



# PID Controller User Manual

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Moku:Lab's PID (Proportional-Integrator-Differentiator) Controller features two fully real-time configurable PID controllers with an output sample rate of 10 MSa/s. 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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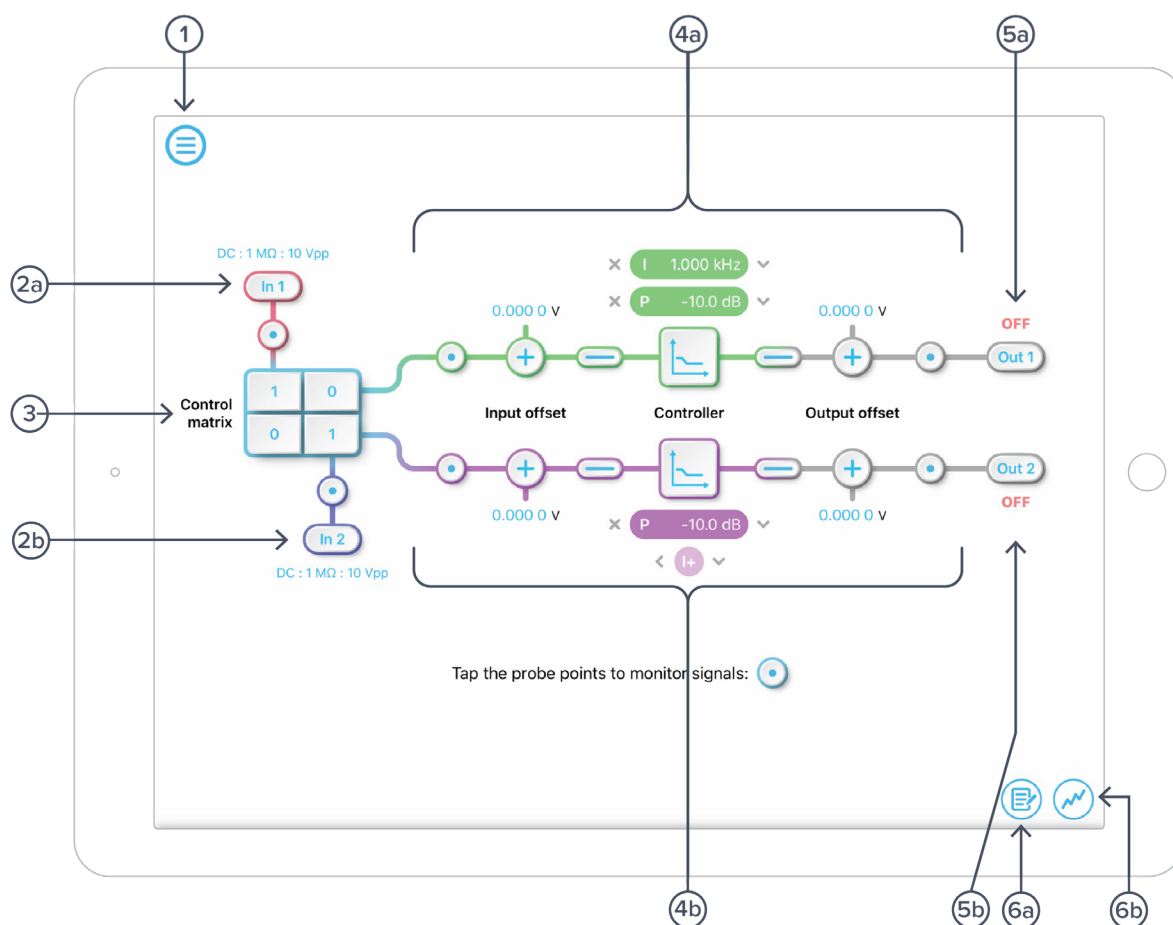


