCII character string AD@-.]

**--- autostatus 2 ---**

!vel 10 ==> [returns "OK..."]
!vel -10 ==> [returns "ERR 5"]
vel 10 ==> [returns nothing (is executed but no "!" reply)]

**--- autostatus 3 ---**

!moa,!mor,m,a,cal,rm ==> [returns completion, 0 ASCIIs only <CR> termination]

**--- autostatus 4 ---**

!moa 10 5 0 ==> [returns !moa 10 5 0]

## 9.2. Extended Mode

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

**Calibration in extmode = 0:**

**!vel** --> The velocity for moving towards a limit switch 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 Limit switch. The unit is 1/100 rev/s.

**Calibration in extmode = 1:**

**!vel** has no influence to the !cal and !rm move, **calbspeed** is no longer used. Now the calibrate (**cal**) and range measure (**rm**) velocities can be assigned once and will be used as speed especially for this instructions.
**!calvel** --> Set velocities for moving towards and out of the cal switch (E0)
**!rmvel** --> Set velocities for moving towards and out of the rm switch (EE)

**Additional differences when in extmode = 1:**

If the pitch or gear parameter is changed, all parameters which are in revolutions/s (e.g. vel) are recalculated internally. So the axis velocities will remain the same.

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

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

### 9.2.1 extmode (Switch to Extended Mode)

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

Description: This instruction switches the TANGO controller into extended mode. This mode offers improved behavior and more instructions than the standard interpreter. For further information please refer to the **Extended Mode** Chapter 9.1.

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

Response: currently used extmode, 0 or 1

Examples:
!extmode 1 Set controller behavior to extended mode
?extmode Read extended mode setting

## 9.3. Scan Mode

By default, with ScanMode deactivated, a single axis move (moa or mor x,y,z,a) causes the specified axis to travel at its own velocity and in case several axes are specified (e.g. moa 10 5 3), up to four axes travel as a vector in order to reach their target positions at the same time. The velocity is recalculated in a way that none of the involved axes exceeds its velocity or acceleration limits.

This means the resulting vector velocity of a multi-axis vector move depends on the axes velocities and travel distances.

Scan Modes 1, 2 and 3 change this behavior:

In some cases it is required that the resulting vector travel velocity is always the same, independent in which direction or angle the vector is pointing. This "continuous path velocity" (parameter '**scanvel**') is applied in ScanMode 1.

ScanMode 2 limits this behavior to multi-axis move instructions only. It causes single axis moves to use their individual velocity (**vel**), which can be used e.g. to drive the Z axis independently while X and Y still travel as a continuous path vector.

ScanMode 3 entirely disables vector moves. All moves, no matter if single axis or multi-axis, are traveling at their own velocity (**vel**) setting and so may reach their target position at different times (they stop individually).
This mode is useful if the system configuration consists of individual axes.

ScanMode 3 might also be of advantage in stop-and-go line scans for image stitching, where X or Y is the scan axis and Z is required to follow a focus map = each position consists of an X position with its individual Z value. One axis might have already settled in its target position then (no more oscillating) when the other axis arrives. This might give an advantage in overall speed compared to the default mode, where the X and Z then would arrive (and oscillate and settle) in their target position at the same time.

## 9.3.1 scanmode (Scan Mode to change Axis Vector Move Behavior)

Syntax: !scanmode or ?scanmode
Parameter: 0, 1, 2 or 3

Description: This instruction switches the TANGO controller into scan mode, which may be used for continuous path control (modes 1,2) or special requirements of move behavior.
Modes 1 and 2 apply a constant vector velocity for automatic moves (moa, mor) which is set by **'scanvel'**.

0 = normal operation (the default TANGO mode)
1 = scan mode 1
2 = scan mode 2
3 = no vector moves (else identical to mode 0)

**Scan mode 0: Normal operation (TANGO default)**
- Single axis moves travel at their individual vel and accel.
- Vector moves are calculated to reach the target position at the same time without exceeding a velocity or acceleration of any of the involved axes. Scanvel is not used.

**Scan mode 1: Resulting move velocityes are always scanvel**
- The resulting travel velocity of automatic moves is **scanvel**.
- The individual **'vel'** settings are ignored.
- Applies to single axis and vector moves,
  e.g. "!moa x 10"→scanvel, "!mor 20 20"→x=y=scanvel/sqrt(2)

**Scan mode 2: Only vector moves are executed with scanvel**
- Similar to scanmode 1, but individually started axes now travel at their original **'vel'** settings. May be useful e.g. when the Z-axis controls the focus.
- The resulting travel velocity of a vector move is **scanvel**.
- The individual **'vel'** settings are used for single axis move, e.g. "!moa z -10"
- Scanvel only applies to vector moves of 2 or more axes, e.g. "!moa 10 20"

**Scan mode 3: No vector moves**
- Similar to mode 0 (normal operation, not a mode as 1 or 2).
- When using vector moves (move instruct. with several axes), each axis travels at its individual **vel** and **accel** settings.

Response: Scanmode (automatic move mode) as integer

Examples:

| | |
|---|---|
| !scanmode 1 | Set controller into scanmode 1 (always traveling at scanvel) |
| ?scanmode | Read controller scanmode |
| *!vel 20 20 10* | (*example*: vel x,y = 20, vel z = 10) |
| *!scanvel 0.1* | |
| **!scanmode 2** | |
| *!moa 50 100* | → vector move with scanvel (vector velocity is now 0.1mm/s) |
| *!mor z 1.5* | → single axis move executed with vel z (this example 10mm/s) |
| !scanmode 0 | Disable scanmode (=default, normal operation) |
| !scanmode 3 | No scanvel, vector moves now let each axis travel at its own vel x,y,z,a setting towards the target<br>e.g. !mor 10 10 5 starts each axis at its own vel setting |

## 9.3.2 scanvel (Vector Velocity for Scanmode and Dissection)

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

Description: This instruction sets or reads the **'scanmode'** vector velocity in millimeters per second. It is also used for the snapshot dissection mode (**snsm** 3) continuous path velocity. There is only one parameter and the unit is always mm/s.

Remarks: The **secvel** velocity restrictions will be applied to the individual axes as long as they are not calibrated and range measured (when **cal** + **rm** are not executed).

Response: Currently selected scanmode velocity in [mm/s]

Examples:
!scanvel 0.1 Set scanmode vector velocity to 0.1 mm/s
?scanvel Read scanmode velocity (returns e.g. 0.100000)

# 9.4. ModuloMode

Modulo Mode can be used for turntable- and for endless rotating applications.

## 9.4.1 modulomode (Define Linear or Turntable Modes)

Syntax: !modulomode or ?modulomode
Parameter: x, y, z, a or none
0, 1, 2, 3 or 4

Description: This instruction sets or reads the axis modulo mode. Modulo mode sets the specified axes from linear into a turntable mode, where the position remains within one revolution, e.g. [0…360[° when **dim** = 3 or [0…1[ when the **'dim'** (displayed unit) is set to 4.

The default linear mode and 4 different turntable modes are available:

**0** : Modulo Mode off (default mode, e.g. for linear axes)
Required for most applicaions.

1 : Travel shortest distance to target position
*(automatically decides to travel forward or backward)*

2 : Only travel in positive direction (forward)
*If the target position is below the current position, the axis travels once around to reach it (e.g. 359°->358°)*

3 : Only travel in negative direction (backward)
*If the target position is above the current position, the axis travels once around to reach it (e.g. 358°->359°)*

4 : Do not travel over Zero
*e.g. for swiveling axes <360° with limited operation range or as cable tear-off protection*
*(the axis remains within one revolution or the limits, travels forward and backward)*

Modes 1,2 and 3 ignore the upper and lower limits of the axis. While mode 4 uses the limits (**cal**,**rm**,**lim**) in order to narrow the possible operating range.

It is possible to switch between the modes (especially 1,2,3) during operation (typ. before a move instruction), to achieve the momentarily required behavior.

Remarks: Endless rotating applications: Modulo Mode 1 in conjunction with the **!speed** instruction can be used to achieve an endless rotating mode (pumps, fans, etc.). (Because in linear mode the rotation will stop at the maximum travel range, e.g. ±2600mm).

Response: Currently selected modulo mode

Examples:
```
!modulomode 0 0 1 (set Z axis to modulo mode 1, X and Y to linear, A unchanged)
!modulomode a 4   (set A axis to modulo mode 4)
?modulomode       => 0 0 1 4 (returns modulo mode of all axes, here: of 4 axes)
?modulomode z     => 1       (returns modulo mode of Z axis, here: e.g. 1)
```

# 9.5. External Display Mode

TANGO controllers with dual interface (USB and RS232) can be configured to support the external position display "PROFILER SCD CL". This display unit connects to the TANGO through RS232.

The internal TANGO position is displayed, independent of closed or open loop operation. If the TANGO uses position correction, the corrected position is shown.

With display enabled (by **"!configdisplay 1"**), the TANGO sends position and status data over its RS232 interface. The RS232 then can't be used for communication with the PC anymore; the PC must be connected via USB.

## 9.5.1 configdisplay (Configure External Display)

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

Description: This instruction enables or disables the external position display "PROFILER SCD CL".

0: disable external display (normal RS232 opreation)
1: enable external display (RS232 occupied by display)

Remarks: Only available if TANGO has two interfaces (USB and RS232, or PCI-E and RS232), e.g. TANGO DT-E/PCI-E and TANGO 3 mini. TANGO firmware 1.67 or higher is required.

Response: Currently selected display mode

Examples:
!configdisplay 0
?configdisplay

# 10. Controller States and Error Messages

## 10.1. statusaxis (Read State of Axis)

Syntax: ?statusaxis or statusaxis or sa
Parameter: x, y, z, a or none

Description: Statusaxis (sa) returns the state of each axis.
Similar to the **'autostatus** 1' response for move instructions, but with an additional '-' after the dot (.- instead of .).
It can be used for polling move states when 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 instruction.
It is recommended to check the returned ASCII character for != 'M' (not equal to 'M', 0x4D hex).

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 ready and may also be controlled manually (by joystick)
S => Limit switches are actuated and prevent further automatic move
A => ok response after cal instruction
D => ok response after rm instruction
E => error response, move aborted or not executed
(e.g. **cal** or **rm** error, or stop input active)
T => Timeout occurred (refer to **'caltimeout'** instruction)
- => Axis is not enabled, not available in hardware

Example: Assume ?statusaxis returns @@@-.-
This means all three axes are enabled and idle.

?statusaxis => JM--.- (2 axis controller, X is idle, Y is traveling)
sa => A@@-.- (3 axis controller after a **!cal x** instruction)
sa x => M (X axis is traveling)

## 10.2. calst (Read Calibration State of Axis)

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

Description:     Calst returns the calibration state of one or all axes.
                 Similar to the 'statuslimit' instruction, it contains the
                 information if the cal or rm routines were executed or not.
                 But In a more easy readable way.

                 0 : Neither Cal nor Rm executed yet
                 1 : Cal executed, Rm not
                 2 : Rm executed, Cal not
                 3 : Cal and Rm executed

Remarks:         It is recommended to check the return value bitwise (by &1,&2)
                 to allow addition of further states for future extensions of
                 this instruction.

Response:        Decimal numbers with containing the bit representation
                 of the cal and rm executed states. One value per axis.

Example:         calst    => 3 3 1 (CAL+RM executed for X and Y, Z only CAL)
                 calst z  => 1     (CAL executed for Z, RM not)
```

## 10.3. corrst (Read Position Correction State)

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

Description:     Read the state of position correction
                 Bit 0 (1) = correction data available
                 Bit 1 (2) = correction requested (by '!corr 1')
                 Bit 2 (4) = correction active

Response:        Bit coded integer number

Example:         corrst   => 7 3 0
                 corrst x => 7      (Bit 0,1,2 are 1 = correction active)
```

## 10.4. status (Read 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 the error number. The error number description can be found in chapter **Error Numbers**. Also refer to '**err**' and '**help**' instructions.

Response: OK... or ERR with error number

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

## 10.5. err (Read Error Number)

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

Description: The 'err' instruction returns the controller error state or 0, if no error occurred. The error state will be updated or reset by the next instruction.
The 'err' or '?err' instruction does not manuipulate the error state (the erro state remains). The error state can be cleared to zero by sending !err, except it is a permanent error as e.g. error 29.

Response: Error number as decimal value
Refer to Chapter 5: **Error Numbers**

Remarks: Errors can be caused by instructions, e.g. if there is a typo or if the parameters are not accepted etc. Those error numbers are typically in the range of 1 to 10. Each instruction overwrites the error state, so 'err' only corresponds to the previously executed instruction. If the previously executed instruction returned no error, the 'err' response is either 0 or if an internal error state is active, the internal error is returned. Those error numbers are typically no. 20 and above.

Example: err => 0
?err => 0 (same as err)

?err => 5
!err (clears the error state to 0 if not a permanent error)
?err => 0

## 10.6. help (Read Error Number with Description String)

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

Description: The 'help' instruction 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.

**Called without a parameter:**
It returns the controller's error state with description

**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   (assuming there is no error)
help    => ERROR 5,number outside range
help 29 => ERROR 29,servo amplifier off
```

## 10.7. service (Print Service Information to Terminal)

Syntax: ?service or service
Parameter: none

Description: Returns a multi-line parameter and state list of the TANGO 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. Each line terminated by a [CR]. From TANGO firmware 1.60C/1.61 (September 02, 2015) and later, the last line sends the string "END_SERVICE_PRINT." indicating the end.

Example: service

## 10.8. pci (Is PCI Bus)

Syntax: ?pci or pci
Parameter: none

Description: Check if the TANGO controller is used as PCI/PCI-E card (plugged into a PC slot).

0 = Controller is a desktop version
1 = Controller is a PCI or PCI-E card, plugged in the PCI(-E) slot of a computer (here: no RS232 or USB communication)

Response: 0 or 1

Example: pci => 0 (e.g. a TANGO Desktop)

## 10.9. isvel (Read Actual Velocities)

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

Description: Read the actual velocitie(s) at which the axis is currently traveling. Unlike **'?vel'** or **'?speed'** this instruction returns the currently traveled (true) speed of the axes, even when contolled by a HDI device.

Optional read-resolution: As an option to read the value with higher precision, the number of required decimal places can be specified with the query "?isvel [0…16 decimal places]". If no precision is defined, the default resolution is 3 decimal places.

Response: Actual axis velocity in [mm/s]

Example:

```
?isvel     => Read actual velocity of all axes
?isvel y   => Read actual velocity of the Y axis (e.g returns 10.000)
?isvel 4   => Read actual velocity of all axes with 4 decimal places (0.0000)
?isvel y 6 => Read actual velocity of the Y axis with 6 decimal places
isvel      => Same as ?isvel
```

## 10.10. iscur (Read Actual Motor Current)

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

Description: Read the momentarily applied motor current, which includes current reduction or switched off states (by **axis**).

Remarks: It is not a measured value.

Response: Applied motor current in [A]

Example:
?iscur => Read applied motor current of all axes
?iscur y => Read applied motor current of the Y axis (e.g returns 1.00)
iscur => Same as ?iscur

# 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 and Velocities)

Syntax: !dim or ?dim
Parameter: x, y, z, a or none
0 to 9

Description: The dim instruction sets the unit (here "dimension") of the input and output parameters related to length, e.g. position or move instructions. Dim 9 also sets the velocity parameters to mm/s (e.g. **'vel'**, **'speed'**), which else remain in motor revolutions per second.

0 = Micro steps
1 = µm
2 = mm (the default: velocities in motor revolutions/s)
3 = 360°
4 = revolutions
5 = cm
6 = m
7 = inch
8 = mil (1/1000 inch)
9 = mm (difference to mode 2: all velocity units in mm/s)

Remarks: For dim modes 3 (=360°) and 4 (=revolutions) it is recommended to use a **spindle pitch** of 1mm.

In dim mode 0, the amount of microsteps per revolution can be specified by the **'usteps'** instruction. This provides compatibility to existing software (which e.g. might require 40000 or 54000 steps/rev) as well as giving flexibility in defining own requirements (e.g. 360 steps/rev).
As the internal resolution of the TANGO is not affected, the full resolution can still be accessed by using fractional ustep values (e.g. "**!moa** 39000.22" or "**!mor** 178.63"). While reading back the position will not contain fractional digits.

Response: Current dim settings

Examples:
!dim 4 1 set dim unit for X to [revolutions] and for Y to [µm]
!dim z 9 set dim unit for Z to [mm and mm/s]
!dim 2 2 2 set dim unit for axes X, Y and Z to [mm]
?dim read dim unit for all axes
?dim a read dim unit of A-axis only

## 11.2. pitch (Spindle Pitch)

Syntax: !pitch or ?pitch
Parameter: x, y, z, a or none
0.0001 to 72 [mm/rev]

Description: This instruction sets or reads the spindle pitch which defines the axis travel distance in millimeter per motor (or gear) revolution.

Optional read-resolution: As an option to read the parameter with higher precision, the number of required decimal places can be specified with the query "?pitch [0…16 decimal places]". If no precision is defined, the default resolution is 4 decimal places.

Remarks: If the required pitch value is an infinite number due to a 1/x function, the **'gear'** parameter can be used instead or in combination.

Response: currently used spindle pitch in [mm per motor revolution]

Examples:

| | |
|---|---|
| !pitch 4 1 | set spindle pitch X=4[mm] and Y=1[mm] |
| !pitch z 28.895 | set spindle pitch Z=28.895[mm] |
| ?pitch | read spindle pitch of all axes (e.g. returns 1.0000 1.0000) |
| ?pitch a | read spindle pitch of A-axis only |
| ?pitch 9 | read spindle pitch of all axes with 9 decimal places |
| ?pitch y 6 | read spindle pitch of Y-axis with 6 decimal places (1.000000) |

## 11.3. gear (Gear Ratio)

Syntax: !gear or ?gear
Parameter: x, y, z, a or none
0.001 to 1000

Description: This instruction sets or reads the axis gear ratio. If there is no gearbox mounted to the axis, this parameter should be left at its default value of 1.

Optional read-resolution: As an option to read the parameter with higher precision, the number of required decimal places can be specified with the query "?gear [0…16 decimal places]". If no precision is defined, the default resolution is 3 decimal places. Please also refer to the examples below.

Remarks: If the required pitch value is an infinite number due to a 1/x function, the **'pitch'** parameter can be used instead or in combination.

Response: currently used gear ratio

Examples:

| | |
|---|---|
| !gear 10 | set gear ratio X=1:10 |
| !gear 4 1 | set gear ratio X=1:4 and Y=1:1 |
| !gear z 12.5 | set gear ratio Z=1:12.5 |
| ?gear | read gear ratio of all axes |
| ?gear a | read gear ratio of A-axis only (e.g. returns 1.000) |
| ?gear 9 | read gear ratio of all axes with 9 decimal places |
| ?gear z 10 | read gear ratio of Z-axis only with 10 decimal places |

## 11.4. motorsteps (Motor Steps Per Revolution)

Syntax: !motorsteps or ?motorsteps
Parameter: x, y, z, a or none
4 to 65532 as multiples of 4

Description: This instruction sets the steps per revolution of the motor, which can be found in the datasheet. Common motors have 200 steps per revolution (1.8° full step). This is the TANGO default value. Other motors may have e.g. 400, 500 or 24 steps per revolution. It is essential for operation to have this parameter set according to the datasheet.
The motor steps paramerer must be a multiple of 4 in the range of 4 to 65532.

Response: Selected motorsteps of the stepper motor(s)

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 | read motorsteps of all axes |
| ?motorsteps a | read motorsteps of A-axis only |

## 11.5. accel (Acceleration)

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

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

Optional read-resolution: Accel can be read with a higher resolution than the default 2 decimal places. To read accel with more (or less) decimal places, the number [0 to 10] can be specified with "?accel [0…10]". See examples below.

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

Response: Currently used acceleration in m/s²

Examples:

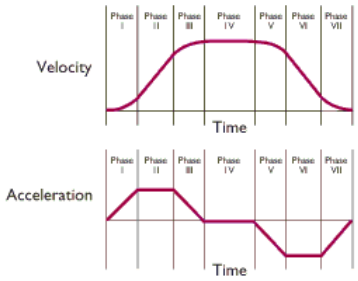
| | |
|---|---|
| !accel 0.5 | set acceleration X=0.5[m/s²]. Other axes are not affected |
| !accel 1 0.55 | set acceleration X=1.0[m/s²] and Y=0.55[m/s²] |
| !accel z 0.2 | set acceleration Z=0.2[m/s²]. Other axes are not affected |
| ?accel | read acceleration of all axes |
| ?accel z | read Z axis acceleration |
| ?accel 6 | => 0.500000 0.123456 0.200000 (read accel with 6 dec. places) |
| ?accel y 4 | => 0.1235 (read Y accel with 4 dec. places) |

# 11.6. accelfunc (Acceleration Ramp Function)

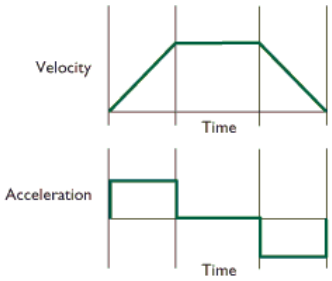
Syntax: !accelfunc or ?accelfunc
Parameter: x, y, z, a or none
0, 1 or 2

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

0 = Linear acceleration and deceleration ramp
1 = s-curve acceleration and deceleration ramp
2 = reserved, currently behaves as 1 (s-curve)




s-curve accel (1)




linear accel (0)

Remarks: The acceleration ramp for **'go'** and **'speed'** instructions and manual control (via HDI) always remains linear accelerated.

Response: Currently used acceleration type

Examples:

| | |
|---|---|
| !accelfunc 1 | set accel function X to s-curve, other axes are not affected |
| !accelfunc x 1 | set accel function X to s-curve, other axes are not affected |
| !accelfunc 1 1 0 | set accel function in X and Y to s-curve, Z to linear accel. |
| ?accelfunc | read acceleration ramp function of all axes |
| ?accelfunc z | read acceleration ramp function of Z axis only |

# 11.7. stopaccel (Emergency Stop Deceleration)

Syntax: !stopaccel or ?stopaccel
Parameter: x, y, z, a or none
0.001 to 200 m/s²

Description: This instruction sets the deceleration for emergency stop conditions. It will be used by:

- abort instructions
- active stop input
- a **'cal'** or **'rm'** move (at the limit switch)
- when detecting an unexpected limit switch

Optional read-resolution: As an option to read the parameter with higher precision, the number of required decimal places can be specified with the query "?stopaccel [0…10 decimal places]". If no precision is defined, the default resolution is 2 decimal places.

Response: Deceleration for stop conditions

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 stop deceleration of all axes |
| ?stopaccel z | Returns the stop deceleration of Z axis only (e.g. 1.50) |
| ?stopaccel 6 | Returns stop deceleration of all axes with 6 fractional digits |
| ?stopaccel z 9 | Returns stop deceleration of Z axis with 9 fractional digits |

# 11.8. vel (Velocity)

Syntax: !vel or ?vel

Parameter: x, y, z, a or none
0.000001 to 200 [rev/s] (or up to 3000 [mm/s] if dim = 9)

Description: Velocity for automatic moves, cal**, rm** and HDI**

Except of dim=9, the velocity unit is always motor revolutions per second. Only in dim=9 the unit is [mm/s].

Optional read-resolution: As an option to read the parameter with higher precision, the number of required decimal places can be specified with the query "?vel [0…16 decimal places] ". If no precision is defined, the default resolution is 3 decimal places.

Remarks: ** If **extmode**=0 (default), vel is also used for

- the HDI (joystick) velocity
- the cal and rm instructions

**extmode**=1 provides separate parameters (**joyvel**,**calvel**,**rmvel**).

Vel can be used to change the travel velocity during a **go** instruction. In such case, setting vel to zero will also end a running go instruction (e.g. !vel z 0, !vel 0 0 0, etc.)

The **velfac** instruction can be used in addition to vel, but is not necessary or recommended.

Response: Currently selected velocity

Examples:

| | |
|---|---|
| !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 | read velocity of all axes |
| ?vel x | read velocity of X axis only |
| ?vel 6 | => 20.000000 0.123456 5.000000 |
| ?vel y 4 | => 0.1235 |

## 11.9. velfac (Velocity Factor)

Syntax: !velfac or ?velfac
Parameter: x, y, z, a or none
0.01 to 1.00

Description: This instruction sets or reads the velocity factor, which is used for all consecutive automatic moves. It is internally multiplied to the velocity (**vel**) and affects the positioning instructions moa, mor, moc, m, cal, rm. It does not affect instructions like go or speed.

Response: Currently used velocity factor [0.01 to 1.00]

Remarks: Velfac is just for backward compatibility and not required anymore, as the **vel** resolution is high enough to achieve the full spectrum of velocities.

Examples:

| | |
|---|---|
| ?velfac | read velocity factor of all axes |
| ?velfac z | read velocity factor of Z axis only |
| !velfac x 0.1 | set velocity factor of X axis to 1/10 of specified velocity |
| !velfac 1 1 1 | set velocity factor of X,Y,Z to specified velocity (default) |

# 11.10. secvel (Secure Velocity)

Syntax: !secvel or ?secvel
Parameter: x, y, z, a or none
0.000001 to 100 [mm/s]

Description: The security speed limitation is intended to prevent mechanical damage as long as the controller does not know the mechanical limits of the axis.
This is required because the mechanical space behind the hardware limit switches often is not sufficient to stop the axis under all velocities once they get actuated.

The security speed limitation is used as long as the axis is not calibrated and range measured (**'cal'+'rm'**, refer to Remarks section below).
The unit is always mm/s and does not depend on the 'dim' setting.

Setting secvel to higher values may be used at own risk, if executing cal and rm is not wanted.

The limitation affects all move and speed instructions as well as manual control e.g. by joystick.

Optional read resolution: As an option to read the parameter with higher precision, the number of required decimal places can be specified with the query "?secvel [0…16 decimal places]". If no precision is defined, the default resolution is 2 decimal places.

Remarks: Axes without any limit switches do not apply secvel at all.
(E0 and EE switches must be disabled by **'swact'** then.)

Axes with only one limit switch (E0/cal) release secvel after cal was executed. (EE/rm switch must be disabled by **'swact'**.)

Axes with both limit switches (or when both limit switches are enabled by **'swact'**) require both **'cal'** and **'rm'** to release the secvel.
A time saving alternate to the **rm** move would be using the "virtual rm" (**vrm**) or having a factory defined axis length stored in the axis.

Response: Currently used secure velocity in [mm/s]

Examples:

```
!secvel 100 100 100 => Set maximum possible velocity for X Y Z
!secvel y 14.5      => Set maximum possible velocity for Y to 14.5 mm/s
?secvel             => 10.00 10.00 10.00 (X Y Z response of a 3 axis controller)
?secvel x           => 10.00

!secvel y 0.0001
?secvel y           => 0.00    (the default readout is not sufficient here)
?secvel y 5         => 0.00010 (read secvel with additional decimal places)

!secvel 0.123456
?secvel x           => 0.12
?secvel x 5         => 0.12346
?secvel x 6         => 0.123456
```

# 11.11. cur (Motor Current)

Syntax: !cur or ?cur
Parameter: x, y, z, a or none
0.03 to [maximum current]

Description: This instruction sets or reads the motor current. The maximum current is limited by hardware or additionally by factory settings (ETS) and may be checked using **'maxcur'** instruction.

If the specified motor current exceeds the maximum current, it is automatically limited to this maximum value and the error state **E5** is set.

Remarks: Please check the motor datasheet first in order not to damage the motor by overcurrent/overtemperature. If setting the motor current too low for the application the axis can lose steps. In open loop systems (no encoder feedback) this can cause loss of position, it mostly happens at very low velocities. It can lead to mechanical damage, because the position information is incorrect and with it the reference for the axis position limits. At least for open loop systems it is required to ensure the axis travels correctly under all required velocities and load situations.

If current reduction is active, the momentarily applied motor currents can be checked any time via the **iscur** instruction.

Response: Motor current in Ampere (e.g. 1.00)

Examples:

| | |
|---|---|
| !cur 1.1 | set X motor current to 1.1[A] |
| !cur 0.7 2.4 | set motor current for X=0.7[A] and Y=2.4[A] |
| !cur z 0.3 | set Z motor current to 0.3[A] |
| ?cur | read motor current of all axes |
| ?cur x | read motor current of X axis only |

# 11.12. reduction (Motor Current Reduction Factor)

Syntax: !reduction or ?reduction
Parameter: x, y, z, a or none
0 to 1.00

Description: Motor current reduction factor when idle, used to reduce the dissipated heat from the motor.
When the axis is idle (stopped), the motor current (**cur**) is reduced by this factor.
Floating point numbers from 0 to 1.00 represent 0 to 100% of the motor current. Reduction is disabled when set to 1 (default).

Remarks: The current reduction can be delayed by the **'curdelay'** instruction.
Without adding a delay, reduction might have an impact on vector throughput, as it takes some extra time to increase the current ahead of each move instruction or joystick deflection.
The decrease and increase rate is 1% (0.01) per 160µs. When reduction is active and a move instruction or joystick deflection is executed, the axis current is first ramped up to 100%. This causes a response delay of e.g. 30%-->100% = 70*160µs = 11.2ms.

While reducing, the axis might also show slight waggle, depening on mechanical load.

In systems with encoders: Reducing the current to less than 0.3 (30%) will disable the permanent **closed loop** while reduction is active (axis stopped and **curdelay** expired).

If current reduction is active, the momentarily applied motor currents can be checked any time via the **iscur** instruction.

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

Examples:

| | |
|---|---|
| !reduction .3 .7 | Set idle current reduction X=0.3*cur[A] and Y=0.7*cur[A] |
| !reduction 1 1 1 | Disable reduction for axes X,Y,Z |
| !reduction z 0.5 | Set Z idle current reduction factor to 0.5*cur[A] |
| ?reduction | Read idle current reduction factor of all axes |
| ?reduction x | Read idle current reduction factor of X axis only (e.g. 1.00) |

## 11.13. curdelay (Delay for Current Reduction)

```
Syntax:           !curdelay or ?curdelay
Parameter:        x, y, z, a or none
                  0 to 65000 [ms]

Description:      At the end of each move, the axis enters idle state. If the
                  motor current reduction factor is set to a value less than 1,
                  this reduction will take effect after the curdelay time.

Remarks:          A delay might be necessary in cases of
                  - long time exposure (to avoid waggle)
                  - high vector throughput (to avoid reduction between the move)
                  - heat reduction when not operating (long, like a screensaver)

Response:         Selected delay time for the current reduction in [ms]

Examples:
!curdelay 100 450 Set delay for motor current reduction X=100[ms] and Y=450[ms]
!curdelay z 15000 Set delay for motor current reduction Z=15 seconds
!curdelay 0 0     Set immediate reduction for X and Y axis
?curdelay         Read motor current reduction delay of all axes
?curdelay x       Read motor current reduction delay of X axis only
```

## 11.14. ecomove (EcoMove Current Level)

```
Syntax:           !ecomove or ?ecomove
Parameter:        x, y, z, a or none
                  0 to 70

Description:      EcoMove reduces the motor current while the axis travels at
                  constant velocity.
                  Like 'reduction' it can be used to greatly reduce the
                  dissipated heat of the motor. But the EcoMove parameter works
                  in a different way: Greater values = greater power saving,
                  which means a eco level value of 0 is 100% current and a eco
                  level of 30 is 70% current.

                  0  = Full motor current (default)
                  70 = Maximum power saving level (low motor heating and force)

Response:         EcoMove level

Examples:         !ecomove 0 0 0 0   (disable ecomove for all axes / 0%)
                  !ecomove x 25      (reduce X current by 25% when moving)
                  ?ecomove           (return all ecomove levels)
```

## 11.15. axis (Enable, Disable, Switch Off Axis)

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

Description:      This instruction enables, disables and switches off axes. The
                  currently selected state can also be read.
                  A disabled axis still powers the motor with its current, while
                  a switched off axis loses its torque.

                   1 = enabled
                   0 = disabled
                  -1 = axis power stage off

Response:         Axis enable state

Examples:
!axis 1 1 1 1     enable all axes
!axis 1 0 1 0     disable Y and A axis, enable X and Z
!axis y -1        switch off Y axis: power stage Y off
?axis x           read axis state of X axis only
?axis             read axis state of all axes
```

## 11.16. axisdir (Axis Direction)

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

Description:      Travel direction of the axes.

                  0 = Normal   axis direrction
                  1 = Reversed axis direrction

Remarks:          Changing the axis direction should only be used once as a
                  general setup of the hardware direction, and not be used
                  during normal operation. It's recommended to save and restart.

                  The hardware limit switches CAL and RM will automatically be
                  reassigned when switching the axis direction. Also swact,
                  swpol, swtyp, readsw etc. Exception: The swin function is not
                  affected.

                  Closed loop will be deactivated when changing the direction
                  and has to be reenabled by cal or reset/power-on.

                  If the axis is position corrected by factory (mapped), the
                  axis direction is an essential part of the mapping process and
                  must not be changed by the customer. If the direction of a
                  position corrected axis is changed by the customer, the axis
                  will no longer meet their specifications (position accuracy).

