Laser Lock Box

Moku:Pro User Manual

Moku:Pro's Laser Lock Box enables you to stabilize a laser's frequency to a reference cavity or atomic transition using high-performance modulation locking techniques. The Laser Lock Box includes a "Tap-to-Lock" feature, enabling you to quickly lock to any zero-crossing on the demodulated error signal. It also features an integrated 4-channel oscilloscope, allowing you to observe signals at any point in the signal processing chain at up to 1.25 GSa/s. Additionally, the built-in data logger feature enables delayed and long-term data logging.

LIQUID INSTRUMENTS

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Introduction

Laser locking systems are widely used to control and match a laser's frequency to an optical frequency reference, such as an optical reference cavity or atomic transition. Such systems are vital for high resolution interferometric measurement, spectroscopy, and time and frequency standards.

Locking a laser by forcing the laser and reference frequency to be equal allows for two scenarios:

- The locking system steers the laser frequency to be equal to the reference frequency, which is referred to as frequency stabilization; and
- The locking system forces the reference frequency to follow the laser frequency, which is referred to as frequency tracking.

Whether used for frequency stabilization or frequency tracking, Moku:Pro's Laser Lock Box is designed to assist in high-performance, high-gain laser locking systems. It offers advanced setup, acquisition, and diagnostic features that makes it easier and quicker to set up and characterize laser locking systems.

Principle of operation

At the core of any laser locking technique is the measurement that provides the difference, or error, between the laser and a frequency reference. Often termed the "error signal", the quality of this signal ultimately determines the precision and accuracy of the entire locking system. A common precise method for obtaining an error signal is the Pound-Drever-Hall (PDH) technique. Using the PDH error signal in feedback systems has proven to give an extremely accurate measure of changes in the laser or cavity, resulting in its use in myriad applications such as absorption spectroscopy and gravitational wave detection. The PDH error signal technique has several key advantages such as:

- The technique provides highly accurate and precise measurements of phase and frequency differences between the laser and the cavity resonance.
- The sensing technique provides a zero-crossing error signal with zero frequency difference corresponding to a null error signal.
- Assuming all signal processing is done digitally, it avoids low frequency noise generated in analog electronics and demodulation circuits.

These advantages do come with some challenges. To obtain such a precise measurement of the frequency/phase, the PDH technique utilizes radio frequency (RF) modulation and demodulation techniques. This adds considerable complexity to the signal processing system as well as some complexity to the optical system. But once understood, these complexities are minor compared to the advantages of the PDH systems.

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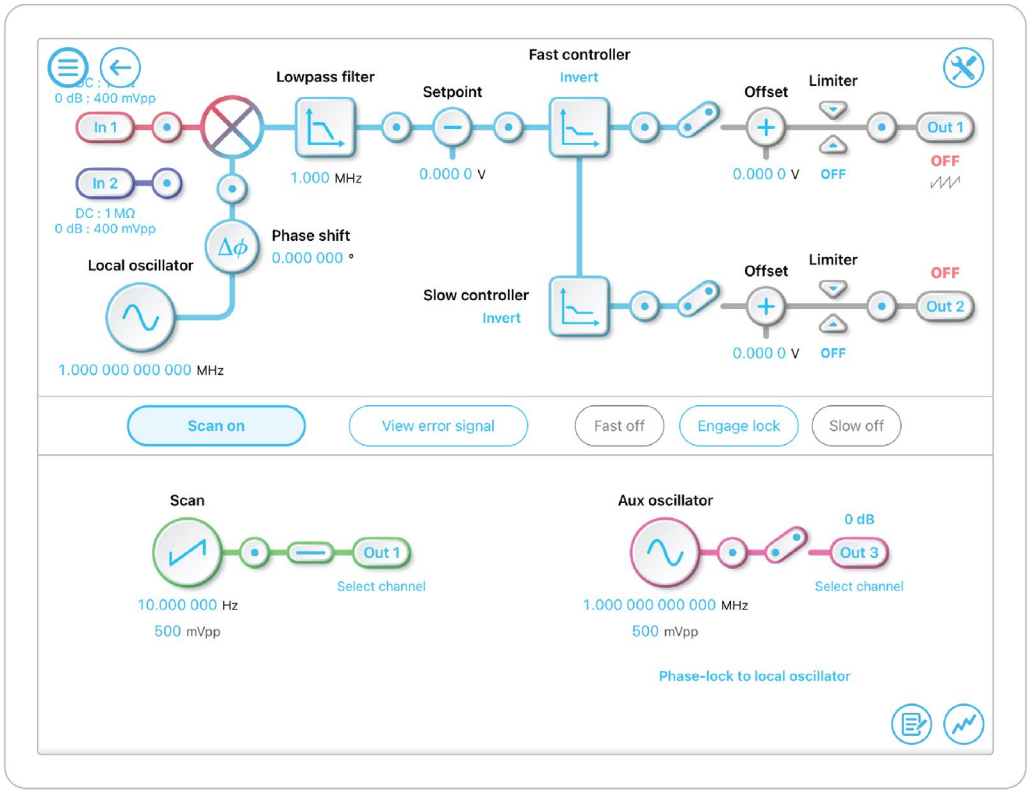
User Interface

