



PID Controller

Moku:Pro User Manual

Moku:Pro's PID (Proportional-Integrator-Differentiator) Controller features four fully real-time configurable PID controllers with a closed-loop bandwidth >100 kHz. This enables them to be used in applications requiring both low and high feedback bandwidths such as temperature and laser frequency stabilization. The PID Controller can also be used as a lead-lag compensator by saturating the integral and differential controllers with independent gain settings.





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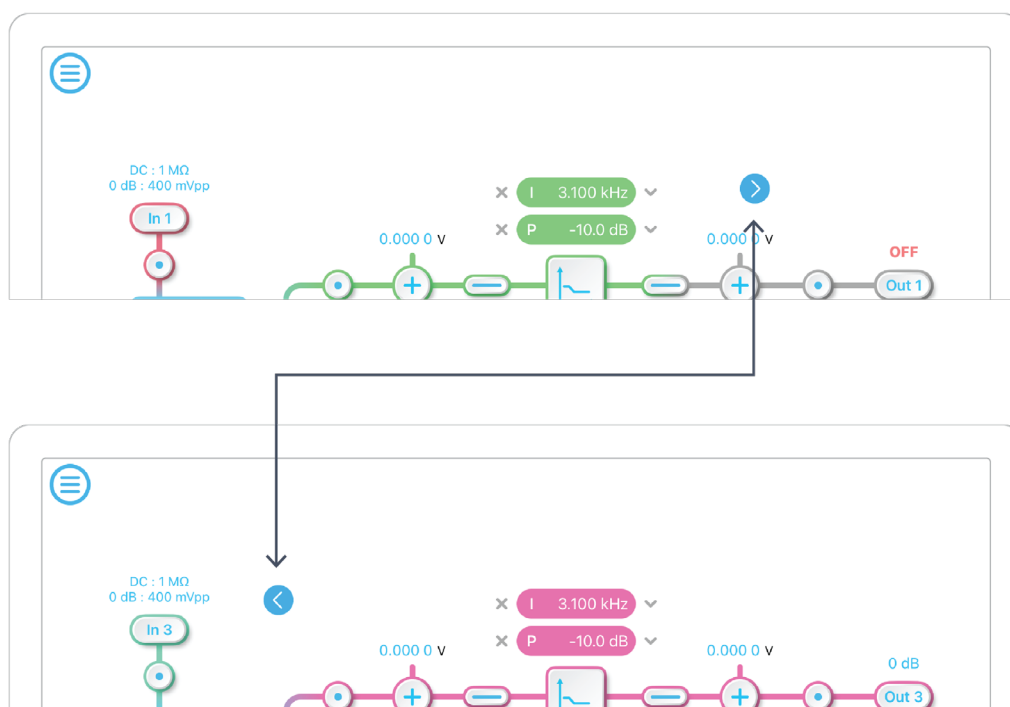
Ensure Moku:Pro is fully updated. For the latest information:

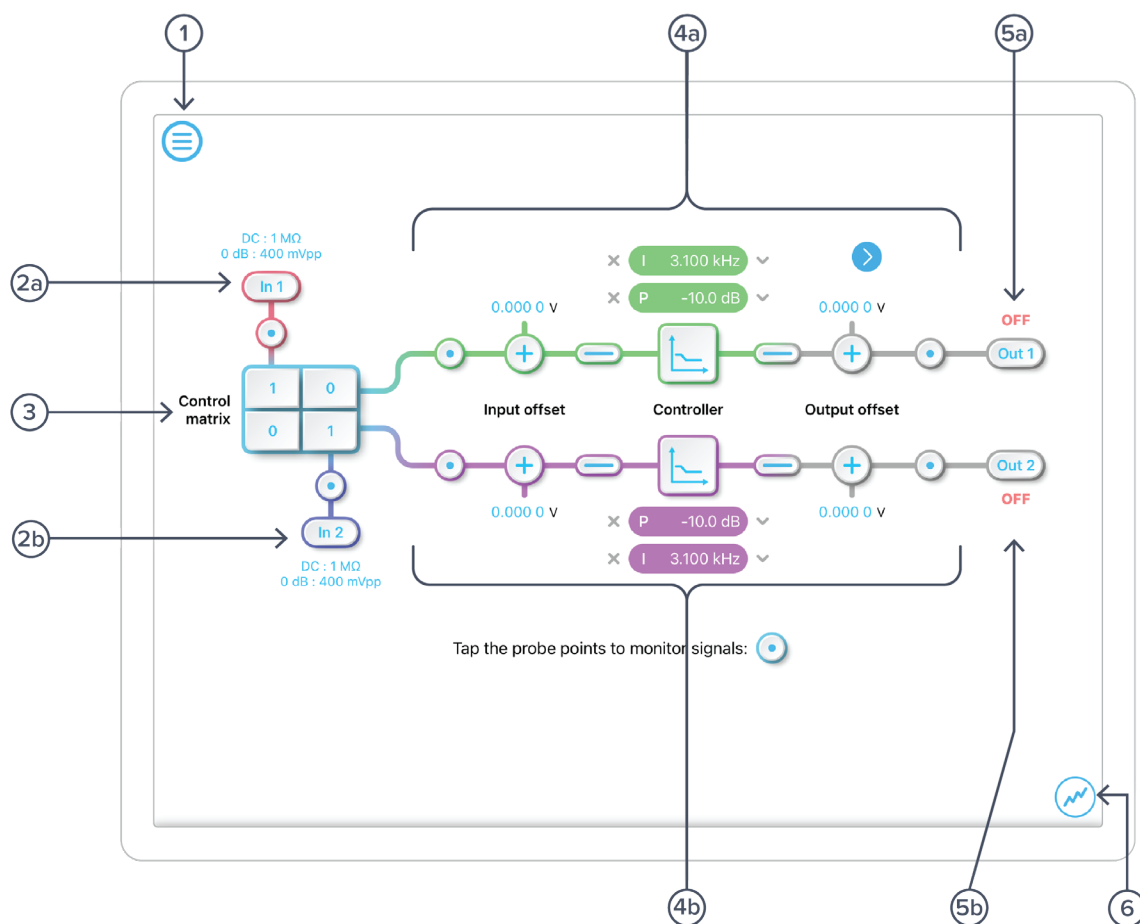
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User Interface

Moku:Pro is equipped with four inputs, four outputs, and four PID controllers. Two control matrices are used to create two multiple-input and multiple-output (MIMO) in groups for PID 1 & 2, and PID 3 & 4. You can tap the  or  icons to switch between MIMO group 1 and 2. MIMO group 1 (inputs 1 and 2, PID 1 and 2, Output 1 and 2) is used throughout this manual. The settings for MIMO group 2 are similar to MIMO group 1.





ID Description

1	Main menu
2a	Input configuration for Channel 1
2b	Input configuration for Channel 2
3	Control matrix
4a	Configuration for PID Controller 1
4b	Configuration for PID Controller 2
5a	Output switch for Channel 1
5b	Output switch for Channel 2
6	Enable the oscilloscope



Main Menu

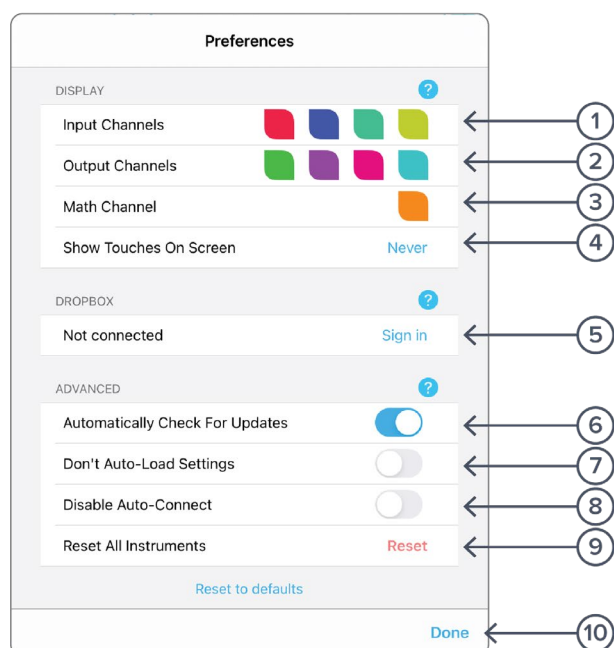
The **main menu** can be accessed by pressing the  icon, allowing you to:





Preferences

The preferences pane can be accessed via the main menu. In here, you can reassign the color representations for each channel, connect to Dropbox, etc. Throughout the manual, the default colors (shown in the figure below) are used to present instrument features.