Response:         Axis direction

Examples:
!axisdir 0 1 0 1  Reverse travel directions of Y and A axis
!axisdir z 1      Set reverse travel direction for Z axis
?axisdir          Read axis direction of all axes
?axisdir x        Read axis direction of X axis only
```

## 11.17. motortable (Motor Correction Table)

Syntax: !motortable or ?motortable
Parameter: x, y, z, a or none
0 or number specified by factory

Description: This instruction adds a motor correction, which can be used to reduce resonances and vibration. The motor has to be measured for the specific application by factory. Then 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 vibrations 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 for x |
| ?motortable | Read the currently used tables for all axes |

## 11.18. usteps (Microstep Resolution)

Syntax: !usteps or ?usteps
Parameter: 360 ... 1638400

Description: This instruction is used in conjunction with the unit **'dim 0'**. As **"!dim 0"** switches the axis unit to microsteps, the "usteps" instruction can be used to select the appropriate number of microsteps that make one revolution of the motor.

Setting usteps to 360 will result in e.g. "!mor 360" causing one revolution of the X-axis motor.

One value applies to all axes that have **'dim 0'** selected.

Remarks: The usteps instruction does not change the resolution of the motor. It only allows to select what number will cause one revolution when the axis is set to **'dim 0'** microsteps mode.

The **'dim 0'** is intended for backward-compatibility to existing software packages that might require positioning in microsteps instead of metric or imperial units.

Older software written for e.g. 40000 or 51200 microsteps per revolution can be used to control the TANGO controller.

As the usteps instruction does not change the physical resolution of the motor (typ. 819200 for a 200 steps motor), positioning instructions such as "moa", "mor", "go" can be executed with fractional values also, e.g. "!mor 12007.3". But the **"?pos"** instruction will always only return integer When in dim 0.

Response: Currently used **dim 0** microstepping resolution in [steps/rev]

Examples:

| | |
|---|---|
| !usteps 51200 | 51200 is the count of microsteps for one revolution in dim 0. |
| ?usteps | Read the microstep resolution |

## 11.19. resolution (Position Number Format)

Syntax: !resolution or ?resolution
Parameter: 0, 1, ... 6

Description: This instruction sets the resolution of position returning instructions for the metric **dim** 1, 2 and 9. It affects the amount of returned fractional digits, as listed below. One value applies to all axes, the default is 4 (100 nm).

| Value | Resolution dim 2,9 | Resolution dim 1 |
|---|---|---|
| 0 | = 1mm | 0.1 µm |
| 1 | = 0.1mm | 0.1 µm |
| 2 | = 0.01mm | 0.1 µm |
| 3 | = 0.001mm | 0.1 µm |
| 4 (default) | = 0.0001mm | 0.1 µm |
| 5 | = 0.00001mm | 0.01 µm |
| 6 | = 0.000001mm | 0.001 µm |

Affected instructions are: ?pos, ?lim, ?maxpos, ?posclr, ?distance, ?twi, ?ctrs, ?ctrdiff, ?caliboffset, ?rmoffset, ?calpos, ?calzeropos, ?trigd, ?snsa, ?snsp.

Response: Responded fractional digits of the **'pos'** and other position returning instructions.

Examples:
!resolution 5 Set position read resolution to 10 nm (5 decimal places if mm) e.g. "?pos x" returns 0.00000 in dim 2 or 9 and 0.00 in dim 1.
?resolution Read the fractional digits resolution

## 11.20. backlash (Mechanical Backlash Compensation)

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

Description: Compensates mechanical backlash of the individual axes. Unit is always micrometer [µm], independent from dim.

0 = Backlash compensation off

Remarks: Backlash compensation is not applied in **closed loop mode.** Backlash compensation does not affect the axis performance. Backlash compensation is also applied in HDI mode, e.g. when using the joystick. Due to compensation the manual control is greatly improved when using high magnifications.

Backlash Info: Mechanical backlash becomes visible when traveling to the same position from both directions, forward and backward. The backlash value is half the amount of this deviation.

Response: Axis backlash in micrometer [µm]

Examples:
!backlash 12.7 21.3 0 Set backlash for X to 12.7µm, Y=21.3µm and Z=none
!backlash x 0 Disable backlash compensation for X
!backlash x 5 Compensate a backlash of 5µm in X
?backlash Read the backlash compensation value of all axes
?backlash z Read the backlash compensation value of Z axis only

## 11.21. lock (Select Parameters to Lock)

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

Description:     Select write protection for TANGO parameters (lock state).
                 Either bitwise: !lock [bit number] [0 or 1]
                 or multi bits : !lock [bit field of 0s and 1s]
                 After selecting the parameters to lock, these have to be
                 applied to the desired axes by 'lockaxis'.

Response:        Specified lock bit state or entire lock bit field, LSB first.
                 The bit positions represent the following parameters:

                 Bit Nr.  Parameter
                 -------  ----------
                  0:      Pitch
                  1:      Gear
                  2:      Cur
                  3:      MotorSteps
                  4:      SwPol
                  5:      SwTyp
                  6:      SwDir
                  7:      EncType,EncTTL
                  8:      EncPeriod
                  9:      AxisDir
                 10:      MotorTable
                 11:      BackLash
                 12:      Anglecorr
                 13:      CalLrnPos
                 14:      CalibOffset
                 15:      RmOffset

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      => Read lock bit field (e.g. "0000000000000000")
                 ?lock 5    => Read lock bit #5 state
```

## 11.22. lockaxis (Apply the Parameter Lock to Axes)

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

Description:     Apply the parameter lock, selected by the 'lock' instruction,
                 to the specified axes. If the 'lock' lockbits or lockaxis are
                 zero, nothing will be locked.

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    => Read if lock bits are applied to the X axis
                 ?lockaxis      => Read all axes (returns e.g. "1 1 0 0")
```

## 11.23. lockstate (Read all internal Lock States)

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

Description: Set/read the internal parameter write protection (lock) state caused by the ETS (factory) and user lock+lockaxis settings. The bit positions represent the following parameters:

| Bit Nr. | Parameter |
|---|---|
| 0: | Pitch |
| 1: | Gear |
| 2: | Cur |
| 3: | MotorSteps |
| 4: | SwPol |
| 5: | SwTyp |
| 6: | SwDir |
| 7: | EncTTL,EncType |
| 8: | EncPeriod |
| 9: | AxisDir |
| 10: | MotorTable |
| 11: | BackLash |
| 12: | Anglecorr |
| 13: | CalLrnPos |
| 14: | CalibOffset |
| 15: | RmOffset |

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

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

## 11.24. stout (Select Status Signal Output)

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

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

0 = Just Status LED, no AUX I/O used (default)
~~1 = AUX I/O Pin 5 (TAKT_OUT)~~ not supported
2 = AUX I/O Pin 6 (VR_OUT)
3 = AUX I/O Pin 7 (SHUTTER_OUT)
4 = AUX I/O Pin 8 (TRIGGER_OUT)

Remarks: In order to turn off the original TANGO Status LED(s), the instruction **'noled'** may be used.

Response: Selected status output mode

Example:
!stout 0 => Only use TANGO Status LED (default)
?stout => Read status output mode (returns 0,1,2,3 or 4)

## 11.25. noled (Force Status LED Off)

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

Description: Permanently force off the TANGO Status LED.
Forcing the LED off may be required in low light applications where no external light source is wanted.

0 = Normal operation, Status LED on (default)
1 = Status LED permanently off

Remarks: Forcing the TANGO Status LED(s) off only affects the TANGO Status LED(s). It does not affect the optional status output signal that can be selected by **'stout'**.

Response: Status LED mode

Example: !noled 1 => Force Status-LED permanently off
!noled 0 => Status-LED normal operation (default)
?noled => Read status output mode (returns 0 or 1)

## 11.26. updelay (Power Up Delay)

Syntax: !updelay or ? updelay
Parameter: -5000 to 5000

Description: Delay time of the TANGO controller on power up in [ms].

This parameter is ment for fixing problems of TANGO PCI/PCI-E card versions with external power supply or long PCI reset times of the computer mainboard.

Applications:
Use negative values to wait for valid motor voltage (e.g. when using master-slave power switches for the external power supply).
Use positive values to wait a fixed time (e.g. when the mainboard generates a too long reset signal, it causes the PCI/PCI-E card to start as a Desktop version. So the virtal PCI COM port is not accessible.)

Positive values: The controller waits for the specified time.
Negative values: The controller waits for valid motor voltage for a maximum of this time or shorter.

Response: Power up delay time in [ms]

Example: !updelay -2000 => Wait max. 2s for valid motor voltage level
!updelay 2500 => Wait 2.5s extra on power up
?updelay => Read the power up delay

# 12. Limit Switch Instructions (Hardware and Software)

## 12.1. lim (Software Limits)

Syntax: !lim or ?lim
Parameter: x, y, z, a or none
+-maximum position range (unit depends on **'dim'**)

Description: This instruction sets or reads the software position limits. Software limits can be used to narrow the positioning range of axes, limiting all move instructions and manual control.
The software limits must be within the maximum positioning range as set by **'cal'**, **'rm'** (or 'vrm') or, when none of the calibration routines are used, the maximum position range of the axes (e.g. +-2.6 meters). Setting the software limits outside of these limitations will not extend the positioning range and the axes still will stop at those maximum limits.
Setting the software limits do not remove the **secvel** velocity limitations. Therefore **'cal'**, **'rm'** or **'vrm'** are required.
The upper and lower software limits must be sent together in a single "!lim" instruction. The unit depends on **'dim'** setting.

Remarks: It is recommended to read the limits axis by axis ('?lim x' etc.), because the '?lim' instruction for all axes has a formatting error of sending an additional [CR] after the X-axis values. If **Extended Mode** is enabled (extmode = 1), the '?lim' instruction returns the limits as a correctly formatted string -> see example below.

By default (**nosetlimit** = 0), the soft limits are overwritten by the **'cal'**, **'rm'** and **'vrm'** instructions. Which (re-)set the soft limits to the mechanical limit switch positions.
-> For setting own software limits, use the '!lim' instruction after **'cal'** or **'cal'+'rm'** (or **'cal'+'vrm'**) was executed.

If a software limit is set below the current axis position, it is only possible to travel towards and below this new limit. Any further movement away from it is not possible.

Response: Currently used software limits [lower] [upper]

Examples:

```
!lim -2000 2000 -2000 2000 0 50     set the software limits for X, Y and Z axes
!lim 0 200 20 80                    set the software limits for X and Y only
!lim z 0 315                        set the software limits for Z to 0 ... 315
!lim z 45.37                        set the lower software limit of Z to 45.37
?lim y                              read upper and lower software limits of Y

?lim                                read all upper and lower software limits
                                    only recommended in extmode=1, as shown:
```

?lim response example for 3 axes, without and whith **extmode** enabled:
--> extmode=0: -2600 2600,**[CR]**-2600 2600, -800 800[CR] (mimics faulty behavior)
--> extmode=1: -2600 2600 -2600 2600 -800 800[CR]

## 12.2. clim (Circular Software Limit)

Syntax: !clim or ?clim
Parameter: center position x,y and radius
or only radius
(units depend on **'dim'**)

Description: This instruction provides circular movement range limitations. The limit can be specified either with XY center position or just with the radius. Then the current XY axis positions will be used as center. The units depend on **'dim'**, x and y must have same dim.

*!clim 0 disables circular limits*
*?clim 1 queries the state (active=1, inactive=0)*

*!clim [centerPosX] [CenterPosY] [Radius]* or
*!clim [Radius]* set the circular limit.

Response: Circular limits [X] [Y] [radius] or active state [0,1]

Examples:

| | |
|---|---|
| !clim 50 70 10 | Set clircular limit of radius 10 at center position X=50,Y=70 |
| !clim 9.5 | Set clircular limit of radius 9.5 around the current position |
| !clim 0 | Disable circular limits |
| ?clim | Read circular limit positions and radius (cenx ceny radius) |
| ?clim 1 | Query if circular limits are enabled (1) or disabled (0) |

## 12.3. limctr (Enable or Disable Limit Control)

Syntax: !limctr or ?limctr
Parameter: x, y, z, a or none
0 or 1

Description: This instruction enables or disables the limit control or returns the current state of it.

0 = disabled
1 = enabled (default from power on)

Attention: Setting limctr to 0 can cause mechanical damage to the axis! If limit controls are disabled, the controller ignores any limits set by **cal**, **rm** or **lim**. Actuating the limit switches is still recognized (as long as they are not deactivated by the **swact** instruction).

Remarks: Limit control is enabled by default from power on each time and cannot be stored permanently.

Response: Limit control state

Example:

| | |
|---|---|
| !limctr z 0 | disable Z limit control, Z axis limits are ignored |
| !limctr 1 1 1 | enable X, Y and Z limit control |
| ?limctr a | read limit control state of A axis only |
| ?limctr | read limit control state of all axes |

## 12.4. nosetlimit (Do not set Limits by Cal/Rm)

Syntax: !nosetlimit or ?nosetlimit
Parameter: x, y, z, a or none
0 or 1

Description: Enables or disables setting of software limits (**lim**) by the calibration (**cal**) and range measure (**rm**) functions. 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 (default)
1 = do not change software limits after !cal 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 | read nosetlimit state of all axes |
| ?nosetlimit a | read nosetlimit state of A axis only |

## 12.5. swtyp (Type of Limit Switch)

Syntax: !swtyp or ?swtyp
Parameter: x, y, z or a (specifying an axis is recommended)
0 or 1, 0 or 1, 0 or 1

Description: Set or read the limit switch type, per axis only.
Assigns a pull-up or pull-down resistor to the switch input.
The sequence is always:

!swtyp [SWITCH_E0] [SWITCH_REF**] [SWITCH_EE]

0 = PNP: applies a pull-down resistor to the switch input
1 = NPN: applies a pull-up resistor (default)

Remarks: ** The REF switch is not used by the TANGO controller.

It is recommended to set each axis individually by using the axis parameter x, y, z or a.
Using no axis parameter will apply the the values to all axes!

Please note that the E0 and EE switches are reassigned by a change of the **axisdir** instruction.

Response: Currently selected limit switch type

Examples:
!swtyp z 0 0 1 set Z axis limit switches E0=PNP, REF(don't care), EE=NPN
?swtyp y read E0, EE switch types of Y axis (returns e.g. 1 0 1)

?swtyp not recommended,
in extmode=0 returns e.g. 1 1 11 1 11 1 1
in extmode=1 returns e.g. 1 1 1 1 1 1 1 1 1

!swtyp 1 0 1 set limit switches to NPN type for all axes at once
(not recommended)

## 12.6. swpol (Polarity of Limit Switch)

Syntax: !swpol or ?swpol
Parameter: x, y, z or a (specifying an axis is recommended)
0 or 1, 0 or 1, 0 or 1

Description: Set or read the active polarity of the limit switches, per axis only. The sequence is always:

!swpol [SWITCH_E0] [SWITCH_REF**] [SWITCH_EE]

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

Remarks: ** The REF switch is not used by the TANGO controller.

It is recommended to set each axis individually by using the axis parameter x, y, z or a.
Using no axis parameter will apply the the values to all axes!

Please note that the E0 and EE switches are reassigned by a change of the **axisdir** instruction.

The **swin** instruction is not affected by the polarity setting, as it returns the TTL logic level and not the actuation state.

Response: Polarity of the limit switches

Examples:

| | |
|---|---|
| !swpol y 1 1 1 | set polarity of Y limit switches (E0 REF EE) to active high |
| !swpol z 0 0 0 | set polarity of Y limit switches (E0 REF EE) to active low |
| ?swpol x | read limit switch polarity of the X axis (returns e.g. 0 0 0) |
| !swpol 1 0 1 | set polarity of limit switches for all axes at once (not recommended) |

## 12.7. swact (Enable or Disable Limit Switches)

Syntax: !swact or ?swact

Parameter: x, y, z or a (specifying an axis is recommended)
0 or 1, 0 or 1, 0 or 1

Description: Enable or disable the limit switches, per axis only.
The sequence is always:

!swact *[SWITCH_E0] [SWITCH_REF**] [SWITCH_EE]*

0 = switch is disabled (actuation state is ignored)
1 = switch is enabled

Remarks: ** The REF switch is not used by the TANGO controller.

It is recommended to set each axis individually by using the axis parameter x, y, z or a.
Using no axis parameter will apply the the values to all axes!

Please note that the E0 and EE switches are reassigned by a change of the **axisdir** instruction.

The **swin** instruction is not affected and can still be used to read the TTL logic level of the inputs.

Secvel velocity: If all switches of an axis are set to inactive, **secvel** will not be applied (no velocity limitation at all). If EE (**rm**) switch is set to inactive, the **secvel** limitation will be released after the cal. If both switches E0+EE are activated, **cal**+**rm** must be executed in order to release the secure velocity.

Response: Limit switch enable states [E0] [REF] [EE] (e.g. 1 0 1)

Examples:

| | |
|---|---|
| !swact z 1 0 1 | set Z limit switches E0=enabled REF=disabled EE=enabled |
| ?swact a | read limit switches enable state of A axis only (e.g. 1 0 1) |
| !swact 1 0 1 | enable cal and rm limit switches for all axes at once (not recommended) |

## 12.8. swdir (Swap Assignment of Cal and Rm Switch)

| | |
|---|---|
| Syntax: | !swdir or ?swdir |
| Parameter: | x, y, z, a or none<br>0 or 1 |
| Description: | Swap the cal(E0) and rm(EE) switch assignment.<br><br>0 = switches are not swapped (default)<br>1 = switches are swapped<br><br>In opposite to the axisdir instruction, which swaps motor direction and limit switch assignment, swdir only swaps the limit switches E0<->EE without changing the axis direction. This may become necessary due to wiring of the axis and depends on the axis hardware. It is independend of axisdir, which works with and without a swapped swdir. |
| Attention: | swdir should only be used to compensate different wiring of the stage limit switches. **Swapping the switches to the wrong assignment may result in mechanical 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 | Read switch assignment of all axes |
| ?swdir z | Read switch assignment of Z axis only |

## 12.9. readsw (Read Status of Limit Switches)

```
Syntax:          ?readsw or readsw
Parameter:       none

Description:     Readsw returns the actuation state of the limit switch.
                 The switch assignment (E0 and EE) depends on axisdir and is
                 reassigned automatically when the axis direction is reversed.
                 Disabled switches (swact set to 0) are read as inactive (0).

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

                 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 returned 12 ASCII 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 instruction)
                 Ref = Reference switch   (not available with TANGO, always 0)
                 EE  = upper limit switch (!rm instruction)

Response:        Actuation state of limit switches as 12 character ASCII string

Examples:        readsw => 000000001000
                 (read all limit switch actuation states, EE of X is actuated)
```

## 12.10. swin (Read Limit Switch Input Level)

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

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

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

                 In opposite to the 'readsw' instruction, swin reflects the
                 TTL input levels. Even disabled switches are represented with
                 their current TTL input signal level. Swin is not affected by
                 the swpol polarity or axisdir setting (doen't exchange E0 and
                 EE switches if axisdir=1) or. The [Ref] signals are not used.

                 Sequence of the 8 ASCII characters is:
                 Axis:    X_____  Y_____  Z_____  A_____
                 Switch: [E0][EE][E0][EE][E0][EE][E0][EE]
                 Index :  0   1   2   3   4   5   6   7 (for individual read)
                 E0  = lower limit switch (cal) for axisdir=0
                 EE  = upper limit switch (rm)  for axisdir=0

Response:        Limit switch input TTL level as 1 or 8 ASCII characters

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

# 12.11. statuslimit (Cal / Rm / Lim Status)

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

Description:      Read the status of the soft- and hardware limits concerning
                  the cal, rm and lim instructions.
                  It can be used to check if the axes were already calibrated
                  (cal) or range measured (rm) and if a software limit was set.

                  The status information is arranged in 4 groups.
                  The ASCII character string positions are:
                   0 …  3: Group 1 => cal state of axis 0-3 (x,y,z,a) '-' or 'A'
                   4 …  7: Group 2 => rm  state of axis 0-3 (x,y,z,a) '-' or 'A'
                   8 … 11: Group 3 => lower soft limit state of axis 0-3 (x,y,z,a) -,L
                  12 … 15: Group 4 => upper soft limit state of axis 0-3 (x,y,z,a) -,L

                  The characters represent the state with 4 possible characters:
                  - => cal or rm not performed, limit not set/modified since power on
                  A => axis is calibrated (!cal)
                  D => axis is range measured (!rm)
                  L => software limit has been modified by (!lim)

                  STRING: "----------------" up to max. "AAAADDDDLLLLLLLL"
                  AXIS  :  xyzaxyzaxyzaxyza
                  LIMIT :  CAL RM  LIM-LIM+

Response:         ASCII string of 16 characters

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

                  This means in detail:

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

# 13. Calibration and Range Measure Instructions

After power on or '!**reset**' of the controller, a calibration (instruction **!cal**) followed by a range measure (instruction **!rm**) should be executed in order to set the axis origin, the hardware position limits, releasing the '**secvel**' velocity limit and enabling the encoders and position correction.
The cal/rm instructions set the limits close to the limit switch positions. An additional position offset for the these limits can be specified with the instructions !**caliboffset** and !**rmoffset**.
Long axes and/or slow velocities may exceed the default calibration timeout of 40 seconds. Therefore, the timeout can be changed by the **caltimeout** instruction.
Please also refer to the optional **extmode** enhancements and **calmode** options for calibration. **?statuslimit** can be used to check, if a **!cal** or **!rm** was performed.

## 13.1. cal (Perform Calibration to lower Limit Switch)

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

Description: This instruction moves either the specified or all axes towards lower positions until the limitswitch E0 is detected. If the corresponding E0 limit switch is disabled (by **swact**), cal will not be performed.
The behavior of CAL depends on the setting of '**extmode**':

**Extmode=0 (mostly the default setting):**
- CAL travels towards switch with the axis velocity '**vel**'
- CAL travels out of switch with '**calbspeed**'

**Extmode=1:**
- CAL travels towards switch with '**calvel**' parameter 1
- CAL travels out of switch with '**calvel**' parameter 2

The movement stops slightly after traveling out of the switch. If required, this travel distance can be increased by specifying a '**caliboffset**'.

Depending on the '**calmode**' setting this position is used as origin (position 0) and if '**nosetlimit**' is set to 0 (default) also as the new lower software limit.

Remarks: The calibration status can be read by checking '**statuslimit**'. Cal can use an encoder reference mark to set a percise zero position. Therefore, '**encref**' must be set to 1.

Response: Depends on **autostatus** settings, which per default is set to 1. Similar to **!moa**, !mor etc., but instead of an '@' it returns a
'**A**' after a successful calibration or
'E' if an error occurred (cal was unsuccessful)
'T' if a timeout occurred (cal was unsuccessful)
'-' the axis is not present

Examples:

```
cal             execute a calibration for all enabled axes => "AAA-."
cal y           execute a calibration for Y axis           => "@A@-."

                This sequence calibrates the X and Z axis  => "A@A-."
                "!axis 1 0 1"
                "!cal"
                "!axis 1 1 1"
```

## 13.2. rm (Perform Range Measure to upper Limit Switch)

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

Description: This instruction moves either the specified or all axes towards higher positions until the limitswitch EE is detected. If the corresponding EE limit switch is disabled (by **swact**), rm will not be performed.
The behavior of RM depends on the setting of **'extmode'**:

**Extmode=0 (mostly the default setting):**
- RM travels towards switch with the axis velocity **'vel'**
- RM travels out of switch with **'calbspeed'**

**Extmode=1:**
- RM travels towards switch with **'rmvel'** parameter 1
- RM travels out of switch with **'rmvel'** parameter 2

The movement stops slightly after traveling out of the switch. If required, this travel distance can be increased by specifying a **'rmoffset'**.

if **'nosetlimit'** is set to 0 (default), rm also sets the rm-position as the new upper software limit.

Remarks: The rangemeasure status can be read by checking 'statuslimit'.

Response: Depends on **autostatus** settings, which per default is set to 1. Similar to **!moa**, !mor etc., but instead of an '@' it returns a
**'D'** after a successful rangemeasure or
'E' if an error occurred (rm was unsuccessful)
'T' if a timeout occurred (rm was unsuccessful)
'-' if the axis is not present (e.g. 4th axis)

Examples:
rm execute a range measure for all enabled axes => "DDD-."
rm y execute a range measure for Y axis => "@D@-."

Or the sequence
"!axis 1 0 1"
"!rm"
"!axis 1 1 1"
range measure the X and Z axis, while Y is not used => "D@D-."

## 13.3. vrm (Virtual Range Measure)

Syntax: !vrm or vrm
Parameter: x, y, z, a or none
Axis length(s) in user **dim**

Description: Can replace the need of an **rm** move, by just defining the axis length without axis travel (time saving).

Same as with the rm instruction the
- **secvel** is released
- corresponding **statuslimit** 'D' entry is set
- hardware limit is set (the internal axis end position)

Vrm requires that **!cal** was performed on the axis.
Vrm does not return any **autostatus** reply (like the @@@-),
It returns immediately.

Warning: Specifying a wrong axis length can cause mechanical damage.

Remarks: Check ?**err** response or **statuslimit** for 'D' entries to make sure the parameters were accepted.

If axes are not **calibrated**, the vrm function causes error 2.

Axes with MR encoders (nanoScale) should always perform a true rm for high accuracy measurement.

Vrm can also be used before executing an **rm** move in order to travel fast (without **secvel** limitation) near the rm limit switch → then rm can be executed (caution: velocity might be high now) to get the real maximum hardware travel range and/or to allow the above mentioned encoder autoadjust which is performed during **rm**. [Example #3]

Response: None

Examples:
vrm 75 50 virtual range measure (define axis lengths of X=75, Y=50)
vrm y 150 virtual range measure for Y axis (define Y=150)

```
Sequence example1:cal x
                  cal y
                  cal z
                  ?statuslimit    => "AAA-------------"
                  vrm 300 300 20
                  ?statuslimit    => "AAA-DDD---------"

Sequence example2:cal x
                  cal y
                  !moa 10 10
                  !pos 0 0      (the lower limit is now at position -10 -10)
                  vrm 300 300   (the upper limit is set to 290 290)

Sequence example3:cal x         (calibrate the X axis)
                  !vel 40       (set X velocity to e.g. 40mm/s)
                  vrm 300       (virtually set X rm for e.g. a 300mm axis)
                  !moa 300      (move to end of X travel range without secvel)
                  !vel 10       (slow down for executing rm)
                  !rm x         (perform true hardware rm from here =time saving)
```

## 13.4. calmode (Closed Loop and Calibration Behavior)

Syntax: !calmode or ?calmode
Parameter: x, y, z, a or none
0, 1, 2, 3, 4 or 5

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

**0** : **cal** instruction sets the zero position (**default**) and the Closed loop is enabled after cal

**1** : the zero position is set at power-up and remains, a cal instruction doesn't set or modify the zero position* Closed loop is enabled from power-up

**2** : **cal** instruction sets the zero position as mode 0, but the Closed loop is enabled from power-up
This is especially useful or required, if the axis is driven by e.g. a bowden wire or Uhing® drive.
Depending on the encperiod size, the axis will more or less wiggle for activating closed loop (MR: about 1mm).

**3** : the axis is used to readout a measuring system only.
Requirements are:
- the encoder must be a TTL or 1Vpp type, no analog MR
- encmask must be enabled
- encpos must be enabled (for reading ?pos)
- encdir must be set to the required counting direction
- axis amplifier should be switched off (e.g. !axis z -1)
  (it might be possible to use the motor independently, but at least a cal will set both, the motor and encoder positions to zero. The pos at encpos=0 belongs to the motor, the pos at encpos=1 to the encoder)

**4** : performs an automatic **cal** move after power-up.
**Caution! The axes will move without notice immediately after reset or after switching on the TANGO controller. It is not possible to communicate with the TANGO while the cal move is running. It is also not possible to stop The axes by the abort instruction.**

Mode 4 is useful in standalone applications (without a PC), where the zero position must be set automatically At power up and/or the position correction of the axis.

The cal is executed axis by axis, starting with X.

The TANGO will not respond to any instruction while the cal moves are executed. If no axis is connected, the cal will consume all the caltimeout of the corresponding axis/axes.
The Status LED can be used as an indicator for a running cal instruction: The LED goes shortly dark about every 2.5 seconds.

The cal is executed at the vel or secvel velocity, depending on which is set to the lowest velocity.
In extmode=1, the calvel will be used instead of vel.

The cal will not release secvel, the secvel velocity limit will only be released if an axlen is specified in the ETS. Else a rm instruction would be required afterwards.

**5** : restores the position at power-up.

The TANGO will remember the axis positions at which the power was switched off and restore them at power-up. Work can continue at the previous position without having to calibrate the axes.

If cal/rm was executed, the TANGO will restore those too, release the **secvel** limits and apply position correction.

Only open loop is supported, closed loop or encoders will not be restored.

Soft limits (set by !lim) are not restored.

**Caution!** The position relies on the last known position where the TANGO was switched off. If the axes are displaced while the TANGO is switched off, the position information is invalid and so might be the limit switches. Which in worst case can cause damage.
So please ensure that the axes remain at their positions during power off when using this calmode 5 functionality.

If the TANGO is switched off while the axes are traveling, the restored positions might not be correct.

Remarks: For activating the closed loop, '**encmask**' of the corresponding axes must be set to 1. If encmask is not set or no encoder is present, the calmode only affects the axis zero position behavior.

Calmode 0 is the default setting for most applications, calmode 2 is useful for axes with encoders, to have closed loop active from power on without requiring a cal for it.

* In calmode 1, the position offset between the CAL switch and the axis position (which is set and remains from the power-up position) can be read out by using '**?calzeropos**', after a **cal** move was executed.

Response: Calmode of the axes

Examples:

| | |
|---|---|
| !calmode 0 0 0 | Calmode behavior of axes X,Y,Z set to default operation |
| !calmode z 2 | Set Z axis to enter closed loop instantly after power-up |
| ?calmode | Read calmode of all axes |
| ?calmode y | Read calmode of Y axis only |

## 13.5. calrequired (Calibration Required)

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

Description:      The calibration required mode offers a mechanism to prevent
                  axis travel until the !cal instruction is executed. It can
                  be used to e.g. prevent collisions until the axis is in a
                  known position.

                  0 = The axis can travel even without !cal (default)
                  1 = The axis is halted until a !cal is executed

Response:         Calrequired setting of the axes

Examples:
!calrequired 0 0 0      No cal required to enable X,Y,Z axis move (default)
!calrequired z 1        Cal required to enable axis move in Z
?calrequired            Read calrequired mode of all axes
?calrequired y          Read calrequired mode of Y axis only
```

## 13.6. caltimeout (Calibration Timeout)

```
Syntax:           !caltimeout or ?caltimeout
Parameter:        x, y, z, a or none
                  1 to 120 (seconds, as integer)

Description:      This instruction specifies the timeout for calibration (cal)
                  and range measure (rm) instructions. It can be set for each
                  axis individually, depending on axis length and velocities.
                  The default value is 40 or 60 seconds.

Remarks:          For long axes (over 350mm) the default timeout of 40...60s
                  becomes insufficient and must be increased, as the typical
                  cal, rm travel velocity is 10mm/s and the cal, rm routines
                  reqire some additional time around the limit switch.

Response:         Calibration+RangeMeasure timeout in seconds

Examples:
!caltimeout 60 60 60    set the cal/rm timeout for X,Y,Z to 60 seconds
!caltimeout x 40        set the cal/rm timeout for X to 40 seconds
?caltimeout             read timeout of all axes
?caltimeout z           read timeout of Z axis only
```

## 13.7. caliboffset (Calibration Offset)

Syntax: !caliboffset or ?caliboffset
Parameter: x, y, z, a or none
Position (0.0 ... 100mm, unit depends on **'dim'**)

Description: This instruction specifies a calibration position offset. When executing a **'cal'** instruction, the axis travels this extra distance away from the limit switch E0 and sets the origin (axis zero position) there.
The unit depends on the current **'dim'** settings. Valid position range is "0.0 to 100mm equivalent". The default value is 0.

Response: Calibration Cal switch position offset

Examples:

| | |
|---|---|
| !caliboffset 10 5.5 0.1 | set the calibration offset for X, Y and Z axis |
| !caliboffset x 0.05 | set the calibration offset for X axis to 0.05 |
| ?caliboffset | read the calibration offset of all axes |
| ?caliboffset y | read the calibration offset of Y axis only |

## 13.8. rmoffset (Range Measure Position Offset)

Syntax: !rmoffset or ?rmoffset
Parameter: x, y, z, a or none
Position (0.0 ... 100mm, unit depends on **'dim'**)

Description: Similar to caliboffset, this instruction specifies an extra position offset for the **'rm'** instruction. The axis travels this extra distance away from the upper limit switch EE and sets upper limit position there.
The unit depends on the current **'dim'** settings. Valid position range is "0.0 to 100mm equivalent". The default value is 0.

Response: Range Measure RM switch position offset

Examples:

| | |
|---|---|
| !rmoffset 1 1 1 | set the range measure offset to 1 (mm at dim 2) for X, Y and Z |
| !rmoffset z 0.1 | set the range measure offset to 0.1 (mm at dim 2) for Z only |
| ?rmoffset | read range measure position offset of all axes |
| ?rmoffset z | read range measure position offset of Z axis only |

## 13.9. caldir (Calibration Direction)

Syntax: !caldir or ?caldir
Parameter: x, y, z, a or none
0 or 1

Description: Dummy instruction, has no function.
**'axisdir'** may be used to change the axis direction.

Response: 0 or 1

Examples:

| | |
|---|---|
| ?caldir | read caldir of all axes |
| ?caldir x | read caldir of X axis only |
| !caldir y 1 | set Y caldir to positive direction |
| !caldir 0 0 1 | set Z caldir to positive direction, X and Y to negative |

## 13.10. calbspeed (Calibration Speed for Retraction)

Syntax: !calbspeed or ?calbspeed
Parameter: x, y, z, a or -1
0.1 to 8000 [*0.01 revolutions/s]

Description: **(Available in EXTMODE=0 only, else use calvel/rmvel)**
Set or read the cal/rm calibration speed which is used for traveling out of the limit switches E0 and EE.

Remarks: RESTRICTIONS APPLY DUE TO BACKWARDCOMPATIBILITY. See examples.
Setting the calbspeed without specifying an axis will set all axes to this one value. It is recommended to access axes individually. Refer to examples below.
Calbspeed is only available in **extmode=0**. For improved behavior and flexibility please refer to the **calvel, rmvel** instructions, which become available with **extmode=1** and replace the calbspeed and vel.

Response: Currently used calibration back speed [in 1/100 motor rev/s]

Examples:

| | |
|---|---|
| !calbspeed 50 50 | *ILLEGAL INSTRUCTION!* |
| !calbspeed 15 | *COMPATIBILITY RESTRICTIONS!* 0.15 [revolutions/s] for all axes! |
| ?calbspeed | *COMPATIBILITY RESTRICTIONS!* returns one parameter! |
| | |
| ?calbspeed -1 | read the the limit switch retraction speed of all axes |
| !calbspeed z 20 | set the limit switch retraction speed for Z only (recommended) |
| ?calbspeed x | read the limit switch retraction speed for X (recommended) |

## 13.11. calrefspeed (Reference Signal Calibration Speed)

Syntax: !calrefspeed or ?calrefspeed
Parameter: x, y, z, a or -1
0.1 to 8000 [*0.01 revolution/s]

Description: Reference mark calibration speed. This speed is used when searching the encoder reference mark. The default value is 32 (0.32 rev/s). There is only one value for all axes.

Remarks: RESTRICTIONS APPLY DUE TO BACKWARDCOMPATIBILITY. See examples.
**It is recommended to use the new instruction 'encrefvel'.**

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

Examples:

| | |
|---|---|
| !calrefspeed 5 5 | *ILLEGAL INSTRUCTION!* |
| !calrefspeed 15 | *COMPATIBILITY RESTRICTIONS!* 0.15 [revolutions/s] for all axes! |
| ?calrefspeed | *COMPATIBILITY RESTRICTIONS!* returns one parameter! |
| | |
| ?calrefspeed -1 | read the the referencing speed of all axes |
| !calrefspeed z 20 | set the referencing speed for Z only (recommended) |
| ?calrefspeed x | read the referencing speed for X (recommended) |

# 13.12. encrefvel (Encoder Ref Signal Calibration Velocity)

Syntax: !encrefvel or ?encrefvel
Parameter: x, y, z, a or none
0.000001 to 3000 [rev/s] (or [mm/s] if dim=9)

Description: Replaces the **!calrefspeed** instruction.
Set or read the velocity, at which the reference mark search is performed (during **!cal**, after releasing the limit switch).

