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Product Manual

NANOBENCH 6000 USER MANUAL

Instructions for use of the Nanobench 6000 PC Application

Version 1.0.19

Table of Contents

Related documents

Document Ref	Title	Usage
EN-002246-UM	NPC-D-5000 NanoMechanism Controller – User Manual	User manual for the 5xx0 series controller
EN-002958-UM	NPC-D-5000 Series NanoMechanism Controller - Command Set And Control System	Lists and explains usage of NPC-D-5xx0 controller commands and structure of control system
EN-014217-UM	NPC-D Series NanoMechanism Controller - Controller Interface Library	Details the usage of controller interface DLL in order to send commands to the controller
EN-014429-UM	NPC-D-6xx0 Series NanoMechanism Controller - Command Set And Control System	Lists and explains usage of NPC-D 6xx0 controller commands and structure of control system
EN-014635-UM	NPC-D-6xx0 Multi-Channel NanoMechanism Controller - User Manual	User manual for the 6xx0 series controller

1 Introduction

1.1 System overview

The Queensgate digital controllers are part of a closed loop positioning system which utilises piezo actuators in a flexure guided NanoMechanism (also referred to as a “Stage”). The controller incorporates a high voltage power amplifier to drive the piezo electric actuator and a precision capacitive positional sensor measurement circuit for closed loop operation.

Software is provided to allow customers to command controller movement and configure controller behaviour for the system in which the controller is used.

The Nanobench 6000 software provides a graphical user interface to allow manual control of this process by an operator, but does not allow control by other software as part of a system. The controller interface DLL is therefore supplied alongside Nanobench 6000. As a simple “C” style DLL, it provides the same commands as Nanobench 6000 but can be easily integrated with any other Windows-based software. The function call API for this DLL is documented separately in the controller interface library user manual EN-014217-UM and will not be covered here.

All users must be clear that the digital controller only provides limited protection against configurations which would cause damage to a connected stage. Clearly customers will wish to configure the system behaviour to meet their own requirements, but configuration must be performed by engineers or technicians who have sufficient expertise to carry it out safely.

1.2 Control system overview

The commanded position may be set from the analogue input or via digital commands from the host PC. Both may be used simultaneously if required, in which case the two commands will be summed. If a feedforward boost is required on command changes, high-pass filters may be used to add this. If step changes in commanded position produce excessive ringing as the stage settles, feedforward limiting of commanded position by acceleration, speed and deceleration may be used to reduce transients.

The controller may be operated in open-loop or closed-loop modes. Open-loop mode allows direct drive of the actuator from the input(s), with the benefits of digital control of the open-loop gain and a digital notch filter to control resonance, as well as accurate reporting of measured position. Closed-loop mode of course acts to control the measured position to the commanded position, again with a digital notch filter to control resonance. When in closed-loop mode, the “in position” status and digital output may be used for external systems to be alerted that the commanded position has been reached.

To reduce system noise in some measurement applications, the actuator may be frozen at the current position. This is typically used for fast measurements where actuator drift will be negligible but noise from closed-loop control may be significant. The controller includes soft-start mechanisms to reduce sudden movements on power-on and on mode changes wherever possible.

2 Installation

2.1 Package

The installation folder may be distributed as a zipped folder, in which case it needs to be extracted before use.

2.2 LabVIEW Runtime Engine

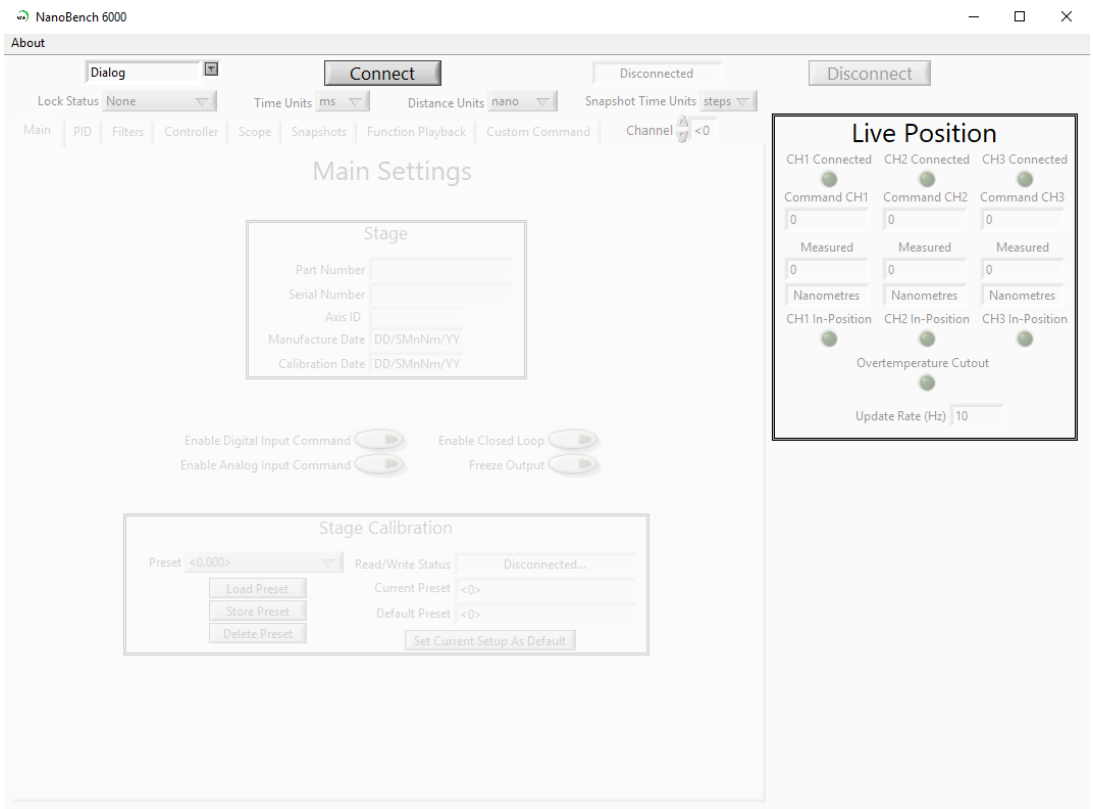
The LabVIEW runtime engine is needed for this application. It can be installed from www.ni.com/download/labview-run-time-engine-2017-sp1/7191/en/, though the software will direct the user to that address if the runtime engine is not already installed.

2.3 Setup

1. Run setup.exe from within the installation package
2. Choose the default installation directory (“C:\Program Files (x86)\NanoBench 6000\”)
3. Click “Next” to begin the installation
4. Wait for the process to complete, then click “Finish”

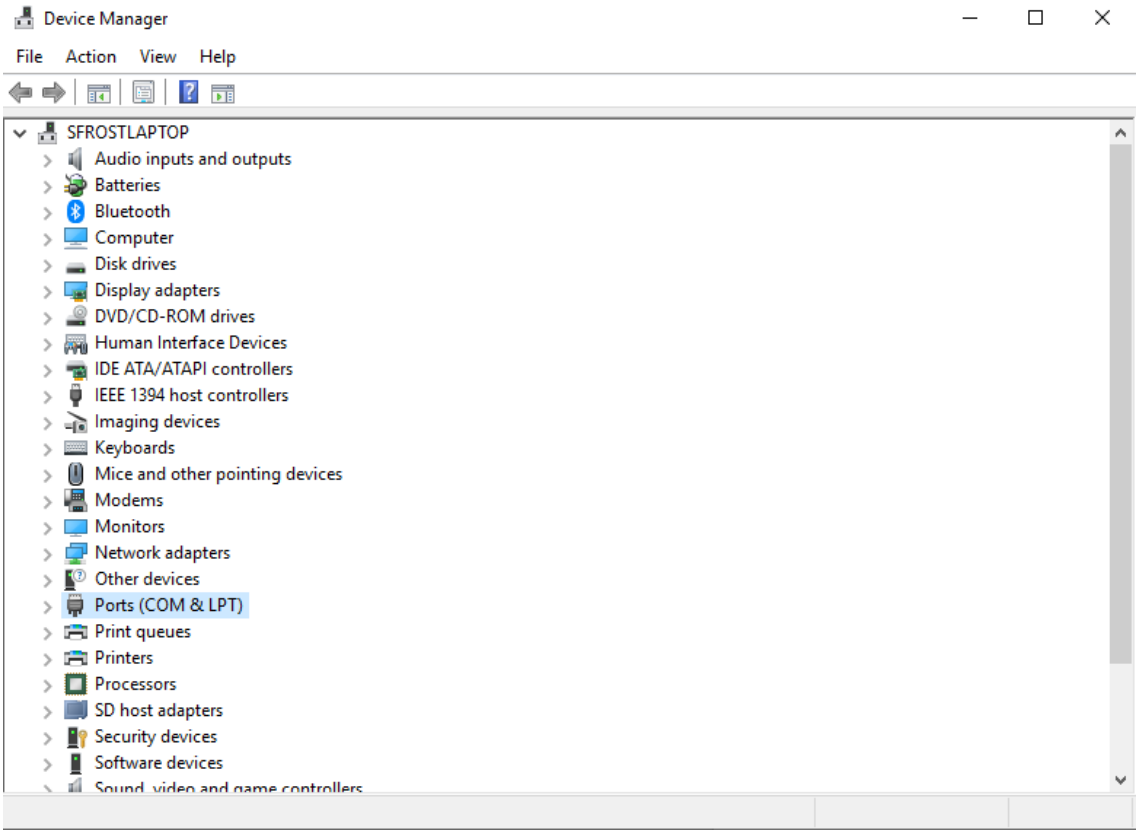
2.4 First Run

A shortcut to the application will be placed on the user’s desktop and in the start menu. Run either of the shortcuts to start the application and you should be presented with the main screen.