ID Description

1	Tap to change the color associated with input channels.
2	Tap to change the color associated with output channels.
3	Tap to change the color associated with math channel.
4	Indicate touch points on the screen with circles. This can be useful for demonstrations.
5	Change the currently linked Dropbox account to which data can be uploaded.
6	Notify when a new version of the app is available.
7	Moku:Pro automatically saves instrument settings when exiting the app, and restores them again at launch. When disabled, all settings will be reset to defaults on launch.
8	Moku:Pro can remember the last used instrument and automatically reconnect to it at launch. When disabled, you will need to manually connect every time.
9	Reset all instruments to their default state.
10	Save and apply settings.



Input Configuration

The **input configuration** can be accessed by tapping the **In 1** or **In 2** icon, allowing you to adjust the coupling, impedance and input range for each input channel.



Details about the probe points can be found in the [Probe Points](#) section.



Control Matrix

The **control matrix** combines, rescales, and redistributes the input signal to the two independent PID controllers. The output vector is the product of the control matrix multiplied by the input vector.

$$\begin{bmatrix} \text{Path1} \\ \text{Path2} \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \times \begin{bmatrix} \text{In1} \\ \text{In2} \end{bmatrix}$$

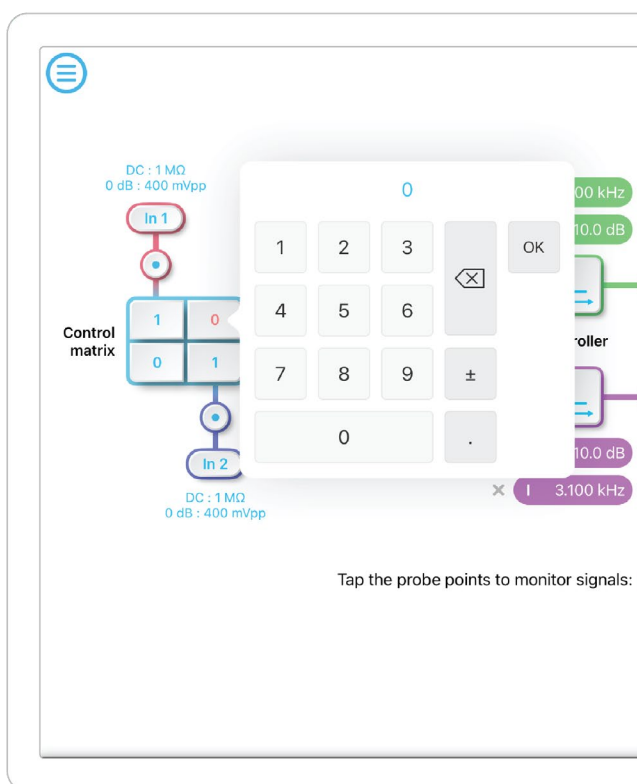
where

$$\text{Path1} = a \times \text{In1} + b \times \text{In2}$$

$$\text{Path2} = c \times \text{In1} + d \times \text{In2}$$

For example, a control matrix of $\begin{bmatrix} 1 & 1 \\ 0 & 2 \end{bmatrix}$ equally combines the **Input 1** and **Input 2** to the top **Path1** (PID Controller 1); multiplies **Input 2** by a factor of two, and then sends it to the bottom **Path2** (PID Controller 2).

The value of each element in the control matrix can be set between -20 to +20 with 0.1 increments when the absolute value is less than 10, or 1 increment when the absolute value is between 10 and 20. Tap the element to adjust the value.

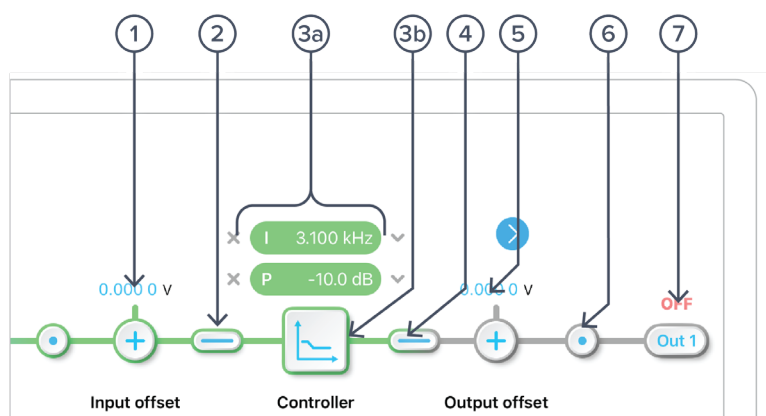




PID Controller

The four independent, fully real-time configurable PID controller are grouped into two MIMO groups. MIMO group 1 is shown here. In MIMO group 1, PID controller 1 and 2 follow the control matrix in the block diagram, represented in green and purple, respectively. The settings for all controller paths are the same.