Response: Currently used encrefvel in [rev/s] or [mm/s] when dim=9

Examples:

| | |
|---|---|
| !encrefvel 5 5 5 | Set encoder reference mark search velocity of X, Y, Z to 5 |
| !encrefvel z 0.5 | Set encoder reference mark search velocity for Z axis to 0.5 |
| ?encrefvel | Read ref mark search velocities of all axes |
| ?encrefvel y | Read ref mark search velocity of Y axis only |

## 13.13. calpos (Calibration Position)

Syntax: !calpos or ?calpos
Parameter: x, y, z, a or none
position value (unit depends on 'dim')

Description: Used in combination with an encoder to measure calibration position accuracy (repeatability of the origin).
During calibration the encoder signal period, where the limit switch E0 was released and the origin (pos=0) was set, is stored. This position value within an encoder period can be read with ?calpos.
The position may also be set to another value. The unit depends on the setting of **'dim'**. Valid range is 0 to 100mm equivalent.

Remarks: This instruction is used for systems with encoders only.

Response: A position within the range of one encoder signal period

Examples:

| | |
|---|---|
| ?calpos y | read calibration position of Y axis (e.g. returns 0.0000) |
| ?calpos | read calibration position of all axes |
| !calpos 0 0 0 | set calibration positions to zero (X, Y and Z) |
| !calpos y 0 | set calibration position of Y axis to zero |

## 13.14. calzeropos (Position at CAL)

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

Description: In **calmode 1**, the axis position is not set to zero by the **cal** instruction. In order to determine the "zero" position after **cal**, calzeropos can be read.

Remarks: CalModes other than 1 (0,2) set the position to zero after executing cal. So the returned position is zero in this cases.

Response: Postion at which the **cal** instruction completed.
The unit depends on **'dim'**.

Examples:

Assuming calmode set to "!calmode 2 1 0 0" and cal already executed on all axes:

| | |
|---|---|
| ?calzeropos y | -153.1433 |
| ?calzeropos | 0.0000 -153.1433 0.0000 0.0000 |
| ?calzeropos x | 0.0000 |

Assuming all axes traveled +10 mm after the cal instruction:

| | |
|---|---|
| ?calzeropos y | -153.1433 (this axis is in calmode 1) |
| ?pos y | -143.1433 => -143.1433 – (-153.1433) = 10.0000 |
| ?calzeropos x | 0.0000 (this axis is in calmode 2) |
| ?pos x | 10.0000 => 10.0000 – 0.0000 = 10.0000 |
| ?calzeropos z | 0.0000 (this axis is in calmode 0) |
| ?pos z | 10.0000 => 10.0000 – 0.0000 = 10.0000 |

# 13.15. calvel (Calibration Velocities for CAL Instruction)

Syntax: !calvel or ?calvel
Parameter: x, y, z, a or none
one or two velocities (depending on dim)

Description: **This instruction is accessible in EXTMODE=1 only.**
If ***extmode*** is set to 1, this instruction replaces the ***calbspeed*** and ***vel*** parameters for the calibration (!cal) instruction:

Parameter 1 : speed towards cal limit switch (find)
Parameter 2 : speed out of cal limit switch (slow release)

Velocity unit: [motor rev/s] for dim = 0 ... 8
[mm/s] for dim = 9

The travel speed towards the limit switch should not be faster than 10mm/s to prevent mechanical damage (axis must be able to stop within a short distance after a limit switch event).
The travel speed out of the limit switch should be low for achieving high position accuracy, e.g. 0.5mm/s

Remarks: calvel can be set per axis only, with x,y,z,a specified

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

Examples:

| | |
|---|---|
| !calvel x 10 0.5 | !cal in X travels towards rm limit switch at a velocity of 10 and out of the limit switch at a velocity of 0.5 |
| !calvel x 10 | set the velocity towards the switch only |
| ?calvel | read cal velocities of all axes (xvel1 xvel2 yvel1 yvel2 etc.) |
| ?calvel y | read cal velocities of Y axis only (e.g. returns 10.000 0.500) |
| !calvel 10 0.5 | not supported, set instruction is per axis only |

## 13.16. rmvel (Range Measure Velocities for RM Instruction)

Syntax: !rmvel or ?rmvel
Parameter: x, y, z, a or none
one or two velocities (depending on dim)

Description: **This instruction is accessible in EXTMODE=1 only.**
If ***extmode*** is set to 1, this instruction replaces the ***calbspeed*** and ***vel*** parameters for the range measure (!rm) instruction:

Parameter 1 : speed towards rm limit switch (find)
Parameter 2 : speed out of rm limit switch (slow release)

Velocity unit: [motor rev/s] for dim = 0 ... 8
[mm/s] for dim = 9

The travel speed towards the limit switch should not be faster than 10mm/s to prevent mechanical damage (axis must be able to stop within a short distance after a limit switch event).
The travel speed out of the limit switch should be low for achieving high position accuracy, e.g. 0.5mm/s

Remarks: rmvel can be set per axis only, with x,y,z,a specified

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

Examples:

| | |
|---|---|
| !rmvel x 10 0.5 | !rm in X travels towards rm limit switch at a velocity of 10 and out of the limit switch at a velocity of 0.5 |
| !rmvel x 10 | set the velocity towards the switch only |
| ?rmvel | read cal velocities of all axes (xvel1 xvel2 yvel1 yvel2 etc.) |
| ?rmvel y | read cal velocities of Y axis only (e.g. returns 10.000 0.500) |
| !rmvel 10 0.5 | not supported, set instruction is per axis only |

## 13.17. autopitch (Measure Pitch after CAL Instruction)

Syntax: !autopitch or ?autopitch
Parameter: x, y, z, a or none
0 or 1

Description: Measures and sets the axis pitch each time when executing a cal instruction. Used for drives with unknown pitch values.
Remarks: Only works if encoders are present.
Not recommended for drives with known pitch, e.g. 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 y 1 | Measure and readjust pitch after each cal instruction in Y |
| ?autopitch | read autopitch setting of all axes |
| ?autopitch x | read autopitch setting of X axis |

Pitch measuring sequence example:
"!autopitch x 1"
"!cal x"
[wait for reply]
"!autopitch x 0"
"?pitch x"
"!save"

## 13.18. refdir (Direction for Searching the Reference Switch)

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

Description:      DUMMY INSTRUCTION. The additional REF switch is not supported
                  by TANGO controllers. Only CAL and RM switches are used.

                  Specifies or reads the direction in which the !ref insruction
                  searches the [REF] reference switch. The !ref instruction is
                  not available.

Response:         0 = search in negative direction (default)
                  1 = search in positive direction

Examples:
!refdir y 1       set the Y-axis reference search to positive direction
!refdir 1 1 0     set the reference search direction of X, Y and Z axis
?refdir           read reference search directions of all axes
?refdir x         read reference search direction of X axis only
```

# 14. Move Instructions

Move instructions cause the TANGO to move axes to certain positions or to travel at a constant, specified velocity. Positioning can be executed for individual axes or combined as a vector move.

Positioning (moa, mor, m, moc) is based on the velocity (vel) and acceleration (accel,accelfunc) settings. If executed as a vector of 2 or more axes, the TANGO automatically selects the leading axis and adjusts the other axes in a way that none of their velocity and acceleration parameters is exceeded.

Moa and mor are similar instructions. Moa travels based on absolute coordinates, defined by the axis origin or the user-defined !**pos**, while **mor** travels relative to the current position.

The '**m**' instruction can be used to achieve high vector throughput with little communication overhead (often combined with **autostatus**=3). The relative distances have to be preset - either the last **mor** or a **distance** instruction.

A special case of positioning is available with the **go** instruction. It does not move as a vector, here each axis travels at its own velocity and accel settings. Also it only provides linear acceleration (accelfunc does not apply).
The advantage of the **go** instruction is that it can be overwritten at any time with no need to abort the currently executed move. It will smoothly change directions. Target applications are e.g. focusing via a slidebar or tracking a mouse cursor position.

The third option for axis travel is a **speed** move. Here velocities are specified instead of positions. The addressed axes travel at those velocities until stopped, aborted or reaching a position limit. As with **go**, the speed instruction is also not executed as a vector and does not use the accelfunc. Speed requires the joystick to be enabled (**joy** and **joydir**).

**Remarks on relative positioning:**
Due to internal resolution, a sequence of many consecutive relative moves may lead to (minor) absolute position deviation. Executing an absolute move at times is recommended.
Also, if HDI is enabled, minor changes in position may occur due to the connected device (Joystick, ERGODRIVE). Which can also accumulate position error when only using relative moves. It is recommended to deactivate the HDI when using relative moves (by instructions **joy** or **joydir**).

## 14.1. moa (Move Absolute)

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

Description: Move one or more axes to the specified position(s). The position unit depends on **dim** settings.

Response: 5 ASCII characters, representing axes 1-4 and terminating '.'
Example: "@@@-."
Depends on **autostatus** settings, which per default is set to 1. Each axis responses a '@' or 'J' after successfully completing the move, or e.g. an 'E' if an error occurred, 'S' for switch. For further information on possible response characters, please refer to **autostatus** and **statusaxis**.

Examples:

| | |
|---|---|
| moa 10 0 20 | axes X,Y,Z travel to the specified positions (vector move) |
| moa 10 0.5 | axes X and Y travel to the specified positions (vector move) |
| moa x 10.2 | X-axis travels to position (e.g. 10.2mm if dim=2) |
| moa 10.2 | same as "moa x 10.2" |
| moa y 34.5 | Y-axis travels to position (e.g. 34.5mm if dim=2) |

## 14.2. mor (Move Relative)

Syntax: !mor or mor
Parameter: x, y, z, a or none
distance values within ±maxpos

Description: Move one or more axes relative to the current position. The position unit depends on **dim** settings.

Response: 5 ASCII characters, representing axes 1-4 and terminating '.'
Example: "@@@-."
Depends on **autostatus** settings, which per default is set to 1. Each axis responses a '@' or 'J' after successfully completing the move, or e.g. an 'E' if an error occurred, 'S' for switch. For further information on possible response characters, please refer to **autostatus** and **statusaxis**.

Examples:

| | |
|---|---|
| mor 10 0 -20 | axes X,Y,Z travel the specified distances (vector move) |
| mor 10 0.5 | axes X and Y travel the specified distances (vector move) |
| mor x 10.2 | X-axis travels the specified distance (e.g. 10.2mm if dim=2) |
| mor 10.2 | same as "mor x 10.2" |
| mor y -34.5 | Y-axis travels e.g. (if dim=2) 34.5mm backwards |

## 14.3. m (Move Relative Shortcut)

Syntax: !m or m
Parameter: none

Description: Similar to **mor**, the m command can be used to move one or more axes relative to their current position. It is useful to speed up communication especially for consecutive identical vectors. With the m command, the positions are defined by a preceeding **distance** or **mor** command. m will move all enabled axes if their **distance** is not set to zero.

Response: 5 ASCII characters, representing axes 1-4 and terminating '.'
Example: "@@@-."
Depends on **autostatus** settings, which per default is set to 1. Each axis responses a '@' or 'J' after successfully completing the move, or e.g. an 'E' if an error occurred, 'S' for switch. For further information on possible response characters, please refer to **autostatus** and **statusaxis**.

To maximize performance, **autostatus** mode 3 can be set, where the position reached response string consists of only a [CR] ([CR] = 0x0d hex, or '\r').

Example: Positioning sequence involving moa,mor,m

```
!moa 1 2 3 4      will move to 1 2 3 4
!mor 1 1 1 1      will move to 2 3 4 5    (mor sets distance)
m                 will move to 3 4 5 6     m continues until:
!distance 1 2 0 0                         (specify m distance)
m                 will move to 4 6 5 6
m                 will move to 5 8 5 6
m                 will move to 6 10 5 6
m                 will move to 7 12 5 6
.
.
.
```

## 14.4. distance (Distance for m)

Syntax: !distance or ?distance
Parameter: x, y, z, a or none
Distance (within ±maxpos)

Description: This instruction sets the travel distance for **!m** instructions. The unit depends on the **'dim'** settings.

Remarks: The distance value is also set by each **'mor'** instruction. Distances must be defined for all axes, axes that shall not move have to be set to distance = 0.

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

Examples:

```
?distance          read distance values of all axes
?distance z        read distance value of Z axis only
!distance 10 20 0  set X and Y distance
!distance 1 2 0.5  set X, Y and Z distance
!distance y 20.2   set Y distance only, other axes keep their distance values
```

## 14.5. moc (Move to Center)

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

Description: The specified or all enabled axes travel to the center position between their lower and upper software limit. It is recommended to first execute the !**cal** and **!rm** instructions.

Response: 5 ASCII characters, representing axes 1-4 and terminating '.'
Example: "@@@-."
Depends on **autostatus** settings, which per default is set to 1. Each axis responses a '@' or 'J' after successfully completing the move, or e.g. an 'E' if an error occurred, 'S' for switch. For further information on possible response characters, please refer to **autostatus** and **statusaxis**.

Examples:
moc all axes travel to their center position
moc y Y-axis travels to the center position

## 14.6. mol (Move to LockPos)

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

Description: The specified or all enabled axes travel to the transportlock position. This special move instruction may be used to position the microscope stage or axes to their transport position, where the fixation screw is inserted.

Requirements: 1) The axes must be calibrated (by !**cal**)
2) The lock position must be stored in the ETS or virtual ETS

Remarks: The factory defined lock positions can be read by **lockpos**. If the position value is greater 0, a lock position is available.

Response: 5 ASCII characters, representing axes 1-4 and terminating '.'
Example: "@@@-."
Depends on **autostatus** settings, which per default is set to 1. Each axis responses a '@' or 'J' after successfully completing the move, or e.g. an 'E' if an error occurred, 'S' for switch. For further information on possible response characters, please refer to **autostatus** and **statusaxis**.

Examples:
mol all axes travel to their transportlock position (if available)
mol y Y-axis travels to to the transportlock position (if available)

# 14.7. go (Go To Position)

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

Description: Intended for tracking a position that changes randomly while the axes are still traveling, e.g. by a mouse or touchscreen. Similar to **'moa'**, it executes a move to an absolute position. For non-interrupted positioning, **'moa'** should always be used.

The differences to a regular **'moa'** instruction are:

- Go can be overwritten any time by another go position, even while traveling
- The velocity can be changed while traveling (**vel**)
- The move can be ended (at the normal acceleration) by sending a go instruction without position value, (or by setting vel=0 or **speed**=0)
  "go" stops all axes, "go y" only the Y axis etc.
- Go is not a vector move, each axis travels at its own velocity (**vel**) and acceleration (**accel**)
- It only supports linear acceleration (no s-curve)
- It might introduce more shake or backlash than moa
- No "@@@" **autostatus** reply on completion (see Remarks)

The unit of the position values depends on **dim**.

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

Use TANGO Firmware 1.68/1.60S3 from March 2017 or higher.
Snapshot Mode **snsm** 6 is ignored by the go instruction.

Response: None.

Examples:

```
go 10.7 14          axes X and Y travel to the specified positions (no vector)
go x 10.2           the X-axis travels to position 10.2 ([mm] assume dim=2)
go 10.2             same as "go x 10.2"
go 10.1 -0.5 0      axes X, Y, Z travel to the specified positions (no vector)
go (or !speed 0 0 0) stops the go instruction for X, Y and Z axis (using accel)
go z (or !speed z 0) stops the go instruction for Z axis only

go 10 100
go 2 11.5           => change in direction while axis is already traveling
```

Sequence examples:

```
!vel z 10
go z 100            => starts an absolute move in Z at a velocity of 10
!vel z 1            => changes the velocity of Z to 1 while still traveling
!vel z 0.1          => changes the velocity of Z to 1 while still traveling
go 0.5 5.2 100.15   => start absolute move for X, Y and Z axis
!vel y 40           => changes the velocity of Y to 40 while still traveling
!vel 20 15 40       => changes velocities of X, Y and Z while still traveling
go 10 100           => starts an absolute move in two axes (X, Y), now...
"go x" or "!vel x 0" or "!vel 0" will end the X move at the default acceleration
"go y" or "!vel y 0"             will end the Y move at the default acceleration
"go"   or "!vel 0 0"             will end the two axis move
```

## 14.8. speed (Speed Move)

Syntax: !speed or ?speed
Parameter: x, y, z, a or none
+-100.0 [rev/s] or [mm/s] in dim=9 only

Description: Lets axes travel (or motors spin) at the specified velocities. A speed move is stopped by setting the speed to zero, by abort (**a**) and when reaching a software- (**lim**) or hardware-limit. Speed uses the acceleration set by **accel** and only provides linear acceleration.

Remarks: **Joydir** must be enabled for the corresponding axes to allow execution of the speed instructions, while the **joy** setting doesn't affect speed.

For endless rotation please refer to **modulomode**=1 or !**zero**.

Setting speed to zero also stops a running **go** instruction.

Unless **dim** 9 is used, the unit of the speed instruction is always in motor revolutions per second. (If dim < 9, e.g. for 1mm/s at a 4mm pitch the !speed must be set to 0.25).

Response: Currently executed speed in [rev/s], or [mm/s] if dim=9
Speed does not generate an **autostatus** reply.

Examples:

| | |
|---|---|
| !speed 29.3 0.01 | start speed move for X=29.3[rev/s] and Y=0.01[rev/s] |
| !speed 10 | start speed move for X-axis to 10[revolutions/s] |
| !speed y 0.001 | start speed move for Y-axis |
| !speed 0 0 0 0 | stop speed move for all axes (or stops a **go** instruction) |
| !speed 0 | stop speed move for X-axis (or stops a **go** instruction in X) |
| !speed z 0 | stop speed move for Z-axis (or stops a **go** instruction in Z) |
| ?speed | read the currently executed speed of all axes |
| ?speed z | read the currently executed speed of Z-axis only |
| ?speed 5 | read the currently executed speeds with 5 fractional digits |
| ?speed z 6 | read the currently executed Z speed with 6 fractional digits |

## 14.9. a (Abort the Current Move)

Syntax: !a or a or [hex 0x03]
Parameter: x, y, z, a or none
-1 or none

Description: Aborts automatic moves (moa,mor,moc,go,...), cal/rm and speed instructions of all axes or of a specified axis and sets them into position reached state. The stop is performed with high acceleration of **stopaccel**. PCI-E and DT-E from Firmware 1.66, others from 1.68, support the optional parameter "-1", where the axis stops at regular **accel** acceleration (** examples).

Most TANGO controllers also provide the "Ctrl+C" (hex 0x03) special character stop, which bypasses the parser (faster response, independent of running instructions) to stop all axes and clear the input buffer.

Remarks: Abort might fail in special cases of closed loop errors. In such case, **closed loop** has to be deactivated as well.

HDI (joystick etc.) movement cannot be stopped by abort. The HDI must be disabled e.g. by setting **joy** or **joydir** to 0.

Response: Depends on the instruction being executed (moa,speed,go etc.) and **autostatus**. If a move is aborted in default **autostatus**=1 and all axes stopped, the aborted axes auto response is 'E'.

Example:
```
a       (abort move of all axes   , with stopaccel)
a y     (abort move of Y axis only, with stopaccel)
a -1    (abort move of all axes   , with accel) **
a z -1  (abort move of Z axis only, with accel) **
```

## 14.10. 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 before executing a move (delayed start). There is only one value for all axes. Applies to: moa,mor,moc,m

Response: Delay time in [ms]

Examples:
!delay 500 Delay the start of a move instruction by 0.5 seconds
?delay Read the delay time

## 14.11. 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 moa,mor,moc or m. There is only one value for all axes.

Response: Pause time in [ms]

Examples:
!pause 10 Delay the **autostatus** response of a move by 10 milliseconds
?pause Read the pause time

## 14.12. pos (Read or Set Position)

Syntax: !pos or ?pos
Parameter: x, y, z, a or none
Position (within ±maxpos)

Description: This instruction either reads or sets the axis position.
If set, this defines a new absolute position of the axis.
The unit depends on the selected dimension (**dim**).

Remarks: Even axes with encoders return the motor position by default.
Returning the encoder position can be achieved by setting the corresponding **'encpos'** to 1.

The effect of manipulating positions with '!pos' can be removed by the instruction **'posclr'**. Also the difference (offset) from the original zero position can be read by it.

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

Examples:

| | |
|---|---|
| ?pos | Read all axis positions |
| ?pos z | Read Z axis position only |
| !pos 100 200 | Set the current X and Y axis positions |
| !pos x 0 | Set the current X position to zero |
| !pos -0.1 | Set the current X position to -0.1 (unit depends on dim) |
| !pos y 2000 | Set the current Y position to 2000 (unit depends on dim) |

## 14.13. posclr (Clear Position Offset)

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

Description: Reset or read the position offset to the axis origin, which was added by a **!pos** instruction.

The absolute position can be redefined by '!pos'. In order to return to the original absolute position, clearpos offers reading or clearing of the changes made by !pos.

Response: Position offsets (depending on **dim**)

Examples:

```
!posclr x          (reset X to original position)
!posclr            (reset all positions to original position)
?posclr            (read position offset of all axes)

?pos       => 1.0000 2.0000 3.0000
!pos y 8      (here a position offset of 8-2=6 is added to Y)
?pos       => 1.0000 8.0000 3.0000
?posclr    => 0.0000 6.0000 0.0000
!posclr     (here the !pos set position offsets are removed)
?pos       => 1.0000 2.0000 0.0000
```

## 14.14. zero (Set Internal Position to Zero)

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

Description: Unlike "!**pos 0**", the "!zero" instruction also resets the internal position counter to zero.
It can be used in applications where axes exceed the position limits, e.g. filter wheels (in such case a "!**pos 0**" instruction is not sufficient, as internal limits will apply).
In order to ensure the reference point remains at the same position, the zero instruction should be executed after completing one or several complete revolutions.

Remarks: For rotational axes '**modulomode**' can be used. In these modes, setting the axes to zero is not required.

Response: none.

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

## 14.15. clearpos (Set Internal Position to Zero)

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

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

Response: none.

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

# 15. HDI Instructions (Joystick, Trackball, ERGODRIVE)

The HDI (human device interface) provides manual control of the axes and also supports special functions.
The HDI interface accepts hot plugging of the devices. It is possible to unplug, plug in, or exchange the input devices during operation of the TANGO controller.

The HDI velocities are limited to the **secvel** velocity as long as no **cal** and **rm** sequence has been executed. The axis travel will stop at either the hardware limit switches or the software limits (defined by **lim** instruction).
The Joystick velocities are either taken from the current axis velocity **vel** or, if **extmode** is enabled, as an independent **joyvel**.
The **keymode** functionality enables selection of different **keyspeed** velocities by pressing the function keys F1-F4 of the joystick. Please refer to **keymode** for further information.
The optional **multi-function wheel**, found on several HDI devices, can be assigned to any axis (instruction **zwaxis**) and the LED100 brightness (via **hdimode**).

## 15.1. joy (Generally Enable/Disable HDI)

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

Description: Generally enanble or disable the connected HDI device (joystick, trackball, ERGODRIVE etc.)
It is recommended to only use the values 0 or 2. For compatibility, a value of 1 has the same effect as 2.

0 = OFF : disable HDI device
2 = ON : enable HDI device (default setting)

Important Advice: If joy is switched from an ON state to OFF (0), an automatic status reply (like "@@@-.") is generated.
If this is not wanted a workaround is using **joydir** to disable the HDI or temporarly disabling **autostatus**.

Response: HDI enable state

Examples:
!joy 0 disable the HDI device (e.g. joystick) and speed instruction
!joy 2 enable the HDI device (default) and speed instruction
?joy read HDI enable state

Behavior examples / sequences:
---
?joy ==> 2 (HDI is enabled)
!joy 0 ==> @@@-. (response when switched enable→disable with autostatus on)
!joy 0 (no response when joy already is disabled)
!joy 2 (no response when joy is enabled)
---
!autostatus 0 (workaround #1 to avoid response when disabling)
!joy 0
!autostatus 1
---
!joydir 0 0 0 0 (workaround #2 is to use **'joydir'** instead)
!joydir 2 2 2 2 (make sure the direction is correct, 2 or -2)
---

## 15.2. joydir (Joystick Direction or Assign Joystick per axis)

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

Description: In addition to the **'joy'** instruction, joydir can be used to enable/disable individual HDI axes and set their directions. For compatibility, a value of 1 or -1 has the same effect as 2 or -2. It is recommended to use the values 2, 0 or -2 only. The options are:

```
  0  = Disable HDI axis (e.g. joystick deflection is ignored)
( 1  = Enable HDI axis, no motor current reduction)
  2  = Enable HDI axis, current reduction supported (default)
(-1  = Same as 1, direction reversed)
 -2  = Same as 2, direction reversed
```

Remarks: To activate the joystick, please also make sure that the joystick is globally enabled by the **'joy'** instruction.

When using a 4 axis controller with a 3 axis joystick, its 3rd axis will be used to control axes 3 and 4. The selection which axis (3 or 4) is controlled must be selected by enabling or disabling the corresponding joydir. By default, the joydir of the 4th axis is disabled (0). Refer to examples below.

This instruction also enables or disables (0) the **'speed'** move for the corresponding axes, but does not affect the speed move directions (joydir 2 or -2 enables **speed**).

Response: HDI directions of the axes or specified axis

Examples:

| | |
|---|---|
| !joydir -2 | enable HDI X-axis in reversed direction |
| !joydir z 0 | disable HDI Z-axis |
| !joydir 2 2 0 2 | set positive direction, allow current reduction, assign the joysticks 3rd axis to the controller A axis instead of Z |
| ?joydir | read HDI enable/direction setting of all axes |
| ?joydir y | read HDI enable/direction setting of Y axis only |

## 15.3. joychangeaxis (Change Joystick X and Y Axis)

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

Description: Change the assignment of the Joystick X and Y axes.

0 = no change (default)
1 = Joystick X and Y axes changed (X=Y, Y=X)

Remarks: Only for Joystick devices.

Response: Joystick X-Y axis change state

Examples:

| | |
|---|---|
| !joychangeaxis 1 | change X and Y axis of the Joystick |
| ?joychangeaxis | read Joystick X,Y change state |

## 15.4. joywindow (Joystick Window)

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

Description:      This instruction sets the center position threshold of the
                  Joystick in digits. A deflection, as long as it is in this
                  window, has no effect. There is only one value for all axes.
                  The default value of ±14 should not be reduced, as this
                  may result in slow unwanted creeping of axes even when the
                  joystick is apparently not deflected. Increasing the value
                  will reduce the velocity resolution (available steps).

Response:         joywindow [in digits]

Examples:
?joywindow        read joystick window
!joywindow 14     set joystick window to ±14
```

## 15.5. joyvel (Joystick Velocity)

```
Syntax:           !joyvel or ?joyvel
Parameter:        x, y, z, a or none
                  0.000001 to 200 [revolutions/s] or equiv. [mm/s] if dim=9

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

Response:         Currently used joystick velocities

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

## 15.6. joyspeed (Joystick Speed Presets for BPZ Device)

```
Syntax:           !joyspeed or ?joyspeed
Parameter:        1, 2 or 3 and
                  0.000001 to 200 [revolutions/s]

Description:      Only used by a customer designed HDI 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 in [rev/s]

Examples:
?joyspeed 1       Read "slow" joystick button speed
!joyspeed 3 30    Set "fast" joystick button speed to 30 [revolutions/s]
```

# 15.7. keymode (Joystick Key Mode)

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

Description: Instead of the usual **vel** (or **joyvel** in extmode 1), keymode assigns the independent **keyspeed** velocities to the joystick. Each axis has its two dedicated **keyspeed**s, which can be selected (toggled) by the joystick function keys. The way how the speeds can be toggled is defined by **'hdimode'**, bit 1.

The different keymodes 1 and 2 can be used to select the preferred speeds which are active on startup.

**Keymode** can be set to:

**0** = keyspeed disabled, vel or joyvel is used (default)

**1** = keyspeed for X,Y and Z velocity, preset is **keyspeed** 1

**2** = same as 1, but preset is **keyspeed** 2

Depending on the selected toggle mode (by **'hdimode'** bit 1), the behavior is

A) **hdimode** bit 1 = 0 (no joystick toggle mode):

F4 : selects keyspeed 1 values of X and Y axis,
F1 : selects keyspeed 2 values of X and Y axis.

F3 : selects keyspeed 1 value of the Z axis,
F2 : selects keyspeed 2 value of the Z axis.

The F-key does not have to be pressed all time, as it immediately switches to the desired keyspeed.

B) **hdimode** bit 1 = 0 (no joystick toggle mode):

F1 : toggles XY between the keyspeed values 1 and 2

F4 : toggles Z keyspeeds 1,2 (firmware 1.56 or higher)

Remarks: Please note that other special functions which require the same joystick buttons (e.g. **snapshot modes**) might interfere with keymode (keymode will still behave as required, but other functions might then be executed as well).

For joysticks with the optional multi-function wheel, three wheel velocities are available by pressing F1, F4 or no key. Please refer to the **'zwtravel'** description.

Response: keymode as decimal number

Examples:
!keymode 1 keyspeed 1 is active on startup
?keymode => 1 (keymode 1 is selected)

## 15.8. keyspeed (Joystick Key Speed Presets)

Syntax: !keyspeed or ?keyspeed
Parameter: x, y, z, a or none
0.000001 to 3000 [mm/s]

Description: Two Joystick velocities can be set for each axis individually. The first parameter is called the slow value and the second parameter is fast. Unit is always mm/s, independent from **dim**. The keyspeeds become available through **keymode**s 1 and 2.

Remarks: In **Keymode**, the X and Y keyspeeds do toggle together by F4/F1, while the Z keyspeeds are toggled separately by F3/F2.
A different toggle mode can be set by **hdimode** bit 1, where F1 toggles between the keyspeeds for X+Y instead of F4/F1 and F4 toggles between the keyspeeds for Z instead of F3/F2.

The keyspeeds are limited to **'secvel'** as long as no **cal**+**rm** sequence is executed.

Hints: Setting one keyspeed to zero could be used to have a startup setting where movement by the joystick is in fact disabled and the user has to press a joystick function key in order to use the joystick (toggle it to a speed different from zero).

Response: Two floating point values per axis (1="slow" and 2="fast")
one axis : [keyspeed1] [keyspeed 2]
more axes: [k.spd.1_x] [k.spd.2_x] [k.spd.1_y] [k.spd.2_y] ...

Examples:

```
?keyspeed x       => 1.00 10.00                      (Read X Joystick keyspeed)
?keyspeed         => 2.00 20.00 2.00 20.00 0.10 1.00 (Reply of a 3 axes TANGO)
!keyspeed z 0.1 1         (Set keyspeed1 to 0.1 and keyspeed2 to 1 [mm/s] for Z)
!keyspeed 5 20 2 10 0.2 2 (Set keyspeed of 3 axes at once)
```

## 15.9. joycurve (Joystick Characteristic)

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

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

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

Remarks: The default (logarithmic) setting is the most useful as it allows very fine positioning at lower deflections and high velocities towards the full deflection.

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       => read characteristic of all axes
```

## 15.10. 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 all 4 or the specified
                 HDI device key(s).

                 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)
                 key 3 => query only key 3 (e.g. F3 Joystick button)
```

## 15.11. keyl (Read HDI Device Latched Key State)

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

Description:     The ?keyl or keyl instruction reads the latched state of the
                 specified or all 4 HDI device keys. The latched state of the
                 requested key(s) is cleared after reading.
                 The instruction !keyl clears the latched state of the
                 specified or all keys to zero (0) without reading.

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

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

Examples:        keyl    => read+clear all 4 keys, returns e.g. 0 1 0 0
                 keyl 1  => read+clear only key 1 (e.g. F1 Joystick button)
                 ?keyl 1 => same as "keyl 1"
                 !keyl 2 => clear latch state of key 2 only (to zero)
                 !keyl   => clear latch state of all 4 keys (to zero)
```

## 15.12. hwfactor (Coaxial-/ERGODRIVE Transmission Factor)

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

Description:      Aaxis travel distance in millimeter per coaxial drive
                  revolution. Negative factors reverse the travel direction.
                  (The hardware provides about 100000 steps per revolution.)

Remarks:          Some HDIs provide a switch to change between two different
                  factors. Please refer to 'hwfactorb'.

Response:         Currently used factor(s)
                  As floating point number(s) between -200.0 and +200.0

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

## 15.13. hwfactorb (Alternate Coaxial-/ERGODRIVE Factor)

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

Description:      Alternate (second) parameter for travel distance per coaxial
                  drive revolution 'hwfactor'. Available with e.g. ERGODRIVE and
                  Pilot stage. Negative factors reverse the travel direction.

Response:         Currently used alternate coaxial drive factor(s)
                  As floating point number(s) between -200.0 and +200.0

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

## 15.14. hwfilter (Coaxial-/ERGODRIVE Noise Filter)

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

Description:      Coaxial drive noise filter.

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

                  The filter is activated/deactivated for X and Y axes at once.
                ** Disabling the filter can result in a finer resolution, but it
                  also causes position inaccuracy e.g. between automatic moves
                  or when the axis is not moving: Its signal noise will cause a
                  permanent slight position jitter.

Response:         State of the coaxial drive noise filter

Examples:
!hwfilter 0       => Disable noise filter
?hwfilter         => Read hwfilter state
```

## 15.15. tbfactor (Trackball Factor)

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

Description:      Set or read the trackball sensitivity (transmission factor),
                  which is a floating point number between -200.0 and +200.0.
                  A negative value can be used to change direction (similar to
                  'joydir'). The default factor is 1.

Response:         Currently used trackball factor(s)

Examples:
!tbfactor x 100   => X axis is 100 times more sensitive than the default setting
!tbfactor y 12.5  => X axis is 12.5 times more sensitive than the default
!tbfactor 0.5 0.5 => X and Y axis set to half the default sensitivity
?tbfactor         => Read sensitivity factor of all axes
```

## 15.16. zwheel (Is Multi-function Wheel Available)

```
Syntax:           ?zwheel or zwheel
Parameter:        none

Description:      Identify if the connected HDI device provides a Wheel.

                  0 = HDI device has no multi-function wheel
                  1 = HDI device has a multi-function wheel

Remarks:          To identify the HDI device, use 'hdi' instruction

Response:         0 or 1

Example:          ?zwheel => 0
```

## 15.17. zwtravel (Multi-function Wheel Travel per Revolution)

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

Description:      Set or read the travel distances for one revolution of the
                  multi-function wheel, available with several HDI devices,
                  e.g. ERGODRIVE and Joystick.