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# User Interface



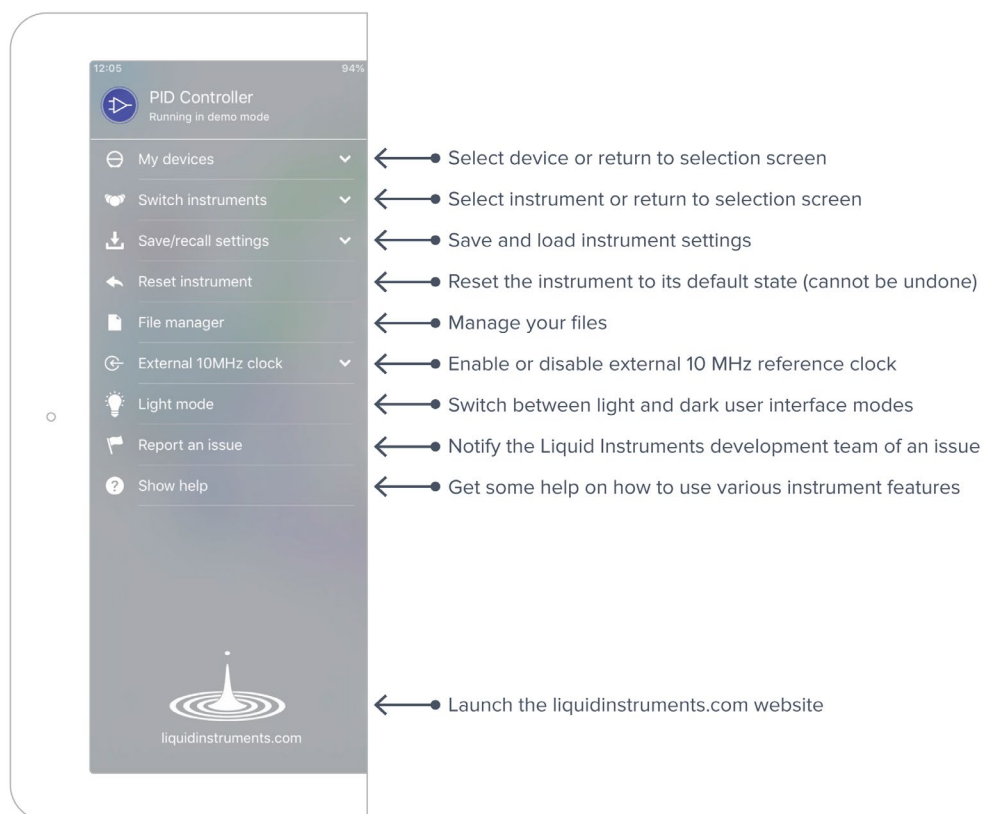
## ID Description

|    |                                    |
|----|------------------------------------|
| 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        |
| 6a | Enable the data logger             |
| 6b | Enable the oscilloscope            |



# Main Menu

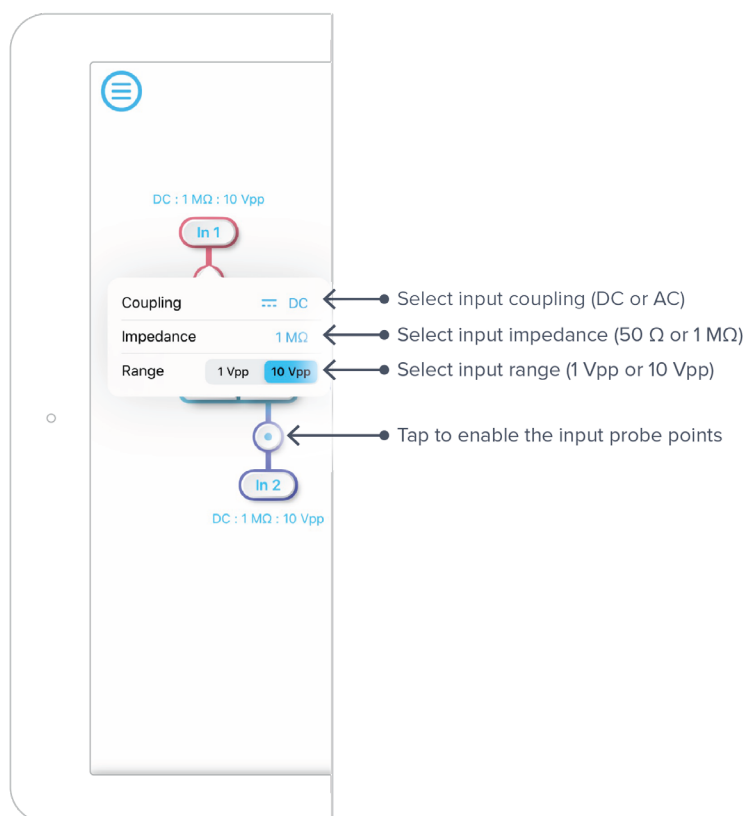
The **main menu** can be accessed by pressing the  icon, allowing you to:





# 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.

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

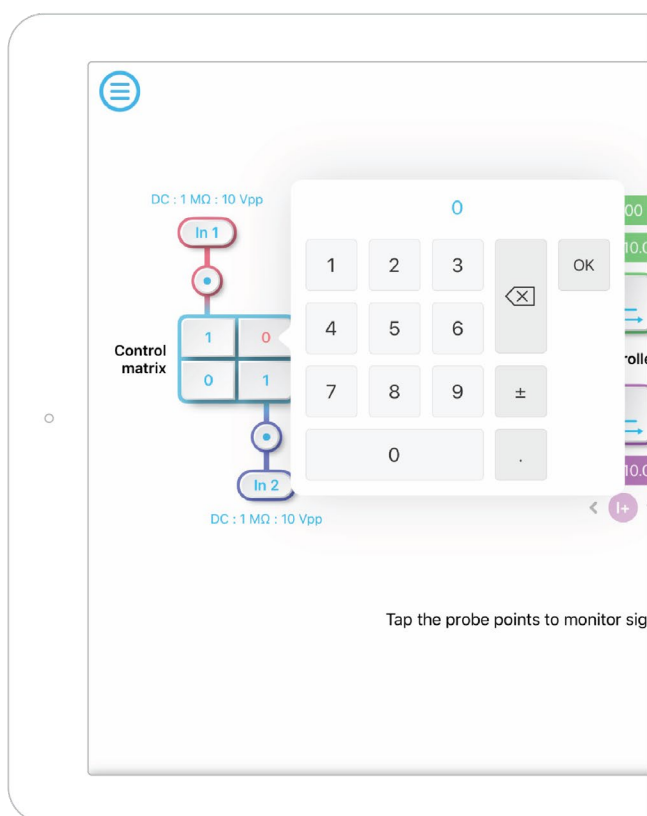
where

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

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

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.

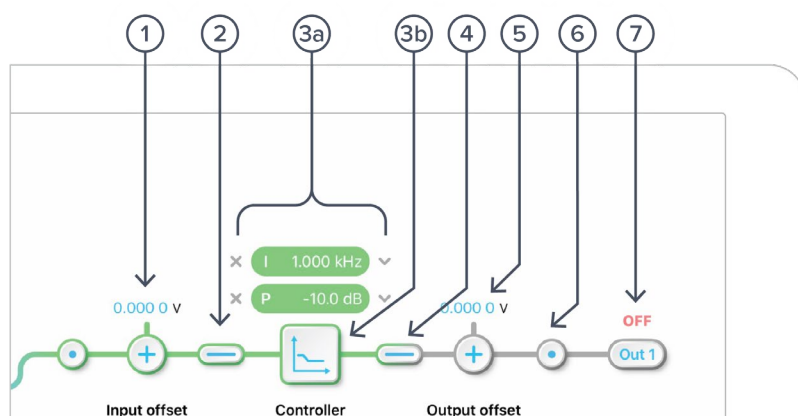




# PID Controller

The two independent, fully real-time configurable PID controller paths follow the control matrix in the block diagram, represented in green and purple for controller 1 and 2, respectively. The PID generates a minimum latency of 733 ns. The latency is about 813 ns with all controllers enabled.

## 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 <a href="#">Probe Points</a> section for details. |
| 7  | Moku:Lab output switch | Tap to enable/disable the Moku:Lab's DAC output.  |