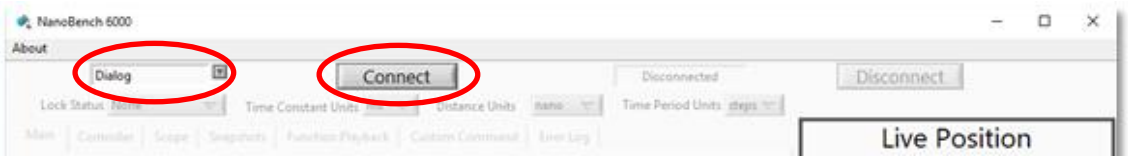
2.5 Connecting Controller

In order to connect to the controller, ensure it is plugged in via USB and identify the COM port. To find the COM port, click the Windows Start button, and type ‘Device Manager’. Open device manager and look under ‘Ports (COM & LPT)’ to find the port number that the controller is connected to.



Select the port in the dropdown circled below, and click “Connect”.

If the connection was successful, parameters will be loaded from the stage and displayed on-screen, with the measured position updating at the selected update rate (10Hz by default).



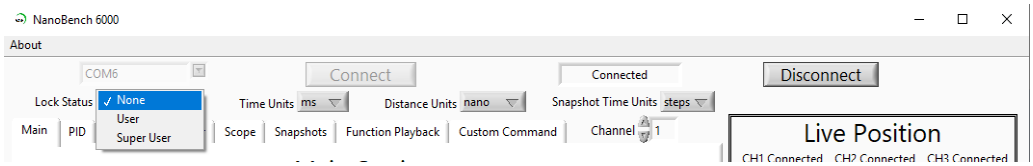
3 General Operation

3.1 Security

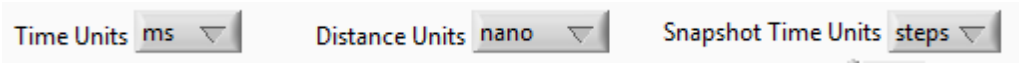
The controller utilises a number of security levels, which enable or disable certain commands/controls depending on the selected level. As a standard customer, the available security levels will be “None”, “User”, and “Super User”. To determine which commands will be available using each security level, consult the API documentation in the document EN-014429-UM (NPC-D series nanomechanism controller - Controller interface command set).

When switching security level, it is important to be aware that certain changes can cause damage to the stage mechanism or controller. For example setting the integrator time constant (“User” security) to too small a value can cause instability which will damage the stage. When switching to a higher security level, the Nanobench software will alert the user to these dangers.

To change the security level from within Nanobench 6000, use the “Lock Status” dropdown.



3.2 Unit Selection



To the right of the “Lock Status” dropdown, there are three unit-selection dropdowns that control the way that parameters appear in the application.

Time units apply to all time-based controls and graphs, and everything labelled as a time constant, for example the “Integrator Time Constant” may appear as 10 when “ms” is selected, or 0.01 when “S” is selected. Options are:

- µs = microseconds (s x 1000000)
- ms = milliseconds (s x 1000)
- s = seconds

Distance units apply to everything that shows a displacement, for example commanded/measured position, snapshot amplitude, and in-position threshold. Options are:

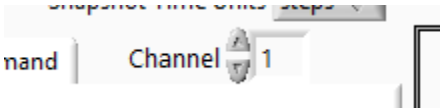
- Pico = picometres / picoradians
- Nano = nanometres / nanoradians
- Micro = micrometres / microradians

Snapshot Time units apply to the snapshot tab, where capture time / leading edge / trailing edge and the graph display are determined by the selected units. Options are:

- Steps = Controller steps, or 0.02ms intervals (1/50k, clock rate of controller)
- µs = microseconds (steps x 20)
- ms = milliseconds (steps x 20,000)
- s = seconds (steps x 20,000,000)

3.3 Channel Selection

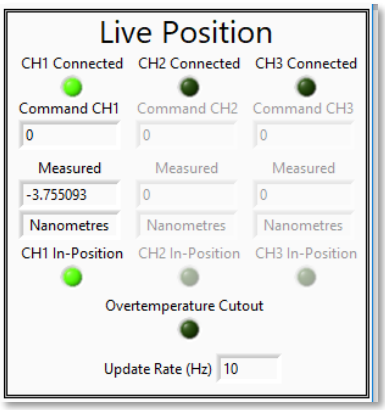
The channel selection control is located at the top of the screen, just underneath the units controls.

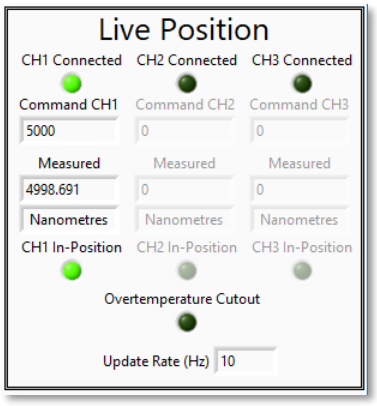


Changing the channel will result in all parameters being read from the newly selected channel and displayed on screen. Always ensure that the correct channel is selected when changing parameters.

3.4 Position Control

In order to control the position of the nanomechanism in the simplest manner possible, simply type a new position in the relevant channel's "Command" box and press enter. The stage will move to the commanded position and display a similar value in the "Measured" box once the move is complete.





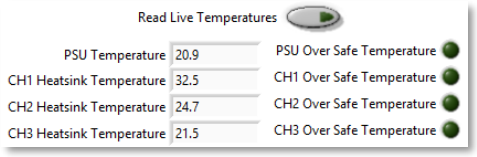
The in-position LED below the measured position indicates when the stage is considered to be at the commanded position. This occurs when the position error (i.e. measured position – commanded position) is less than the "In-Position Error Threshold".

3.5 Temperature Cutout

The "Overtemperature Cutout" LED illuminates if the controller has performed a safety shutdown because certain areas of the controller circuit board have reached a temperature that may cause damage to the controller.

If this occurs, check that the air vents in the controller are not covered, as this will hamper air flow and therefore allow the controller to heat up. If the vents are uncovered but the overtemperature cutout reoccurs, contact Queensgate for an assessment.

For more in-detail information, go to the “Controller” tab and check the displayed temperatures.

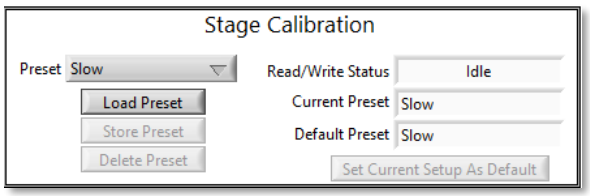


4 Main Tab

4.1 Mode Controls

The buttons at the top of the main tab control the “mode” of the stage. Closed loop with digital input is the standard configuration, however some customers also have analogue input turned on as default as well. Freeze output is only used for debugging/investigation purposes.

4.2 Stage Calibration



Each stage calibrated at Queensgate will be shipped with a minimum of three dynamic setups. These setups are a collection of settings that can be reloaded as needed, with each setup having an ideal use-case. For example, the “Slow” settings are usually better for low-bandwidth, low-noise measurements, whereas the “Fast” settings are usually better for faster bandwidth and dynamic step/settle response.