The main user interface is divided into upper and lower screen sections. The upper user interface displays the processing chain and principal controls of the Laser Lock Box.



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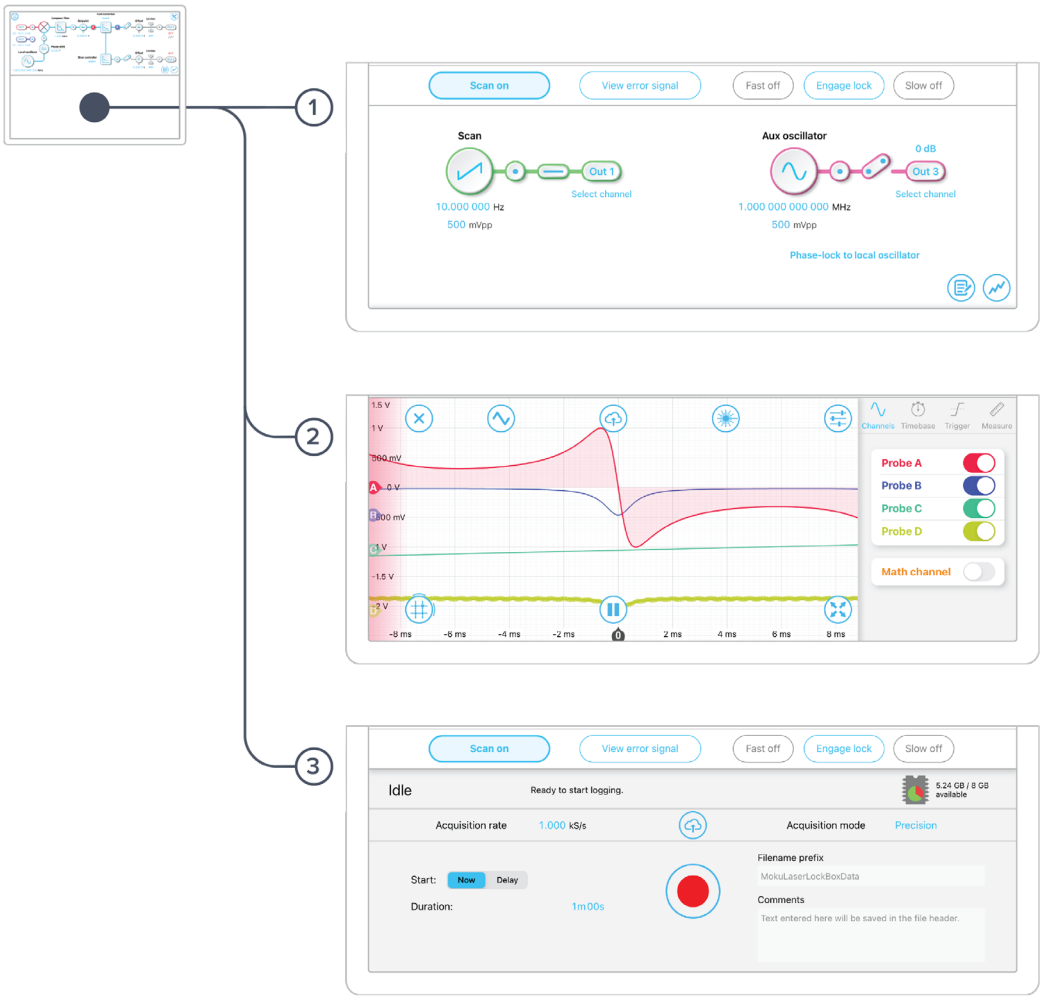
The lower half is readily set to display one of three parameter control panels: scan and aux oscillators, oscilloscope, and data logger.