User Interface



ID	Parameter	Description
1	Input offset	Tap to adjust the input offset (-1 to +1 V).
2	Input switch	Tap to zero the input signal.
3a	Quick PID control	Tap to enable/disable controllers and adjust the parameters. Not available in advanced mode.
3b	Controller view	Tap to open full controller view.
4	Output switch	Tap to zero the output signal.
5	Output offset	Tap to adjust the output offset (-1 to +1 V).
6	Output probe	Tap to enable/disable the output probe point. See Probe Points section for details.
7	Moku:Pro output switch	Tap to disable or enable DAC output with 0 dB or 14 dB gain.

Input / Output Switches



Closed/Enable



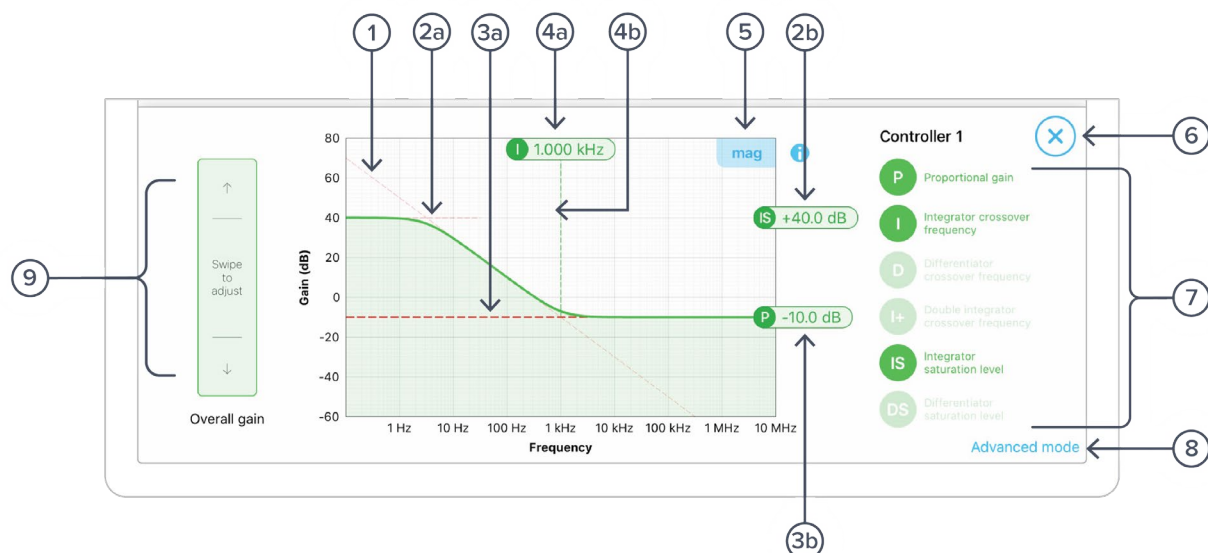
Open/disable



Controller (Basic Mode)

Controller Interface

Tap the  icon to open the full controller view.