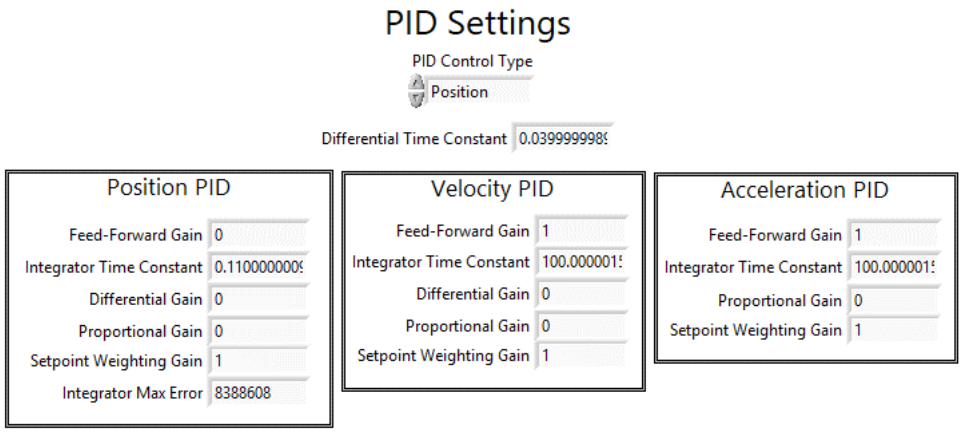
To load a setting, select it in the list and click “Load Setup”. Be very careful when overwriting or deleting setups as you may lose important settings. The “Fast”, “Medium”, and “Slow” setups cannot be overwritten by customers as they are configured by Queensgate as factory presets.

4.2.1 Non-Volatile Settings

Note that any time settings are changed, they will persist until the controller reboots. When this happens, the default preset will be loaded. If settings were not stored to a preset (e.g. customer 1) before rebooting then they will be lost. All controls on the ‘Main’ tab are stored in presets using the stage calibration controls.

5 PID Tab

5.1 PID Settings



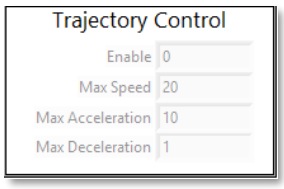
The control loop consists of three PID control loops, controlling position, velocity, and acceleration respectively. The 'PID Control Type' drop-down allows the selection of position, position & velocity, or position & velocity & acceleration.

The controller relies on a number of parameters to determine how these PID control loops work, for example the speed of the integrator term or the proportional gain. These settings can be tuned to improve stage dynamic performance in certain applications, for example if the stage load has changed.

In most cases, the settings stored by Queensgate during calibration will be the best settings possible, however in some cases these parameters can be improved – preferably with the assistance of Queensgate engineers.

Please do not modify these parameters without being aware of the risks – incorrect settings can cause stage instability which can cause mechanical damage. Damage that occurs under these circumstances will not be covered by any Queensgate warranty.

5.2 Trajectory Control

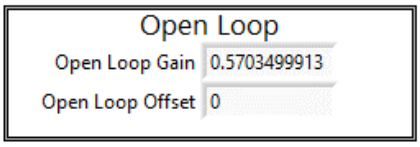


Trapezoidal trajectory control is used to limit the acceleration, deceleration, and speed of the stage. This may be used to reduce motion speed to improve step settle times, by reducing ringing imparted by high kinetic energy movements. This is particularly useful if the stage is driving a load that has its own mechanical resonances which the user wants to avoid exciting with high accelerations / decelerations.

The speed is set in nanometres per millisecond, and the acceleration/deceleration are set in nm/ms^2. For example, setting a speed of 1000 will limit the maximum travel speed of the stage to 1 micron per millisecond.

As with the other settings, these are calibrated at Queensgate and should be set up optimally, but can be adjusted if needed, preferably with Queensgate assistance.

5.3 Open Loop



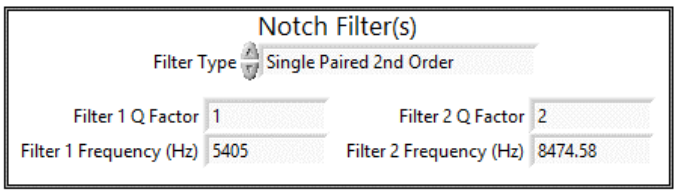
The open loop section defines the gain and offset applied to position commands while the stage is in open loop mode.

This is useful for configuring the stage where closed-loop control is not needed.

6 Filters Tab

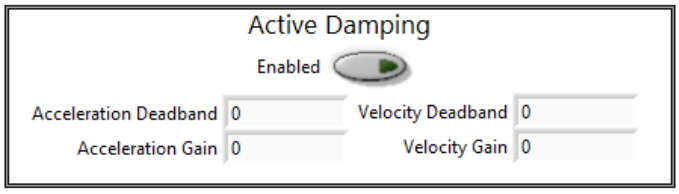
6.1 Notch Filter(s)

The controller implements a notch filter that is designed to prevent the control system exciting the first dominant resonance of the stage, and as such improve dynamic response. The notch filter settings can be adjusted if it is found that the resonance of the stage has changed when it is put into the final operating position, due to the stage being loaded or mounted differently.



Most of the time these settings will be optimal after calibration at Queensgate, but if adjustment is required it is suggested that the customer contact Queensgate for assistance.

6.2 Active Damping



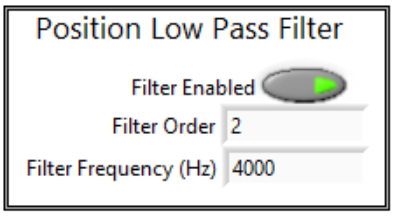
Active damping feeds back measured velocity and acceleration in anti-phase to damp stage movement. Active damping on velocity adds “virtual friction”, whereas active damping on acceleration adds “virtual mass/inertia”. The result is to add stiffness to the system through software control. Notch filters and active damping are available in both closed-loop and open-loop modes.

This can make the digital controller an attractive proposition even in open-loop applications where digital control would traditionally be considered overly complex or expensive. As with closed-loop control (see section 6.10), active damping requires that the phase shifts on measured velocity and acceleration calculations (see section 6.8) are acceptable at the frequencies of interest.

This is especially relevant for active damping; closed-loop control may have a bandwidth below the stage’s first resonance, but active damping will typically be required to operate at frequencies well above this.

Setting the filter cutoff appropriately for velocity and acceleration calculations is therefore vital when using active damping.

6.3 Position Low Pass Filter

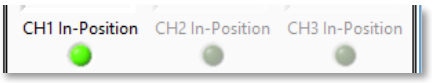


A low pass filter is implemented in order to smooth the stage position output. The settings for this low pass filter can be adjusted here, however these settings are very rarely changed unless a specific use-case is put forward. Contact Queensgate for assistance if needed.

6.4 In-Position Settings

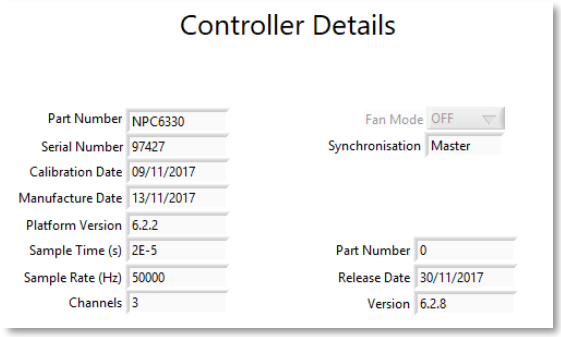
The controller includes functionality that indicates when the stage is within a certain tolerance of the commanded position, which can be used for timing of repeated movements/measurements. The in-position output on the controller is also displayed on the front panel in the live data section.

The algorithm uses a low pass filter to measure position without high-frequency interference, and determines if the measured position is within the ‘Error Threshold’ of the commanded position.



7 Controller Tab

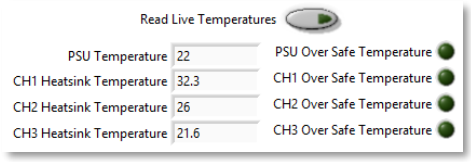
7.1 Controller Information



The controller tab gives basic information about the software and hardware in the controller. Most of the information is self-explanatory, however some may not be clear at first sight. On the left, the platform version refers to the firmware platform running on the controller. The sample time and rate refer to the clock speed of the circuit.

On the right, the part number, release date, and version relate to the firmware application installed on the controller, and the synchronisation field shows if this controller is set up to be a slave to another.

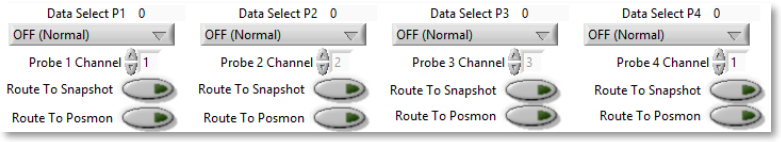
7.2 Temperature Monitoring (NPC-D-6xx0 only)



The controller is capable of monitoring temperatures at certain key points on the controller. The PSU temperature refers to the power supply circuit, while the heatsink temperatures refer to each channel's dedicated heatsink. The warning LED's illuminate when the controller has exceeded its safe operating temperature at the relevant monitoring point. These values will update when the controller is connected or whenever a new setup is loaded, unless "Read Live Temperatures" is selected in which case they will update at the chosen update rate as with measured positions.