ID	Description
1	Oscilloscope
2	Scan and aux oscillator control
3	Datalogger

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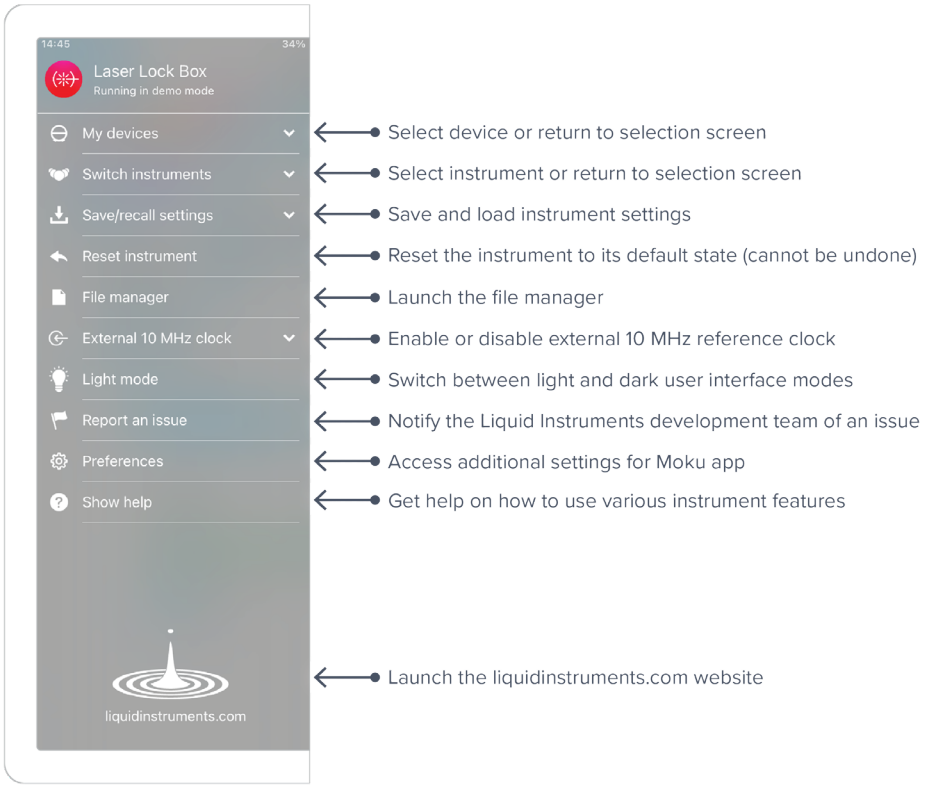
Main Menu

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



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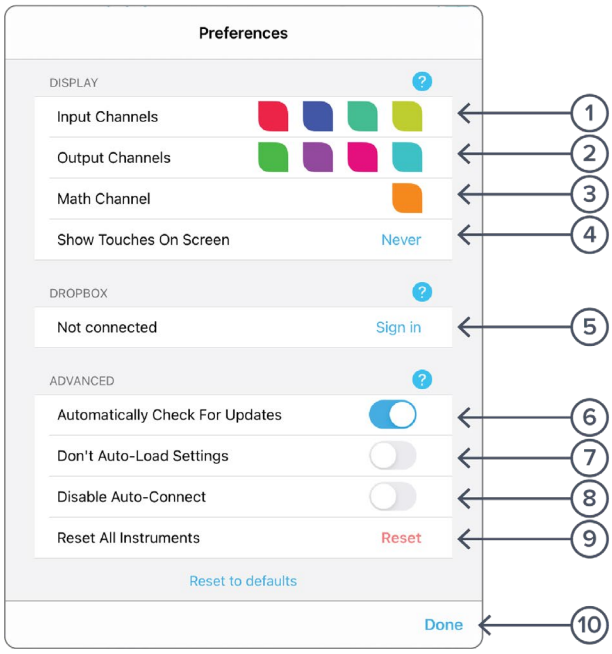
Preferences