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

                  Presets for travel distance are
                  1: 0.1  mm/rev (default factor)
                  2: 0.01 mm/rev (alternate factor, factory preset to slow)
                  3: 1.0  mm/rev (alternate factor, factory preset to fast)

Remarks:          ERGODRIVE and Pilot stage only offer switching between two
                  travel distances. In this case distance parameter 1 remains
                  the default; parameter 3 is used as alternate second factor.

                  'secvel' and 'vel' (or 'joyvel' in extmode 1) may prevent
                  faster traveling when turning the wheel.

                  It is possible to set negative values and by this offering
                  direction change via HDI key.

                  The multi-function wheel can also be assigned to other axes
                  with the 'zwaxis' instruction. By default it is set to Z.

Hints:            For safety reasons, the default travel can be set to zero.
                  So the axis will move only when a key is pressed (F1, F4).

Response:         Travel distance(s) of the multi-function wheel

Examples:
?zwtravel         Read all 3 travel distances: [1:default] [2:slow] [3:fast]
?zwtravel 1       Read "default" travel distance
?zwtravel 2       Read "slow"    travel distance
!zwtravel 3 2.5   Set  "fast"    travel distance to 2.5 [mm/revolution]
!zwtravel 1 0     Set  "default" parameter to zero (inactive without keypress)
```

## 15.18. zwaxis (Multi-function Wheel Axis)

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

Description:     Assign multi-function wheel to an axis (default: z)

Response:        x, y, z or a

Example:         !zwaxis a       (assign wheel to axis 4)
                 !zwaxis x       (assign wheel to axis 1)
                 ?zwaxis    => z (wheel is currently assigned to axis 3)
```

## 15.19. zwfactor (Multi-function Wheel Factor)

```
Syntax:          !zwfactor or ?zwfactor
Parameter:       0, 1, 2 ... to 20

Description:     For custom designed applications only.
                 Increase Wheel transmission multiplier, default=1.

                  0  = Wheel has no effect
                  1  = Wheel default (1:1)
                  .
                  .
                  .
                 20  = Wheel travels 20 times more distance

Remarks:         Useful in custom designs where the application requires a
                 different rotary encoder to provide the wheel functionality.
                 If the chosen encoder type provides less resolution than the
                 Joystick multi-function wheel, zwfactor can be used to adapt
                 the behavior (here: to achieve correct zwtravel distances).
                 The multi-function wheel has a resolution of 480 counts/rev.
                 In example if the encoder has 128 counts/rev, zwfactor can be
                 set to 4.

Response:        Multiplier

Example:         !zwfactor 1     (set default multiplier, as for TANGO HDIs)
                 !zwfactor 5     (set multiplier for lower res. encoder wheel)
                 ?zwfactor       (read the currently used multiplier)
```

## 15.20. zwpos (Multi-function Wheel Position Counter)

```
Syntax:          !zwpos, zwpos or ?zwpos
Parameter:       none

Description:     Read or set the independent position counter
                 of the Multi-function Wheel.

Remarks:         The wheel resolution is 480 counts/rev, counts always,
                 zwfactor settings have no influence.

Response:        Counter value as 32 Bit signed integer

Example:         !zwpos 0      (set position counter to zero)
                 !zwpos 2000   (set position counter to 2000)
                 zwpos         (read the position counter, same as ?zwpos)
```

## 15.21. tvrjoy (Pulse and Direction Joystick Functionality)

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

Description: Enables and assigns the AUX IO pulse&direction inputs TAKT_IN, V/R_IN to an axis, providing a pulse and direction interface. The behavior is similar to the trackball, which is available as HDI device.

Remarks: The function does not provide absolute positioning accuracy. It can be compared to a HDI device behavior.

This function is also available without connecting a HDI device, by entering **tvr mode** 5 for the corresponding axis

0 = Disabled (default)
z = Assigned to Z-axis
a = Assigned to A-axis

Response: Currently assigned axis

Examples:
!tvrjoy 0 Disable AUX I/O tvr joystick function
!tvrjoy z Assign AUX I/O tvr joystick function to Z-axis
?tvrjoy Query assigned axis

## 15.22. tvrjoyf (Pulse and Direction Joystick Factor)

Syntax: !tvrjoyf or ?tvrjoyf
Parameter: -200.0 to +200.0

Description: Set or read the AUX I/O tvrjoy transmission factor as floating point number between -200.0 and +200.0. A sign change can be used to change direction. The default setting is 1.

Response: Currently used tvr factor

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

# 15.23. hdi (Read HDI ID)

Syntax: ?hdi or hdi
Parameter: none or -1

Description: Read the ID number of the connected hdi device.
The second value shows how good the hardware ID code matches the theoretical ID value [in %]. This value should be more than 30 [%] for secure device identification.

The additional ?hdi -1 option is available from firmware 1.68. It returns the ID and % match plus a descriptive text, which also includes the optional multi-function wheel.

ID numbers: 0, 1, 2, ... 15, (16 or -1 = no device connected)
ID match : 0 (poor) ... 100 (good)

| ID | DEVICE |
|---|---|
| 0 | (Reserved for special devices) |
| 1 | Coaxial drive |
| 2 | Custom designed console |
| 3 | ERGODRIVE |
| 4 | SmartMove |
| 5 | Custom device |
| 6 | Custom device |
| 7 | Stand alone Jogwheel/Multi-Function Wheel |
| 8 | - |
| 9 | - |
| 10 | 2x 2-Axis Joystick or 4-Axis Jogbox |
| 11 | Trackball with 2-Axis Joystick |
| 12 | Joystick 2-Axis |
| 13 | Trackball with 3-Axis Joystick |
| 14 | Trackball |
| 15 | Joystick 3-Axes |
| 16 | No device connected |
| 17 | (Device identification in progress) |
| 18 | (Device initialization in progress) |
| -1 | No device connected (Digital HDIs) |

Remarks: The instruction may be used to identify the connected HDI device. Additionaly, **'zwheel'** can be used to identify if the device provides an additional multi-function wheel.

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

Example:
```
?hdi    =>  16 99 (ID ≥16 = no hdi connected)
?hdi    =>  12 97 (meaning: HDI ID = device nr. 12, 97% match)
?hdi -1 =>  12 97 [Joystick 2 axis] (device description text)
?hdi -1 =>  15 93 [Joystick 3 axis with MF-Wheel]
```

# 15.24. hdimode (HDI Mode Options)

Syntax: ?hdimode or !hdimode
Parameter: a string of 0s and 1s -> to set LSB or more bits at once
or two numbers, 0 to 15 and 0 or 1 -> to set a single bit

Description: Select extended HDI device options.
Options may either be set by a string of bits (0s and 1s)
or by specifying bit number and logic state (on/off = 1/0).
The string is LSB first (bit 0 is the first and leftmost)
and can be truncated at any length (not all 16 bits required).
Setting a bit to 1 enables the functionality, 0 disables it.

| Bit | Function |
|---|---|
| 0: | Toggle Mode for ERGODRIVE XY and Z Keys (0=off, 1=on) |
| 1: | Toggle Mode for Joystick (in KeyMode 1 or 2)<br>0=select KeySpeed velocity XY with F1+F4, Z with F2+F3<br>1=toggle KeySpeed velocity XY by just pressing F1<br>F4 is used to toggle Z (firmware 1.56 and higher) |
| 2: | LED100 brightness control via Joystick or ERGODRIVE (1=enabled). The AUX I/O TAKT_OUT pin is controlled automatically then (LED digitally switched of at 0%)<br>Remarks: If enabled, it can interfere with the **second Trigger Output** respectively **adigout 0**. |
| 3: | LED100 fine manual brightness control,<br>16x finer with Multifunction Wheel<br>4x finer when controlled via Joystick Y deflection<br>(1=fine mode enabled, only in conjunction with Bit 2) |
| 4: | LED100 as main function of the Multifunction Wheel.<br>The function key (Joystick: F2, ERGODRIVE: F1) which must be pressed to control the LED is now used to drive the assigned axis instead. |
| 5: | - reserved - |
| 6: | Joystick Z knob drives the A axis (axis 4 instead of 3) |
| 7: | Diagonal mode (HDI X applied to X and Y simultaneously) |
| 8: | Trackball Y axis drives the Z axis (X then is disabled) |
| 9: | Joystick Y drives Z axis (and Z drives Y, if 3 axis JS) |
| 10: | Joystick Z knob is autodisabled while X or Y deflected |
| 11: | - reserved - |
| 12: | - reserved - |
| 13: | - reserved - |
| 14: | - reserved - |
| 15: | - reserved - |

Response: Single mode bit or all 16 mode bits in one ASCII string

Examples:

| | |
|---|---|
| !hdimode 2 1 | Set mode bit 2 to 1 (on) = LED100 brightness control via HDI |
| !hdimode 3 0 | Set mode bit 3 to 0 (off)= Coarse LED100 brightness control |
| !hdimode 1 | Set mode bit 0 to 1 (on) (equal to "!hdimode 0 1") |
| !hdimode 100010 | Set mode bits 0 and 4 to "on", bits 1,2,3,5 to "off". Bits 6...15 are left unchanged. |
| ?hdimode | 1000100000000000 Read the state of all 16 mode bits, LSB left |
| ?hdimode 0 | Read the state of mode bit 0 (ERGODRIVE toggle mode) |

# 15.25. configaxsel (Joystick Axis Select Option)

| | |
|---|---|
| 1 Syntax: | !configaxsel or ?configaxsel |
| Parameter: | 0 or 1 |
| Description: | Used in TANGO 4 axes systems.<br>Enable the axis select functionality when the joystick Z-axis should drive both, the controller Z and A axes.<br>If the A axis joystick is enabled (by joydir a/see remarks), the Z knob of the joystick either drives Z (F4 key released) or A (F4 key pressed).<br><br>1 = axis select enabled (pressing F4 key → A-axis used)<br>0 = axis select disabled (default: joystick Z always Z-axis) |
| Remarks: | Please make sure that the joystick function for A axis is enabled (**'joydir a'** instruction) |
| Response: | Axis select configuration |

Examples:

| | |
|---|---|
| !configaxsel 1 | Axis select enabled (F4 applies Z->A with 3 axes joystick) |
| !configaxsel 0 | Axis select disabled (default) |
| ?configaxsel | Read the axis select configuration (returns 0 or 1) |

# 16. Joystick Function Key Assignments

The Joystick provides 4 function keys, F1-F4. The key states can be read by the **key** and **keyl** instructions. Several operating modes of the TANGO controller also assign special functions to the F-keys. The chart shows the key assignments for the different modes:

| Mode / Key | | F1 | F2 | F3 | F4 |
|---|---|---|---|---|---|
| **SnapShot Mode** | **0** | - | set new point | - | - |
| | **1** | - | next point | - | - |
| | **2** | previous point | next point | prehome & first point | prehome & home |
| | **3** | - | start dissection | - | - |
| | **7** | Move sequence prehome & home | autoinc from 1st point | pause/continue | pause & previous point |
| | **9** | Relative Jump back | Relative Jump forward | - | - |
| **Axis Select Mode** [2] | | - | - | - | Joystick Z-Axis controls A-Axis[1] |
| **KeyMode** | | Select X,Y KeySpeed2 | Select Z KeySpeed2 | Select Z KeySpeed1 | Select X,Y KeySpeed1 |
| **KeyMode+Toggle** | | Toggle X,Y KeySpeed | Toggle Z KeySpeed | - | - |
| **Joystick has wheel** | | zwtravel3 (fast) [1] | - | Wheel "Joystick" [1] | zwtravel2 (slow) [1] |
| **LED Mode no wheel** | | - | - | Y-axis controls LED brightness [1] | - |
| | | | | F3+F4: Store LED brightness | |
| **LED Mode w. wheel** | | zwtravel3 (fast) [1] | Wheel controls LED brightness[1] | Wheel "Joystick" [1] | zwtravel2 (slow) [1] |
| | | | | F3+F4: Store LED brightness | |

1) Function selected only as long as key pressed.
In all other cases the function is selected or executed by pressing the key.

2) F4 can be configured as Axis Select (Z<->A). Please refer to **'configaxsel'**.

Remarks: When selecting more than one mode, function keys may become assigned to several functions at once.

Joysticks with multi-function wheel behave different in case of LED control than josticks without a wheel (refer to chart above).

# 17. Digital and Analogue I/O

TANGO Desktop, TANGO PCI/PCI-S/PCI-E and TANGO 3 mini controllers provide several I/O options which become available with

**1) the optional auxiliary I/O port (AUX I/O)**
Which provides 5V digital I/O, analogue output(s), analogue input and more. In case of TANGO 3 mini the AUX mini is always present, has different functions. Refer to **adigin**, **adigout**, **anain**, **anaout**, **anamode** and in case of TANGO 3 mini also **adigintyp** and **adiginfunc**.

**2) optional I/O extension port modules (Multi I/O preferred)**
TANGO PCI-E based controllers with optional **I/O1** or **Multi I/O** port module provide additional 24 or 12 digital inputs and 8 digital outputs via **digin**, **digout**, **edigin**, **edigout** etc. **det** may be used to check if a module is installed. A preset value can be assigned to the outputs which defines the initial state after power up.

Remarks: In case of I/O1 and Multi I/O Modules, the **brake** functionality can interfere with the digital outputs. If a motor brake is activated, it occupies the specified output pin(s) which are controlled by the brake and can't be set by digout, edigout.

## 17.1. digin (I/O1 Digital Inputs)

```
Syntax:           ?digin or digin
Parameter:        none or 0 to 23

Remarks:          Only available with TANGO PCI-E/DT-E extension module I/O1.
                  For Multi I/O modules, please refer to 'edigin'.

Description:      This instruction reads the logic state of one or all digital
                  inputs of the optional digital I/O1 extension.
                  If called without parameter, all inputs are returned as a
                  string of 24 characters. If called with parameter (input
                  number), only the state of the specified input is returned.

Response:         logic state of digital input(s)
                  ASCII string 0 or 1, LSB (IN0) is the first/leftmost character
                  0 = low, 1 = high (depends on the polarity setting diginpol)

Examples:
?digin            read all 24 digital inputs (e.g. 000000000000000000000000)
?digin 8          read logic level of input 8 (response e.g. 1)
```

## 17.2. digout (I/O1 Digital Outputs)

```
Syntax:           !digout or ?digout
Parameter:        string of up to 8 characters 0 and 1,
                  or single bit access with output number 0 to 7 and state 0, 1

Remarks:          Only available with TANGO PCI-E/DT-E extension module I/O1.
                  For Multi I/O modules, please refer to 'edigout'.

Description:      This instruction sets or reads back the logic level of one or
                  all digital outputs of the optional digital I/O1 extension.
                  Outputs may be set either by a string of levels (up to eight
                  0s and 1s) or by output number and signal level.
                  The string is LSB first (output 0 is the leftmost).

Response:         current output state(s)

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 100       The digital output 0 is set to logic '1' and the outputs 1 and
                  2 are set to logic '0'. Outputs 3 to 7 are left unchanged.
!digout 5 1       set digital output 5 to logic 1 (high)
!digout 7 0       set output 7 to 0 (low)
?digout           read the state of all outputs
?digout 5         read the state of output 5
```

## 17.3. diginpol (I/O1 Digital Input Ploarity)

```
Syntax:           !diginpol or ?diginpol
Parameter:        string of up to 24 characters 0 and 1,
                  or single bit with two numbers 0 to 23 and 0 or 1

Remarks:          Only available with TANGO PCI-E/DT-E extension module I/O1.
                  For Multi I/O modules, please refer to 'ediginpol'.

Description:      This instruction sets or reads back if the I/O1 input signal
                  inverters are activated or not. Each of the 24 inputs can be
                  inverted individually.
                  The inverter may be set either by a string of levels (up to 24
                  0s and 1s) or by specifying the input number and inverter
                  state. The string is LSB first (input 0 is the leftmost).

Response:         current inverter setting(s)

Examples:
!diginpol 010000000000000000000000 Set all inverter states (IN1 to inverted)
!diginpol 11000   The digital inputs IN0 and IN1 are set inverted, IN2, 3 and 4
                  are set to non inverted, input IN5 to IN23 settings are left
                  unchanged
!diginpol 5 1     activate inverter of digital input IN5 only
!diginpol 17 0    disable inverter of digital input IN17 only
?diginpol         read the inverter setting of all 24 inputs
?diginpol 5       read the inverter setting of input 5 only
```

## 17.4. digintyp (I/O1 Digital Input Type)

```
Syntax:           !digintyp or ?digintyp
Parameter:        string of up to 6 characters 0 and 1,
                  or single bit access with block number 0 to 5 and state 0, 1

Remarks:          Only available with TANGO PCI-E/DT-E extension module I/O1.
                  24 Volt configured I/O1 modules only work with pull-down (0).
                  For Multi I/O modules, please refer to 'edigintyp'.

Description:      This instruction sets or reads back if the I/O1 pull-up /
                  pull-down resistor settings for the 24 inputs.
                  The resistors are arranged in 6 blocks. Therefore inputs can
                  only be accessed blocks of 4: IN0-3, IN4-7, ... IN20-IN23

                  0 = pull down
                  1 = pull up

                  The pull up/down may be set either by a string of levels (up
                  to 6 0s and 1s) or by specifying the block number and level.
                  The string is LSB first (block 0 is the leftmost).

Response:         current pull up/down setting(s)

Examples:
!digintyp 110000  Set all pull up/downs (IN0-IN7 to pull up, rest to pull down)
!digintyp 001     Set pull up/down of IN0-IN7 to pull down, IN8-IN11 to pull up
                  the settings for IN12 to IN23 are left unchanged
!digintyp 4 1     set block 4 (IN16-IN19) to pull up
!digintyp 2 0     set block 2 (IN8-IN11) to pull down
?diginpol         read the pull up/down setting of all 6 blocks
?diginpol 5       read the pull up/down setting of input 5 only
```

# 17.5. digoutpreset (I/O1 Digital Output Presets)

```
Syntax:           !digoutpreset or ?digoutpreset
Parameter:        string of up to 8 characters 0 and 1,
                  or single bit access with output number 0 to 7 and state 0, 1

Remarks:          Only available with TANGO PCI-E/DT-E extension module I/O1.
                  For Multi I/O modules, please refer to 'edigoutpreset'.

Description:      This instruction sets or reads back the logic levels of one or
                  all digital outputs of the optional digital I/O1 extension,
                  which are applied after power up of the TANGO.
                  Output preset levels may be set either by a string of levels
                  (up to eight 0s and 1s) or by output number and signal level.
                  The string is LSB first (output 0 is the leftmost).

Response:         output preset value(s)

Examples:
!digoutpreset 11110000  After power on, the digital outputs 0,1,2,3 are set to
                        logic '1' and the outputs 4,5,6,7 are set to logic '0'
!digoutpreset 100  After power on, the digital output 0 is set to logic '1' and
                   the outputs 1 and 2 are set to logic '0'. Outputs 3 to 7 are
                   left unchanged.
!digoutpreset 5 1  set preset value of output 5 to logic 1 (high)
!digoutpreset 7 0  set preset value of output 7 to 0 (low)
?digoutpreset      read the state of all outputs
?digoutpreset 5    read the state of output 5
```

## 17.6. edigin (Multi I/O Digital Inputs)

```
Syntax:           ?edigin or edigin
Parameter:        none or 0 to 11

Remarks:          Only available with the Multi I/O port of TANGO PCI-E/DT-E.

Description:      This instruction reads the logic state of one or all digital
                  inputs of the optional Multi I/O digital extension port.
                  If called without parameter, all inputs are returned as a
                  string of 12 characters. If called with parameter (input
                  number), only the state of the specified input is returned.

Response:         logic state of digital input(s)
                  ASCII string 0 or 1, LSB (IN0) is the first/leftmost character
                  0 = low, 1 = high (depends on the polarity setting ediginpol)

Examples:
?edigin           read all 12 digital inputs (e.g. 000000000000)
?edigin 8         read logic level of input 8 (response e.g. 1)
```

## 17.7. edigout (Multi I/O Digital Outputs)

```
Syntax:           !edigout or ?edigout
Parameter:        string of up to 8 characters 0 and 1,
                  or single bit access with output number 0 to 7 and state 0, 1

Remarks:          Only available with the Multi I/O port of TANGO PCI-E/DT-E.

Description:      This instruction sets or reads back the logic level of one or
                  all digital outputs of the optional Multi I/O extension port.
                  Outputs may be set either by a string of levels (up to eight
                  0s and 1s) or by output number and signal level.
                  The string is LSB first (output 0 is the leftmost).

Response:         current output state(s)

Examples:
!edigout 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'.
!edigout 100      The digital output 0 is set to logic '1' and the outputs 1 and
                  2 are set to logic '0'. Outputs 3 to 7 are left unchanged.
!edigout 5 1      set digital output 5 to logic 1 (high)
!edigout 7 0      set output 7 to 0 (low)
?edigout          read the state of all outputs
?edigout 5        read the state of output 5
```

## 17.8. ediginpol (Multi I/O Digital Input Ploarity)

```
Syntax:           !ediginpol or ?ediginpol
Parameter:        string of up to 12 characters 0 and 1,
                  or single bit access with input number 0 to 11 and state 0, 1

Remarks:          Only available with the Multi I/O port of TANGO PCI-E/DT-E.

Description:      This instruction sets or reads back if the Multi I/O input
                  signal inverters are activated or not. Each of the 12 inputs
                  can be inverted individually.
                  The inverter may be set either by a string of levels (up to 12
                  0s and 1s) or by specifying the input number and inverter
                  state. The string is LSB first (input 0 is the leftmost).

Response:         current inverter setting(s)

Examples:
!diginpol 010000000000 Set all inverter states (IN1 to inverted)
!diginpol 11000   The digital inputs IN0 and IN1 are set inverted, IN2, 3 and 4
                  are set to non inverted, input IN5 to IN11 settings are left
                  unchanged
!diginpol 5 1     activate inverter of digital input IN5 only
!diginpol 7 0     disable inverter of digital input IN7 only
?diginpol         read the inverter setting of all 12 inputs
?diginpol 5       read the inverter setting of input 5 only
```

## 17.9. edigintyp (Multi I/O Digital Input Type)

```
Syntax:           !edigintyp or ?edigintyp
Parameter:        string of up to 12 characters 0 and 1,
                  or single bit access with input number 0 to 11 and state 0, 1

Remarks:          Only available with the Multi I/O port of TANGO PCI-E/DT-E.
                  24 Volt configured Multi I/O only works with pull-down (0).

Description:      This instruction sets or reads back if the Multi I/O pull-up /
                  pull-down resistor settings for the 12 inputs.  Each of the 12
                  resistors can be set individually.

                  0 = pull down
                  1 = pull up

                  The pull up/down may be set either by a string of levels (up
                  to 12 0s and 1s) or by specifying the input number and level.
                  The string is LSB first (input 0 is the leftmost).

Response:         current pull up/down setting(s)

Examples:
!edigintyp 110000000000  Set all pull up/downs (IN0,IN1 to pull up, rest down)
!edigintyp 001    Set IN0+IN1 to pull down, IN1 to pull up, rest left unchanged
!edigintyp 4 1    set IN4 to pull up
!edigintyp 2 0    set IN2 to pull down
?ediginpol        read the pull up/down settings of all 12 inputs
?ediginpol 5      read the pull up/down setting of input 5 only
```

## 17.10. edigoutpreset (Multi I/O Digital Output Presets)

```
Syntax:           !edigoutpreset or ?edigoutpreset
Parameter:        string of up to 8 characters 0 and 1,
                  or single bit access with output number 0 to 7 and state 0, 1

Remarks:          Only available with the Multi I/O port of TANGO PCI-E/DT-E.

Description:      This instruction sets or reads back the logic levels of one or
                  all digital outputs of the optional Multi I/O extension port,
                  which are applied after power up of the TANGO.
                  Output preset levels may be set either by a string of levels
                  (up to eight 0s and 1s) or by output number and signal level.
                  The string is LSB first (output 0 is the leftmost).

Response:         output preset value(s)

Examples:
!digoutpreset 11110000  After power on, the digital outputs 0,1,2,3 are set to
                        logic '1' and the outputs 4,5,6,7 are set to logic '0'
!digoutpreset 100  After power on, the digital output 0 is set to logic '1' and
                   the outputs 1 and 2 are set to logic '0'. Outputs 3 to 7 are
                   left unchanged.
!digoutpreset 5 1  set preset value of output 5 to logic 1 (high)
!digoutpreset 7 0  set preset value of output 7 to 0 (low)
?digoutpreset      read the state of all outputs
?digoutpreset 5    read the state of output 5
```

## 17.11. edigrly (Multi I/O Relay Option Access)

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

Remarks:          Only available with the Multi I/O port of TANGO PCI-E/DT-E
                  and installed relay option.

Description:      Switch the optional relay to

                  1 = ON
                  0 = OFF

Response:         Relay ON/OFF state

Examples:
!edigrly 1        Switch relay to ON
?edigrly          read relay state (e.g returns 0)
```

## 17.12. adigin (AUX I/O Digital Input)

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

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

                  0 = Bit 0: AUX I/O Pin 1 (Takt In) **
                  1 = Bit 1: AUX I/O Pin 2 (V/R In)
                  2 = Bit 2: AUX I/O Pin 3 (Stop)
                  3 = Bit 3: AUX I/O Pin 4 (SnapShot2)

Remarks **:       Bit 0 (Takt In) is only available with TANGO PCI-E and DT-E.

TANGO 3 mini:     The TANGO 3 mini controller has a different bit assignment:

                  0 = Bit 0: AUX mini        Pin 1 (Takt In)
                  1 = Bit 1: Motor Connector Pin 7 (TrIn)
                  2 = Bit 2: not available         (Dummy)
                  3 = Bit 3: AUX mini        Pin 2 (SnapShot)

Response:         Logic state of the digital input(s)

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

## 17.13. adigintyp (TANGO 3 mini Digital Input Type)

```
Syntax:           !adigintyp or ?adigintyp
Parameter:        input bit: none or 0 to 3
                  and type : 0 or 1

Description:      Available with TANGO 3 mini only.
                  This instruction selects either a pull-up or pull-down
                  resistor for the digital inputs:

                  0 = Bit 0 = AUX mini        Pin 1 (Takt In)
                  1 = Bit 1 = Motor Connector Pin 7 (TrIn)
                  2 = Bit 2 = not available         (Dummy)
                  3 = Bit 3 = AUX mini        Pin 2 (SnapShot)

                  And 1 to select pull-up (default) or 0 to select pull down.

Response:         State of the digital input pull-up/pull-down resistors

Examples:
!adigintyp 0111   Set input 0 (Takt In) to pull-down, other inputs to pull-up
!adigintyp 2 0    Set "TrIn" to pull-down, other inputs remain at their setting
?adigintyp        read all four digital input pull-ups (response e.g. 1111)
?adigintyp 3      read resistor polarity of digital input 3 (SnapShot, e.g. 1)
```

# 17.14. adiginfunc (TANGO 3 mini Digital Input Function)

Syntax: !adiginfunc or ?adiginfunc
Parameter: input bit : none or 0 to 3
and function: 0, 1 or 2

Description: Available with TANGO 3 mini only.
This instruction selects a function for the digital inputs.

Input bit:
0 = Bit 0 = AUX mini Pin 1 (Takt In)
1 = Bit 1 = Motor Connector Pin 7 (TrIn)
2 = Bit 2 = not available (Dummy)
3 = Bit 3 = AUX mini Pin 2 (SnapShot)

And function:
0 = input pin for **adigin** readout only
1 = stop function (also refer to **stoppol** and **adigintyp**)
2 = snapshot function (also refer to **snsl** and **adigintyp**)

The stop input function is a software stop. It can be set to a variety of behaviors as described in **stoppol**.

It is possible to assign the same function to several inputs.

By default, SnapShot is assigned to the SnapShot input (3) and stop is not used (is assigned to the not available input 2).

Response: Currently selected input pin function(s)

Remarks: If selecting a stop or snapshot function for one or several inputs, please ensure that the correct pull-up/pull-down resistor is set by **adiginfunc** and the correct polarity is chosen by **stoppol** or **snsl**.

When connecting the MW liquid dispenser to the AUX mini port, please ensure that the SnapShot function is assigned to the correct pin, else the **drop** counter will not work correctly.

Examples:

| | |
|---|---|
| !adiginfunc 1 2 | Set a single input by specifying bit and function, here: Assign snapshot function (2) to input 1 (Motor connector TrIn) |
| !adiginfunc 0 1 0 2 | Set all 4 input functions: input 0 as input (0), input 1 as stop input (1), (input 2 is don't care) and input 3 to snapshot function. |
| !adiginfunc -1 | Reset all inputs to their default function |
| ?adiginfunc → 0 0 1 2 | Returns the function of all digital inputs |
| ?adiginfunc 3→ 2 | Returns the function of input 3 (SnapShot) |

# 17.15. adigout (AUX I/O Digital Output)

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

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

0 = Bit 0: AUX I/O Pin 5 (TAKT_OUT, default LED100 on/off pin)
1 = Bit 1: AUX I/O Pin 6 (VR_OUT)
2 = Bit 2: AUX I/O Pin 7 (SHUTTER_OUT)
3 = Bit 3: AUX I/O Pin 8 (TRIGGER_OUT)

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

TANGO 3 mini: 0 = Bit 0: AUX mini Pin 6 (TAKT_OUT, def. LED100 on/off pin)
1 = Bit 1: AUX mini Pin 7 (VR_OUT)
2 = Bit 2: AUX mini Pin 8 (SHUTTER_OUT)
3 = Bit 3: AUX mini Pin 9 (TRIGGER_OUT)

Remarks: Some outputs might be occupied when the **trigger** is activated. Shutter out can be controlled by the **shutter** instruction also. In manual LED control mode (**hdimode** bit 2), TAKT_OUT will be set high/low automatically depending on brightness (0%=high).

Response: Output state(s), 0 or 1

Examples:

| | |
|---|---|
| !adigout 1011 | digital outputs 0,2,3 are set to high, output 1 is set to low |
| !adigout 10 | digital outputs 0 and 1 are set: output 0 to high, 1 to low, outputs 2 and 3 are left unchanged |
| !adigout 0 | set digital output 0 to logic 0 (e.g. LED100 on) |
| !adigout 1 | set digital output 0 to logic 1 (e.g. LED100 off) |
| !adigout 1 0 | set digital output 1 to logic 0 |
| !adigout 2 1 | set digital output 2 to logic 1 |
| ?adigout | read the level of all outputs (e.g. returns 0000) |
| ?adigout 3 | read the level of output 3 (e.g. returns 0) |

# 17.16. anain (Analogue Input)

Syntax: ?anain or anain
Parameter: c (c = channel) or v (v = higher precision with newer TANGOs)
0 to 15 (channel number), further numbers see below

Description: This instruction reads the current value of the analogue inputs. 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 | Joystick A |
| 4 | HDI | 5 | Speedpoti |
| 5 | HDI | 6 | IN1B |
| 6 | HDI | 7 | IN2B |
| 7 | HDI | 8 | IN3B |
| 8 | HDI | 9 | IN4B |
| 9 | HDI | 10 | (HDI-ID) |
| **10** | **AUX I/O** | **9** | **ANAIN0** |
| 11 | internal | - | (PSE) |
| 12 | internal | - | V-MOT |
| 13 | EXT | 20 | X-ID0 |
| 14 | EXT | 18 | X-ID1 / Temp |
| 15 | internal | - | REF (2.5V) |

To calculate the internal motor voltage:

- PCI-E, DT-E, TANGO mini, Pilot, TANGO 3 mini:
  U_mot[V] = [anain c 12] * 0.05792
- TANGO Integrale:
  U_mot[V] = [anain c 12] * 0.03545
- TANGO PCI,PCI-S,DT,DT-S: (PCI-E,DT-E is compatible)
  U_mot[V] = [anain c 12] * 29.63 / [anain c 15]
- To calculate the internal PSE voltage:
  U_pse[V] = [anain c 11] * 7.819 / [anain c 15]

TANGO 3 mini: Responds on channels 17 to 31:

```
17 = PSE ON     (0/1: PSE pin level, 1=ON, for voltage: see 26)
18 = 5V USB     (0/1: 5V detect        , 1=USB connected to PC)
19 = P GOOD     (0/1: Input power good , 1=GOOD)
20 = 5V ENC     (0/1: Encoder       +5V, 1=supply voltage ok)
21 = 5VEXT1     (0/1: Motor cable   +5V, 1=supply voltage ok)
22 = 5VEXT2     (0/1: AUX mini      +5V, 1=supply voltage ok)
23 = 5V HDI     (V)  (HDI connector +5V supply voltage)
24 = 24V BRAKE  (V)  (Brake output voltage 0~24V)
25 = VBUS24     (V)  (AUX mini +24V output voltage)
26 = VCC5       (V)  (TANGO internal +5V supply)
27 = U-PSE      (V)  (voltage on PSE input pin)
28 = V-MOT      (V)  (motor voltage, usually =input voltage)
29 = I-24V      (A)  (input current     of the TANGO 3 mini)
30 = Power      (W)  (power consumption of the TANGO 3 mini)
31 = I-24V peak(A)   (peak input current since last read of 31)
```

Example:

```
anain c 10  → 510    Read channel 10 (AUX I/O analogue input pin 9)
anain v 10  → 509.75 Read value with higher resolution (e.g. 12 bit resoluton,
                     if not available, the same as with "anain c" is returned).
```

# 17.17. anaout (Analogue Output)

Syntax: !anaout or ?anaout

Parameter:
0 to 100 in percent (for anaout values)
c or p (c = single channel keyword, p for preset)
0, 1 or 2 (single channel number, when using c or p)

Description: Sets or reads back the AUX I/O analog output signal level in percent. It can be accessed either directly or by specifying an individual channel with the 'c' keyword (refer to examples)

Power-on presets can be specified to provide a certain output voltage after switching on the controller. The functionality can be accessed by the 'p' keyword and stored permanently by using **'save'**.

The signal resolution is 14 bit (100%/16384) with PCI-E and PCI-S based TANGO controllers and the TANGO 3 mini. Fractional numbers can be used for higher resolution.

100% corresponds to 10 Volts (TANGO 3 mini: 5 Volts).

| Channel | Connector | Signal Name | TANGO AUX I/O Pin | TANGO 3 mini AUX mini Pin |
|---|---|---|---|---|
| 0 | AUX I/O | ANOUT0 | 10 | 11 |
| 1 | AUX I/O | ANOUT1 | 11 | - |
| 2 | reserved | - | - | - |

Instructions:

```
!anaout [level of anaout0] [optional also level of anaout1]
!anaout c [channel no.] [level of specified anaout channel]
!anaout p [channel no.] [preset value of specified channel]
```

Remarks: Channel 0 is used for brightness control of the LED100 illumination. In order to entirely switch off the LED, use **'adigout'**. Also refer to manual LED control via **hdimode**.

In case of TANGO 3 mini the output voltage is 0~5 Volts and only one output is available: ANOUT0 at AUX mini pin 11. For compatibility, ANOUT1 is kept as a dummy value which remains at 0.00%.

Response: Analogue output signal level(s) in percent

Examples:

```
!anaout 100 50.08 Set channel 0 = 100% (10V) and channel 1 = 50.8% (5.008V)

!anaout 75.4      Set channel 0 = 75.4%  (7.54V)

!anaout c 1 25.3  Set channel 1 to 25.3% (2.53V)

!anaout p 0 10    Set channel 0 power-on preset value to 10% (1 Volt)
save

?anaout           Read output level of all channels    (e.g. 0.00 0.00 0.00)

?anaout c 0       Read output level of channel 0 only  (e.g. returns 100.00)
```

# 17.18. anamode (Analogue Output Mode)

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

Description: Defines the behavior of the optional analog outputs, available with the AUX I/O connector. Older TANGO Firmware versions before 1.69 do not support storing this parameter. When using those older versions, anamodes different from 0 must be set each time after power up or reset if required.

0 : default mode - output controlled by '!**anaout**'
or by HDI devices in LED100 mode (**hdimode**)
1 : ANOUT0 controled by anain (0~5Vin --> 0~10Vout)
2 : ANOUT1 controled by anain (0~5Vin --> 0~10Vout)
3 : ANOUT1 controled by Z-axis position (0~10V out, 14bit)
4 : ANOUT1 controled by A-axis position (0~10V out, 14bit)

Remarks: Anamode is available with PCI-S/DT-S and PCI-E/DT-E TANGOs.
The optional AUX I/O connector is required (output pin 11).

TANGO 3 mini: TANGO 3 mini supports anamodes 0 and 3 only.
The 14bit output voltage range is 0~5 Volts.

Response: Selected mode as integer

Examples: !anamode 3 (set mode 3 to drive analog piezo stage with Z)
?anamode ==> 3

**Anamode 3 or 4 - Controlling a Piezo Z-Stage**

In anamodes 3 or 4, the analog output ANOUT1 follows the Z or A axis position. So it is possible to control a piezo stage through the 0-10 Volts output signal on the AUX I/O port, instead of having a stepper motor on the motor connector.

The 0-10 Volts output ANOUT1 then corresponds to the absolute piezo position.

The spindle **pitch** must be set to achieve the required travel of the piezo axis.

Example of a 0...10V piezo stage which travels 0.3mm at 10 Volts input signal:

**!dim z 2**
**!pitch z** [stage travel in mm @ 10V]*12.5 (e.g. 0.3mm*12.5 = !pitch z 3.75)
**!lim z 0** [stage travel in mm @ 10V] (e.g. !lim z 0 0.3 )
**!anamode 3**

Now the 10 Volts output corresponds to pos z = 0.3mm and the axis can travel between the absolute positions 0.0 and 0.3 mm (**moa**, **mor** etc. can be used).

Velocity and acceleration can be adjusted if required.

Dim 1 also works, but then lim must be specified in µm (here e.g. !lim z 0 300).

**For anamode 4, replace z of the example above by a and set !anamode 4.**

TANGO 3 mini has a 0-5V analog output signal.
This signal either has to be amplified externally to 0-10V or the travel range will be limited to 50% of the usual 0-10V range. In this case, the pitch for z must be doubled in order to achieve the correct travel distance within 0-5V.

# 17.19. stoppol (Mode and Polarity of Stop Input Signal)

Syntax: !stoppol or ?stoppol
Parameter: 0 to 5 or 8 to 13

Description: Operating mode of the AUX I/O "Stop" input.
Signal polarity and behavior of the TANGO can be set:

**0,1 Stop only as long as stop signal is applied**
**HDI (joystick) remains active!**
0 : active low
1 : active high

**2,3 Stop only as long as stop signal is applied**
**HDI (joystick) is also disabled**
2 : active low
3 : active high

**4,5 Stop signal is latched (sticky),** must be released by sending a "!stop 0" instruction
**HDI (joystick) is also disabled**
4 : active low
5 : active high

6,7 *Not available*

**8,9** Same as 0,1 but **a running move will be completed first ***

**10,11** Same as 2,3 but **a running move will be completed first ***

**12,13** Same as 4,5 but **a running move will be completed first ***

Requirements: A stop signal must be applied for at least 50µs.

***) Stoppol modes 8-13 (all, including the latched modes):**
**In order to stop, the stop signal must remain active until all axes have completed their currently running move instruction. If the stop signal is removed while an axis is still traveling, no stop will be performed.**

TANGO 3 mini: TANGO 3 mini has no dedicated stop input. It can be assigned by **adiginfunc** and pull-up/down can be adjusted by **adigintyp**.

Remarks: Usually the stop input has an internal pull-up resistor to +5V, please refer to the corresponding TANGO operating manual.

If closed loop '**ctrsm**' mode is set to 4, an error condition of the closed loop will modify the stoppol to a latched mode by internally oring the current stoppol with 4 (0-->4 etc.).

Sending "**!stop 1**" in latched stop modes immediately applies a stop, even in modes 10-13.

TANGOs without a stop input may use the latched stoppol modes in conjunction with manually sending "!stop 1" and "!stop 0".

Response: Operating mode of AUX I/O stop signal input as integer

Example:
!stoppol 5 Set the AUX I/O stop input to latched stop active high.
!stoppol 13 Same as above, but a currently running move is completed first and only the following moves will be suppressed.
?stoppol => 0 Current stoppol mode is mode 0

## 17.20. stop (Release, Force or Check Stop Condition)

```
Syntax:          !stop or ?stop
Parameter:       0, 1

Description:     Release or force a stop condition in latched 'stoppol' modes
                 4, 5, 12 and 13. Or read if stop condition is active.

                 0 = Release stop condition (in stoppol modes 4,5,12,13)
                 1 = Force stop condition   (in stoppol modes 4,5,12,13 only)

Remarks:         in stoppol modes 12 and 13, a forced stop by sending "!stop 1"
                 stops the axes immediately (same as in stoppol modes 4,5).

Response:        Internal stop state of the controller (0, 1)

Example:         !stop 0    release a latched stop
                 !stop 1    force a stop (in latched stoppol modes only)
                 ?stop      read if stop is currently active (=1)
```

## 17.21. shutter (Shutter Out Signal of AUX I/O)

```
Syntax:          !shutter or ?shutter
Parameter:       0, 1

Description:     Set the AUX I/O shutter out signal to the desired TTL level:

                 0 = signal low
                 1 = signal high

Response:        Output level of shutter signal

Example:
!shutter 1       Set the shutter out signal to TTL high state
```

## 17.22. flash (Defined Pulse at AUX I/O Takt Out)

Syntax: flash or !flash
Parameter: +-0.00001 ... 32500 [ms]

Description: Sends a pulse of defined length to the AUX I/O TAKT_OUT pin.
Used e.g. for LED strobes.

Floatingpoint numbers in [ms].
Range 0.00001 (10ns) to 32500 (32.5s).
Resolution is 1/132µs.

Pulse Polarity depends on sign:

- Positive numbers generate an active high pulse
- negative numbers generate an active low pulse

For safe operation it is recommended to once send one dummy pulse when initializing in order have the correct polarity.

Remarks: **Available with TANGO PCI-S/PCI-E,DT-S/DT-E and TANGO 3 mini.**
Might interfere with secondary trigger output(refer to **trigo**).

Response: None

Example:
flash 0.001 (high pulse with duration of 1µs)
flash -0.01 (low pulse with duration of 10µs)

## 17.23. tvr (Pulse and Direction Input Function)

Syntax: !tvr or ?tvr
Parameter: x, y, z, a or none
0, 5

Description: Set the TVR Mode, used to drive an axis through an externally applied pulse and direction signal.

Mode
0 = disabled
(1) = ~~enabled without tvrf factor~~
(2) = ~~enabled with tvrf factor~~
(3) = ~~enabled without tvrf factor, requires ext. start/stop~~
(4) = ~~enabled with tvrf factor, requires ext. start/stop~~
5 = enabled with tvrjoyf factor

Remarks: Only available with TANGO PCI-E and DT-E controllers.

Response: Currently selected tvr mode(s)

Example:
!tvr 0 0 0 0 (disable tvr on all 4 axes)
!tvr z 5 (enable tvr mode 5 for Z axis)
?tvr z (read tvr mode of Z axis)
?tvr (read tvr mode of all axes)

Example for TVR via AUX I/O standalone operation:
!tvrjoyf 1.0
!tvr z 5
!tvrjoy z

# 17.24. brake (Axis Brake Function)

Syntax: !brake or ?brake
Parameter: x, y, z, a or none
0,1...8 or -255...0

Description: Function for electrically released brakes, intended to hold axes if their motor is turned off due to switched off axes, amplifiers, undervoltage or PSE. Individual, combined or shared IO outputs can be selected for each axis.

Each axis can be applied to an output by integer values 1~8. Negative values can be used to apply several output pins or combine/share pins - even with other axes. They represent a bit mask of 8 bit (0x00~0xFF) as integer values 0 to -255.

| **I/O:** | **[OUT7]** | **[OUT6]** | **[OUT5]** | **[OUT4]** | **[OUT3]** | **[OUT2]** | **[OUT1]** | **[OUT0]** |
|---|---|---|---|---|---|---|---|---|
| **PIN:** | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| **BIT:** | -128 | -64 | -32 | -16 | -8 | -4 | -2 | -1 |

```
  0 = brake function disabled
  1 = apply brake to 1st IO pin (OUT0)     PIN specified
  2 = apply brake to 2nd IO pin (OUT1)     PIN specified
  3,4,5,6,7 ...
  8 = apply brake to 8th IO pin (OUT7)     PIN specified

 -1 = apply brake to 1st IO pin (OUT0)     BIT specified
 -2 = apply brake to 2nd IO pin (OUT1)     BIT specified
      etc.  ...
-17 = apply brake to 1st and 5th pin (OUT0 + OUT4)    BITs
```

Behavior: Motor amplifier is on : Output = high (to release brake)
Motor amplifier is off: Output = low (0V)

The brake function does not recognize **current reduction** or a motor current set to 0 Ampere. (Only TANGO PCI-E/DT-E with Firmware 1.70 and greater recognizes current reductions < 30%)

As output "low" is the safe brake state, when sharing outputs with several axes the output state zero is dominant.
If the TANGO provides both IO1 and Multi-IO extensions, the Multi-IO is used for the brake functionality.

Remarks: **Ony available with TANGO PCI-E/DT-E controllers in conjunction with an IO1 or Multi-IO extension or with TANGO 3 mini.**

The assigned pins cannot be accessed by IO write instructions !**digout**, !**edigout**. But reading the digital output state with ?**digout**, ?**edigout** does return the state of the brake output.

TANGO 3 mini: TANGO 3 mini provides one brake output (OUT0). So axes that affect the brake can be enabled or disabled by 1s and 0s only.

Response: Integer value(s), 0 or -255 to 8

Examples:

```
!brake z 1           => Enable brake for Z axis on (OUT0), also for TANGO 3 mini
!brake 1 3 8 0       => Enable brakes for XYZ axes on different pins, disable A
!brake 4             => Enable brake for X axis on 4th pin (OUT3)
!brake -17 -18 -20   => Enable brake for XYZ on pins 123, create XYZ common pin 5
?brake               => Read brake setting for all axes (e.g. returns 0 0 0)
?brake z             => Read brake setting for Z axis only (e.g. returns 0)
```

# 17.25. brakepos (Move to Initial Motor Pole Position)

Syntax: !brakepos or brakepos
Parameter: x, y, z or a
1, -1 or none

Remarks: **Only available with TANGO PCI-E/DT-E controllers and firmware 1.70 or greater.**

Description: Drives the motor to the nearest motor pole, which also is the initial position after a power-on or reset of the TANGO.

If brakepos is executed before power down or before activating the motor brake, it avoids a "jump" of the motor at power up. This jump can be within ±2 motor steps, depending on where the axis was positioned before.

While this jump usually is not an issue, it can cause a problem on Z-axes with heavy load: When the **brake** is released, this jump, under certain conditions, can cause the motor to stall and the axis then runs down until its mechanical limit.

So for heavy loaded Z-axes with attached motor **brake**, the brakepos instruction can be used to prevent the axis from running down at power-up (when the **brake** is released).

The brakepos instruction can only be executed for individual axes, so the axis specifier **x,y,z or a is required.**

There also is an **optional parameter** 1, -1 or none, which can be used to specify the travel direction in which brakepos is executed:

**[none]** = positions the motor to the nearest pole positive or negative rotation **

**1** = positions the motor to the next pole in positive direction **

**-1** = positions the motor to the next pole in negative direction **

** The parameter can be used to ensure the axis is traveling forward (or backward) only, to avoid possible collisions.

If the axis is standing within a limit switch, the direction is set to "out of the switch" automatically, independent oft the direction parameter.

The normal axis **velocity** and **acceleration** is used.
For a typical motor with 200 steps, the travelled distance is less than 4/200 = 0.02 revolutions or 7.2 degrees.

Response: none (but brakepos blocks all following instructions until the move is completed, usually within milliseconds)

Examples:

```
brakepos z          => Travel to the nearest motor pole in Z

brakepos z 1        => Travel forward to the next motor pole in Z...
?err                => and wait for executipon by using the ?err reply

brakepos z -1       => Travel backward to the next motor pole in Z...
!pa0                => then turn off the amplifiers without waiting, as brakepos
                       blocks the !pa 0 instruction until it has completed.
```

# 17.26. drop (Liquid Dispenser – Generate Drops)

Syntax: !drop or ?drop
Parameter: 0, 1, ... 6000

Description: Used with the Märzhäuser Liquid Dispenser.
Generates drops or reads back the amount of generated drops.

The instruction supports two dispenser types:

**1) For upright microscopes**
Drops are generated and counted.

**2) For inverted microscopes**
Liquid is dispensed for the specified amount of seconds or 1/10 seconds (depends on dispenser setup). Time is counted.

**!drop 0** resets the counter to zero
**!drop *N*** generates *N* drops (or *N* seconds), N=1...6000
**?drop 0** reads amount of drops still to be generated by the recent !drop instruction, this countdown can be used to identify the drop instruction has finished (=0). Here it's not required to reset the counter.
**?drop** reads amount of drops/time since counter was resetted

Remarks: **Only available with TANGO PCI-E, TANGO DT-E and TANGO 3 mini.**
Might interfere with trigger and snapshot functionality.

TANGO 3 mini: The drop counter is connected to the AUX I/O SnapShot input.
In case of TANGO 3 mini, the snapshot pin assigned by **adiginfunc** is used.

Response: Amount of counted drops or time, depending on the device.
The drop counter counts to a maximum of 65535 then rolls over.

Example:

| | |
|---|---|
| !drop 10 | generate 10 drops, or dispense liquid for 10 seconds, (depends on hardware) |
| ?drop 0 | => 7 (still 7 drops or seconds to generate, not finished yet) |
| ?drop 0 | => 0 (all drops have been generated, ready) |
| !drop 0 | reset the drop counter for ?drop |
| ?drop | read the drop counter (counting since it has been resetted) |

# 17.27. pump (Liquid Dispenser – Manually Add Air Pressure)

Syntax: !pump or ?pump
Parameter: 0, 1

Description: Used with the Märzhäuser Liquid Dispenser.
Manually overwrites the air pressure pump.
Can be used to ensure sufficient pressure before dispensing liquids in inverted applications (time interval mode). The dispenser switches the pump on and off automatically, but in case of the time interval dispenser it might be safer to ensure sufficient pressure before dispensing by this instruction.
For generating drops it might not be required to ensure pressure because they are counted. It then just may take longer.

1 = Air pressure pump on
0 = Air pressure pump off

It is ensured by design that the maximum pressure won't be exceeded.

Remarks: **Only available with TANGO PCI-E, TANGO DT-E and TANGO 3 mini.**
Might interfere with trigger and snapshot functionality.

Response: 0 (pump is off), 1 (pump is on)

Example:
!pump 1 switch pump on
!pump 0 switch pump off

?pump => 0 (pump is off)

## 17.28. vbus (TANGO 3 mini – AUX mini +24V On/Off)

Syntax: !vbus or ?vbus
Parameter: 0, 1

Description: Instruction for TANGO 3 mini only.
Switches the +24V pin of the AUX mini connector on or off.

1 = +24V on
0 = +24V off

Remarks: **Only available with TANGO 3 mini.**
After power up or reset, the +24V is not provided on the AUX mini connector. It must be switched on by the vbus instruction or configured to always on by **'configvbus'**.

Response: 0 (+24V is off), 1 (+24V is on)

Example:
!vbus 1 switch +24V on
!vbus 0 switch +24V off

?vbus => 0 (+24V is off)

## 17.29. configvbus (TANGO 3 mini – AUX mini +24V behavior)

Syntax: !configvbus or ?configvbus
Parameter: 0, 1

Description: Instruction for TANGO 3 mini only.
Sets the behavior of the AUX mini +24V pin after power up or reset.

1 = +24V on after power up
0 = +24V off after power up (default)

Remarks: **Only available with TANGO 3 mini.**
The +24V pin on the AUX mini connector might not powered by default. To change this behavior, configvbus can be used.
The +24V can also be temporarily switched on and off during operation by the **'vbus'** instruction.

Response: 0 (+24V is off after power up), 1 (+24V is on after power up)

Example:
!configvbus 1 +24V on after power up (and +24V is immediately switched on)
!configvbus 0 +24V off after power up (+24V is not immediately switched off)

?configvbus => 0 (+24V is configured to off)

# 18. Encoder Instructions

The encoder interface supports incremental 1Vpp, 5Vpp MR and RS422-TTL encoders. The encoder type can be selected by the **enctype** instruction. Most TANGO encoder interfaces support reference marks (except TANGO mini 2-axis).

(Please also refer to the encoder interface description of the TANGO controller for further information: TANGO mini 2-axis and TANGO integrale have limitations in travel velocity when using 1Vpp or RS422 TTL encoder signals. For RS422 TTL, those even require a hardware change. Single ended TTL encoders always require additional circuitry.)

To enable encoder functionality, the encoder mask **encmask** must be set for the corresponding axes. If encmask is set, the encoders are activated after calibration **cal** or at power-up, depending on the selected **calmode**.
This also enables the selected Closed Loop mode (set by **ctr**).

**calmode** also offers mode 3, which only reads out measuring systems.

If the encoders are activated can be checked by reading **enc**.
Manually setting the encoders **enc** state to 1 is not recommended, as it might cause unpredictable behavior in closed loop mode. Also, in case of analog MR encoders the signal correction will not be applied, which leads to positioning errors.

Reference marks can be activated by **encref**, the search velocity sets **encrefvel**.

Encoders that provide an active low error signal can be supported by **encnas**.

## 18.1. encmask (Encoder Mask)

Syntax: !encmask or ?encmask
Parameter: x, y, z, a or none
0 or 1

Description: Reads or sets the encoder globally enable mask, which is required to activate the encoders (to turn **enc**-->1).

The encoders then will be detected and activated after

A) a successful calibration instruction '**cal**'
or
B) after power up, when **calmode** 1 or 2 is selected

0 = clear enable mask (encoder will be ignored, not activated)
1 = set enable mask (TANGO will try to activate the encoder)

Response: Encoder enable mask as 0s and 1s

Example:
!encmask 1 1 0 Globally enable encoders for X, Y and disable Z-axis
!encmask z 0 Globally disable encoder for Z-axis
?encmask Read encoder mask state of all axes (e.g. 1 1 0)

## 18.2. enc (Encoder Active)

Syntax: ?enc (or !enc)
Parameter: x, y, z, a or none
0 or 1

Description: Query if the encoders are active (successfully activated by a **cal** instruction or at power up in **calmode** 2, 1 or 4).
**enc** is activated by the TANGO through **cal** or the calmodes.
It is not recommended to manually activate the encoders by sending a "!enc 1" instruction, because the counting direction might be wrong and because some encoders (as MR 5Vpp) require a dedicated calibration procedure or signal check.
For error free Closed Loop behavior and best measuring accuracy, encoders must be activated by the TANGO controller.
This depends on **calmode**, **cal** and **encmask**. Please refer to the above-mentioned instructions and to the remarks below.

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

Response: Encoder active state

Example:

| | |
|---|---|
| ?enc | Read encoder active state of all axes (e.g. 1 1 0 for 3 axes) |
| ?enc y | Read encoder active state of Y-axis |
| !enc z 0 | Disable encoder of Z-axis |
| !enc 1 1 0 | (Manually activate encoders of X, Y and disable Z-axis) ** |
| !enc x 1 | (Manually activate the X-axis encoder) ** |

Remarks: ** Manual activation of the encoders (by !enc 1) is not recommended. In general, this is not recommended if the axis runs in closed loop. In case of MR encoders a special calibration procedure has to be performed, which is only available by !cal or instant closed loop (**calmode** 2 or 1).
An exception can be if the axis is only used for measuring purposes and a TTL or 1Vpp encoder is attached (no MR).

If the application requires to disable and enable the encoders during operation (e.g. !enc 0 0 … !enc 1 1), it is possible to check if the encoder once was successfully activated by cal or instant closed loop - even if it is now set to zero: ?enc 1 / ?enc x 1 will return a 1 if the encoders once were activated by cal or instant closed loop and no error occured. This option is available since firmware 1.71.

Examples:

```
[power on or reset]
?enc   => 0 0     (the encoders are off, not activated)
?enc 1 => 0 0     (encoders never were successfully activated)

[power on or reset]
!cal x => A@--.   (here: the X-encoder gets activated by cal)
?enc   => 1 0     (the X-encoder is on)
?enc 1 => 1 0     (the encoder has been activated (by cal))
!enc 0 0          (the application forces the encoders off)
?enc   => 0 0     (the encoders are off)
?enc 1 => 1 0     (the X-encoder once was activated (by cal))
!enc x 1          (it is okay to manually switch it on again)
?enc   => 1 0     (the X-encoder is on again)
```

## 18.3. encperiod (Encoder Signal Period)

```
Syntax:           !encperiod or ?encperiod
Parameter:        x, y, z, a or none
                  0.000002 to 4.0 [mm]

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

                  Optional read-resolution: As an option to read the parameter
                  with higher precision, the number of required decimal places
                  can be specified with the query "?encperiod [0…16 decimal
                  places]". If no precision is defined, the default resolution
                  is 4 decimal places.

Response:         Encoder signal period(s)

Example:
!encperiod 0.5 0.5 0.001      Set encoder period for X and Y to 500µm, Z to 1µm
!encperiod z 0.02             Set encoder period of Z-axis to 20µm
!encperiod 0.00001960784      Set encoder period of X-axis
?encperiod                    Read encoder period of all axes
?encperiod z                  Read encoder period of Z-axis
?encperiod 12                 Read period of all axes with 12 fractional digits
?encperiod z 9                Read period of Z-axis with 9 fractional digits
```

## 18.4. encdir (Encoder Counting Direction)

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

Remarks:          Setting the encoder direction is not required and should
                  never be changed by this instruction, as the TANGO identifies
                  the correct counting direction itself.
                  The only exception might be if the connected encoder is used
                  as a truly independend measuring system, and never by the
                  TANGO for closed loop operation.

Description:      Set or read the encoder counting direction.
                  Do not set this parameter when the TANGO is in closed loop!
                  The encoder direction is set by the TANGO automatically (e.g.
                  after calibration cal or instant closed loop during power-on).

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

Response:         Encoder counting direction

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

a

## 18.5. encvel (Encoder Auto-Ajust Velocity)

```
Syntax:           !encvel or ?encvel
Parameter:        x, y, z, a or none
                  0.01 ... 20.0 [mm/s]

Description:      The velocity for encoder auto-calibration can be set or read
                  by this instruction. It is recommended to keep the default
                  setting. The unit is always [mm/s].

Response:         Velocity used for Encoder detection and calibration in [mm/s]

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

# 18.6. enctype (Encoder Type Configuration)

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

Remarks:          Newer versions of the TANGO Controller, running Firmware 1.60
                  or higher, provide a Universal Encoder Interface.
                  This new interface can be configured by software to support
                  5Vpp MR, 1Vpp or digital RS422 incremental encoders.
                  In order to provide the new features, the encttl instruction
                  was replaced by enctype (encttl should not be used anymore).

Description:      The instruction reads or sets the encoder signal type.

                  0 = MR 5Vpp   analog sin/cos interpolation
                  1 = TTL RS422 A/B digital incremental signal
                  2 = 1Vpp      analog sin/cos interpolation

                  The read instruction provides two options:
                  By using an additional parameter "1" with the read
                  instruction, the effectively by hardware applied encoder
                  type is returned. Without the parameter the instruction
                  returns the selected encoder type.

Remarks:          If digital encoders (A/B-TTL, RS422) are used and the
                  interface by mistake is programmed to an analog signal
                  mode, this can cause a sporadic malfunction (encoders
                  become deactivated) due to analog signal monitoring.

Response:        -1 = not available, invalid configuration
                  0 = MR 5Vpp   analog sin/cos interpolation
                  1 = TTL RS422 A/B digital incremental signal
                  2 = 1Vpp      analog sin/cos interpolation

Example:
!enctype 1 0 2    Set X encoder to A/B-TTL, Y to MR and Z to 1Vpp
!enctype 1 1      Set X and Y encoder to A/B-TTL
?enctype          Read the demanded encoder type of all axes
?enctype x        Read the demanded encoder type of X axis
?enctype 1        Read the in fact applied encoder type of all axes
?enctype y 1      Read the in fact applied encoder type of Y axis
?enctype a        => 0
?enctype a 1      => -1     (A axis encoder not available)
?enctype          => 0 0 2  (5Vpp for X and Y, 1Vpp for Z)
?enctype 1        => 1 1 1  (the applied type is TTL, either because set
                             or because interpolation was not purchased)
```

## 18.7. encttl (Encoder Configured for TTL Signal)

Syntax: !encttl or ?encttl
Parameter: x, y, z, a or none
0 or 1

Remarks: In newer versions of the TANGO Controller - with Universal Encoder Interface and Firmware 1.60 or higher - this instruction is replaced by **'enctype'** and therefore encttl should no longer be used, except for compatibility.

Description: This instruction reads or sets the type of encoder signal. If digital encoders (A/B-TTL, RS422) are used with an analog encoder interface (configured for 1Vpp or 5Vpp MR), the corresponding encoder has to be set to TTL mode. Else the TTL signal will be found as invalid (due to signal level) and not be used or deactivated during opration (sporadic malfunction).

0 = Analog sin/cos encoder (1Vpp or MR is defined by hardware)
1 = Digital quadrature A/B encoder (e.g. RS422)

Response: Currently selected encoder signal type(s)

Example:

| | |
|---|---|
| !encttl 0 0 1 | Set X and Y axis encoders to analog, Z to digital A/B-TTL |
| !encttl z 1 | Set Z encoder type to digital |
| ?encttl | Read encoder signal type of all axes |
| ?encttl x | Read encoder signal type of X-axis |

## 18.8. encref (Use Encoder Reference Signal)

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

Description: Enable or disable the use of encoder reference marks. If enabled, the **'cal'** instruction will - after reaching the lower limit switch - travel to the reference mark and set the axis position to zero.

In case of MR encoders, there is an option to store the sin/cos signal constellation outside the limit switch (done by factory through 'callrn') which greatly improves accuracy and repeatability of the origin without having a reference mark. Therefore, encref mode 2 was introduced.

0 = Encoder reference signal not used
1 = Encoder reference signal used for calibration
2 = MR signal constellation used as reference (set by callrn)

Remarks: The velocity towards the reference mark is set by **encrefvel**.

Response: 0, 1 or 2

Example:

| | |
|---|---|
| !encref 1 1 0 | Use encoder reference signal as origin for X and Y-axis |
| !encref y 1 | Use encoder reference signal as origin for Y-axis |
| ?encref | Read Encoder reference signal usage of all axes |
| ?encref z | Read Encoder reference signal usage of Z-axis (e.g. 1 1 0) |

## 18.9. encnas (Use Encoder NAS Error Signal)

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

Description:      Before enabling this functionality, please make sure that
                  the connected encoder provides a NAS error signal.
                  If enabled, an encoder NAS error generates an internal
                  'encerr' error state. The NAS input is active low.

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

Remarks:          The NAS signal state can be read by 'encnasstatus'.

Response:         Encoder NAS signal used / not used for error detection

Example:
!encnas 1 1 0     Use encoder NAS signal for X and Y-axis, ignore for Z
!encnas x 1       Use encoder NAS signal for Y-axis
?encnas           Read encoder NAS signal use state of all axes
?encnas x         Read encoder NAS signal use state of X-axis
```

## 18.10. encrefstatus (Encoder REF Signal State)

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

Description:      Returns the REF signal input state.

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

Response:         Encoder reference signal state

Example:
encrefstatus      Read REF signal state of all axes
encrefstatus x    Read REF signal state of X-axis only
```

## 18.11. encrefstatusl (Latched Encoder REF Signal State)

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

Description:      Returns the latched REF signal input state.
                  If the REF signal was active since last reading of
                  encrefstatusl, a 1 is returned. The corresponding
                  latch state(s) are cleared after reading.

                  0 = REF signal is and was inactive since last read
                  1 = REF signal is/was active (encoder is or was on
                                                a reference mark)

Response:         Latched encoder reference signal state

Example:
encrefstatusl     Read+clear latched REF signal state of all axes
encrefstatusl x   Read+clear latched REF signal state of X-axis only
```

## 18.12. encnasstatus (Encoder NAS Error Signal State)

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

Description:      Returns the NAS error signal input state. (This signal is
                  usually ignored, but can be enabled by encnas as error source)

                  0 = NAS signal is inactive (High=the encoder reports no error)
                  1 = NAS signal is active   (Low =the encoder reports an error)

Response:         Encoder NAS error signal state (=inverted NAS input pin level)

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

## 18.13. encerr (Encoder Error State)

```
Syntax:           !encerr or ?encerr
Parameter:        x, y, z, a or none
                  0

Description:      This instruction reads or resets the encoder error state.
                  On error, e.g. a low encamp signal amplitude or active
                  NAS error signal from the encoder 'encnas'+'encnasstatus',
                  the encoder signal is invalid and the closed loop for the
                  corresponding axis is switched off.

                  0 = No error, normal function
                  e = Encoder error

Response:         Encoder error state, 0 or e

Example:
!encerr 0         Reset encoder error
?encerr           Read encoder error states of all axes, e.g. "0 0 e" for 3 axes
?encerr x         Read encoder error state  of X-axis only
```

## 18.14. encamp (Encoder Signal Amplitude)

```
Syntax:           ?encamp or encamp
Parameter:        x, y, z, a or none
                  Optional parameter 1

Description:      Read the encoder signal amplitude.
                  100 (percent) represents the maximum undistorted
                  signal amplitude.

Remarks:          In case of single ended TTL encoders the amplitude
                  might be returned as 0.

Response:         Encoder signal amplitude in percent as integer

Example:
?encamp           Read all encoder signal amplitudes (returns e.g. 57 74 0)
?encamp x         Read X encoder signal amplitude
?encamp 1         Read all amplitudes with 1 fractional digit (57.3 73.8 0.5)
?encamp x 1       Read X encoder signal amplitude with 1 fractional digit (57.3)
```

# 18.15. encpos (Encoder Position)

Syntax: !encpos or ?encpos
Parameter: x, y, z, a or none
0 or 1

Description: Set or read the position source for the **?pos** instruction.
Only affects the readout position values of pos and snsa.
If encpos is set to 1 and the encoder **'enc'** is activated,
**pos** returns the encoder position, else the motor position.

Remarks: For compatibility, sending a single 0 or 1 without
specifying an axis applies the setting to all axes.

**enc** is activated by the TANGO through 'cal' or the calmodes,
not by the user.

The setting of encpos is volatile, but from Firmware 1.72,
a power-on preset setting can be stored by **'configencpos'**.

Response: Position source
0 = pos instruction returns motor position (default)
1 = pos instruction returns encoder position (if enc. active)

Example:

| | |
|---|---|
| !encpos 1 | a 'pos' instruction will return the encoder position for all axes (if the axes encoders are active) |
| !encpos 0 0 1 | encoder position is enabled for Z and disabled for X and Y |
| !encpos x 1 | 'pos' will return the encoder position for the X-axis |
| ?encpos | Use of ?encpos is not recommended. Just for compatibility, this instruction reads the "ored" position source of all axes (it returns just one 0 or 1, it returns a 1 if at least one axis has encpos enabled) |
| ?encpos x | Read position source of the X-axis |
| !encpos 0 1 0 | → ?encpos -1 => 0 1 0<br>→ ?encpos => 1<br>→ ?encpos z => 0 |
| !encpos 1 | → ?encpos -1 => 1 1 1 |

Sequence example of a 3 axis TANGO:

| | |
|---|---|
| ?calmode | => 0 0 0 |
| !encpos 1 1 0 | (pos should return the encoder position in X and Y) |
| ?enc | => 0 0 0 |
| ?pos | => [motor pos] [motor pos] [motor pos] |
| **!cal x** | => @@@-. |
| ?enc | => **1** 0 0 |
| ?pos | => [**encoder pos**] [motor pos] [motor pos] |
| **!cal y** | => @@@-. |
| ?enc | => 1 **1** 0 |
| ?pos | => [encoder pos] [**encoder pos**] [motor pos] |

# 18.16. configencpos (Configure Encoder Position Preset)

Syntax: !configencpos or ?configencpos
Parameter: x, y, z, a or none
0 or 1

Description: Set or read the predefined power-up setting for **encpos**.
The TANGO will use it as preset value for **encpos** after power-up or reset.

Remarks: As the **encpos** setting is volatile and commonly used, e.g. by SwitchBoard, it should not be storable.
In cases where encpos must be activated at power-up, e.g. standalone applications without a PC, configencpos can be used.

Setting "!configencpos" also sets the current encpos.