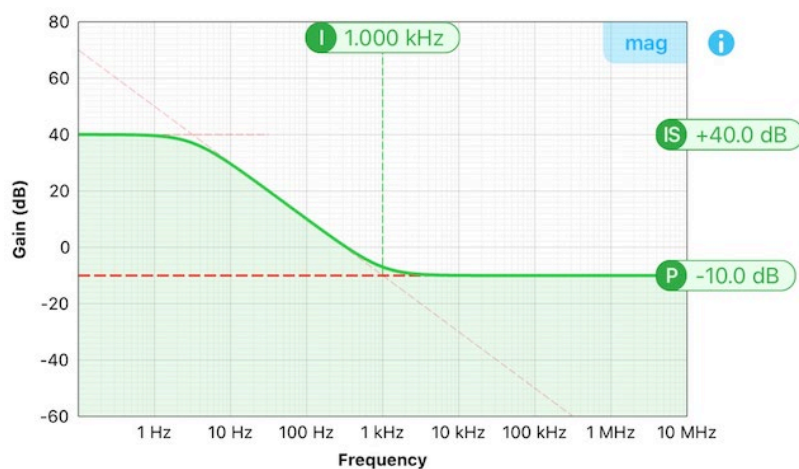


ID	Parameter	Description
1	Design cursor 1	Cursor for Integrator (I) setting.
2a	Design cursor 2	Cursor for Integrator Saturation (IS) level.
2b	Cursor 2 reading	Reading for IS level. Drag to adjust the gain.
3a	Design cursor 3	Cursor for Proportional (P) gain.
3b	Cursor 3 reading	Reading of the P gain.
4a	Cursor 4 reading	Reading for I crossover frequency. Drag to adjust the gain.
4b	Design cursor 4	Cursor for I crossover frequency.
5	Display toggle	Toggle between magnitude and phase response curve.
6	Close controller view	Tap to close the full controller view.
7	PID control switches	Turn on/off individual controller.
8	Advanced mode	Tap to switch to the advanced mode.
9	Overall gain slider	Swipe to adjust overall gain of the controller.



PID Response Plot

The PID Response Plot provides an interactive representation (gain as a function of frequency) of the controller.



The green/purple solid curve represents the active response curve for PID Controller 1 and 2, respectively.

The green/purple dashed vertical lines (④) represent the cursors crossover frequencies, and/or unity gain frequencies for PID Controller 1 and 2, respectively.

The red dashed lines (① and ②) represent the cursors for each controller.

The bold red dashed line (③) represents the cursor for actively selected parameter.

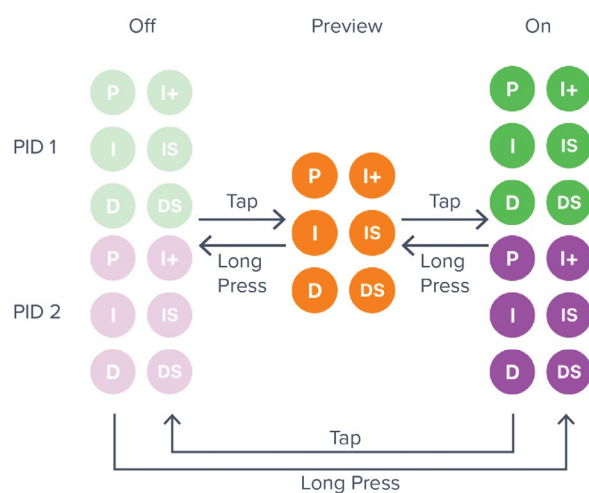


PID Paths

There are in total six switch buttons for the controller paths in area ⑥. The function of each button can be found below:

ID	Description	ID	Description
P	Proportional gain	I+	Double integrator crossover frequency
I	Integrator crossover frequency	IS	Integrator saturation level
D	Differentiator	DS	Differentiator saturation level

Each button has three states: off, preview, and on. Tap the buttons to circle these states. Long press the buttons to go reverse order.





PID Path Preview

PID path preview allows the user to preview and adjust the settings on the PID response plot before engaging.

Preview



Engaged



List of Configurable Parameters in Basic Mode

Parameters	Range
Overall gain	± 60 dB
Proportional gain	± 60 dB
Integrator crossover frequency	3.125 Hz to 312.5 kHz
Differentiator crossover frequency	31.25 Hz to 3.125 MHz
Integrator saturation level	± 60 dB or limited by the crossover frequency/proportional gain
Differentiator saturation level	± 60 dB or limited by the crossover frequency/proportional gain



Controller (Advanced Mode)

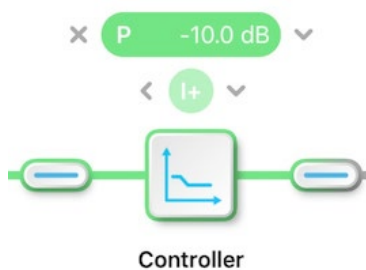
In **Advanced Mode**, users can build fully customized controllers with two independent sections (A and B), and six adjustable parameters in each section. Tap the **Advanced Mode** button in the full controller view to switch to the **Advanced Mode**.