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 this 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

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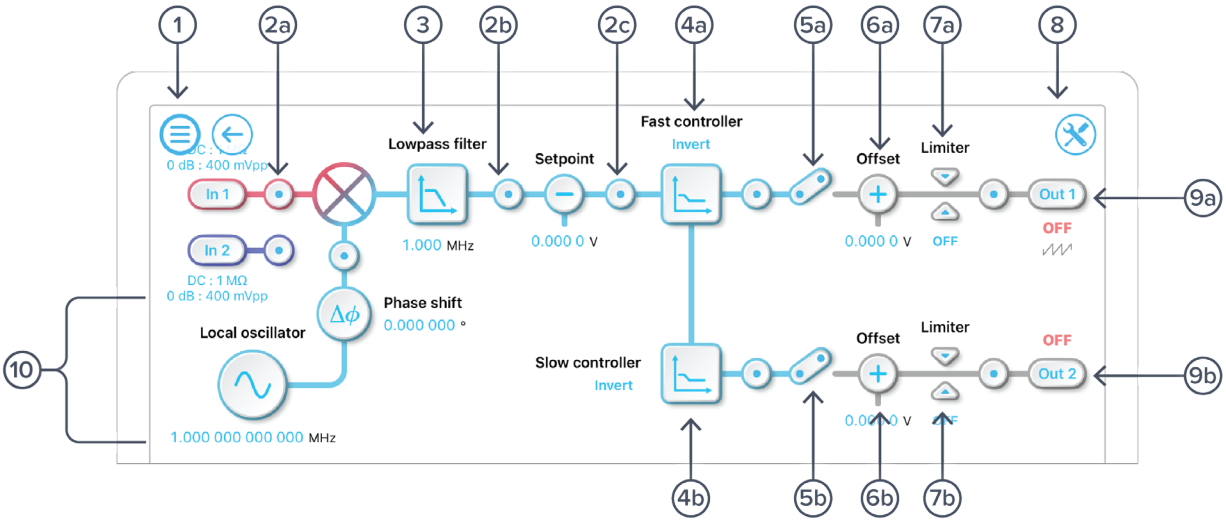
Upper User Interface



ID	Description	ID	Description
1	Main menu	6b	Apply DC offset to slow PID chain
2a-c	Tap to drop oscilloscope probe points to examine signals within the processing chain	7a	Configure output limiter on fast PID chain
3	Tap to configure the digital filter	7b	Configure output limiter on slow PID chain
4a	Tap to configure fast PID controller	8	Configure local oscillator
4b	Tap to configure slow PID controller	9a	Turn Output 1 output on/off
5a	Turn on/off fast PID chain output	9b	Turn Output 2 output on/off
5b	Turn on/off slow PID chain output	10	Control local oscillator frequency and phase shift
6a	Apply DC offset to fast PID chain		