Response: Position source
0 = pos instruction returns motor position (default)
1 = pos instruction returns encoder position (if enc. active)

Example:

```
!configencpos 0 0 1     Set power-up preset for encpos to X,Y=motor, Z=encoder

!configencpos 1         Set power-up preset for encpos to X=encoder

!configencpos z 0       Set power-up preset for encpos to Z=motor

?encpos                 Read the encpos preset values of all axes

?encpos y               Read the encpos preset values of the y axis


Sequence example of a 3 axis TANGO:

?encpos -1              => 0 0 0    after power-on, the encpos is 0
!configencpos 0 0 1                 configuring the !configencpos...
?configencpos           => 0 0 1
?encpos -1              => 0 0 1    ...also changes the encpos...
!save                               ...and if saved...
!reset
?encpos -1              => 0 0 1    ...works as a preset for encpos.
```

## 18.17. encsync (Analog Encoder Synchronization Status)

```
Syntax:           ?encsync or encsync
Parameter:        x, y, z, a or none
                  -1 or none

Description:      Returns the synchronization state of the encoder signal and
                  the digital hardware counter.
                  Called without parameter, it returns if the encoder(s) are
                  synchronized. When called with "-1", the quadrants of the
                  analog and digital signal paths are shown and the applied
                  correction (deviation) of the digital quadrant.
                  The deviation should never exceed ±1. This instruction is
                  available from TANGO PCI-E/DT-E firmware 1.71 and above.

Response:         none: Encoder synchronized = 1, not synchronized = 0
                  -1  : encoder signal analog, digital quadrants and deviation.
                        Quadrants are 0,1,2,3, the deviation is 0 or +-1.
                  Please refer to the examples below.

Example:
encsync x         ==> 1      (1 = X encoder synchronized, 0 = not synchronized)
encsync           ==> 1 1 0  (3 axis TANGO, X and Y are synchronized, Z not)
encsync x -1      ==> 2 3 -1 (X encoder an.quad=2, dig.quad=3,quad.comp.d->a=-1)
encsync -1        ==> 2 3 -1  2 2 0  0 0 0  (response from a 3 axis TANGO X,Y,Z)
```

## 18.18. hwcount (Hardware Counter)

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

Description:      Returns the positions of the independent quadrature encoder
                  counter. It counts the signal edges without further signal
                  interpolation, meaning one signal period corresponds to a
                  counter increment of 4, half a period to 2 etc.
Remarks:          Refer to 'clearhwcount' for setting the counter(s) to zero.

Response:         Encoder hardware position-counter

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

## 18.19. clearhwcount (Clear Hardware Counter)

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

Description:      Set the encoder quadrature hardware-counter positions to zero.
Remarks:          Only affects the position returned by ?hwcount only.

Response:         none.

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

# 19. MR Encoder Instructions

## 19.1. mra (MR Amplitude Correction Factor)

```
Syntax:           !mra or ?mra
Parameter:        x, y, z, a or none
                  0.8 to 1.2

Description:      This instruction 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' instruction.

Response:         Currently used correction factor(s)

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

## 19.2. mro (MR Offset Correction Value)

```
Syntax:           !mro or ?mro
Parameter:        x, y, z, a or none
                  -2048 to +2048

Description:      This instruction 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' instruction.

Response:         Currently used correction values

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

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

```
Syntax:           !mrp or ?mrp
Parameter:        x, y, z, a or none
                  -2048 to +2048

Description:      This instruction 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.

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

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

## 19.4. mrt (MR Signal Level)

```
Syntax:           ?mrt
Parameter:        x, y, z, a or none
                  1 to 32767 and -1 to -32767

Description:      This instruction reads the corrected sine and cosine A/D
                  converter results of the analog encoder interface as signed 16
                  bit integer.

                  In case of MR encoders, specifying a negative number returns
                  the corrected analog value (offset, amplitude).

                  The number of data samples (lines) to read should be
                  specified, e.g. '?mrt 1' for returning one sample.
                  If there is no number specified, the instruction returns 10
                  sampling results per default.

Response:         [sine] [cosine] results as signed 16 bit values
                  or [x_s] [x_c] [y_s] [y_c] [z_s] [z_c] for all
                  Each data line is terminated by a [CR].

Example:
?mrt              Returns 10  lines with all axes (up to 6 values per line)
?mrt 1            Returns one line  with all axes (up to 6 values)

?mrt x            Returns 10   lines with [x_sin] [x_cos] signal digits
?mrt x 1          Returns one  line  with [x_sin] [x_cos] signal digits
?mrt y 2          Returns two  lines with [y_sin] [y_cos] signal digits
?mrt y 1000       Returns 1000 lines with [y_sin] [y_cos] signal digits

?mrt -1           Returns one line , all axes with MR correction applied
?mrt x -10        Returns 10  lines, X axis   with MR correction applied
```

# 20. Closed Loop Instructions

The closed loop control pulls the axis towards the measuring system position, compensating the inaccuracies of the drive.

The closed loop mode is set by the **ctr** instruction. It also requires setting **encmask** for the individual axes (encmask requests enabling of the encoders, which is a precondition for enabling closed loop).
Closed loop is finally activated by either executing a calibration (**cal**) or after power-up by selecting the power-up modes (**calmode** 2, 1 or 4).

The **ctrstatus** instructions may be used to check if the closed loop is activated.

Remarks:

Activating closed loop fails if the **pitch**, **gear** or **encperiod** settings are incorrect. The error tolerance of these parameters is about a factor of 2.

The closed loop target window (**twi**, in combination with **ctrd**, **ctrt**) is the condition to identify if the axis has reached its target position.
In the default closed loop mode (**ctr** = 2) the axis will (continue to) travel precisely to the target position, even if the target window is already reached.

When the optional motor current **reduction** is set below 0.3 (30%), closed loop will be disabled during reduction (axis has stopped and **curdelay** has expired).

The closed loop behavior can be set to different behaviors for reliability or safety, when exceeding a specified deviation. The instructions **ctrsm** and **ctrs** may be used.

# 20.1. Setting Up the Closed Loop

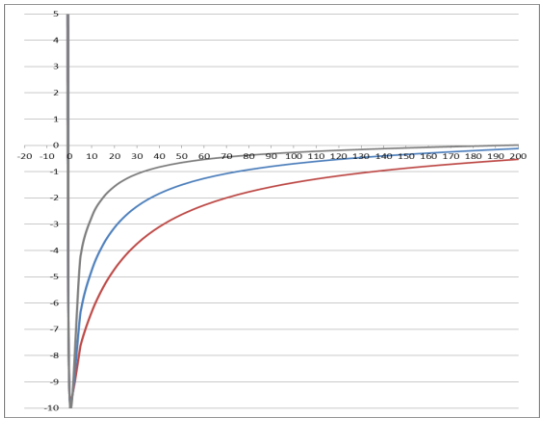
The closed loop circuit provides several instructions to adjust, optimize and customize its behavior:

- **ctr** - the closed loop mode
- **ctrff** - the closed loop amplification multipliers
- **twi** - the "position reached" deviation criteria
- **ctrd** - the "position reached" time criteria
- **ctrt** - the maximum waiting time for the criteria (timeout)
- **ctrsm** - the behavior at greater deviation
- **ctrs** - the definition of greater deviation

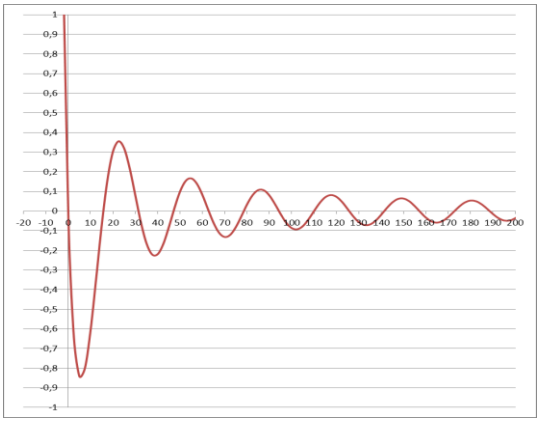
**Positioning with Closed Loop - twi and ctrd**

In closed loop mode the position reached reply is delayed until the specified criteria are fulfilled. The criteria consist of a deviation limit and a time, during which the deviation limit must be kept.
The **twi** and **ctrd** instructions define a window with the height of ±twi and the width of ctrd. If the deviation exceeds ±twi, the delay time begins again. So the (±twi*ctrd) window travels along, until the criteria are fulfilled or until the timeout (**ctrt**) is reached. In such case the position reached reply will be sent even without fulfilling the criteria.

The window definition is required, as position deviation of the axis isn't just constantly decreasing, there is also oscillation of the axis position:



***P1* Deviation at the end of a move compensated by the closed loop**



***P2* Oscillation at the end of a move (sinusoidal decay)**

So without defining a ctrd delay time criterion, the position reached reply would be sent as soon as the deviation once went below the twi value. But as *P2* shows, this might be just temporary and the deviation will build up again (oscillation). To be safe, ctrd time must be at least the oscillation period, which makes sure both, minima and maxima of the deviation are checked within the ciriteria window.

Example: twi is ±0.2µm and ctrd is 30ms. In *P2*, the twi limit is exceeded at 1ms and remains exceeded until about 14ms. During this time, the ctrd time countdown of 30ms is constantly restarted. At 18ms the twi limit is exceeded once again until about 29ms, during this time the ctrd time is restarted again. After 29ms, the deviation remains within ±twi. So ctrd keeps counting down its 30ms and replies the position reached event 29+30 = 59ms after the original move has completed.

**Closed Loop Setup**

The closed loop factor **ctrff** can be used in order to reach the **twi** and **ctrd** criteria more quickly.

In general, its default values of 2 and 2 provide a good base to start from. Ctrff has two parameters per axis. The first one is the factor applied when the axis is traveling, the second is applied when the axis stopped traveling and is idle. Picture *P1* shows how increasing the second factor influences compensation of position error at the end of a move. Greater values cause the axis to compensate faster, but from a certain point might begin to be unstable.

**Closed Loop behavior**

**Ctr** sets the general behavior of the closed loop, which might be off, always on or on until position is reached.

In addition, a behavior can be set when the position deviation exceeds a certain limit. Please refer to the **ctrsm** and **ctrs** instructions.

**Examples**

***1: enable closed loop for X and Y axes only***

```
!ctr 2 2 0
!encmask 1 1 0
!cal
```

***2: enable closed loop individually for Z axis***

```
!ctr z 2
!encmask z 1
!cal z
```

***3: enable closed loop for X and Y from power-on***

```
!ctr 2 2
!encmask 1 1
!calmode 2 2
save
(then cycle power or send reset instruction)
```

## 20.2. ctr (Control Enable)

Syntax: !ctr or ?ctr
Parameter: x, y, z, a or none
0,1,2,3,4

Description: Sets, reads or changes the closed loop mode.

0 = Closed Loop OFF
1 = Closed Loop inactive when position is reached
2 = Closed Loop always active (default, recommended)
3 = (not supported, behaves like mode 1)
4 = (not supported, behaves like mode 2)

Closed loop mode is activated by either executing **cal** or after a power up or reset (refer to **calmode**).

If encoders were activated at power on (**encmask** = 1), closed loop can be switched on (0->1, 0->2) afterwards. Closed loop mode can also be changed during operation.

Preconditions for successfully entering closed loop are having **ctr** and **encmask** set.

Pros and Cons: Mode 1: (+) Axis is stopped after reaching the target window
(-) Position is scattered within ±**twi** range
(-) Position deviation may occur due to external influence (drive concept, gravity, etc.)
(-) Is only active when moving
(-) Can cause a position jump at the beginning of a move, if a deviation exists (see influences above)

Mode 2: (+) Always stays closest possible to target position
(+) Compensates external influences (required with several dirve concepts or with Z axes)
(-) Might still travel after position is reached (after the "@@@" reply of the target window) as it always travels towards zero deviation
(-) Might not absolutely stand still after reaching a position. Depending on drive concept, slip stick effects can cause the axis to slightly bounce between positions within e.g. ±50 nanometers. similar might happen with TTL encoders of coarse resolution. Then mode 1 might be preferred.

Remarks: Using closed loop mode 2 is recommended for most applications.

Mode 1 is recommended only if the application does not stand still sufficiently in the end position (e.g. long exposures). In this case, the HDI - especially an ERGODRIVE - should be disabled, too (by e.g.!**joydir** 0 0 0 0 or !**joy** 0 instruction).

Response: Closed loop mode(s)

Examples:

| | |
|---|---|
| !ctr 0 0 0 0 | Closed loop off for all axes (here: 4 axes) |
| !ctr 2 2 | Closed loop for X- and Y-axis permanently on |
| !ctr z 1 | Closed loop for Z-axis switches off after position reached |
| ?ctr | Read closed loop states of all axes |
| ?ctr x | Read closed loop state of X axis |

## 20.3. ctrf (Control Factor)

```
Syntax:           !ctrf or ?ctrf
Parameter:        x, y, z, a or none
                  0.0 to 25.0

Description:      CTRF IS FOR COMPATIBILITY ONLY - PLEASE USE CTRFF.
                  This instruction reads or sets the closed loop factor.
                  Higher values result in more stiffness and faster settling.
                  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.

Remarks:          Even if setting the parameter supports floating point, the
                  return value is integer (for compatibility).
                  It is recommended to use ctrff instead of ctrf.

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             Read closed loop factors of all axes (as integer)
?ctrf y           Read closed loop factor of Y axis (as integer)
```

## 20.4. ctrff (Extended Control Factor)

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

Description:      This instruction reads or sets 2 closed loop factors per axis.
                  Higher values result in more stiffness and faster settling.
                  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 specified)

                  Parameter1: Is used while axis is traveling
                  Parameter2: Is used when axis is idle or while trying
                              to settle within the target window (twi)

                  Parameter 2 can 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) as fractional numbers

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 x 0.5 1    Set closed loop factors for X axis 0.5(moving) and 1(reached)
!ctrff x 0 0      Disable closed loop regulation in X, while loop still active
?ctrff            Read closed loop factors of all axes (2 parameters per axis)
?ctrff y          Read closed loop factors of Y axis only (2 parameters)
?ctrff            2.0 2.0 2.0 2.0 2.0 2.0 (response of a 3 axis TANGO)
?ctrff y          => 2.0 2.0
```

## 20.5. ctrd (Control Target Window Delay)

Syntax: !ctrd or ?ctrd
Parameter: 0 to 1000 [ms]
optional axis x,y,z,a

Description: This instruction reads or sets the target window delay that is used as a position reached criteria in closed loop mode.
The position deviation at the end of a move must remain inside the target window (**twi**) for this amount of time, then the "position reached" state is set. If the target window is left before the delay time is over, the delay starts counting again. Please also refer to the **ctrt** timeout, which aborts the waiting for twi+ctrd after a certain amount of time.
Either one delay for all axes can be set or axes can be set individually.

Remarks: Setting the delay time to zero forces the axis to immediately reply without waiting for the axis to match the target window.

In all other cases, ctrd delay times must be set higher than the **ctrc** interval (>5ms).

While the default target delay of 100ms works with most drive concepts, it may be optimized for performance individually. In order to find the optimal setting, the sinusoidal decay of the axis must be measured. The ctrd delay time should be at least half the signal period of the mechanical oscillation.

Response: Closed loop control delay in milliseconds.

Examples:

| | |
|---|---|
| ~~!ctrd 50 50 50~~ | Not supported! |
| !ctrd 100 | Closed loop target window delay to 100 ms for ALL AXES |
| !ctrd x 100 | Closed loop target window delay to 100 ms for X axis |
| ?ctrd | Read closed loop target window delay (for backw.compatibility) |
| ?ctrd y | Read closed loop target window delay of Y axis |
| ?ctrd -1 | Read closed loop target window delay of all axes |

## 20.6. ctrt (Control Timeout)

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

Description: This instruction reads or sets the control timeout.
It specifies the maximum time the closed loop tries to reach the desired **target window**. If the ctrd+twi condition could not be fulfilled within this ctrt time, it will be aborted.
The ctrt timeout should be set to a value higher than **ctrd**, usually to the default of 1 second.
The unit is milliseconds. Only one parameter for all axes.

Remarks: Setting the timeout to zero forces all axes to immediately reply without waiting to match their target windows.

Response: Closed loop control timeout in milliseconds.

Examples:

| | |
|---|---|
| !ctrt 1000 | Closed loop tries to reach the target window for 1 second |
| ?ctrt | Read closed loop timeout |

## 20.7. twi (Target Window)

Syntax: !twi or ?twi
Parameter: x, y, z, a or none
±window size, unit depends on **dim**, range = 0.00001 to 1 mm

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 closed loop timeouts (higher ctrd, ctrt values required). The unit depends on **dim**.

Remarks: The target windows minimum size shouldn't be set smaller than the encoder resolution and noise. Please make sure the masuring system is able to deliver the required signal quality. For analog encoders the limit might be between 1/1000 to 1/5000 of the signal period, which in case of MR encoders about 0.5µm and for a 4µm optical scale 4nm.

Response: Closed loop target window. The unit depends on **dim**.

Examples:

| | |
|---|---|
| !twi 0.001 0.001 | Closed loop target window ±1µm (if dim=2) for X and Y-axis |
| !twi y 0.005 | Closed loop target window ±5µm (if dim=2) for Y-axis |
| ?twi | Read target window of all axes |
| ?twi z | Read target window of Z-axis only |

## 20.8. ctrc (Control Call)

Syntax: !ctrc or ?ctrc
Parameter: 1 to 100 [ms] **DO NOT CHANGE!**

Description: This instruction reads or sets the controller call interval. It specifies the time interval in which the closed loop circuit checks the position deviation.

The unit is milliseconds. There is only one parameter which applies to all axes. **THE DEFAULT FACTORY SETTING (3 or 5 ms) depends on the TANGO controller and SHOULD NOT BE CHANGED.** 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 | Read closed loop call interval |

## 20.9. ctrsm (Control behavior outside Lock-in Range)

Syntax: !ctrsm or ?ctrsm
Parameter: x, y, z or none

Description: Behavior of the closed loop circuit when outside the lock-in range (**ctrs**). When outside the ctrs lock-in range, which is regarded to be an error, the TANGO controller can treat this condition as follows:

0 = Continue as usual, motor might possibly stall (default)
1 = Limit the closed loop velocity (avoid stalling the motor)
2 = Disable closed loop until returning to lock-in range
3 = Disable closed loop permanently
4 = Axis is set to latched stop condition (read remarks)**
5 = Switch off all power stages (like !pa 0)

Remarks: ** **stoppol** is manipulated by this function in order to achieve a latched stop (stoppol value is or'ed by 4).
The stop condition must be released by sending **"!stop 0"**

ctrsm 1 assures to return from large deviations without stalling the motor. If outside the **ctrs** lock-in range, a slow return velocity is applied. In most cases it is the better, reliable alternate to the default ctrsm 0.

Ctrsm modes 3 to 5 may be used for safety.

Response: Selected Behavior of the axes (as integer value)

Examples:

| | |
|---|---|
| !ctrsm z 1 | Select slow mode in Z (to avoid stalling of the motor) |
| !ctrsm 5 5 5 | Select switch off mode for safety (e.g. collision detection) |
| ?ctrsm | Read all behaviors |
| ?ctrsm y | Read behavior of Y-axis only |

## 20.10. ctrs (Control Lock-in Range)

Syntax: !ctrs or ?ctrs
Parameter: x, y, z or none
0.001 [mm] to [**maxpos**]

Description: Lock-in range of the closed loop circuit.
When the closed loop position difference exceeds this limit, the behavior defined with **ctrsm** is applied to the axis/axes.
The unit depends on **dim**.

Response: Closed loop lock-in range.

Examples:

| | |
|---|---|
| !ctrs 0.5 0.5 0.2 | Set lock-in range of X=0.5mm, Y=0.5mm, Z=0.2mm (if dim=2 or 9) |
| !ctrs z 0.1 | Set lock-in range of Z=0.1mm (if dim= 2 or 9) |
| ?ctrs | Read lock-in range of all axes |
| ?ctrs z | Read lock-in range of Z-axis only |

# 20.11. ctrstatus (Control Status)

Syntax: ?ctrstatus or ctrstatus
Parameter: x, y, z, a or none
0, 1, 2, 3 or none

Description: Read the internal closed loop states of the specified or all axes. Options and responses are:

**A) Called without parameter:**
Returns the internally applied **ctr** state which is set when the closed loop gets enabled by the controller (after !cal or when in calmode=1 or 2).
0 = Closed loop permanently off (or not activated yet)
1 = Closed loop only active while axis is travling
2 = Closed loop always on (the default closed loop mode)
(3 Closed loop only active while axis is travling)
(4 Closed loop always on)

**B) Called with parameter "1":**
Check if the closed loop is currently active.
0 = Closed loop not active
(e.g. ctr=0, ctr=1, !cal running, encerr, limit swich)
1 = Closed loop active

**C) Called with parameter "2":**
Check if closed loop is in target window.
0 = Position outside target window
1 = Position in target window

**D) Called with parameter "3":**
Check if closed loop is in lock-in range.
0 = Position outside lock-in range
1 = Position in lock-in range

**E) Called with parameter "0": (All in one request)**
Returns the internally applied **ctr** state, like **A)** does and a second hex parameter representing all state bits of the calling parameter 1,2,3 like cases **B,C,D** above:
Bit 0 (0x1): Closed Loop Active
Bit 1 (0x2): Closed Loop in Target Window
Bit 2 (0x4): Closed Loop in Lock-In Range

Response: Closed loop state, 1 or 2 decimal numbers. See "Description".

Examples:

| | |
|---|---|
| ?ctrstatus | Returns the internally running ctr mode of all axes |
| ?ctrstatus y | Returns the internally running ctr mode of the Y-axis |
| ?ctrstatus 1 | Returns the Closed Loop active state of all axes, e.g. "1 1 0" |
| ?ctrstatus x 1 | Returns the Closed Loop active state of the X-axis, e.g. "1" |
| ?ctrstatus 2 | Returns if Closed Loop is in target window, e.g. "1 1 0" |
| ?ctrstatus z 2 | Returns if Closed Loop of the Z-axis is in target window |
| ?ctrstatus 3 | Returns if Closed Loop is in lock-in range, e.g. "1 1 0" |
| ?ctrstatus z 3 | Returns if Closed Loop of the Z-axis is in lock-in range |
| ctrstatus x 0 | ➔ 2 7 (ctr mode 2 is applied, is active/in window/in range) |
| ctrstatus 0 | ➔ 2 7 2 7 0 0 (response of 3 axes X X Y Y Z Z) |

# 20.12. ctrdiff (Control Position Difference)

Syntax: ?ctrdiff or ctrdiff
Parameter: x, y, z, a or none
None, 1, 2, 3 or 4

Description: This instruction returns the momentary measured closed loop position difference between the motor- and encoder position.

From TANGO Firmware 1.69 and above, ctrdiff can be used without a leading '?'. Newer firmware versions might have additional options. Please refer to the examples below.

From TANGO Firmware 1.72 and above, when called with an axis (x, y, z or a), ctrdiff returns at least 5 fractional digits (10nm resolution) and a second parameter which indicates if the motor is running (=1) or idle (=0) when called with none, 1, or 2 parameters.Refer to examples below.

The unit of the returned value depends on the **dim** settings. For higher resolutions the **resolution** value can be increased.

Remarks: Difference is only calculated when closed loop is activated. To measure position deviations without closed loop influence, the closed loop **ctrff** parameters can temporarily be set to 0 in order to suppress regulation.

Response: Momentary position difference, refer to examples.

Examples:

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

From Firmware 1.69:

| | |
|---|---|
| ?ctrdiff | Returns the position difference of all axes |
| ctrdiff | same as ?ctrdiff, question mark not required |
| ctrdiff z | Returns the position difference of the Z-axis |
| ctrdiff x 1 | Returns the internal closed loop circuit output signal of X |
| ctrdiff 1 | Function not available, behavior is same as ctrdiff |

From Firmware 1.71:

| | |
|---|---|
| ctrdiff | same as ?ctrdiff, question mark not required |
| ctrdiff z | Returns the position difference of the Z-axis |
| ctrdiff x 1 | Returns the internal closed loop circuit output signal of X |
| ctrdiff 1 | Returns the internal closed loop output signal of all axes |
| ctrdiff 2 | Returns the internal motor position shift of all axes |
| ctrdiff x 2 | Returns the internal motor position shift of the X axis |
| ctrdiff y 3 | Returns position difference AND output signal of Y |
| ctrdiff 3 | Not supported |
| ctrdiff y 4 | Returns position difference AND motor position shift of Y |
| ctrdiff 4 | Not supported |

Examples for Firmware ≥ 1.72:

| | |
|---|---|
| ctrdiff z | => -0.13852 0 (5 fractional digits and "motor idle") |
| ctrdiff z | => 0.06331 1 (5 fractional digits and "motor running") |
| ctrdiff x 1 | => 17.88353 1 (5 fractional digits and "motor running") |
| ctrdiff x 2 | => 22.06331 1 (5 fractional digits and "motor running") |
| ctrdiff x 3 | (as with earlier firmware) |
| ctrdiff y 4 | (as with earlier firmware) |

# 21. Trigger Output Functionality (option)

Trigger functionality must be configured by factory.

To identify if the Trigger functionality is configured, use **'?det'** or **'detext'**.

The trigger output generates TTL signals dependent either on axis positions or as a constant frequency. It can be used to synchronize external devices like e.g. a camera. TANGO Desktop, PCI/PCI-E and TANGO 3 mini provide up to 2 trigger outputs via the optional AUX I/O connector. See **mode** and **output description.**

A special trigger mode – ideal for on the fly scanning applications – is provided by the **!trigr** instruction. This mode achieves the highest accuracy.
A more sophisticated mode is provided by **!trigp**, an individual position list.

The trigger can be based on the motor position or on the more accurate encoder position, if the axis provides position encoders.

Axis positions and analog inputs can be captured on trigger by **SnapShot Mode 8**.

The LED100 illumination is active low and typically wired to OUT2 (TAKT_OUT).
Remarks: If **hdimode** controls the LED100, it can interfere with TAKT_OUT.

The trigger signals are processed in a 40 microsecond interval.

Before enabling the trigger function by **'!trig 1'**, please ensure that all trigger settings have been made.

```
Example1:   !trig 0[CR]            Disable trigger globally
            !trigm 0[CR]           Select trigger mode 0
            !triga x[CR]           Set 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 and set start position

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

Optional: "**!trigcount 0**" instruction may be executed to reset the event counter.

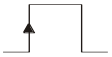
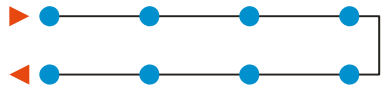
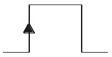
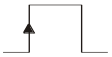
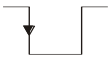
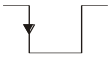
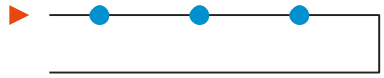
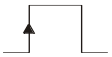
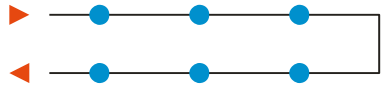
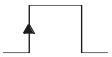
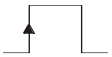
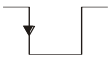
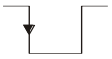
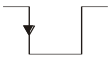
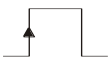
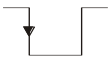
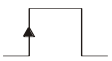
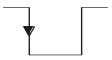
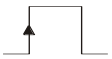
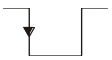
## 21.1. trig (Trigger)

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

Description:     This instruction enables or disables the trigger circuit.
                 The position at which "!trig 1" is executed also defines
                 the start position for trigger modes 0 to 11 (→current pos).

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

Response:        0 or 1

Examples:
!trig 1          Enable trigger circuit (and define the start position = here)
?trig            Read enable state of trigger circuit
```

## 21.2. trigm (Trigger Mode)

Syntax: !trigm or ?trigm
Parameter: 0 to 11, 100 to 105

Description: This instruction selects the required trigger mode.

| Trigger Mode | Trigger Generation | Trigger Signal | Remarks |
|---|---|---|---|
| 0 |  | High active  | First pulse when move starts *Direction forward* |
| 1 |  | High active  | First pulse when move starts *Bidirectional* |
| 2 |  | High active  | First pulse when move starts *Direction backward* |
| 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 *Direction forward* |
| 7 |  | High active  | Triggers shifted by trigd/2 *Bidirectional* |
| 8 |  | High active  | Triggers shifted by trigd/2 *Direction backward* |
| 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 | **Periodic trigger** signal the frequency can be set by "trigf" instruction | High active  | Does not depend on position |
| 101 | | Low active  | |
| 102 | **Manually forced** trigger signals by the "trigger" instruction which releases one or several pulses | High active  | Does not depend on position or time |
| 103 | | Low active  | |
| 104 | **Position reached** trigger signal when all moves including the specified axis "triga" have completed | High active  | Comes with the "@@@-." response, → **'autostatus'** must be on (not 0) |
| 105 | | Low active  | |

Remarks: The start position is defined by the position where the trigger was globally enabled (by "**!trig 1**" instruction).

Trigger modes 20 and 21 are used internally by the **trigr** and **trigp** instructions. In those two cases trigger mode 20 is for increasing positions (pos. direction), trigger mode 21 is for decreasing positions (neg. direction).

Response: Trigger mode as integer: 0 to 11, (20,21), 100 to 105

Examples:

```
!trigm 0          Select trigger mode 0
?trigm            Read current trigger mode (returns e.g. 0)
```

## 21.3. 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 y Select Y-axis as trigger source
?triga Read current trigger axis (returns x,y,z or a as lower case)

## 21.4. trigo (Trigger Output)

Syntax: !trigo or ?trigo
Parameter: 0 to 15

Description: This instruction selects the trigger outputs.

The secondary output TAKT_OUT provides extended functionality:
2, 3: 1:1 mode, generating the same signal as output 1
6, 7: precise width
10,11: high precision delay
14,15: precise (and optionally even higher) frequency

TAKT_OUT is also the default output to control the LED100.

| Output / Mode | STANDARD | PREC.WIDTH2 | PREC.DELAY2 | PREC.FREQUENCY2 |
|---|---|---|---|---|
| **No output** No signal out | **0** | (4) | (8 PCI-E) | (12) |
| **Primary** TRIGGER OUT | **1** | (5) | (9 PCI-E) | (13) |
| **Secondary **** TAKT OUT | **2** | **6** | **10** (PCI-E) | **14** |
| **Both, P&S **** TRIGGER+TAKT | **3** | **7** | **11** (PCI-E) | **15** |

A combined delay and width of 40µs resolution is available in standard modes 1,2,3 by the **trigs** instruction.

****** For further information on the second trigger output, please refer to **trigs**, **trigbwidth**, **trigbdelay**, **trigbf** and the description of the **second trigger signal output**.

Remarks: Options depend on hardware: TANGO PCI-E/DT-E and TANGO 3 mini controllers with AUX I/O connector offer all features.
PCI-S based controllers do not provide the precision delay function (only a precise edge is generated there) and TANGO mini or integrale provide none or one trigger output.

Response: Selected trigger outputs

Examples:
!trigo 0 No output signal
!trigo 1 Default trigger output (TRIGGER_OUT)
!trigo 2 Secondary trigger output (AUX I/O TAKT_OUT, LED100)
!trigo 3 Both trigger outputs 1:1 (TRIGGER_OUT and TAKT_OUT)
?trigo Read back the selected trigger output mode

## 21.5. trigs (Trigger Signal Length)

Syntax: !trigs or ?trigs
Parameter: 0 to 2500000 [µs]
or optional 3x 0 to 2500000 with secondary trigger option

Description: This instruction sets the trigger pulse width in the range of 40 microseconds to 2.5 seconds in increments of 40.
(0 = shortest trigger signal width, narrow pulse)
If the parameter is not a multiple of 40 it will be rounded to the nearest multiple: e.g. 90 → 80, 100 → 120.
When read back, the corrected (nearest) value is returned.

Remarks: **Secondary Trigger Option:** TANGO controllers with a secondary trigger output (AUX I/O) offer a **1:1 mode**. When !trigs is called with 3 parameters, OUT2 provides the option of a delay and individual width. Both parameters must be specified and may be set from 0 to 2500000 (µs) in increments of 40 (µs), as mentioned above.

The 2nd trigger signal must be active within the range of the 1st signal. At the end of signal 1, signal 2 is set back to inactive, too. For further information, refer to the trigger description of the **Standard 1:1** output mode.

Example: !trigs 120 40 80
Generates 120µs on OUT1 and a 40µs delayed 80µs long pulse on OUT2. The 2nd and 3rd parameter cannot be read back by ?trigs, it only returns the signal length of output OUT1.

Response: 0 to 2500000 (µs) trigger signal length

Examples:

| | |
|---|---|
| !trigs 40 | Set Trigger pulse width to 40 µs |
| !trigs 2500000 | Set Trigger pulse width to 2.5 s |
| ?trigs | Read current trigger pulse width |
| !trigs 200 40 80 | Set Trigger output 1 pulse width, delay, output 2 pulse width<br>The two additional parameters cannot be read back with ?trigs |

## 21.6. trigd (Trigger Distance)

Syntax: !trigd or ?trigd
Parameter: >0.0 to 5000000 (unit depends on **dim** of the selected axis)

Description: This instruction sets or reads the trigger distance.
Equidistant trigger signals are generated in this position interval.

Remarks: The trigger axis (**triga**) should be defined before setting trigd.

Response: Trigger distance (the unit is defined by **dim**)

Examples:

| | |
|---|---|
| !trigd 3.01 | Set trigger distance to 3.01mm (if dim of selected axis is 2) |
| ?trigd | Read the trigger distance |

# 21.7. trigcomp (Trigger Compensation)

Syntax: !trigcomp or ?trigcomp
Parameter: -10000 ... +10000 [µs] (smallest step is 10µs)

Description: Time delay compensation for position trigger (look ahead).
It releases the trigger at an earlier (+) or later (-) time in order to be executed at the required position.

It can be used to compensate time delays in the signal chain or to center a trigger pulse around the target position.

**Application 1:**
To avoid stitching mismatch with bidirectional scans (and so increase performance by not requiring unidirectional)

At high velocity on the fly scans, the delay of the trigger signal chain has an effect on where the sample is taken. When scanning in both directions, this effect becomes visible typically by a comb-like appearance of the stitched image. This can be greatly improved or entirely removed by the trigcomp delay compensation. The default setting is 0.

Example: If a camera has a shutter release delay of 100µs and the axis travels at 10mm/s, an uncompensated bidirectional scan will cause a 1µm shift in each direction, causing a 2µm shift between forward and backward direction. When this delay is compensated by "!trigcomp 100", the trigger is released at an 100µm earlier position (which the TANGO calculates internally, based on the current velocity) and the camera now will take the picture without any position shift.

Remarks:
The described comb effect can also be caused by a mechanical backlash of the scan axis. On open loop axes without encoder feedback, the effect can possibly be minimized by using the **backlash** compensation.