8 Scope Tab (NPC-D-6xx0 Only)

8.1 Overview



The firmware offers functionality that allows certain points on the control loop to be ‘probed’ and the measured values read back. These values can be displayed on-screen, routed to a ‘snapshot’ (see Snapshot Tab section), or (for scope points 1-3) to the corresponding Posmon output. This is useful for monitoring IO, tuning control loop parameters, or general debugging.

There are four scope points that can be used to report data from any available channel. Each scope point specifies a “data selection”, which dictates the location at which the probe measures. For example, selecting “Analogue Input” and channel 2 on any of the four probe points would read the voltage from the analogue input BNC on controller channel 2.

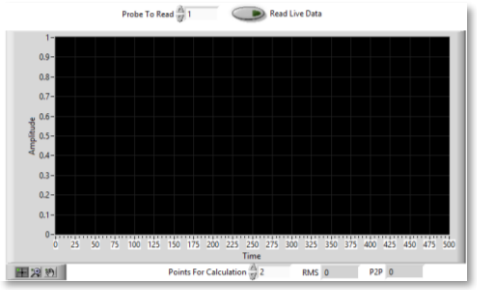
8.2 Data Selection

The data selection control defines where the probe is measuring. Refer to the command set manual EN-014429 section 5 which shows the control loop and which points can be monitored, and section 8.2 which lists all data selection options.

8.3 Snapshot/Posmon Output

These buttons allow the output from a probe to be routed to the snapshot function or the posmon (analogue output) BNC. If the “Route to Snapshot” button is selected, the next time a snapshot is run the relevant channel data will come from the probe instead of the measured position. This is useful if the probe needs to be measured at a high sample rate. If “Route to Posmon” is selected, the output from the Posmon BNC on the controller front panel will come from the relevant scope probe. This can also be useful for viewing the scope output on a physical oscilloscope.

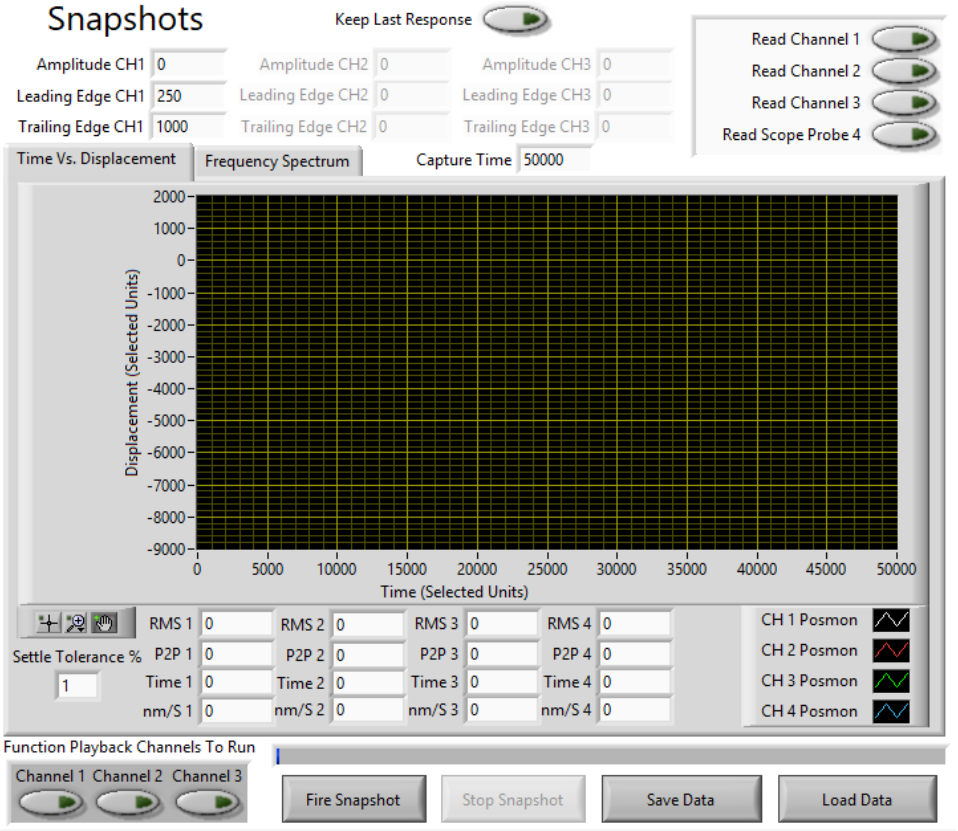
8.4 Graph



The graph is a tool for viewing the selected probe channel in real time. If “Read Live Data” is selected, the graph will update with the selected probe channel measurement at the selected update rate. This can be useful for seeing what is happening with a probe measurement in real time. The root mean square and peak-to-peak calculations can be seen underneath.

Note that the graph can only display a single probe’s data, and only at the selected update rate (max 150Hz). At lower sample rates the waveform may not display accurately due to aliasing. For more detailed analysis or multiple channels, use the output to snapshot function.

9 Snapshot Tab



9.1 Overview

The snapshot function allows the reading back of a finite period of data of up to 10 seconds (500k samples on NPC-D-5xx0 at 50kHz, 1.2M samples on NPC-D-6xx0 at 120kHz).

The default is that each channel reads back the measured position on the relevant controller channel, however if “Route to Snapshot” is selected on the scope tab then the channel output will come from the selected scope data.

9.2 Step Response

Each connected stage can be commanded to move a user-defined distance at a user-defined time in the finite period, which is intended to allow easy analysis of the step response. If more complex waveforms are needed, function playback can be used (see Function Playback Tab section).

9.3 Snapshot Setup

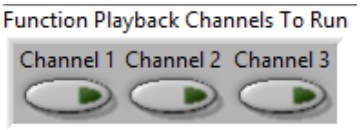
Each of the three controller channels can be commanded to step with user defined amplitude at a specific time during the snapshot, and return to the start position at a later time. The ‘Amplitude’ control defines the size of the step, and uses the selected ‘Distance Units’. The ‘Leading Edge’ and ‘Trailing Edge’ controls define when the step will begin and end respectively, and both use the selected ‘Time Period Units’. The ‘Capture Time’ control defines the total time/length of the snapshot, and also uses the selected ‘Time Period Units’.

In order to read back a channel, the relevant button on the right (‘Read Channel/Scope X’) must be selected. Up to four channels can be measured simultaneously in one snapshot. Note that the fourth snapshot channel will only ever come from a scope point.

The ‘Live Readback’ button will force the data to be displayed on the graph as it is read back. Although this can be better from a visual perspective, it does have performance implications and takes longer to read for larger capture times. ‘Keep Last Response’ will keep all previous data on the graph when the next snapshot runs, which is useful for comparing data before/after a change.

To run the snapshot, click ‘Fire Snapshot’. A snapshot will normally run to completion, or it can be stopped with ‘Stop Snapshot’.

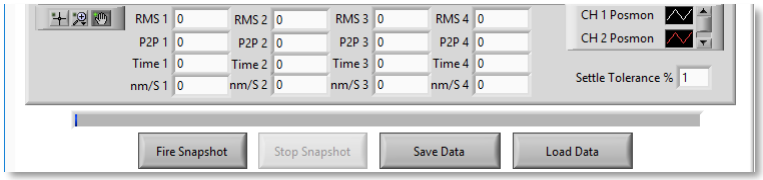
9.4 Function Playback Control



The user can choose to run any or all of the loaded function playback waveforms on the available channels. Selecting a channel will cause the function playback to start simultaneously with snapshot capture when ‘Fire Snapshot’ is clicked. This allows for easy analysis of the generated waveform and the behaviour of the stage during playback.

For more information on the function playback functionality, refer to section 10.

9.5 Data Processing



Once the snapshot has run and the data has been read back, a number of calculations will be run on the data. The RMS and P2P values are the root mean square and peak-to-peak values for the full dataset on each channel. RMS is calculated on the average position, i.e. as if the data averaged 0.