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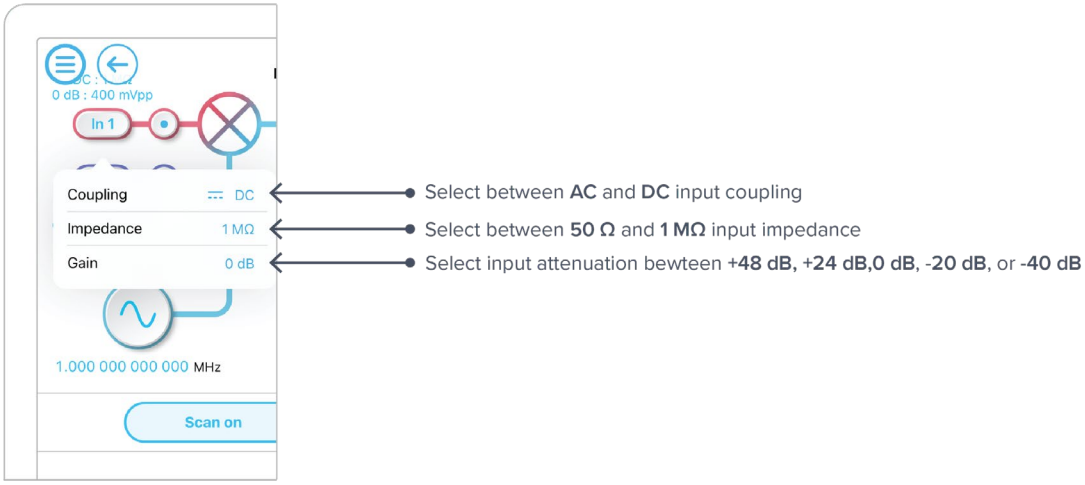
Signal input

Tap the In 1 icon to configure the input settings for the signal input. Similar configurations can be made on input 2



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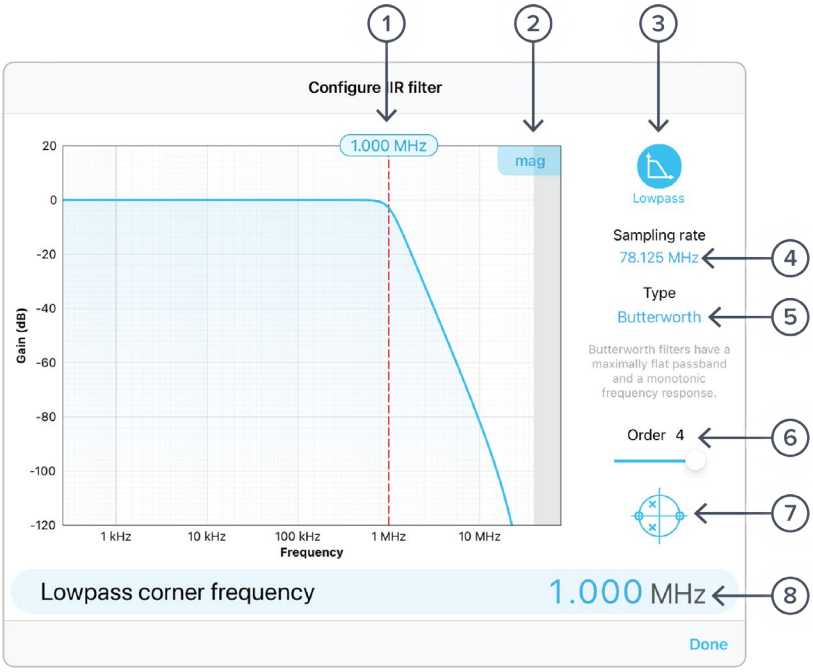
Digital filter configuration

Immediately after the demodulator function, there is a digital filter designed to remove unwanted signal components. This is highly configurable; just tap the low pass filter icon.



ID	Description	ID	Description
1	Configure lowpass filter corner frequency: tap to enter frequency or touch and drag	5	Tap to select filter type
2	Toggle between magnitude or phase plots	6	Tap to select filter order
3	Tap to select filter shape	7	Toggle view of poles/zeroes of filter
4	Fixed sample rate of 78.125 MHz	8	Tap to enter corner frequency

Filter Shapes

The shape of the filter can be selected by tapping the filter icon. There are two pre-defined filter shapes and a fully customizable filter option.