**Application 2:**
To generate a symmetrical trigger pulse, which is active for a certain time before and after the trigger position.
Example: The pulse is 200µs long and should be active 100µs before and after the trigger position
→ **trigs** 200, trigcomp 100

Response: Compensated delay in [µs]

Examples:

| | |
|---|---|
| !trigcomp 130 | Compensate trigger signal chain delay of 130µs |
| ?trigcomp | Read the compensation delay (e.g. returns 0) |

## 21.8. trigenc (Trigger on Encoder)

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

Description: Trigger position source select, encoder or motor position.

0 = Trigger position from motor position (default)
1 = Trigger position from encoder (true position)

Remarks: Triggering on encoder signals is designed for analogue 1Vpp or MR encoders.
When using A/B-TTL encoders, the available position range might be extremely limited due to the low encoder period.
The valid trigger position range is ±32000 encoder periods
Examples:
- MR @ 500µm * ±32000 = ±16000 mm
- 1Vpp @ 20µm * ±32000 = ±640 mm
- TTL @ 1µm * ±32000 = ±32 mm

In order to use trigenc=1, the encoder must be activated.
Without active encoder (?**enc** = 0), the motor position is used.

Response: Currently selected trigger position source

Examples:
!trigenc 1 Trigger based on the encoder signal, if available
?trigenc Read the trigger position source, e.g. 0

## 21.9. trigf (Trigger Frequency)

Syntax: !trigf or ?trigf
Parameter: 0.01 to 25000

Description: This instruction sets the frequency for periodic trigger output modes **trigm** 100 and 101.
The internal frequency resolution is in steps of 1/40µs.

Response: Trigger frequency

Remarks: As the internal resolution has 40µs steps, the resulting frequency might not always match the requested frequency.
The higher the frequency, the more deviation may occur (e.g. 2500 exactly meets the frequency, 2600 does not).
In order to identify the resulting frequency,?trigf can be used.

For highly accurate frequencies with fine resolution, the second trigger output can be used (refer to **trigbf**).

From TANGO firmware 1.60C / 1.61 it is also possible to send a fixed number of trigger pulses at the specified trigf by using the manual trigger modes 102, 103 and calling the manual **!trigger** instruction with the number of pulses as parameter. Refer to **trigger** description.

Examples:
!trigf 2500 Periodic trigger pulses at 2.5kHz (signal every 0.4ms)
?trigf Read trigger signal frequency (the true value)

## 21.10. trigbdelay (Precise Trigger Delay for second output)

Syntax: !trigbdelay or ?trigbdelay
Parameter: 0.00 to 32500000 [µs]

Description: Precise delay for secondary trigger output signal (TAKT_OUT).
Applies to trigger output settings !**trigo** 10 and 11.
Unit in microseconds [µs], resolution is 1/132µs.

Remarks: Secondary trigger can either have precise width or delay.
**Only available with TANGO PCI-E, Desktop-E and TANGO 3 mini.**
**TANGO PCI-S and Desktop-S only provide a delayed signal edge (rising or falling), while the signal state before and after the trigger pulse remains in an active state.**

Response: Delay time in µs

Examples:
!trigbdelay 0.35 Delay the secondary trigger signal by 350ns (to TRIGGER_OUT)
?trigbdelay Read the secondary trigger delay (e.g. returns 0.00)

## 21.11. trigbwidth (Precise Signal Width for second output)

Syntax: !trigbwidth or ?trigbwidth
Parameter: 0.00 to 32500000 [µs]

Description: Precise width for secondary trigger output signal (TAKT_OUT).
Applies to trigger output settings !**trigo** 6 and 7.
Unit in microseconds [µs], resolution is 1/132µs.

Remarks: Secondary trigger can either have precise width or delay.
**Only available with TANGO PCI-S, PCI-E, Desktop-S, Desktop-E and TANGO 3 mini.**

Response: Signal width in µs

Examples:
!trigbwidth 5.01 Set secondary trigger signal width to 5.01µs
?trigbdelay Read the secondary trigger signal length (e.g. returns 40.00)

## 21.12. trigbf (Precise Trigger Frequency for second output)

Syntax: !trigbf or ?trigbf
Parameter: 0.010 ... 66000000 [Hz]

Description: Precise frequency for secondary trigger output (TAKT_OUT).
Applies to trigger output settings !**trigo** 14 and 15.
Unit is microseconds [µs], resolution is 1/132µs.

Remarks: Trigcount does not count the precise trigger events.
**Only available with TANGO PCI-S, PCI-E, Desktop-S, Desktop-E and TANGO 3 mini.**

Response: Output frequency [Hz] for precise frequency output mode.

Examples:
!trigbf 0.01 Set secondary trigger frequency to 0.01Hz
!trigbf 50000005 Set secondary trigger frequency to 50.000005 MHz
?trigbf Read the secondary trigger frequency (e.g. returns 1000.000)

## 21.13. trigcount (Trigger Counter)

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

Description: Read or set the trigger event counter.
Trigcount increments on every executed trigger pulse.

Response: Number of executed triggers

Examples:
?trigcount Read trigger counter
!trigcount 0 Clear trigger counter
!trigcount 110 Set trigger counter to 110 counted events

## 21.14. trigger (Force Trigger Signal)

Syntax: !trigger or trigger
Parameter: None or 0 to 127

Description: This instruction generates one trigger output pulse or a fixed amount of pulses, refer to description below. Manual trigger is available in manual **trigger modes** 102 and 103 only. The pulse width depends on **trigs** setting.

From TANGO firmware 1.60C / 1.61 it is also possible to manually generate a fixed number of 1 to 127 trigger pulses by calling the instruction with an additional count parameter. The pulse frequency depends on the **trigf** setting.

Remarks: When executing multiple triggers (trigger was called with parameter), the function does not return until all trigger pulses are executed (the command interpreter is blocked). To identify if the instruction completed – and that the TANGO controller is able to receive new instructions – it is recommended to send an ?err request and wait for it to return. → Refer to Example 2(b).

Response: None

Example1: trigger (Force one trigger pulse now)

Example2: (Minmum requirement is TANGO firmware 1.60C / 1.61)

*!trig 0 (Disable trigger)*
*!trigf 1000 (Set frequency of trigger signal in Hz)*
*!trigs 400 (Set duration of trigger pulse in µs)*
*!trigm 102 (Set trigger mode to manual trigger 102 or 103)*
*!trig 1 (Enable trigger)*

trigger 5 (Manually force 5 trigger pulses at 1000 Hz)

Example2(b): *err (Optional wait for trigger function to complete by waiting for err response, e.g. zero)*

→ *0*

# 21.15. trigr (Set Trigger Range)

Syntax: !trigr or ?trigr

Parameter: x, y, z, a or none
start position
end position
number of equidistant trigger signals within a position range

Description: Provides the *range trigger mode*, which
- begins and ends at defined positions
- generates a defined number of equidistant, unidirectional trigger signals (10000 max.)

Setting a trigger mode is not required, !trigr sets it to mode 20 (up) or 21 (down) automatically.

If no axis is specified, the trigger axis is used (?**triga**).
If an axis is specified (x,y,z,a) the trigger axis is set to this axis and remains set until changed.

Trigger signals are generated within a position range.
The scan direction is set by the start,end positions:
- start < end = trigger in positive travel direction
- start > end = trigger in negative travel direction

Start and end position units are defined by **dim**, e.g. mm.

The number of trigger signals defines their distance:
The first trigger is generated at the start position and the last trigger is generated at the end position (n+1).
e.g. to achive 1mm distance from 0 to 10 mm = 11 signals.

If only one trigger position is specified (start = end), the trigger direction is determined from the current position:
- If the trigger position is greater than the axis position, the trigger direction is set to positive (up, forward).
- If the trigger position is lower than the axis position, the trigger direction is set to negative (down).

Once set, the trigger range remains and is reactivated automatically when the axis travels back behind the start position. If required, !trigr can set new parameters ahead of every move instruction.

For bidirectional scans, !trigr must be set to the required travel direction before each move (from pos -> to pos).
The move must start from below the start position and travel past the end position.

Remarks: The signal polarity for this special trigger mode can be set by the **!trigl** instruction.
In order to apply the signal polarity immediately, the trigger mode can be set to **!trigm** = 20 or 21 before setting **trigl**.

The trigr instruction clears and overwrites possibly existing **trigp** position lists of the specified axis and vice versa.
(!trigr internally writes its positions to the trigp list.)

Response: Currently applied values: [startpos] [endpos] [num of trigger]

Examples for trigr:

**--- Preparation ---**

**- Globally disable the trigger:**

```
!trig 0
```

**- Select trigger polarity:**

```
!trigm 20          (mode 20 or 21 to apply trigl immediately)
!trigl 1           (set trigger signal level to active high)
```

**- Specify the axis:**

```
( !trigenc 1 )     (optional if the axis provides an encoder)
  !triga x         (can also be specified or changed by !trigr)
```

**--- Trigger ---**

**- A) Trigger in positive direction:**

```
!moa 9             (move X to position below the trigger range)
!trigr 10 20 11    (one trigger every mm, 10,11,12,…20)
!trig 1            (globally enable the trigger**)
!moa 21            (move X to position past the trigger range)
```

**- B) Trigger in negative direction:**

```
!moa 21            (move X to position below the trigger range)
!trigr 20 10 11    (one trigger every mm, 20,19,18,…10)
!trig 1            (globally enable the trigger**)
!moa 9             (move X to position past the trigger range)
```

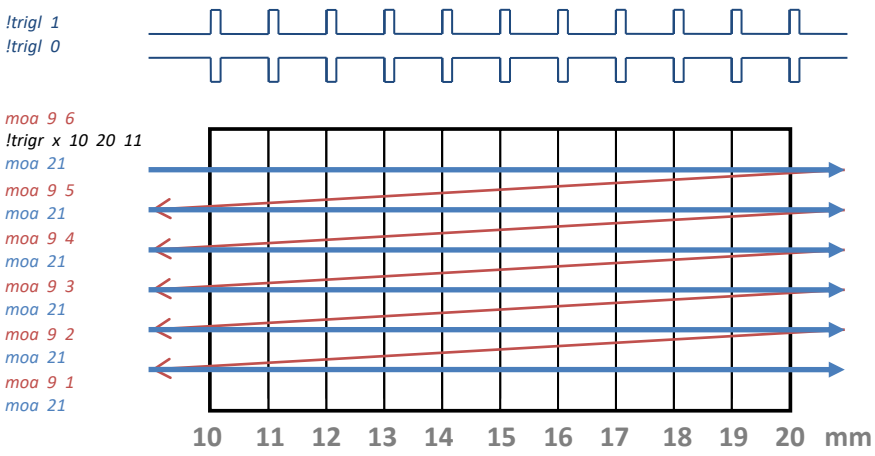
**- C) Single trigger position:**

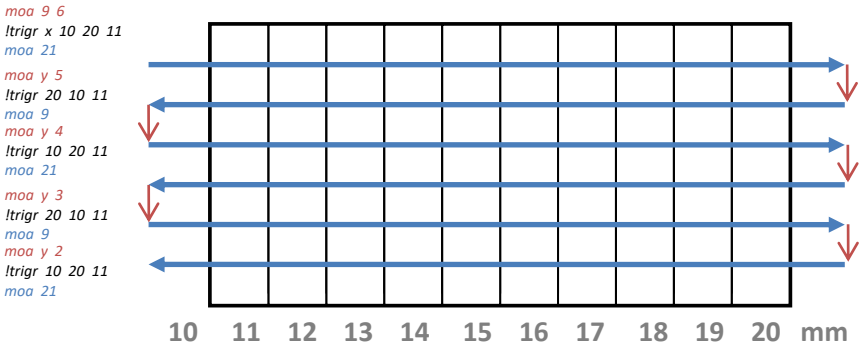
```
!moa 19            (move X to position below the trigger range)
!trigr 20 20 1     (one trigger at 20mm)
!trig 1            (globally enable the trigger**)
!moa 21            (move X to position past the trigger range)
```

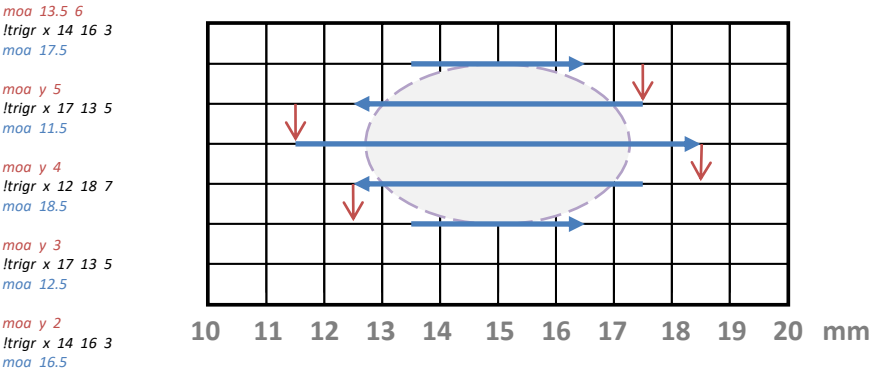
```
!trigr y 11.5 16 10                (select y axis for trigger from 11.5 to 16)
!trigr 11.5 16 10                  (use recently set axis for trigger)
?trigr ➔ 11.5000 16.5000 11        (read trigger settings)
?triga ➔ y
```

** Trigger should be globally disabled for the initial configuration and may remain enabled afterwards, even if the !trigr parameters are modified.

## Trigger Range Functionality (!trigr)



# 21.16. trigp (Trigger Position List Entry)

Syntax: !trigp or ?trigp
Parameter: none or x, y, z, a
List index and position value

Description: Provides a list of individual, unidirectional trigger positions. The position unit depends on **dim** (mm,µm,…).
Up to 10000 list entries are possible.

Setting a trigger mode is not required. !trigp sets **trigm** to mode 20 (up) or 21 (down) automatically.

The entries are only valid for the specified axis. If the axis has to be changed, all entries must be rewritten to the list.

If no axis is specified, the trigger axis is used (**triga**).
If an axis is specified (x,y,z,a) with the first entry or when clearing the list, the trigger axis (**triga**)is set to this axis and remains set until changed. Later attempts of change are ignored and an error will be returned.

Trigger signals are generated at the specified position(s).
The entries must be either of increasing or decreasing value, as the scan direction is identified by the first two entries.
In case of only one list entry, the direction is determined from the current axis position here or when '!**trig 1**' is set:
- If the trigger position is greater than the axis position, the trigger direction is set to positive (up ≙ **trigm** 20).
- If the trigger position is lower than the axis position, the trigger direction is set to negative (down ≙ **trigm** 21).

Once set, the position list remains and is reactivated automatically when the axis travels back behind the first trigger position in the list. If required, the !trigp list can be loaded with new parameters ahead of every move instruction.

For bidirectional scans, !trigp must be filled in the required travel direction before each move (from pos -> to pos).
The move must start from before the first trigger position.

```
!trigp 0       Discard the entire position list
!trigp x 0     Sets !triga to X axis and discards the X list
!trigp -1 2.5  Append a position to the list (here e.g. 2.5 mm)
!trigp x -1 9  Only possible if the list is empty (trigc=0):
               Set the first position and select trigger axis
!trigp 1 5.3   Set or modify the first list entry (here 5.3 mm)
!trigp 5 9.1   If entries >= 5: Replace the 5th list entry
               If entries  = 4: Append entry (like -1 does)
?trigp -1      Read back the last entry on the list
?trigp 7       Read back the 7th list entry
```

Remarks: The signal polarity for this special trigger mode can be set by the '**!trigl**' instruction.

The number of enries can be read by the '**trigc**' instruction.

In order to apply the signal polarity immediately, the trigger mode can be set to !**trigm** = 20 or 21 before setting **trigl**.

Response: Requested trigger position list entry in the current **dim**

Examples for trigp:

**--- Preparation ---**

**- Globally disable the trigger:**

```
!trig 0
```

**- Select trigger polarity:**

```
!trigm 20          (mode 20 or 21 to apply trigl immediately)
!trigl 1           (set trigger signal level to active high)
```

**- Specify the axis:**

```
( !trigenc 1 )     (optional if the axis provides an encoder)
  !triga x         (can also be specified or changed by !trigp)
```

**- Empty the position list** (if required, appending is also possible)

```
!trigp 0           (remove all existing entries from the list)
```

**--- Trigger ---**

**- A) Trigger in positive direction:**

```
!moa 105           (move X to position below the trigger range)
!trigp -1 110.5    (append a position value, here: first entry)
!trigp -1 125.7    (append a position value)
!trigp -1 200.3    (append a position value)
!trig 1            (globally enable the trigger**)
!moa 205           (here: move X past the last entry)
```

**- B) Trigger in negative direction:**

```
!moa 205           (move X to position above the 1st entry pos)
!trigp -1 200.3    (append a position value, here: first entry)
!trigp -1 125.7    (append a position value)
!trigp -1 110.5    (append a position value)
!trig 1            (globally enable the trigger**)
!moa 105           (here: move X past the last entry)
```

**- C) Single trigger position:**

```
!moa 105           (move X before the position)
!trigp -1 110.5    (set only one trigger position)
!trig 1            (globally enable the trigger**)
!moa 115           (move X to position past the trigger range)
```

```
!trigp y 11.5                    (set y as trigger axis, overwrities !triga)
!trigp -1 11.5                   (use recently set axis for trigger)
?trigc                           (read the number of list entries)
?trigp 1                         (read the first trigger position entry)
?triga y                         (read the trigger axis)
```

** The trigger should be globally disabled for the initial configuration and while filling or modifying the trigger position list.

During a scan it is not necessary to disable/enable the trigger, as the trigger re-enables itself when the axis moves before the first position.

More examples for trigp:

```
!trig 0                                  Globally disable the trigger
!trigm 20                                mode 20 or 21 to apply trigl immediately
!trigl 1                                 set trigger signal level to active high
!trigenc 1                               optional, set the encoder as trigger source

moa 5                                    position the x axis below the 1st triggerpos
```

| EXAMPLE1 (strict) | EXAMPLE2 (alternate) | |
|---|---|---|
| !triga x | | |
| !trigp 0 | !trigp x 0 | Select trigger axis and erase position list |
| !trigp 1 10 | !trigp -1 10 | Insert 1st trigger position |
| !trigp 2 10.5 | !trigp -1 10.5 | ... |
| !trigp 3 11 | !trigp -1 11 | |
| !trigp 4 11.5 | !trigp -1 11.5 | |
| !trigp 5 12 | !trigp -1 12 | |
| [1] | | |
| !trigp 6 20 | !trigp -1 20 | |
| !trigp 7 20.5 | !trigp -1 20.5 | |
| !trigp 8 21 | !trigp -1 21 | |
| !trigp 9 21.5 | !trigp -1 21.5 | |
| !trigp 10 22 | !trigp -1 22 | |
| [1] | | |
| !trigp 11 30 | !trigp -1 30 | |
| !trigp 12 30.5 | !trigp -1 30.5 | |
| !trigp 13 31 | !trigp -1 31 | |
| !trigp 14 31.5 | !trigp -1 31.5 | ... |
| !trigp 15 32 | !trigp -1 32 | Insert last trigger position |

The following instructions would now deliver:

```
?trigc      => 15                        read the amount of entries
?trigi      => 1                         read the list index (here: at 1st entry)
?trigp 3    => 11.0000                   read 3rd entry of trigger axis (here: X)
?trigp x 3 => 11.0000                    read 3rd entry of X (redundant information)
?trigp -1   => 32.0000                   read last list position
```

It is possible to overwrite entries, e.g. `!trigp 11 30.25`
It is possible to shorten the list, e.g. `!trigc 10` (=positions 30...32 mm deleted)
It is possible to append positions, e.g. `!trigp -1 40.225`
Which is the same as `?trigc` → 15 `!trigp 16 40.225`

```
!trig 1                                  Globally enable the trigger

moa 37                                   Travel x past the last trigger position
```

Now 15 triggers are generated (examples here: 3 regions of interest with individual gaps inbetween).

[1]

**Important note:** Sending a !trigp list to the TANGO cannot be done in one block. As with all instruction sequences, it must be ensured that the 256 byte input buffer does not run over. Good practice might be to read back **"err"** or ?trigc after each !trigp position, at least every few !trigp positions. This will ensure no data gets lost during transmission.

## 21.17. trigc (Number of Trigger Position List Entries)

Syntax: !trigc or ?trigc
Parameter: none or [0 to trigc]

Description: Read the number of position list entries, which are made by **!trigp** or **!trigr**.
Or reduce the position list size by specifying a lower amount of entries.

Remarks: Only for special trigger functionality of **!trigp** and **!trigr**.

Response: Amount of trigger position list entries.

Examples:
```
?trigc     (read the amount of trigger position list entries)
!trigc 0   (clear the trigp position list)
!trigc 5   (reduce the entries to 5, only possible if greater)
```

## 21.18. trigi (Trigger Position List Index)

Syntax: !trigi or ?trigi
Parameter: none or 1 to 10000 (less or equal to the current **trigc** count)

Description: This instruction reads or sets the trigger position list pointer of the selected trigger axis (**triga**).
The behavior is similar to snsi of the snapshot array, except the index here is consistent from 1 to N (snsi is 0...N-1).

In trigger modes 20 and 21 this pointer access can be used to read back where in the position list the trigger unit currently is. Or it can be used to manipulate the list index (position pointer) of the entries made by trigp or trigr.

The value must not exceed the amount of **trigc** list entries.

Response: Current trigger position list pointer

Example:
```
?trigi      Read the current trigger position list pointer (e.g returns 1)
!trigi 1    Set position list pointer to the first element
!trigi      Same as !trigi 1
!trigi 21   Set position list pointer to the 21st element
```

# 21.19. trigl (Trigger Level)

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

Description: Select the trigger signal polarity for trigger modes 20 and 21 (**!trigr**, **!trigp** functionality).

0 = Trigger signal is active low
1 = Trigger signal is active high

Remarks: Only for special trigger functionality of **!trigp** and **!trigr**. For all other cases, the polarity is defined by their **trigger mode**.

Response: Trigger signal polarity for trigger modes 20 and 21.

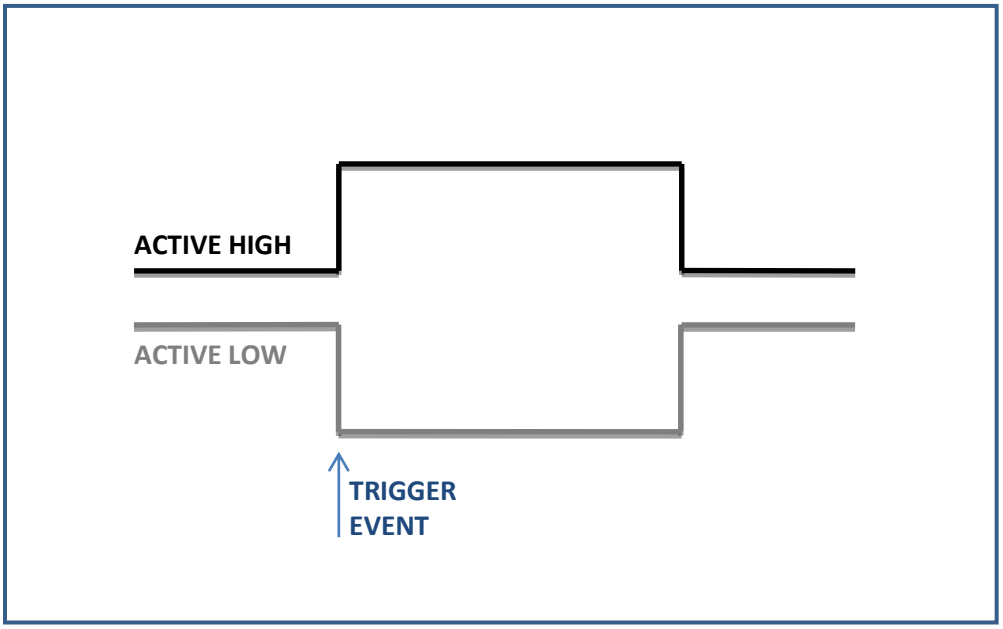
Examples:
```
!trigl 0   (set to active low)
!trigl 1   (set to active high)
?trigl     (read trigger level, e.g. returns 1 = active high)
```

# 22. The Second Trigger Signal Output

## 22.1. Introduction

TANGO PCI/PCI-S/PCI-E TANGOS, Desktop TANGOs and the TANGO 3 mini provide two trigger output signals on the AUX I/O connector (TRIGGER_OUT, TAKT_OUT). Only the PCI-E, Desktop-E and TANGO 3 mini support the full functionality as described in this chapter.

Depending on the **trigger mode**, the output signals are active high or active low. This description shows the trigger signals in active high mode.




Up to two output signals are available and can be selected with the **'trigo'** instruction:

- TRIGGER_OUT (here called OUT1)
- TAKT_OUT (here called OUT2)

OUT2 is provided by PCI/PCI-E or Desktop TANGOs and TANGO 3 mini only.

Both outputs share the same polarity setting and trigger source.

The optional LED100 illumination uses OUT2.

The minimum OUT1 width of 40µs results in 12.5 kHz max. signal frequency. If the OUT1 signal width is set to zero, a short spike is still generated. This allows edge trigger events of up to 25 kHz.

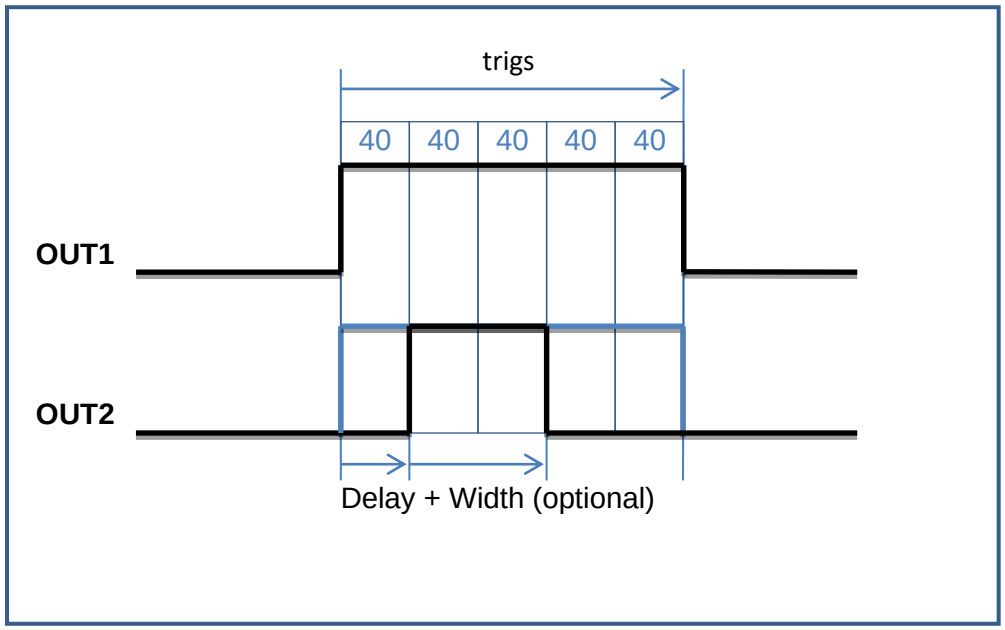
## 22.2. Standard 1:1

**Signal:** OUT2 provides the same signal as OUT1 plus optional delay and width

**Options:** When the **trigs** signal width instruction is sent with 3 parameters,
OUT2 provides the option of a delay and individual width.
OUT2 becomes inactive latest when OUT1 returns to inactive state.
OUT2 must be within the active range of OUT1.

**Remarks:** Can be used with any **trigger mode.**
Parameter in increments of 40µs (0; 40; 80; … 2,500,000)
Values inbetween the 40µs get rounded to nearest, e.g. <20=0,≥20=40

**Application:** Camera shutter and LED flash




**OPTIONS**

***!trigo 1*** → **OUT1 only, OUT2 set to inactive level**
***!trigo 2*** → **OUT2 only, OUT1 set to inactive level**
***!trigo 3*** → **OUT1 and OUT2**

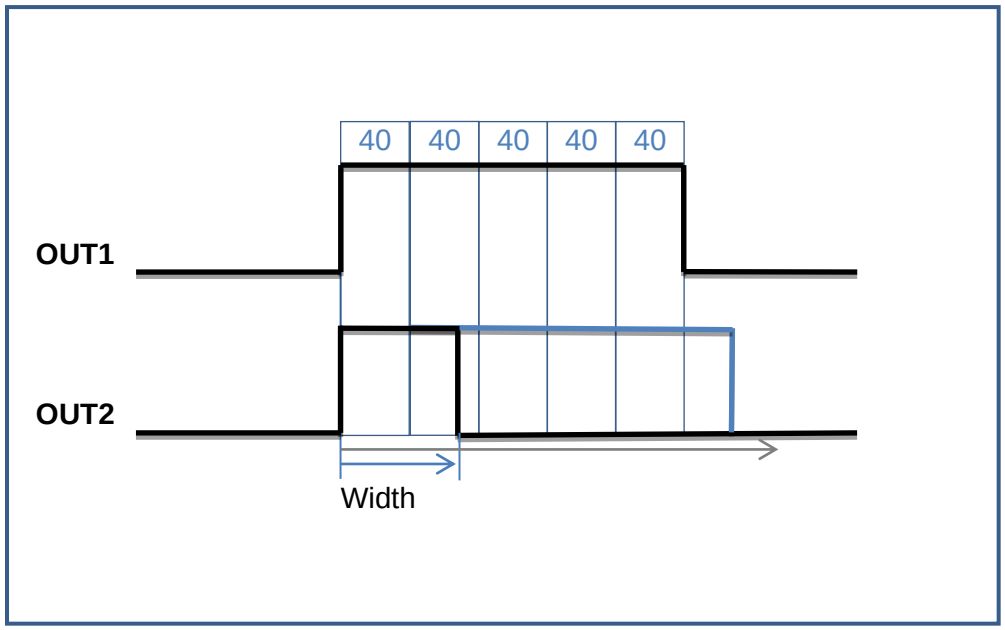
**EXAMPLE**

***!trigo 3***
***!trigs 200 40 80*** → **Set OUT1 signal width & maximum duration (200µs), Delay (40µs) and Width (80µs) for OUT2**
or ***!trigs 200*** → **Set OUT1 and OUT2 signal width to 200µs**

## 22.3. Precise Width

**Signal:** OUT2 starts with OUT1 but has individual, high resolution width.

**Remarks:** Can be used with any **trigger mode** of OUT1.
OUT2 resolution is in 7.6ns steps, up to 32.5 seconds.
OUT2 width can be longer than OUT1.




**OPTIONS**

***!trigo 5*** → **OUT1 only, OUT2 set to inactive level**
***!trigo 6*** → **OUT2 only, OUT1 set to inactive level**
***!trigo 7*** → **OUT1 and OUT2**

**EXAMPLE**

***!trigo 7***
***!trigs 200***
***!trigbwidth 67.4*** or ***!trigbwidth 230***

# 22.4. Precise Delay

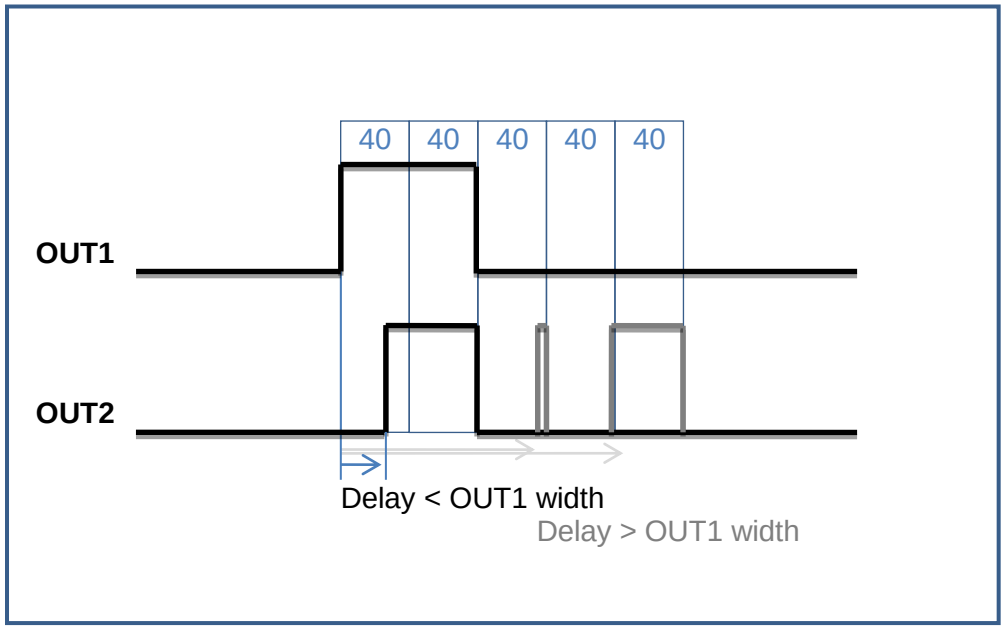
**Signal:** OUT2 provides a precise edge delay to OUT1.

**Remarks:** Can be used with any trigger mode of OUT1.
Very low jitter between the two edges OUT1 --> OUT2 <10ns.
OUT2 resolution is in 7.6ns steps, up to 32.5 seconds.
OUT2 delay can be longer than (past) the OUT1 signal width.

If the OUT2 pulse starts at last 1µs before the OUT1 pulse ends, then the OUT2 pulse is resetted with the OUT1 pulse.

Else the OUT2 pulse is resetted with the next 40µs interval. In this case, OUT2 signal widths of 100ns to 40µs may occur which makes only sense in edge triggered applications. Refer to the third OUT2 pulse "!trigbdelay 159.7" in the figure below.