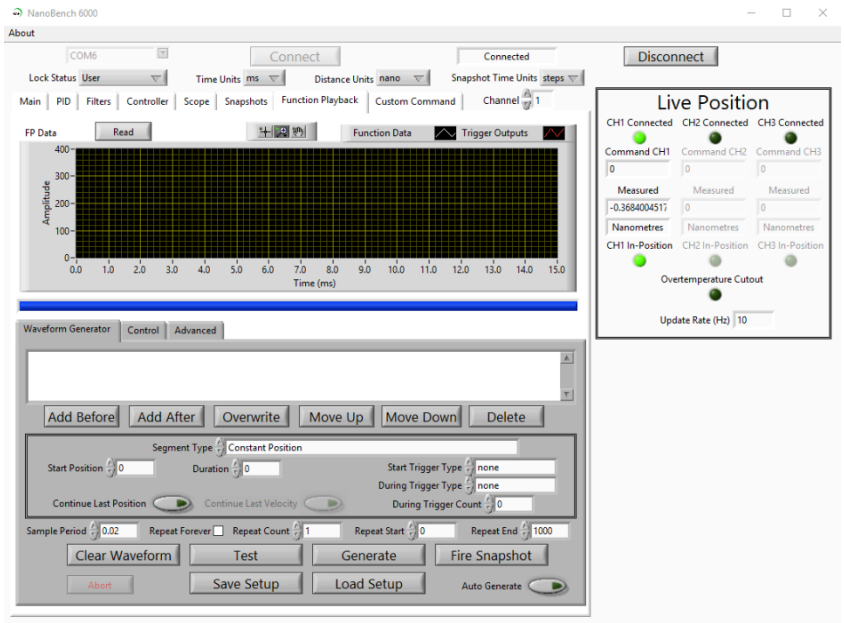
The ‘Time’ value is the calculated settle time, and is only relevant when a step is performed. The calculation uses the ‘Settle Tolerance %’ value to determine a window around the commanded position, the ‘Time’ value is then the last time the measured position was outside the tolerance window. For example, on a 100nm step with a tolerance of 5%, the ‘Time’ value will be the last time the measured position was >105nm or <95nm.

The ‘nm/S’ value is a calculation of the maximum movement speed that the data shows, in nanometres per second.

Data from the snapshot can be stored in a file by using the ‘Save Data’ button, and old snapshot data can be loaded back from files by using the ‘Load Data’ button.

10 Function Playback Tab (NPC-D-6xx0 Only)

10.1 Overview



Function playback allows pre-programmed position command waveforms to be played back on one or more channels. This allows the user to construct complex steps or ramps, sine waves, raster scans, or any other waveform as required. For less sophisticated controllers, this would typically require the PC to be fitted with a high-resolution DAC interface to drive the controller's analogue input, and software to be written which would send the appropriate commands to the DAC. With function playback this can be achieved much more easily, with much greater accuracy, and without requiring expensive additional hardware or complex software.

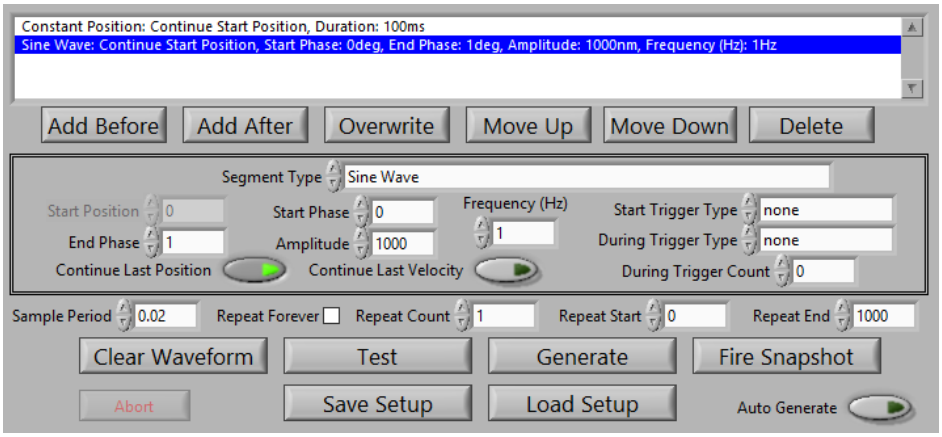
Each channel controlling a stage has its own function playback and waveform setup. Function playback may be run independently for each channel, where stages control elements of a system which are not connected. Alternatively function playback can be run simultaneously for two or three channels on multi-axis systems, allowing complex 2D or 3D paths to be programmed.

The function playback waveform generator allows the construction of complex waveforms with relative ease. Waveforms are constructed from "segments", where each segment of a waveform carries out some action. There are numerous different segment types, covering ramping, stepping to a position, various acceleration and deceleration curves, sine waves, and so on. For example, a waveform which ramps to a position, runs one cycle of a sine wave, ramps to a second position, holds position there for a fixed time and then ramps back to the start might be formed of 5 waveform segments carrying out the sequence "ramp up, sine wave, ramp up, hold a constant position, and ramp down" with appropriate configurations.

Note that generating or loading waveforms applies to the currently selected channel ONLY.

10.2 Segments (Waveform Generator Tab)

The below screenshot shows the segments list. This list shows all segments that are currently configured on the controller, including the type of segment and the relevant parameters.



10.2.1 Segment Type & Parameters

To add a new segment, first choose a segment type from the drop down list. For a full description of each segment type, see the command set user manual (EN-014429-UM).

Once a segment type is selected, the controls will rearrange to show the parameters for the chosen type. Enter values as necessary, again reference EN-014429-UM for further information on each of the parameters.

10.2.2 Trigger Outputs

The controller has one digital trigger output per channel which may be pulsed synchronously with the waveform during function playback to activate external equipment. The controller manual (EN-014635-UM for the 6000 series) specifies digital output connectors and logic levels, which will not be repeated here. Note that each channel only has one trigger output; there is no facility for one channel to trigger multiple outputs.

The trigger output may be activated at the start of a segment, or at evenly-spaced intervals during a segment. There is no provision for triggering at the end of a segment; set a trigger at the start of the next segment instead. Triggers can also be set at the start and end of the entire waveform.

To active these triggers, use the ‘Start Trigger Type’, ‘During Trigger Type’, and ‘During Trigger Count’ controls.

10.2.3 Continue Position/Velocity

For each segment, the user also has the option of whether to continue from the previous segment’s final commanded position (and commanded velocity for some segment types), making it easy to construct smooth waveforms, or whether to step to a new position.

The ‘Continue Last Position’ and ‘Continue Last Velocity’ buttons control this behavior.

10.2.4 Adding/Removing/Rearranging Segments

To add a new segment, set up the required parameters and click ‘Add Before’ or ‘Add After’. If the list is currently empty, either button will add the segment to the first position in the list. If the list is not empty, the buttons will add the configured segment either before or after the currently selected segment in the list.

Segments can be edited by selecting the segment in the list, editing the segments parameters, and clicking ‘Overwrite’. They can also be deleted by clicking ‘Delete’.

Segments can be rearranged by clicking the ‘Move Up’ and ‘Move Down’ buttons to change the position of the selected segment in the list.

10.3 Waveform Setup (Waveform Generator Tab)

10.3.1 Sample Period

Waveform segments are not played directly. Instead, the waveform generator must generate a series of sampled data points for the waveform which can be played back by the controller. The controller allows up to 500,000 points of sampled data in a function generator waveform, which equates to 10s of sample-accurate waveform playback at the controller’s 50kHz sample rate.

If a longer waveform is required, the sample rate for function generator waveform playback can be set slower. 500,000 points at a sample rate of 1ms would allow up to 500s of waveform playback, for instance.

A slower sample rate may also be chosen to allow the waveform generator to prepare data points more quickly. The more data points the waveform generator is required to calculate, the longer the preparation process takes. At slower sample rates, the controller ramps linearly between data points to reduce the impact of the slower sample rate

10.3.2 Repeat Controls

The waveform generator allows a section of the waveform to be repeated a number of times as required. The start and end segments of the repeat section and the repeat count are specified. After the section has carried out the specified number of repeats, the remainder of the waveform is run.

Repeated waveforms often require an initial section which moves the system to the required position, and a final section which returns the system to zero. Setting the start and end segments (using ‘Repeat Start’ and ‘Repeat End’ controls) for the repeated section allows this to be configured. Alternatively if the entire waveform is to be repeated, the start/end segments should reflect the first (0) and last segment.

Repeated waveforms may also be required to repeat forever. This is selected by setting the repeat count to zero. If the waveform needs to be stopped, the user must stop it manually using an appropriate “stop” command.

10.3.3 Testing & Generating the Waveform

The first step in waveform generation is to check that the waveform is valid. Parameters for segments must be validated, the time to carry out each segment must be calculated, and the entire waveform must be checked to ensure it fits within the number of sample points available.

To do this, click the ‘Test’ button. This will show a popup, which will show if the waveform is valid, or if there is an issue with a certain segment.

If the waveform is valid, the final step is to generate the waveform. Click ‘Generate’, which will signal the controller to begin calculating the required data points. This usually takes under a second, but can take a few seconds for longer waveforms. Once complete, the generated waveform will be read back from the controller and displayed in the graph at the top of the page, the progress of this read back is shown with the progress bar below the graph.

10.3.4 Auto Generate

The application contains a feature that performs a check on the waveform segments with every change that is made to the waveform, for example if a parameter on a segment is changed. This allows mistakes to be picked up more quickly.

To turn on this feature, click the ‘Auto Generate’ button.

Note that for longer waveforms, this may appear to slow down the user interface slightly.

10.3.5 Snapshot Test

The snapshot functionality in the controller can be taken advantage of in order to test the generated waveform. Clicking the ‘Fire Snapshot’ button will trigger the function playback to begin at the same time as the snapshot.