ID	Parameter	Description
1	Display toggle	Toggle between magnitude and phase response curve.
2	Close controller view	Tap to close the full controller view.
3a	Section A pane	Tap to select and configure Section A.
3b	Section B pane	Tap to select and configure Section B.
4	Section A Switch	Master switch for Section A.
5	Overall gain	Tap to adjust the overall gain.
6	Proportional panel	Tap the switch to enable/disable proportional path. Tap the number to adjust the gain.
7	Integrator panel	Tap the switch to enable/disable integrator path. Tap the number to adjust the gain.
8	Differentiator panel	Tap the switch to enable/disable differential path. Tap the number to adjust the gain.
9	Additional Settings	
	Integrator corner frequency	Tap to set the frequency of the integrator corner.
	Differentiator corner frequency	Tap to set the frequency of the differentiator corner.
10	Basic mode	Tap to switch to the basic mode.

Quick PID Control

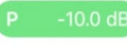
This panel allows user quickly to view, enable, disable, and adjust the PID controller without open the controller interface. It is only available in basic PID mode.



Tap the  icon to disable active controller path.


Tap the  icon to select the controller to adjust.

Tap the faded icon (i.e. ) to enable the path.

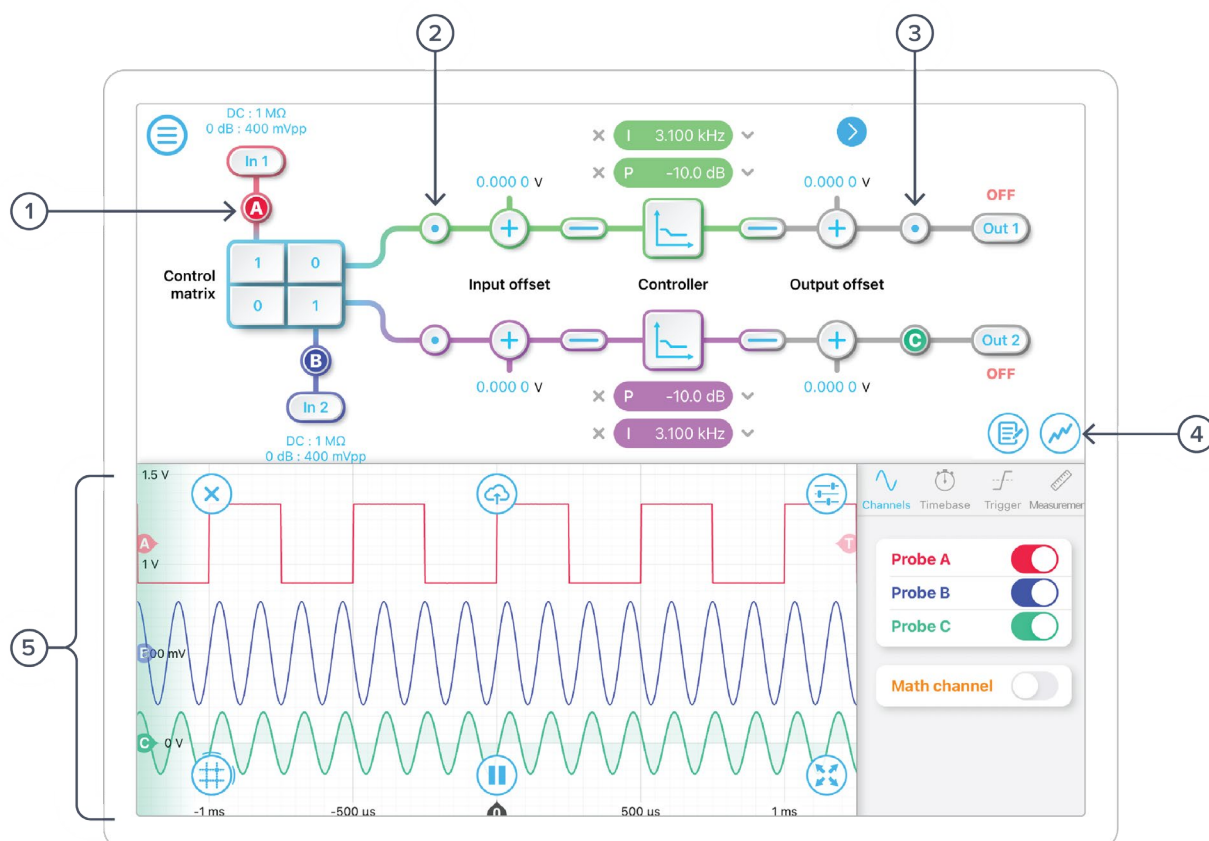
Tap the active controller path icon (i.e. ) to enter the value. Hold and slide to adjust the value.