**Application:** Precisely delayed trigger edges for transducer and receiver




**OPTIONS**
***!trigo 9*** → **OUT1 only, OUT2 set to inactive level**
***!trigo 10*** → **OUT2 only, OUT1 set to inactive level**
***!trigo 11*** → **OUT1 and OUT2**

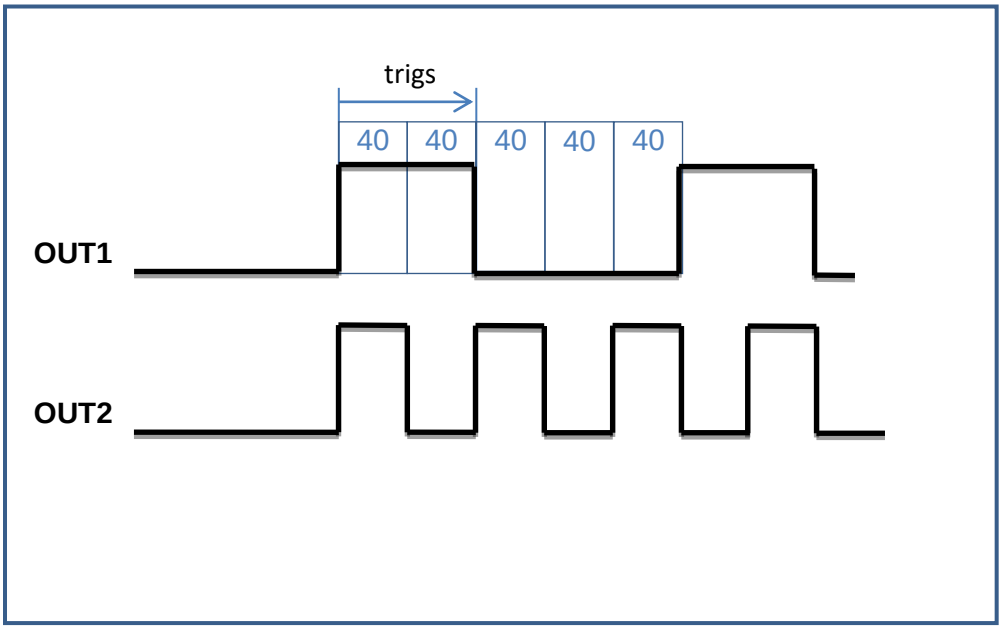
**EXAMPLE**
***!trigo 11***
***!trigs 80***
***!trigbdelay 25.5*** or *!trigbdelay 112.03* or *!trigbdelay 159.7*

**REMARKS**
The TANGO PCI-S and Desktop-S controllers provide limited delay functionality. Here only the leading edge (active high = rising, active low = falling edge) of OUT2 is valid. The signal level inbetween is on active level (not inactive as shown above). When using those controllers, the delay function only makes sense with edge sensitive devices and not with level sensitive ones.

# 22.5. Precise Frequency

**Signal:** OUT1 and OUT2 provide individual output frequencies.
OUT2 can be used for higher frequencies and high resolution.

**Remarks:** OUT1 can run in an individual trigger mode (position dependent,etc.)
OUT1 width can be specified by **'trigs'**
OUT1 frequency is limited to 0.01 to 25000 Hz and 1/40µs resolution
OUT2 provides 0.010...66,000,000 Hz high resolution and low jitter
OUT2 has fixed width of 50%
OUT1 and OUT2 are in phase only if the frequencies match (multiples)




**OPTIONS**
***!trigo 13*** → **OUT1 only, OUT2 set to inactive level**
***!trigo 14*** → **OUT2 only, OUT1 set to inactive level**
***!trigo 15*** → **OUT1 and OUT2**
***!trigm can be set to an independent behavior, must not be frequency output***

**EXAMPLE**
***!trigo 15***
***!trigs 80***
***!trigf 5000***
***!trigbf 12500***
***!trigm 100***

# 23. Snapshot – The Trigger Input Functionality (option)

Snapshot functionality must be configured by factory.

To identify if the Snapshot functionality is configured, use **?det** or **detext**.

The snapshot functionality allows capturing of X,Y,Z,A axis positions by either pressing a HDI key (e.g. Joystick F2), an external signal or a trigger-out event. Hardware dependent, analog input signals from the AUX I/O connector are captured as well. The values are appended to the snapshot array. The snapshot array can also be filled, extended or manipulated by **snsa**, **!snsp** instructions. Please refer to **snsm** for available snapshot modes.

In **snsm** 1 or 5 a snapshot event can command the TANGO controller to move to positions stored in the snapshot array. Every snapshot event goes to the next array entry and wraps around at the end of the array. It can i.e. be used to move to positions (points of interest) captured in snapshot mode **snsm** 0 or 4.

In **snsm** 6, **moa**, **mor**, **speed** and **go** instructions wait for a snapshot event on the specified **snsaxis**.

The snapshot event can be triggered by either
A) the Joystick key F2
B) via the SnapShot signal input (depends on hardware, AUX I/O connector option)
C) by a software instruction (**snse**)

The position unit depends on the selected dimension (**dim**). The setting of **encpos** defines if the motor position or the measured encoder position is read from the array. A maximum of 1024 snapshot positions can be captured.

For changing the snapshot configuration please disable the snapshot (!**sns** 0) and then re-enable it (!**sns** 1) after all settings have been made.

**Remarks:**

Most of the snapshot settings cannot be stored permanently to the controller.

**Requirements:**

The TANGO controller must be ordered with this function enabled, as it is not available by default or might require additional hardware (e.g. connector).

As the snapshot signal is sampled every 160µs, it should have an active and inactive time of at least 200µs. Else the signal may not be recognized by the controller. Also refer to '**snsf**' for the debounce filter time.

**Example: Three snapshot positions are captured with a 3 axis TANGO**

| Index | Position X | Position Y | Position Z | Position A |
|---|---|---|---|---|
| **1** | 1.0000 | 1.2345 | 1.2345 | 0 |
| **2** | 2.1200 | 1.3520 | 0.9343 | 0 |
| **3** | 3.5900 | 1.9000 | 0.8341 | 0 |
| **4** | *invalid* | *invalid* | *invalid* | *invalid* |
| **5** | *invalid* | *invalid* | *invalid* | *invalid* |
| ... | ... | ... | ... | ... |
| **1024** | *invalid* | *invalid* | *invalid* | *invalid* |

Here: ?snsc → 3 ?snsa 2 → 2.1200 1.3520 0.9343 ?snsa y 1 → 1.2345

## 23.1. sns (Snapshot enable/disable)

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

Description: This instruction globally enables or disables the snapshot functionality. Snapshot is globally enabled by default (power-on) in order to support stand-alone applications. Latched key pressed events or the **snsm**=6 waiting state of a move is cleared when enabling/disabling the Snapshot (sns0,1).

0 = disabled
1 = enabled (default)

Response: Snapshot state

Examples:
!sns 0 Disable snapshot
?sns Read snapshot enable state

## 23.2. snsl (Snapshot Level / Polarity)

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

Description: This instruction sets the snapshot input signal polarity.
0 = active low (falling edge)
1 = active high (rising edge)

Response: Currently used snapshot polarity

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

## 23.3. snsf (Snapshot Filter)

Syntax: !snsf or ?snsf
Parameter: 0 to 255 [ms]

Description: Reads or set the snapshot filter time in ms, which is used to debounce the snapshot signal (HDI F2 button or snapshot input). Default is 10ms. The filter time does not delay the reaction to the signal, it only delays the next detection of a signal change.

Requirements: The minimum high and low times of the input signal must be greater or equal to 200µs to be recognized.

Remarks: Debouncing is recommended for push-buttons, switches, etc. For digitally generated signals, the filter time can be 0.

Response: Snapshot filter time

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

# 23.4. snsm (Snapshot Mode)

Syntax: !snsm or ?snsm
Parameter: 0, 1, ... 11

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

**0** = Capture positions to list with Joystick key F2

**1** = Move forward through position list with Joystick key F2
(wraps around at the last element)

**2** = Extended move with Joystick keys:
F1: Move backward through position list (wraps around)
F2: Move forward through position list (wraps around)
F3: Move to **'prehome'** then start of list (first element)
F4: Move to **'prehome'** with 'vel' then **'home'** with 'secvel'

**3** = Simple continuous path control in conjunction with pre-loaded **snsa**/**snsp** positions (dissection mode).
The path travel velocity is set by **'scanvel'**.
Start with Joystick key F2 or corresponding **'snse** 2'.
HDI must be enabled by **joy** and **joydir** = 2.

**4** = Like mode 0, but snapshot I/O input is used instead of F2

**5** = Like mode 1, but snapshot I/O input is used instead of F2

**6** = Triggered start: Move and Speed instructions will wait for the I/O connector snapshot event to start moving.
Axes must be assigned by the **'snsaxis'** instruction.

**7** = Custom HDI mode with Prehome, Home and auto increment in a time interval set by the **'delay'** instruction

**8** = A Trigger-OUT event (not a snapshot event) captures axis positions and the ANIN0 analogue signal (of the optional AUX I/O connector, available with DT and PCI/PCI-E TANGOs)

**9** = Move relative **'snsj'** Jump distances with Joystick keys
F2 = jump, F1 = jump in reversed direction (back)

**10**= Like mode 9, but snapshot I/O input is used instead of F2

**11**= Z axis follows an X-Z position list (e.g. focus for scan)

Remarks: F1-F4 key events can also be generated by **'snse'** 1 to 4.

Position capture modes (0,4,8) also capture the analog voltage at the AUX I/O ANIN0 input pin. It can be read by **'?snsv'**.

A snapshot is always executed on all active axes. Capture and move. For snapshot move the position list must be filled with valid positions for all axes.

When setting snsm Snapshot mode, latched key events (**keyl**) or a pending snapshot mode 6 waiting state is cleared.

Response: Currently selected snapshot mode

Examples:

| | |
|---|---|
| !snsm 0 | Set snapshot mode to capture (with joystick key F2) |
| !snsm 1 | Set snapshot mode to move (with joystick key F2) |
| !snsm 2 | Set snapshot mode to extended move |
| !snsm 8 | Set snapshot mode to capture at trigger out events |
| ?snsm | Read current snapshot mode |

# 23.5. Snapshot Mode Description and Examples

**Snapshot Mode 1,2,3,7,9 move functions, accessible via Joystick F1-F4 keys or !snse 1-4 instruction:**

| Key | **Mode** function | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** (DISSECTION) | **7 ***** | **9** |
| **F1** = | - | previous point** | - | prehome* & home | jump back |
| **F2** = | next point | next point** | start dissection | auto inc from 1st point | jump fwd |
| **F3** = | - | prehome*& first point | - | pause/continue | - |
| **F4** = | - | prehome*& home | - | pause & previous point | - |

***** Remarks: A move to the **"prehome"** positions always travels at **secvel**.

**Prehome & home** means that the axes move to prehome and from there to home.
This is used to avoid possible collisions on the way to the home position.
**Prehome & first point** means that the axes move to prehome and after reaching directly to the first position in the position list. This sequence is also for collision prevention.

If prehome is not required, it can be set to the same position as home.
For graphical explanation of home & prehome positions, refer to Figure 1 below.

**** SnapShot mode 2:**

F3 function must be executed in order to enable the F1 and F2 functionality
F4 disables the F1 and F2 functionality, so pressing F3 is required again

Instruction sequence example for snsm 2:

```
!cal
!rm
!sns 0
!prehome [Xpos] [Ypos] [Zpos] [Apos]          (specify a redirection to avoid obstacles)
!home [Xpos] [Ypos] [Zpos] [Apos]             (specify home, e.g. load, unload position)
!snsa 0                                       (clear the snapshot array / position list)
!snsa 1 [Xpos] [Ypos] [Zpos] [Apos]           (load position list, at least one entry)
!snsa 2 ...                                   (load position list) ...
... !snsa N ...                                ...
!snsm 2                                       (enter snapshot mode 2 for F1-F4 functionality)
!sns 1                                        (activate snapshot function globally)
```

***** SnapShot Mode 7:**

1. Execute a !cal and !rm instruction to define the repeatable, absolute position (origin).
2. Define the !prehome and the !home positions.
3. Define a position list of points using the !snsa instruction.
4. Specify a user delay between the positions by using the !delay instruction.
5. Enter snapshot mode 7 by sending the !snsm 7 instruction.

All information is lost when the TANGO controller is switched off or resetted.
The delay also applies to all move instructions. So when leaving the snapshot mode 7 it is recommended to reset the delay value back to zero (!delay 0).
Snapshot mode 7 uses the joystick keys F1 to F4 according this specification:

F1 = Go to load/unload position (as defined with the !home and !prehome instructions)
F2 = Start Auto Movement from Point 1 (through position list, defined by the !snsa instruction and using a delay as defined by the !delay instruction)
F3 = Pause/Continue from current position (halt the automatic move)
F4 = Move back one position in the list (when in pause, else it is paused after reaching the next position and then it moves back.)

Instruction sequence example for snsm 7:

```
!cal
!rm
!sns 0
!delay 3000                                   (delay between moves, e.g. 3 seconds)
!prehome [Xpos] [Ypos] [Zpos] [Apos]          (specify a redirection to avoid obstacles)
!home [Xpos] [Ypos] [Zpos] [Apos]             (specify home, e.g. load, unload position)
!snsa 0                                       (clear the snapshot array / position list)
!snsa 1 [Xpos] [Ypos] [Zpos] [Apos]           (load position list)
!snsa 2 ...                                   (load position list) ...
... !snsa N ...                                ...
!snsm 7                                       (enter snapshot mode 7 for F1-F4 functionality)
!sns 1                                        (activate snapshot function globally)
```

Autoincrement can be aborted by the **abort (a)** instruction.

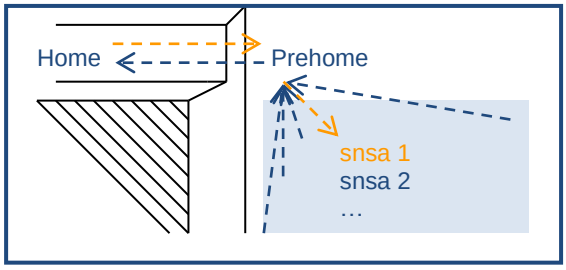



**Figure 1: home & prehome (in modes 2 and 7)**

**SnapShot Mode 3 (dissection, simple continuous path functionality):**
Typical applications are laser dissection or evaporation, or adhesive dosers/dispensers.
Remarks: All axes must be idle and all axis positions must be loaded with valid entries.
Joy and joydir must be enabled (e.g. set to 2) for all required axes (as with !speed).
The continuous path functionality has a continuous increase in position deviation which will build up during the sequence. The interpreter is blocked during execution.

```
!scanvel [mm/s]                              (set the path/vector velocity)
!sns 0
!snsa 0                                      (clear the snapshot array / position list)
!snsa -1 [Xpos] [Ypos] [Zpos] [Apos]         (write first entry to position list, here: append)
?err                                         (read back if accepted, also prevents buf.overrun)
!snsa -1 [Xpos] [Ypos] [Zpos] [Apos]         (continue as above for all entries ...)
?err
...
!snsm 3                                      (enter snapshot dissection mode 3)
!sns 1                                       (activate snapshot function globally)
!snse 2                                      (start the dissection sequence, or press F2 key)
?err                                        (send a request and wait for reply → completed)
```

**SnapShot Mode 11 (X-Z focus list):**
In snapshot mode 11, Z follows a position list dependent on the X axis position.
Typically used for focus applications under high magnification.
Best performance with piezo Z-stages, which are able to follow more precisely and at higher velocities.

The snapshot array can be loaded with X-Z position pairs of increasing X value.
The X distances can be random, no equal distance or match with e.g. trigger distances required.
When snsm 11 is activated, Z travels at interpolated positions between the X points.
X positions below the first snapsot array entry will cause Z to remain at the first Z position.
X positions higher than the last entry will cause Z to remain at the last Z position.
The Z positioning will begin as soon as the snapshot mode is activated.
Z then is controlled by the snapshot array position list.
The snapshot array positions of Y and A axes are ignored in snsm 11.

```
!sns 0
!snsa 0                                      (clear the snapshot array / position list)
!snsa 1 [Xpos] [don't care] [Zpos]           (load X-Z position list first entry)
!snsa 2 ...                                  (load X-Z position list) ...
... !snsa N ...                               ...
!snsm 11                                     (enter X-Z focus mode)
!sns 1                                       (activate snapshot function globally)
?err                                         (send a request and wait for reply → completed)
```

Example: `!snsa 1 5.1 0 2.33`
`!snsa 2 7.1 0 5`
`!snsa 3 11.7 0 1.65`

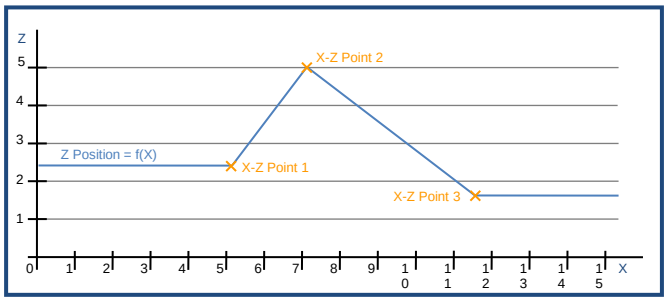



**Figure 2: X-Z focus application (snapshot mode 11)**

## 23.6. snsc (Snapshot Counter)

| | |
|---|---|
| Syntax: | !snsc or ?snsc |
| Parameter: | none, 0 or 1 to 1024 (not greater than the current snsc count) |
| Description: | This instruction reads or sets the snapshot counter, which shows the snapshot array entries (counted snapshot events). This instruction may also be used to reset the counter to zero or reduce the size of an existing array. |
| Response: | Current snapshot array entries (number of snapshot events) |
| Example: | |
| ?snsc | Read the number array entries (e.g. captured snapshots) |
| !snsc | Clear snapshot counter to zero elements |
| !snsc 0 | Clear snapshot counter (same as !snsc without parameter) |
| !snsc 50 | Reduce snapshot array entries to 50 (only if the current snsc value is equal or higher than the new value) |

## 23.7. snsi (Snapshot Index)

| | |
|---|---|
| Syntax: | !snsi or ?snsi |
| Parameter: | none or 0 to 1023 (less than the current snsc count) |
| Description: | This instruction reads or sets the snapshot array pointer.<br><br>In snapshot modes 1 and 5 this pointer access can be used to manipulate the array index where move target positions are read from.<br><br>Opposed to other snapshot instructions the index range here is [0...N-1] instead of [1...N]. The value must be less than the amount of **snsc** array entries. |
| Remarks: | The pointer is only used for the snapshot move. It does not define the array index where positions are written to. Captured positions are always appended as the last element of the array. For array manipulations by software please refer to **'snsa'** and **'snsp'**. |
| Response: | Current snapshot array pointer |
| Example: | |
| ?snsi | Read the current array pointer position |
| !snsi 0 | Set array pointer to the first element |
| !snsi | Same as !snsi 0 |
| !snsi 20 | Set array pointer to the 21st element |

## 23.8. snsaxis (Snapshot Axis)

Syntax: !snsaxis or ?snsaxis
Parameter: x, y, z, a or none
0 or 1

Description: Defines which axes should wait in Snapshot mode 6.
Please refer to '**snsm**' for further information.
When sending a moa, mor or speed instruction with snsm 6, axes can be specified that should not execute the move until triggered by a snapshot-in event. This can be used in cases where precise start timing has to be controlled by an external signal (maybe also set the '**trigf**' value to zero then).

**1** = move or speed of this axis will wait for snapshot signal
**0** = axis does not wait for snapshot signal (default operation)

Remarks: If not all axes are set to waiting mode, a vector move may start some of the axes wihle the others are waiting.
Such problem does not exist when using single axis move/speed instructions.

Response: Wait mode setting of the axes

Example:

| | |
|---|---|
| !snsaxis 1 0 1 | Set axis X, Z to waiting mode, Y does not have to wait |
| !snsaxis y 1 | Set axis Y to waiting mode |
| ?snsaxis | Read waiting mode of all available axes (e.g. returns "0 0 0") |
| ?snsaxis z | Read waiting mode of Z axis only (e.g. returns "1") |

## 23.9. snsp (Snapshot Position)

Syntax: !snsp or ?snsp
Parameter: x, y, z, a or none
Positions (unit depends on **'dim'**)

Description: Read the last captured Snapshot Position or append a new snapshot array position. The snapshot counter **'snsc'** is incremented automatically.

Remarks: Only motor positions can be read. For reading a captured encoder position, please refer to **'?snsa -1'**.

Response: Last captured Snapshot position(s) of the specified axis or of all available axes. The unit depends on **'dim'**.

Examples:

| | |
|---|---|
| ?snsp | Read last captured snapshot position of all axes |
| ?snsp z | Read last captured snapshot position of Z axis only |
| !snsp 8.5 50.2 | Append a new X and Y entry (then only X and Y axes will be used for positioning, Z and A will remain at their positions) |
| !snsp y 20.5 | Append a new position entry with Y-axis position only |

## 23.10. snsa (Snapshot Array)

Syntax: !snsa or ?snsa
Parameter: x, y, z, a or none
-1, 0 or 1 to 1024 and up to 4 positions in the current **'dim'**

Description: Read, fill, modifiy or clear the snapshot position array, which may contain up to 1024 entries.
For reading a valid entry, the index must have a value between 1 and the snapshot counter value **'?snsc'**.

| **Index** | **Function** |
|---|---|
| **-1** | read the last entry or append a new entry |
| **0** | clear the entire array (also sets snsc to 0) |
| **1...1024** | r/w access to the corresponding array entry |
| **[*snsc*+1]** | like -1, an index of the number of entries +1 can be used to append a new entry |

Remarks: Captured positions can be read as motor- or encoder positions, depending on the **'encpos'** setting. Axes without encoders or array entries written by software (via !snsa or !snsp) only return the motor position.
When writing array entries via !snsa or !snse, only the here specified axes will be used for positioning in e.g. **snsm** 1. See examples below. Captured positions always move all axes.

Response: Snapshot array position(s) in **'dim'** units.

Examples:

| | |
|---|---|
| ?snsa 1 | Read all axis positions of the first snapshot entry |
| ?snsa -1 | Read all axis positions of the last snapshot entry |
| ?snsa z 99 | Read the Z-axis position of the 99$^{th}$ snapshot entry |
| ?snsa y -1 | Read the Y-axis position of the last snapshot entry |
| !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 50 50 2.8 7 | Set or overwrite all 4 axis positions of the 2$^{nd}$ array entry |
| !snsa -1 8.5 50.2 | Append a new X and Y entry (only X and Y axes will be used for positioning, Z and A will remain at their positions) |
| !snsa y -1 20.5 | Append a new array entry with Y position only |

## 23.11. snse (Snapshot Event)

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

Description: Executes HDI F-key Snapshot functions via the communication interface. Instead of pressing a Joystick button or using the AUX I/O signal, the functions can be triggered by software:

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

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

Response: -

Example:
snse 2 Execute F2 Snapshot event (e.g. capture current position to the snapshot position array)

## 23.12. snsv (Snapshot Voltage)

Syntax: !snsv or ?snsv
Parameter: 1 to 1024 or -1 to -1024

Description: Read the AUX I/O ANIN0 input voltage (0...5V), captured at the specified position array index. The value can also be written to (i.e. as temporary data storage)
Index > 0: read Voltage in [mV]
Index < 0: read raw ADC data

Remarks: The specified index must be in the range of ±1 to ± ?**snsc**.
The [mV] values are always calculated with the internal voltage reference, while the raw data is the direct ADC sampling result which may be less accurate (only PCI-E based TANGOs have an accurate ADC sampling result).
The raw data range is always 12bit, but with PCI-S based controllers the 2 LSBs are always zero (10bit resolution).

Response: Voltage in [mV] or in [12bit ADC raw data]

Example:
?snsv 2 Read captured Voltage [mV] of 2nd snapshot array entry
?snsv -2 Read captured Voltage [raw] of 2nd snapshot array entry
!snsv 5 1234 Store the value 1234 in 5th snapshot array voltage element

# 23.13. snsj (Snapshot Jump)

Syntax: !snsj or ?snsj
Parameter: x, y, z, a or none
Positions (unit depends on **'dim'**)

Description: Sets the jump distance for snapshot-initiated relative moves. The unit of the position depends on the **'dim'** setting. Depending on the snapshot mode **'snsm'**, the jump is executed either by HDI (e.g. Joystick) function keys or via the AUX I/O snapshot input:

snapshot mode **snsm** 9:

- HDI F2 key = jump (move relative) in the specified direction
- HDI F1 key = jumps in the opposite direction (backwards)
- The **snse** 1 and **snse** 2 instructions can be used also

snapshot mode **snsm** 10:

- AUX I/O snapshot input jumps in the specified direction only

Response: Position value(s)

Examples:

```
!snsj z 1.5         Set the jump distance for Z axis to 1.5 (mm if dim= 2 or 9)
!snsj 1 -10 0 0.2   Set the jump distance for all axes (here Z does not move)
?snsj y             Read the jump distance of the Y axis
?snsj               Read the jump distance of all axes
```

## 23.14. prehome (Snapshot PreHome Position)

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

Description: This instruction sets the prehome position used by the snapshot extended move. The unit of the position depends on the setting of **'dim'**.

Remarks: Used in snapshot modes (**snsm**) 2 and 7.

Response: Position value(s)

Examples:

| | |
|---|---|
| !prehome y 10.2 | Set prehome position Y-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 position of X axis only |
| ?prehome | Read currently used prehome positions of all axes |

## 23.15. home (Snapshot Home Position)

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

Description: This instruction sets the home position used by the snapshot extended move. The unit of the position depends on the setting of **'dim'**.

Remarks: Used in snapshot modes (**snsm**) 2 and 7.

Response: Position value(s)

Examples:

| | |
|---|---|
| !home y 10.2 | Set home position Y-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 position of X axis only |
| ?home | Read currently used home positions of all axes |

# 24. Glossary

**TANGO** Motion controller for stepper motors, also called « controller ».

**PCI-S,DT-S** TANGO controller type for PCI slots.
Name is TANGO DT-S if used in TANGO Desktop.

**PCI-E,DT-E** TANGO controller type for PCI-E slots. Offers greater functionality compared to the PCI-S. Name is TANGO DT-E if used in TANGO Desktop.

**TANGO mini** A small 2 axis / 1.0 ampere controller with RS232 connector.

**TANGO 3 mini** Same size as the TANGO mini, but with up to 3 axes / 1.25A and much more features, performance and functionality of a TANGO DT-E.

**AUX I/O** Optional extension connector for PCI-S and PCI-E based TANGOs and TANGO Desktop. Provides analog and digital I/O, safety and trigger functionality. For TANGO 3 mini please refer to AUX mini.

**AUX mini** AUX I/O of the TANGO 3 mini controller.

**HDI** Human Device Interface, manual control of the axes, e.g. a Joystick.

**LED100** Optional LED illumination unit for microscopes

**Multi-IO** Optional I/O connector for TANGO DT-E, PCI-E: 12xIN/8xOUT (24/12/5V)
**IO1** Optional I/O connector for TANGO DT-E, PCI-E: 24xIN/8xOUT (24/12/5V)

**Cal** Causes axes to travel towards the lower limit switch (E0).
Usually the zero position is also set by this instruction.

**Rm** Causes axes to travel towards the upper limit switch (EE).
Usually executed directly after cal, he nit also disables the secvel velocity limitation.

**Secvel** Secure velocity which limits the axis travel velocity as long as no cal and rm has been executed. Ment to protect the axes from damage when traveling too fast into the axis hardware limits.

**Snapshot** Trigger input functionality, also available with joystick key F2.

**Closed Loop** The axis position is controlled according to a measuring system.

# 25. Document Revision History

| No. | Revision | Date | Changes | Remarks |
|---|---|---|---|---|
| 01 | A | 27. March 2012 | Newly revised and extended document version | Based on TANGO firmware revision 1.57 |
| 02 | B | 16. April 2012 | Added instructions:<br>Ecomove, noled, calrequired, joychangeaxis, ctrsm, ctrs, trigo, trigcomp, trigenc, snsi, snsaxis, snsv, zwfactor, detext, posclr, maxaxis, trigbwidth, trigbdelay, trigbf, encrefvel, vrm, flash, etspresent, stagesn<br>Added stop and stoppol modes<br>!joy instruction autostatus behavior | Based on TANGO firmware revision 1.57 |
| 03 | C | 03. May 2012 | caldir marked as dummy, naming conventions, version instruction | |
| 04 | D | 18. July 2012 | Remarks concerning closed loop behavior and (current) reduction | |
| 05 | - | 30. July 2012 | digin, digout, diginpol, digintyp, digoutpreset | Based on TANGO firmware revision 1.57 |
| 06 | Prelim E | 06. Sept. 2012 | Added:<br>Glossary of common terms,<br>Joystick Key Assignment chart<br>Second Trigger Output description<br>Multi I/O instructions edigin, edigout, ediginpol, edigintyp, edigoutpreset<br>Adapted to naming conventions<br>Improved description of HDI | Based on TANGO firmware revision 1.58 |
| 07 | E | 18. Feb. 2013 | Added: anamode, trigr, corrst | Based on TANGO firmware revision 1.60 |
| 08 | F | 25. June 2013 | Added I/O communication error 77<br>?ver instruction “Ver:” to “Vers:”<br>Improved vrm description | |
| 09 | G | 23. Aug. 2013 | Improved go, speed, vel description | Final documentation of firmware 1.60 |
| 10 | Prelim H | 23. Aug. 2013 | Extended functionality of “go” and “vel” instructions | Based on TANGO firmware revision 1.60C |
| 11 | H | 04. Sept. 2013 | Added “!mol” and “lockpos” | Based on TANGO firmware revision 1.60C |
| 12 | I | 16. Oct. 2013 | Added “!pa 2” | Based on TANGO firmware revision 1.58 |
| 13 | Prelim J | 02. Dec. 2013 | Added multiple manual trigger pulses description | Based on TANGO firmware revision 1.60C |
| 14 | Prelim J | 06. Dec. 2013 | Added scanmode 3 | Based on TANGO firmware revision 1.63 |
| 15 | J | 20. Oct. 2014 | Corrected “limctr” description<br>Added new ctrstatus option,<br>Added hdimode options for LED100<br>Added “zwpos”,“enctype”, “brake”, “trigl” instructions<br>Improved descriptions<br>Added snapshot mode “snsm 9” (jump mode) and “snsj”<br>Added calvel, rmvel with one parameter<br>Mentioned “trigenc” encoder trigger position limitations<br>Added snsm 10<br>Extended description of “trigs”<br>Revised closed loop descriptions<br>Added “calzeropos” and”tvr” instructions | Final documentation of firmware 1.65 |

| No. | Revision | Date | Changes | Remarks |
|---|---|---|---|---|
| 16 | Prelim K | 02. April 2015 | Corrected snsm 10 description, added liquid dispenser instructions “drop” and “pump”, extended “a” description, added LED100 example for adigout | Based on TANGO firmware revision 1.66 |
| 17 | Prelim K | 21. Sept. 2015 | Added “clim” instruction, added hdimode bit 8 | Based on TANGO firmware revision 1.66 |
| 18 | Prelim K | 21. Oct. 2015 | Extended trigr description | Based on firmware 1.66 and 1.60H/1.60S |
| 19 | Prelim K | 30. Oct. 2015 | Extended speed and velfac description | |
| 20 | K | 10. Nov. 2015 | Document released for TANGO Firmware 1.66 | Based on TANGO firmware revision 1.66 |
| 21 | - | 01. Dec. 2015 | Corrected trigenc description for TTL Added lock and lockstate bits 14, 15 | |
| 22 | L | 22. Dec. 2015 | Revised release for TANGO Firmware 1.66 | Based on TANGO firmware revision 1.66 |
| 23 | M | 13. Jan. 2016 | Improved trigger, “trigs” and 1:1 trigger output mode description | |
| 24 | | 20. Jan. 2016 | Improved descriptions of LED100 | |
| 25 | | 27. Jan. 2016 | Improved and corrected encoder descriptions (encerr = e) etc. | |
| 26 | N | 16. Feb 2016 | Added “trigp”, “trigc”,”trigi”, “iscur”, “snsm 11”, Improved trigger description, Improved and extended snapshot mode “snsm” descriprion | Final documentation of firmware 1.67 |
| 27 | O | 11. July 2016 | Improved descriptions, added “?hdi -1”, corrected response description for cal/rm and move instructions. | Based on TANGO firmware revision 1.68 |
| 28 | | 20. July 2016 | Corrected ”refdir” description,<br>Improved descriptions | |
| 29 | | 31. Aug. 2016 | Added “edigrly”,<br>Added “anamode” setup example<br>Corrected “?anain” motor voltage calculation | |
| 30 | | 06. Sept. 2016 | Added “hdimode” bit 9: Swap Joystick Y and Z axes | Based on TANGO firmware revision 1.68 |
| 31 | | 18.Oct. 2016 | Added “configdisplay”, improved “noled” and “accelfunc” descriptions | Based on TANGO firmware revision 1.67 |
| 32 | | 20. Dec. 2016 | Added adigintyp, adiginfunc<br>Added TANGO 3 mini sections to anain, anaout, anamode, adigin, adigout, brake, stoppol and drop<br>Added new Error Numbers<br>Improved descriptions | Based on TANGO 3 mini firmware 1.68 |
| 33 | | 01. March 2017 | Added "ctrd" parameter -1, Imroved ctrd+ctrc description | Based on TANGO firmware 1.68 |
| 34 | | 29. March 2017 | Improved "scanmode" and "modulomode" description | |
| 35 | P | 15. May 2017 | Removed formatting error (20 was shown instead of the parameters throughout the document)<br>Improved trigger description, added TANGO 3 mini | Based on TANGO firmware 1.68 |
| 36 | Q | 12. Jan. 2018 | Improved I/O description and influence of the brake function<br>Improved "anaout", "keymode" and “keyspeed” descriptions | |

| No. | Revision | Date | Changes | Remarks |
|---|---|---|---|---|
| 37 | | 09. March 2018 | Added hdimode bit 10 description<br>Added ctrdiff 1 option<br>Changed Firmware from 1.68 to 1.69<br>Extended anamode description | Based on TANGO firmware 1.69 |
| 38 | R | 26. March 2018 | Added decription of cal, rm behavior and nosetlimit to the !lim instruction | |
| 39 | | 25. May 2018 | Moved autostatus description from chapter "Controller States and Error Messages" to "Operating Modes" | |
| 40 | | 01. Aug. 2018 | Added "calst" instruction<br>Improved introduction, improved descriptions of closed loop and several instructions | Based on TANGO firmware 1.70 |
| 41 | S | 12. Sept. 2018 | Added "brakepos" instruction | Based on TANGO firmware 1.70 |
| 42 | T | 22. Nov. 2018 | - | Release for TANGO firmware 1.70 |
| 43 | | 09. May 2019 | Updated "ctrdiff" documentation<br>Added "?enc 1" option | Based on TANGO firmware 1.71 |
| 44 | | 22. May 2019 | Added "encsync" instruction | |
| 45 | U | 04. June 2019 | Improved "lim" and "secvel" description | Release for TANGO firmware 1.71 |
| 46 | | 25. June 2019 | Improved "usteps" description | |
| 47 | | 18. July 2019 | Improved description of the second trigger output and the snsj instruction | Based on TANGO firmware 1.72 |
| 48 | | 28. Aug. 2019 | Extended and updated "encpos" description<br>Added "configencpos" description<br>Added "calmode" 3, 4, 5 description<br>Extended and updated "uptime" description | Based on TANGO firmware 1.72 |
| 49 | V | 06. Nov. 2019 | Added “!pa 3” | Final documentation of firmware 1.72 |
| | | 09. March 2020 | "adigintyp" and "adiginfunc" changed from AUX mini to TANGO 3 mini | |
| | | 13. March 2020 | Improved description of "go" | |