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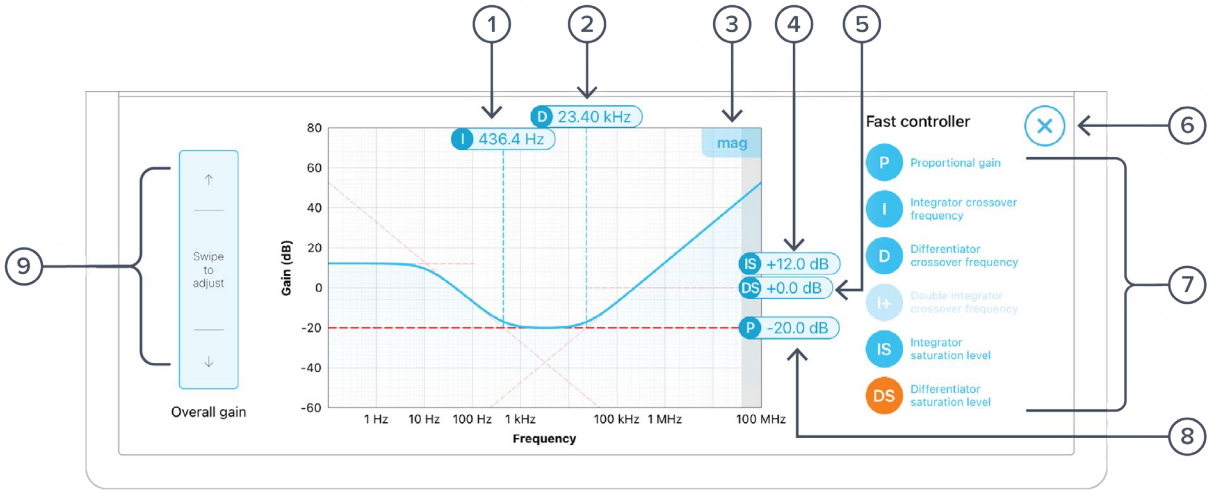
PID controllers

Moku:Pro's Laser Lock Box implements two cascaded PID controllers, a fast controller and a slow controller. The input of the slow PID controller is the output of the fast PID controller.

Both the fast and slow PID controllers can be configured graphically by dragging interactively on the magnitude chart or by tapping on cross-over tabs and entering frequency or gain on the soft keypad.

The PID controller provides full control over proportional, integral and derivative gain profiles with saturation levels available for the integral and derivative components. The PID's transfer function is updated in real-time.



ID	Description	ID	Description
1	Drag or tap to enter integrator crossover frequency	6	Close the PID controller interface
2	Drag or tap to enter differentiator crossover frequency	7	Proportional, integrator, differentiator, double integrator (only on the fast controller), integrator saturation, and differentiator saturation settings
3	Toggle between magnitude or phase plots	8	Drag or tap to enter proportional gain
4	Drag or tap to enter integrator saturation	9	Swipe to adjust selected PID parameter
5	Tap to set differentiator saturation		

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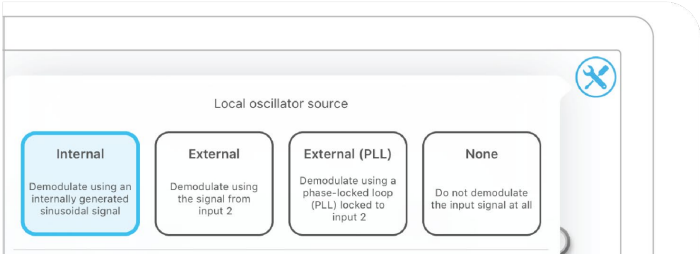
Local oscillator

The demodulation signal source can be configured in the settings dialog.

Select between **Internal**, **External**, **External (PLL),** and **None** demodulation modes



Demodulation

The demodulation mode determines which reference oscillator is used to demodulate the input signal.

Internal

The input signal can be demodulated with an internally generated reference signal. This *local oscillator* is derived from Moku:Pro's internal clock and thus shares the same time-base. The frequency range of the internal reference is 1 mHz to 600 MHz.

External (direct)

The input signal can be demodulated by a direct external reference, permitting the use of non-sinusoidal demodulation of the input signal applied on input 2.

External (PLL)

External (PLL) mode enables the Laser Lock Box to lock to an externally sourced demodulation reference applied to input 2. This mode uses a digitally implemented phase-locked loop (PLL) to track the phase of the external reference with a user configurable bandwidth. To configure the bandwidth of the PLL, tap the PLL icon to select the bandwidth between 10 Hz to 10 kHz. The PLL will automatically lock to the strongest harmonic of the external reference in the range of 1 MHz to 600 MHz with a manually configurable local phase shift. For lower frequencies, the PLL can be manually set as low at 1 kHz. The reacquire button can be used to re-lock to the external reference.