## Input / Output Switches



Closed/Enable



Open/disable

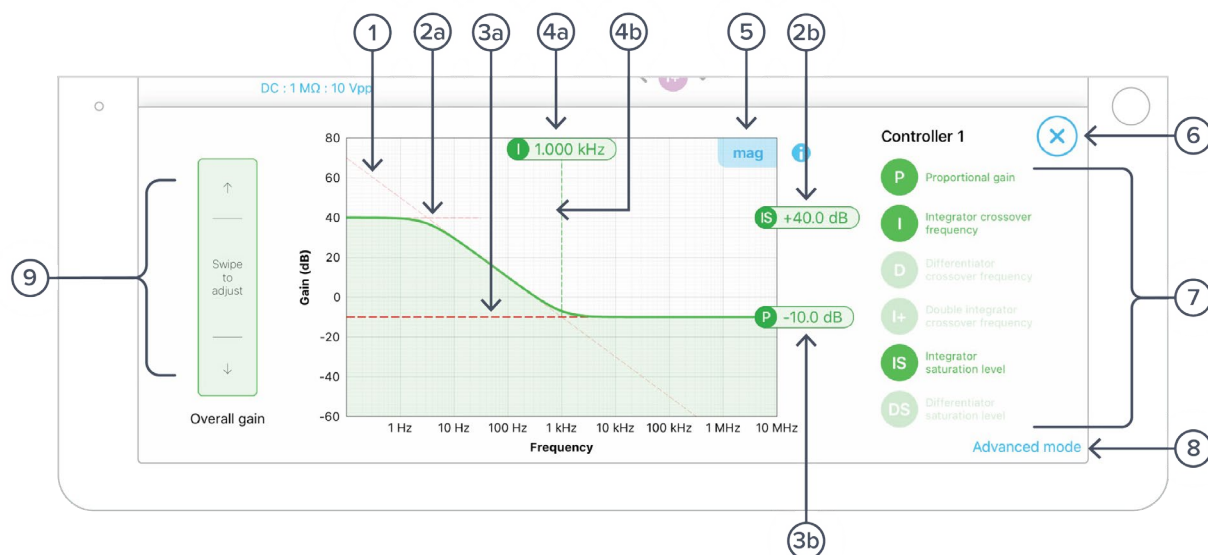




# Controller (Basic Mode)

## Controller Interface

Tap the  icon to open the full controller view.

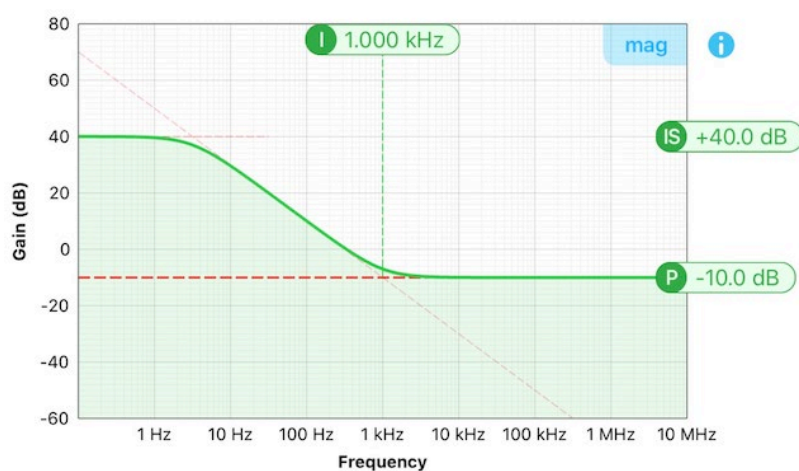


| ID | Parameter             | Description   |
|----|-----------------------|---|
| 1  | Design cursor 1       | Cursor for Integrator (I) setting.                          |
| 2a | Design cursor 2       | Cursor for Integrator Saturation (IS) level.                |
| 2b | Cursor 2 reading      | Reading 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.