Note that the snapshot must be set up correctly on the ‘Snapshots’ tab before using this functionality. For example, if the snapshot is configured for a step command, or is set with too low of a capture time, results can be skewed.

After ‘Fire Snapshot’ is clicked, the function is executed and the true stage position is read back on the Snapshots tab. This allows the actual output of the actuator to be measured during playback of the waveform, which offers confirmation and finer tuning of a generated waveform.

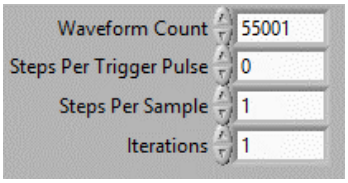
10.4 Saving/Loading Waveform Setups (Waveform Generator Tab)

Waveform setups can be stored to a given file on the PC, allowing a setup to be re-loaded easily at a later date.

To do this, click ‘Save Setup’, and select a file to store the information to. To reload a previously stored setup, click ‘Load Setup’ and select the relevant file.

10.5 Controlling Waveform Playback (Control Tab)

10.5.1 Generated Waveform Controls



Once the waveform is generated, a number of further controls come into play in relation to the generated datapoints.

‘Waveform Count’ specifies the number of clock cycles in the waveform, and will be set to the length of the waveform automatically when the waveform is generated. For example, a 100ms waveform would have a count of 5000 points (Clock rate 50k cycles per second, 0.02ms per cycle). This can be adjusted to cut the length of the waveform without editing the setup or re-generating. For example, changing count from 5000 to 2500 would cut playback to half of the original waveform.

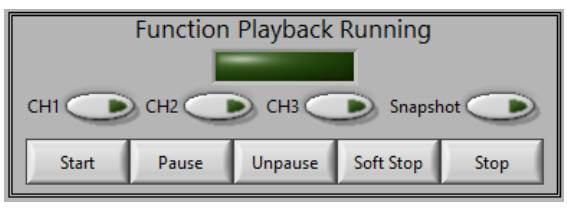
‘Steps Per Trigger Pulse’ relates to the trigger outputs selected in the waveform generator. For example, a value of 100 would mean that each trigger pulse causes the output to go high for 100 clock cycles (2ms).

‘Steps Per Sample’ defines the time that the controller will wait at each point on the waveform. For example, setting this to 2 would make the controller wait 2 clock cycles at each waveform point rather than the standard 1, which would turn a 10Hz waveform into a 5Hz waveform with less resolution.

‘Iterations’ defines how many times to repeat the waveform. For example, to repeat a 100ms waveform for a full second, set iterations to 10. Set iterations to 0 to repeat continuously. Note that if the start and end positions of the data are not the same a step will occur when the waveform repeats.

Note that all setup parameters are relevant to the selected channel.

10.5.2 Running/Stopping the Waveform



The waveform playback is commanded using the controls on the ‘Control’ tab. These controls are channel specific, allowing channels to be run separately or simultaneously as required.

Once a waveform is loaded and the required settings are in place, the function playback can be controlled using the buttons at the bottom of the page. The buttons can command the function playback on any channel to start, pause, un-pause (resume), soft stop (return to zero), or stop.

The channels to which the commands are applied are defined by which of the buttons on the right are selected. For example to start the function loaded in channels 1 and 2, select the ‘CH1’ and ‘CH2’ controls, then click the ‘Start’ button. To then pause the playback on channel 2 only, deselect ‘CH1’ (leaving ‘CH2’ selected) and click pause.

When stopping the playback, ‘soft stop’ resets the stage to its nominal position, whereas using ‘stop’ will leave the stage command position at the location where the playback was stopped. If the function is then started again after a non-soft stop, it will be offset by the residual command position.

10.6 Advanced Controls (Advanced Tab)

Note that this section is intended for those with a good understanding of the workings of the waveform generator and function playback functionality.

10.6.1 Custom Waveform (CSV File)

Waveforms can be generated manually by entering data into a .csv spreadsheet. To load a generated waveform into the controller, click ‘Load from File’ and select the waveform file. Once data is loaded it will be displayed on the “Function Data” tab – check the waveform before use

10.6.1.1 File Format

The generated waveform files are in .csv format, with the first column defining the index and the second column defining the command position. To set up custom waveforms, simply create a .csv spreadsheet with the first column starting at 0 and incrementing 1 each row, then put the desired command positions into the second column. Note that each index is one controller cycle, which on the NPC-6xx0 controller is 1/50k = 0.02ms.

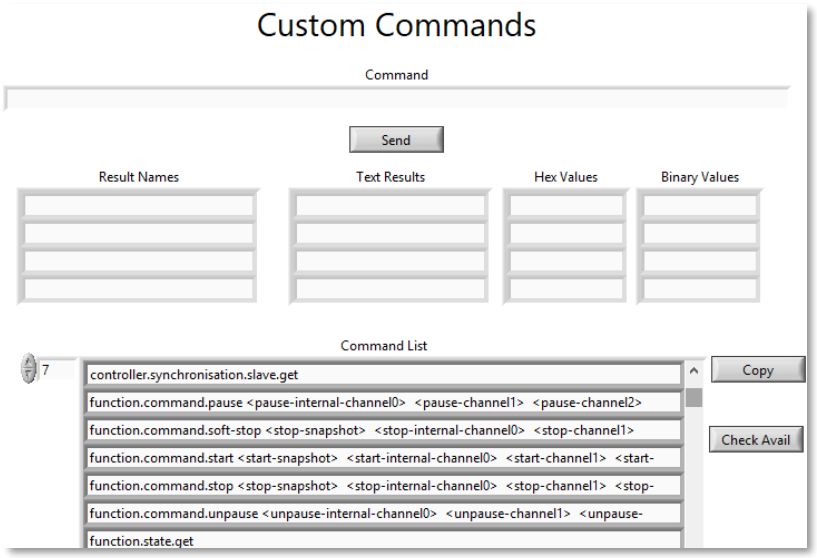
10.6.2 Command Transition

Command transition allows the controller to ramp smoothly from one point to the next when playing back a waveform, instead of stepping as quickly as possible. The number of clock cycles taken to ramp from one point to the next is defined by ‘Steps Per Sample’ as explained in the ‘Waveform Playback Setup’ section above. For example, if the distance between two points on the waveform is 100nm and command transition is on with 4 steps per sample, the controller will step from 0 to 25nm, 50nm, 75nm, and 100nm over 4 clock cycles (0.08ms), rather than stepping from 0 to 100nm in one clock cycle.

Command transition is set per waveform step, so command transition could be on for the move between waveform index/point 0 and 1, then off for the move between index/point 1 and 2. To turn on transition for a certain index, scroll to the index that will be moved to (for example to change the setting for transition between indexes 1 and 2, go to index 2), then turn on ‘Transition On’.

To read back all command transition settings for the loaded waveform (i.e. checking each index from 0 to ‘waveform count’), click the ‘Read’ button. Note this will take ~1ms per index, so completion time in seconds will be roughly the waveform count divided by 1000.

11 Custom Command Tab



11.1 Custom Commands

The custom commands tab lists all commands that are available on the selected security level. This allows the user to see all commands, run them manually, and read back the response rather than using the on-screen controls.

To run a command, simply enter it into the ‘command’ box and click ‘Send’. The command will run on the controller and the results will be listed below. Results are split into four sections, the name of the result (i.e. what it is), then the result itself in text, hex, and binary format.

Commands can be copied directly from the list using the ‘Copy’ button; clicking this will copy the top line of the command list into the command box. Enclosed words like this <channel> indicate that they should be replaced by a parameter, for example “identity.stage.part.get <channel>” becomes “identity.stage.part.get 1”.

12 Control/Command Quick Reference

*Note – all settings in blue are applied to the currently selected channel. All others are channel independent or are labelled with the relevant channel.