None

The demodulation step can be bypassed by selecting "None". This enables new modulation-free locking techniques such as DC locking, fringe-side locking, and tilt locking.

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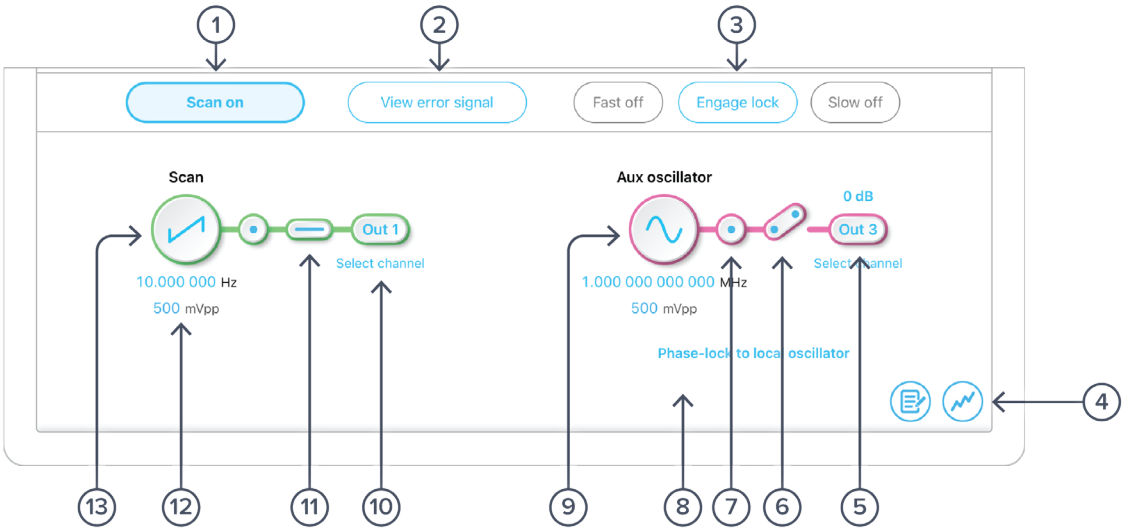
Lower User Interface

The lower user interface is used to either control the scan and aux oscillator, or to display the half screen oscilloscope or data logger.

Scan and aux oscillator



ID	Description	ID	Description
1	Turn off/on scan function	8	Phase lock aux to local oscillator
2	View error signal in oscilloscope	9	Configure aux oscillator frequency and amplitude
3	Engage lock enables the fast and slow PID controller outputs	10	Switch channel for scan waveform
4	Toggle oscilloscope view	11	Turn on/off scan waveform
5	Switch channel for aux oscillator	12	Configure scan amplitude and frequency
6	Turn on/off aux oscillator	13	Tap to configure scan as positive ramp, negative ramp, or triangle
7	Drop point for built-in oscilloscope		

* The summation of the signal sources is output when multiple sources are assigned to a single output.

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Oscilloscope

Moku:Pro's Laser Lock Box includes a built-in oscilloscope, enabling you to observe and record data of up to four signals at a time in the Laser Lock Box's processing chain. More details about Moku:Pro's Oscilloscope can be found in the Oscilloscope manual.

ID	Description	ID	Description
1	Close oscilloscope panel	7	Tap to select timebase tab
2	Toggle scan sync mode*	8	Tap to select trigger tab
3	Share oscilloscope data	9	Tap to select measurements tab
4	Select tap-to-lock**	10	Set oscilloscope to full screen
5	Reveal/hide settings sidebar	11	Pause/run oscilloscope
6	Acquisition tab selected	12	Tap to add time/voltage cursors, or drag right or drag up to create a cursor

The oscilloscope will appear automatically when a probe point is activated.

You can hide the oscilloscope by pressing the icon and reveal it by pressing the icon.