Probe Points

Moku:Pro's PID controller has an integrated oscilloscope and data logger that can be used to probe the signal at the input, pre-PID, and output stages. The probe points can be added by tapping the  icon.

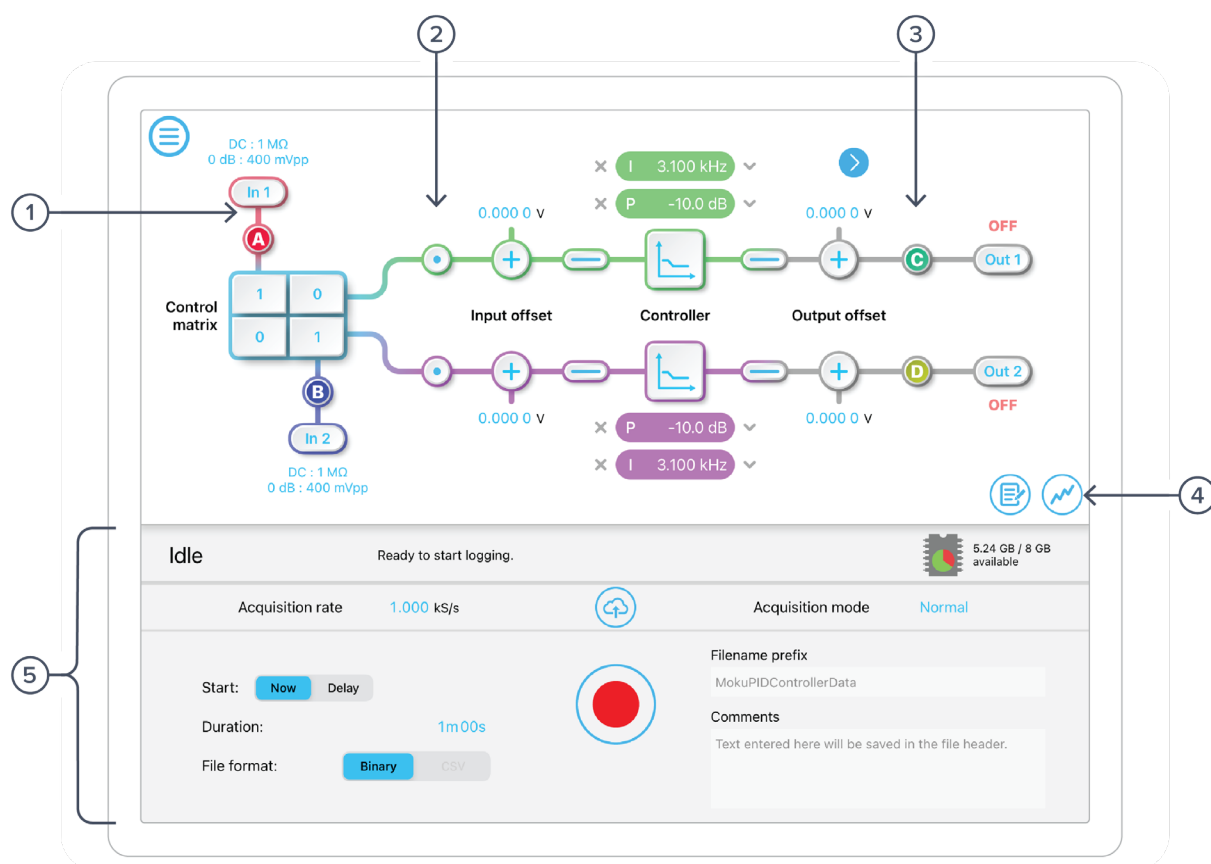
Oscilloscope



ID	Parameter	Description
1	Input probe point	Tap to place the probe point at input.
2	Pre-PID probe point	Tap to place the probe after the control matrix.
3	Output probe point	Tap to place the probe at output.
4	Oscilloscope/data logger toggle	Toggle between built-in oscilloscope or data logger.
5	Oscilloscope	Refer to the Moku:Pro's Oscilloscope manual for the details.



Data Logger



ID	Parameter	Description
1	Input probe point	Tap to place the probe point at input.
2	Pre-PID probe point	Tap to place the probe after the control matrix.
3	Output probe point	Tap to place the probe at output.
4	Oscilloscope/data logger toggle	Toggle between built-in oscilloscope or data logger.
5	Data Logger	Refer to the Moku:Pro's Data Logger manual for the details.



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