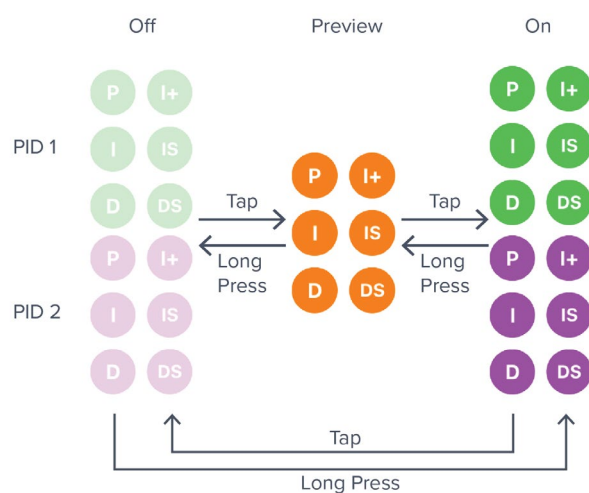


## PID Paths

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                           |
|----------|--------------------------------|-----------|---------------------------------------|
| <b>P</b> | Proportional gain              | <b>I+</b> | Double integrator crossover frequency |
| <b>I</b> | Integrator crossover frequency | <b>IS</b> | Integrator saturation level           |
| <b>D</b> | Differentiator                 | <b>DS</b> | 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                       | $\pm 60$ dB   |
| Proportional gain                  | $\pm 60$ dB   |
| Integrator crossover frequency     | 1 Hz to 100 kHz   |
| Differentiator crossover frequency | 10 Hz to 1 MHz  |
| Integrator saturation level        | $\pm 60$ dB or limited by the crossover frequency/proportional gain |
| Differentiator saturation level    | $\pm 60$ dB or limited by the crossover frequency/proportional gain |



## Controller (Advanced Mode)

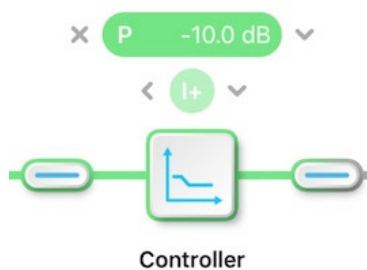
In **Advanced Mode**, users can build fully customized controllers with two independent sections (A and B), and six adjustable parameters in each section. Tap the **Advanced Mode** button in the full controller view to switch to the **Advanced Mode**.



| 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

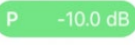
This panel allows user quickly to view, enable, disable, and adjust the PID controller without open the controller interface. It is only available in basic PID mode.



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.

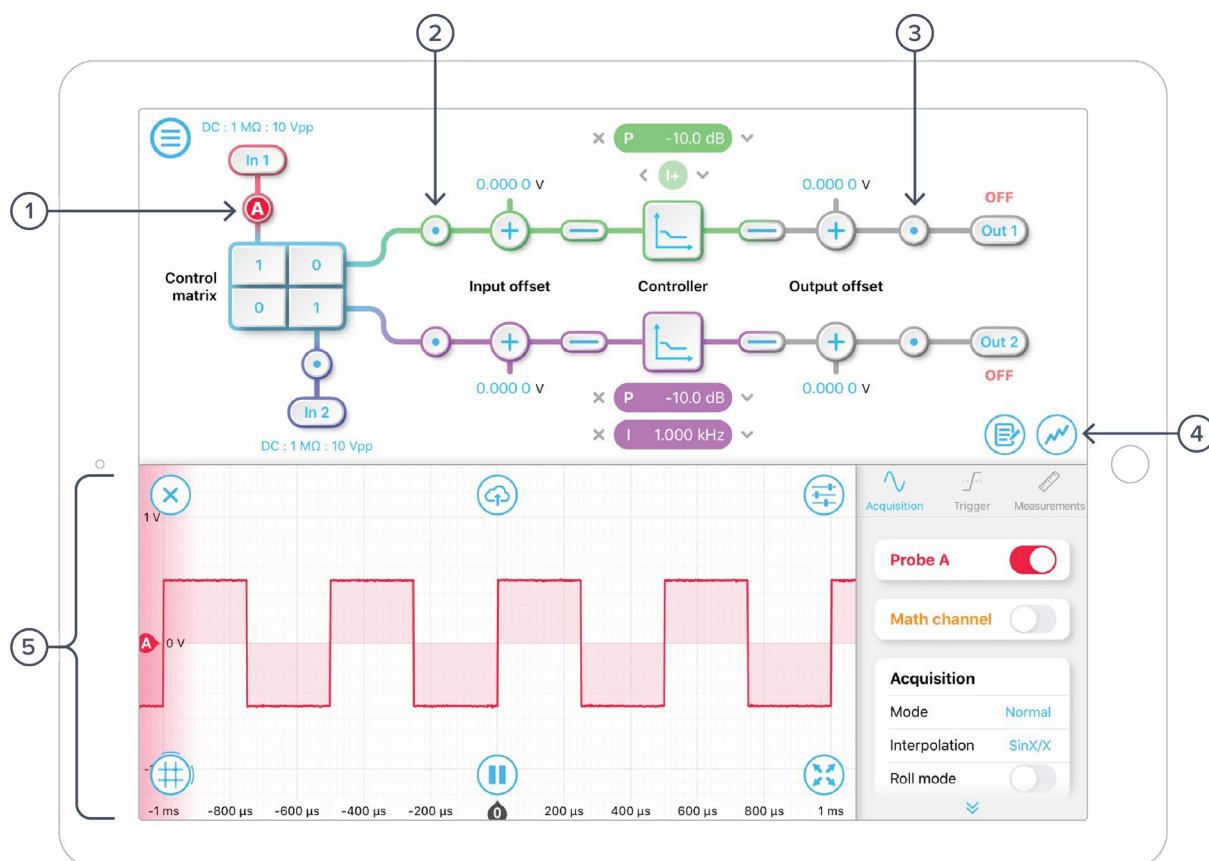
Tap the active controller path icon (i.e. ) to enter the value. Hold and slide to adjust the value.