*Scan sync mode

When the scan sync mode is enabled, the error signal is displayed as a function of scan output.

**Tap-to-lock feature

When the tap-to-lock mode is enabled, the laser lock box automatically finds the zero-crossings and marks them on the display. Once a lock point is selected, the instrument sets the scan offset to the lock point and connects the PID to the output. Please note that the tap-to-lock feature does not automatically optimize the PID controller.

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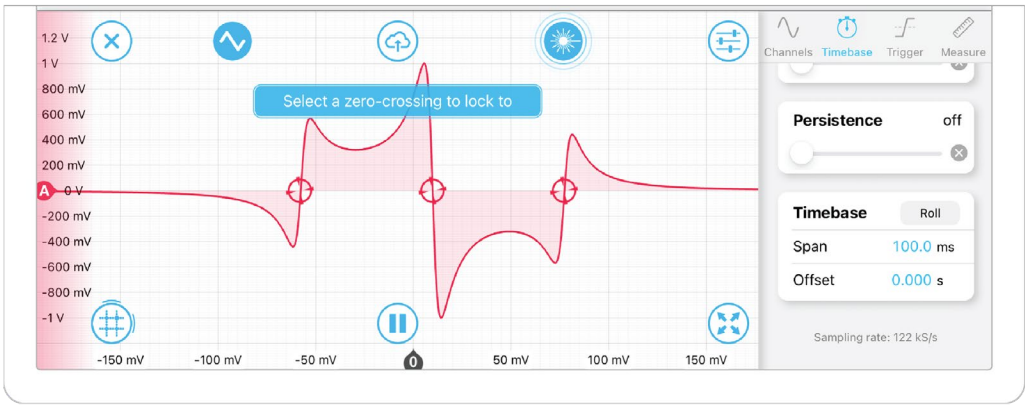

Additional details about the oscilloscope can be found in **Moku:Pro's Oscilloscope** manual.

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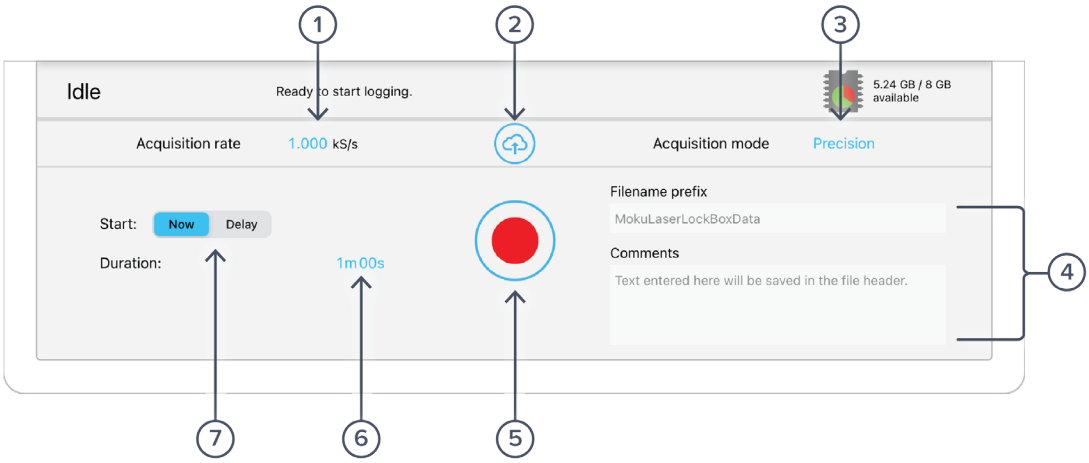
Data logger

The built-in data logger allows you to acquire data from up to four probe points at a time at a maximum sampling rate of 10 MSa/s. To access the data acquisition menu, press the icon. More details about data logger can be found in the **Moku:Pro's Data Logger** manual.



ID	Description
1	Select the sampling rate at which your measurement is recorded
2	Upload saved data
3	Select between **Normal**, **Precision**, or **Peak Detection** acquisition modes
4	Change filename and comments for the logged file
5	Record a new measurement
6	Configure measurement duration
7	Configure when to begin recording data

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