12.1 Live position sidebar

Tab Name	Control Name	Function	Available Data Entry
Live Position	CH1 (/2/3) Connected	Shows if the relevant channel is connected to the controller	Non-editable
Live Position	Command CH1 (/2/3)	Digital command position for the relevant channel	+/- ½ closed loop range (Distance Units)
Live Position	Measured CH1 (/2/3)	Digital measured position for the relevant channel	Non-editable (Distance Units)
Live Position	Units CH1 (/2/3)	The chosen units for the relevant channel	Non-editable
Live Position	CH1 (/2/3) In-Position	Shows whether the channel is “in-position” (i.e. close to command position)	Non-editable
Live Position	Overtemperature Cutout	Illuminates if the controller has reached an unsafe temperature and powered down for safety	Non-editable
Live Position	Update Rate (Hz)	Controls the speed at which the UI updates (i.e. measured position / scope)	1 to 150

12.2 Main tab

Tab Name	Control Name	Function	Available Data Entry
Main	Enable Digital Input Command	If enabled (lit), the stage in the selected channel will respond to digital (PC issued) position commands	• On (lit) (Default) • Off (unlit)
Main	Enable Analog Input Command	If enabled (lit), the stage in the selected channel will respond to analogue (voltage) position commands	• On (lit) • Off (unlit) (Default)
Main	Enable Closed Loop	If enabled (lit), the controller will actively control the stage in the selected channel’s	• On (lit) (Default) • Off (unlit)

Tab Name	Control Name	Function	Available Data Entry
		position, if not the stage is in “open loop” mode	
Main	Freeze Output	If enabled (lit), the servo output to the stage in the selected channel is frozen	• On (lit) • Off (unlit) (Default)
Main - Stage	Part Number	Shows the part number of the stage in the selected channel	Non-editable
Main - Stage	Serial Number	Shows the serial number of the stage in the selected channel	Non-editable
Main - Stage	Axis ID	Shows the axis that the stage in the selected channel is set to	Non-editable
Main - Stage	Manufacture Date	Date that the stage in the selected channel was built	Non-editable
Main - Stage	Calibration Date	Date that the stage in the selected channel was calibrated	Non-editable
Main – Stage Calibration	Preset (Dropdown)	Allows the user to select a preset to load from or store to	Fast / Medium / Slow /Customer Preset 1/2/3/4/5
Main – Stage Calibration	Load Preset	Loads the parameters from the selected preset into the stage memory	One-Press Button
Main – Stage Calibration	Store Preset	Stores the current settings to the selected preset – **WARNING – this will overwrite settings stored in the preset**	One-Press Button
Main – Stage Calibration	Delete Preset	Deletes the selected preset from stage memory – WARNING – irrevertable	One-Press Button
Main – Stage Calibration	Read/Write Status	Current status of the preset memory – indicates if an operation is underway	Non-editable
Main – Stage Calibration	Current Preset	Shows the currently loaded preset	Fast / Medium / Slow /Customer Preset 1/2/3/4/5

Tab Name	Control Name	Function	Available Data Entry
Main – Stage Calibration	Default Preset	Shows the preset that will load by default when the stage/controller powers on	Fast / Medium / Slow /Customer Preset 1/2/3/4/5
Main – Stage Calibration	Set Current Setup As Default	Sets the currently loaded preset as the default	One-Press Button

12.3 PID Tab

Tab Name	Control Name	Function	Available Data Entry
PID	PID Control Type	Sets the type of control loop used from the available position/velocity/acceleration PID loops	• Position • Velocity • Acceleration
PID	Differential Time Constant	Sets the PID loop 'Td' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information (Time Units)
PID – Position PID	Feed Forward Gain	Sets the PID loop feed-forward gain parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Position PID	Integrator Time Constant	Sets the PID loop 'Ti' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information (Time Units)
PID – Position PID	Differential Gain	Sets the PID loop 'Gd' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Position PID	Proportional Gain	Sets the PID loop 'Gp' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Position PID	Setpoint Weighting Gain	Sets the PID loop 'Gsp' parameter. Consult the user manual for information	Stage specific – consult Queensgate for more information

Tab Name	Control Name	Function	Available Data Entry
		about PID control. WARNING – can cause stage damage if set incorrectly	
PID – Position PID	Integrator Max Error	Sets the PID loop 'eMax' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Velocity PID	Integrator Time Constant	Sets the velocity PID loop 'Ti' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information (Time Units)
PID – Velocity PID	Differential Gain	Sets the velocity PID loop 'Gd' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Velocity PID	Proportional Gain	Sets the velocity PID loop 'Gp' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Velocity PID	Setpoint Weighting Gain	Sets the PID loop 'Gsp' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Acceleration PID	Integrator Time Constant	Sets the velocity PID loop 'Ti' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information (Time Units)
PID – Acceleration PID	Differential Gain	Sets the velocity PID loop 'Gd' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Acceleration PID	Proportional Gain	Sets the velocity PID loop 'Gp' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information
PID – Acceleration PID	Setpoint Weighting Gain	Sets the PID loop 'Gsp' parameter. Consult the user manual for information about PID control. WARNING – can cause stage damage if set incorrectly	Stage specific – consult Queensgate for more information

Tab Name	Control Name	Function	Available Data Entry
PID – Open Loop	Open Loop Gain	Controls the command scaling when the stage is in open loop mode	Stage specific – consult Queensgate for more information
PID – Open Loop	Open Loop Offset	Controls the command offset when the stage is in open loop mode	Stage specific – consult Queensgate for more information
PID – Trajectory Control	Enable	Enables or disables command trajectory control	• 0 = Off • 1 = On
PID – Trajectory Control	Max Speed	If enabled, controls the maximum speed in nm per ms that the stage is allowed to move	32 bit floating point
PID – Trajectory Control	Max Acceleration	If enabled, controls the maximum acceleration in nm per ms per ms that the stage can undergo	32 bit floating point
PID – Trajectory Control	Max Deceleration	If enabled, controls the maximum deceleration in nm per ms per ms that the stage can undergo	32 bit floating point

12.4 Filters Tab

Tab Name	Control Name	Function	Available Data Entry
Filters – Notch Filter	Filter Location	Sets the ‘location’ of the notch filter (for firmware <6.6.1), i.e. where and how it is applied	0 – 5, consult command set manual
Filters – Notch Filter	Filter Type	Sets the ‘type’ of the notch filter (for firmware >=6.6.1) i.e. where and how it is applied	0 – 4, consult command set manual
Filters – Notch Filter	Filter 1 (/2) Q Factor	Sets the ‘Q’ factor for the notch filter (i.e. notch width)	32 bit floating point
Filters – Notch Filter	Filter 1 (/2) Frequency (Hz)	The frequency at which the notch filter is set	1Hz to 1MHz
Filters – Active Damping	Enabled	Determines if the active damping is applied or not	• On (lit) (Default) • Off (unlit)

Tab Name	Control Name	Function	Available Data Entry
Filters – Active Damping	Acceleration Deadband	The deadband applied to the active damping acceleration term. Consult the user manual for information	32 bit floating point
Filters – Active Damping	Acceleration Gain	The gain applied to the active damping acceleration term. Consult the user manual for information	0 - 10
Filters – Active Damping	Velocity Deadband	The deadband applied to the active damping velocity term. Consult the user manual for information	32 bit floating point
Filters – Active Damping	Velocity Gain	The gain applied to the active damping velocity term. Consult the user manual for information	0 - 10
Filters – Position Low Pass Filter	Filter Location	Sets the location/action of the low pass filter	• 0 = Off • 1 = On • 2 = Posmon Only
Filters – Position Low Pass Filter	Filter Enabled	Determines if the low pass filter is enabled (for firmware <6.6.1)	• On (lit) (Default) • Off (unlit)
Filters – Position Low Pass Filter	Filter Q Factor	Sets the 'Q' factor for the low-pass filter	32 bit floating point
Filters – Position Low Pass Filter	Filter Order	Sets the order of the LPF filter	0 - 4, consult command set manual
Filters – Position Low Pass Filter	Filter Frequency (Hz)	The frequency at which the low-pass filter is set	1Hz to 1MHz
Filters – In-Position	In-Position LPF Time Constant	The frequency at which the in-position debouncing low pass filter runs	1e-6 to 1
Filters – In-Position	In-Position Error Threshold	The error threshold which determines when the stage is in-position (measured – command = error)	32 bit floating point (Distance Units)

12.5 Controller tab

Tab Name	Control Name	Function	Available Data Entry
Controller	Part Number	Shows the part number of the controller	Non-editable
Controller	Serial Number	Shows the serial number of the controller	Non-editable
Controller	Manufacture Date	Date that the controller was built	Non-editable
Controller	Calibration Date	Date that the controller was calibrated	Non-editable
Controller	Board Version	The version of the controller circuit board	Non-editable
Controller	Platform Version	The firmware platform version installed on the controller	Non-editable
Controller	Sample Time (S)	Time between controller clock ticks	Non-editable
Controller	Sample Rate (Hz)	Controller clock rate	Non-editable
Controller	Channels	Number of channels available on controller	Non-editable
Controller	Fan Mode	The current fan mode, allows debugging with fan off	Non-editable
Controller	Synchronisation	Indicates if the controller is acting as a slave in a synchronised pair	Non-editable
Controller	Part Number	Part number of the firmware installed on the controller	Non-editable
Controller	Release Date	Release date of the firmware installed on the controller	Non-editable
Controller	Version	The firmware application version installed on the controller	Non-editable
Controller	Read Live Temperatures	If turned on, the temperature readings below will be read at the set update rate. If not, they will not be read back live	On / Off
Controller	PSU Temperature	Temperature of the circuit board PSU	0 – 150 degrees C
Controller	CH1 (/2/3) Heatsink Temperature	Temperature of the heatsink for the relevant channel	0 – 150 degrees C