# Probe Points

Moku:Lab'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.

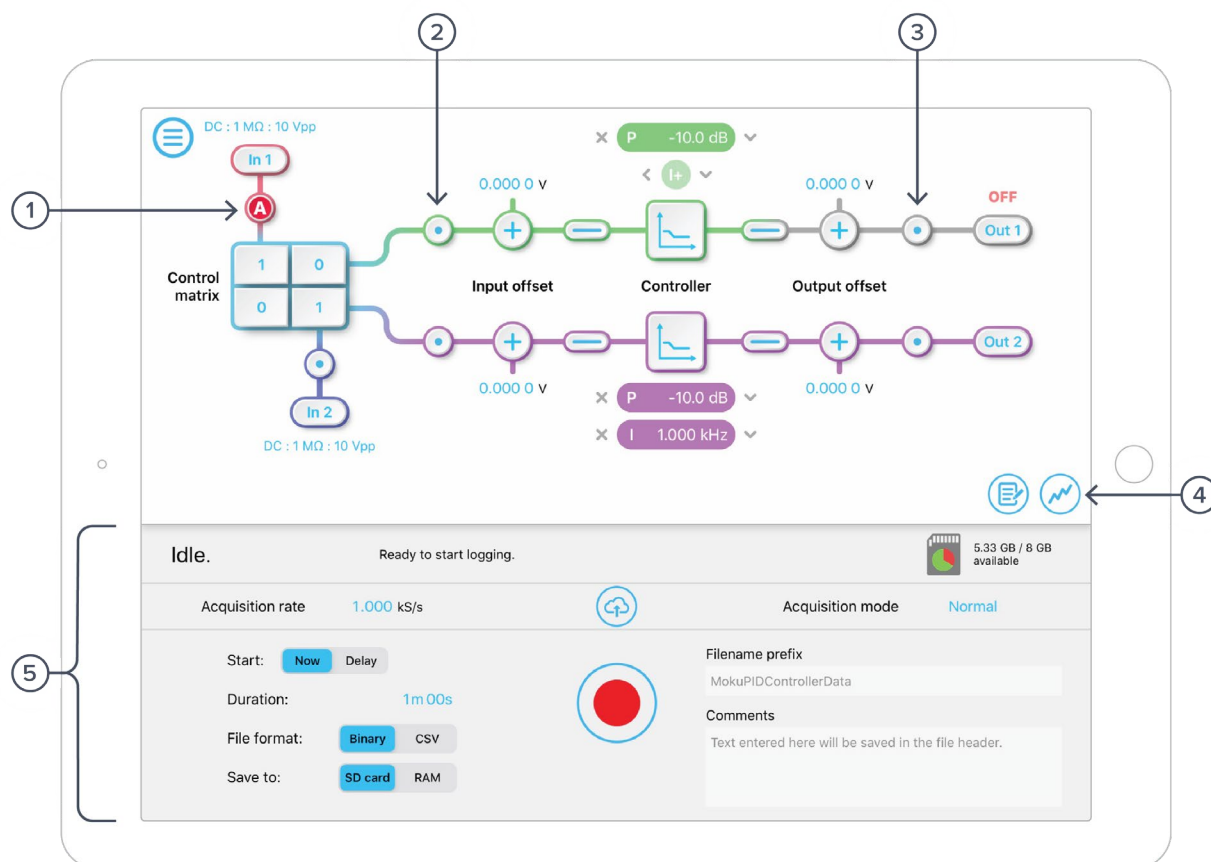
## Oscilloscope



| 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 <b>Moku:Lab's Oscilloscope</b> 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 <b>Moku:Lab's Data Logger</b> manual for the details. |





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