Tab Name	Control Name	Function	Available Data Entry
Controller	PSU Over Safe Temperature	Indicates that the temperature of the PSU is above the safety cutout temperature	0 – 150 degrees C
Controller	CH1 (/2/3) Over Safe Temperature	Indicates that the temperature of the relevant channel heat sink is above the safety cutout temperature	0 – 150 degrees C

12.6 Scope tab

Tab Name	Control Name	Function	Available Data Entry
Scope	Data Select P1 (/2/3/4)	Selects the point at which the relevant probe channel is measuring	Consult command set manual
Scope	Probe 1 (/2/3/4) Channel	Selects the controller channel that the relevant probe channel is measuring	1 to 3
Scope	Route To Snapshot (CH1/2/3/4)	Redirects the output of the relevant scope channel to the snapshot function	On / Off
Scope	Route To Posmon (CH1/2/3/4)	Redirects the output of the relevant scope channel to the posmon (analogue) output on the controller front panel	On / Off
Scope	Probe To Read	Selects the probe channel to display on the graph when reading live data	1 to 4
Scope	Read Live Data	If enabled, the selected probe channel will be measured at the update rate and displayed on the graph	On / Off
Scope	Points For Calculation	The number of points to use for the RMS and P2P calculations. Higher update rates should use more points.	32 bit integer
Scope	RMS	The root mean square value of the probe data over the selected number of points	Non-editable
Scope	P2P	The peak to peak range of the probe data over the selected number of points	Non-editable

12.7 Snapshots tab

Tab Name	Control Name	Function	Available Data Entry
Snapshots	Amplitude CH1 (/2/3)	The step amplitude for the snapshot on the relevant channel	32 bit floating point (Distance Units)
Snapshots	Leading Edge CH1 (/2/3)	The time before the step is commanded after the snapshot begins	1 to 10,000ms (Time Period Units)
Snapshots	Trailing Edge CH1 (/2/3)	The time before the stage returns to its original position after the snapshot begins	1 to 10,000ms (Time Period Units)
Snapshots	Keep Last Response	If enabled, the previous snapshot(s) will remain on the graph when another snapshot is fired	On / Off
Snapshots	Live Readback?	If enabled, the snapshot data will appear on-screen as it is read from the controller (note for larger snapshots this will be slower)	On / Off
Snapshots	Read Channel/Scope 1 (/2/3/4)	If selected, the relevant channels snapshot data are read into the graph	On / Off
Snapshots	Capture Time	The amount of time that the snapshot runs for	1 to 10,000ms (Time Period Units)
Snapshots	RMS 1 (/2/3/4)	The root mean square value for the snapshot data on the relevant channel	Non-editable (Distance Units)
Snapshots	P2P 1 (/2/3/4)	The peak to peak range value for the snapshot data on the relevant channel	Non-editable (Distance Units)
Snapshots	Time 1 (/2/3/4)	The time taken for the relevant channel to settle to within the given Settle Tolerance of the target amplitude	Non-editable (Time Period Units)
Snapshots	Nm/S 1 (/2/3/4)	The maximum movement speed of the data in the relevant channel in nanometres per second	Non-editable
Snapshots	Settle Tolerance %	The percentage window used to determine when the stage has settled	0 to 100%

12.8 Function Playback tab

Tab Name	Control Name	Function	Available Data Entry
Function Playback	Function Data - Read	Reads the function playback waveform stored in the controller for the selected channel	One-Press Button
Function Playback – Waveform Generator	Segments	List of segments currently in controller memory	Non-editable
Function Playback – Waveform Generator	Add Before / Add After	Adds a segment with the configured parameters to the segments list	One-Press Button
Function Playback – Waveform Generator	Overwrite	Overwrites the currently selected segment with the configured parameters	One-Press Button
Function Playback – Waveform Generator	Move Up / Move Down	Moves the selected segment up or down in the list	One-Press Button
Function Playback – Waveform Generator	Delete	Removes the selected segment from the list	One-Press Button
Function Playback – Waveform Generator	Segment Type	The type of the segment to be generated	Drop-Down list – see command set manual
Function Playback – Waveform Generator	Segment Parameters	Control the parameters of the chosen segment type – specific parameters are dependent on the segment type	32 bit floating point
Function Playback – Waveform Generator	Start Trigger Type	Defines the type of trigger (if any) to execute at the beginning of the segment	Drop-Down list – see command set manual

Tab Name	Control Name	Function	Available Data Entry
Function Playback – Waveform Generator	During Trigger Type	Defines the type of trigger (if any) to execute during the segment (During Trigger Count pulses)	Drop-Down list – see command set manual
Function Playback – Waveform Generator	During Trigger Count	Defines the number of trigger pulses to output during the segment	32 bit integer
Function Playback – Waveform Generator	Sample Period	Defines the time-based resolution of the generated waveform	32 bit floating point - 0.02 to 1 in intervals of 0.02
Function Playback – Waveform Generator	Repeat Forever	If checked, the repeat count will be set to 0 which causes the waveform to repeat indefinitely	Check box – on / off
Function Playback – Waveform Generator	Repeat Count	Defines the number of times the waveform will repeat between segments defined in 'Repeat Start' and 'Repeat End'	32 bit unsigned integer 0 = indefinite
Function Playback – Waveform Generator	Repeat Start	The first segment index from which the repeated section of the waveform will begin	0 to 999
Function Playback – Waveform Generator	Repeat End	The last segment index at which the repeated section of the waveform will finish	0 to 999
Function Playback – Waveform Generator	Clear Waveform	Clears all waveform data from the controller to give a clean start	One-Press Button
Function Playback – Waveform Generator	Test	Commands the controller to analyze the provided waveform parameters to determine if the waveform is valid	One-Press Button

Tab Name	Control Name	Function	Available Data Entry
Function Playback – Waveform Generator	Generate	Commands the controller to begin generating the waveform with the given parameters	One-Press Button
Function Playback – Waveform Generator	Fire Snapshot	Commands the controller to begin waveform playback while simultaneously acquiring snapshot data	One-Press Button
Function Playback – Waveform Generator	Save Setup	Stores the waveform configuration parameters to a file on the PC	One-Press Button
Function Playback – Waveform Generator	Load Setup	Loads waveform configuration parameters from a file on the PC	One-Press Button
Function Playback – Waveform Generator	Auto Generate	Causes the waveform to be automatically generated every time a waveform parameter is changed	On / Off
Function Playback – Waveform Generator	Abort	Aborts read-back of the waveform data	One-Press Button
Function Playback – Control Tab	Waveform Count	The amount of points for the function playback to ‘play’	NPC-5xx0: 1 to 1.2m NPC-6xx0: 1 to 500k (Time Period Units)
Function Playback – Control Tab	Steps Per Trig Pulse	The length of the output pulse in controller ticks when a trigger output is sent	32 bit unsigned integer
Function Playback – Control Tab	Steps Per Sample	Number of controller ticks that each point of the function should persist for. If transition is selected, number of ticks to ramp to the next point over.	32 bit unsigned integer

Tab Name	Control Name	Function	Available Data Entry
Function Playback – Control Tab	Iterations	The number of times the function should repeat. 0 for unlimited	32 bit unsigned integer
Function Playback – Control Tab	Start	Starts the function playback for the selected channel(s)	One-Press Button
Function Playback – Control Tab	Pause	Pauses the function playback for the selected channel(s)	One-Press Button
Function Playback – Control Tab	Unpause	Unpauses the function playback for the selected channel(s)	One-Press Button
Function Playback – Control Tab	Soft Stop	Stops the function playback for the selected channel(s) and returns to 0 command	One-Press Button
Function Playback – Control Tab	Stop	Stops the function playback for the selected channel(s) immediately at the current position	One-Press Button
Function Playback – Control Tab	CH1 / CH2 / CH3 / Snapshot	If selected, the relevant channel will be controlled by the start/stop etc commands above.	On / Off
Function Playback – Advanced Tab	Load From CSV File	Loads function data into the controller from a simple CSV file	One-Press Button

12.9 Custom Command tab

Tab Name	Control Name	Function	Available Data Entry
Custom Command	Command	The text command to execute. Usually comes from the list below using “Copy”	Text entry
Custom Command	Send	Sends the command to the controller and reads back the response	One-Press Button
Custom Command	Result Names	The name of each returned result from the executed command.	Non-editable

Tab Name	Control Name	Function	Available Data Entry
Custom Command	Text Results	The results from the executed command in text format	Non-editable
Custom Command	Hex Values	The results from the executed command in hexadecimal format	Non-editable
Custom Command	Binary Values	The results from the executed command in binary format	Non-editable
Custom Command	Command List	The complete list of available commands at the current security level	Non-editable
Custom Command	Copy	Copies the currently selected command (top of the list) into the command box, ready for sending to the controller	One-Press Button
Custom Command	Check Avail	Rechecks the available commands, helpful for debugging.	One-Press Button

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