Oscilloscope

Moku:Pro User Manual

Moku:Pro's Oscilloscope features four highspeed, ultra-low noise input channels with up to 600 MHz analog bandwidth. An innovative blended ADC technology combines the information from 10 bit and 18 bit ADCs to cover a broad spectrum, providing class-leading input noise performance better than 30 nV/√Hz @ 100Hz with full dynamic range. The built-in four-channel waveform generators are capable of producing waveforms with a maximum bandwidth of 500 MHz.

LIQUID INSTRUMENTS

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V24-0925

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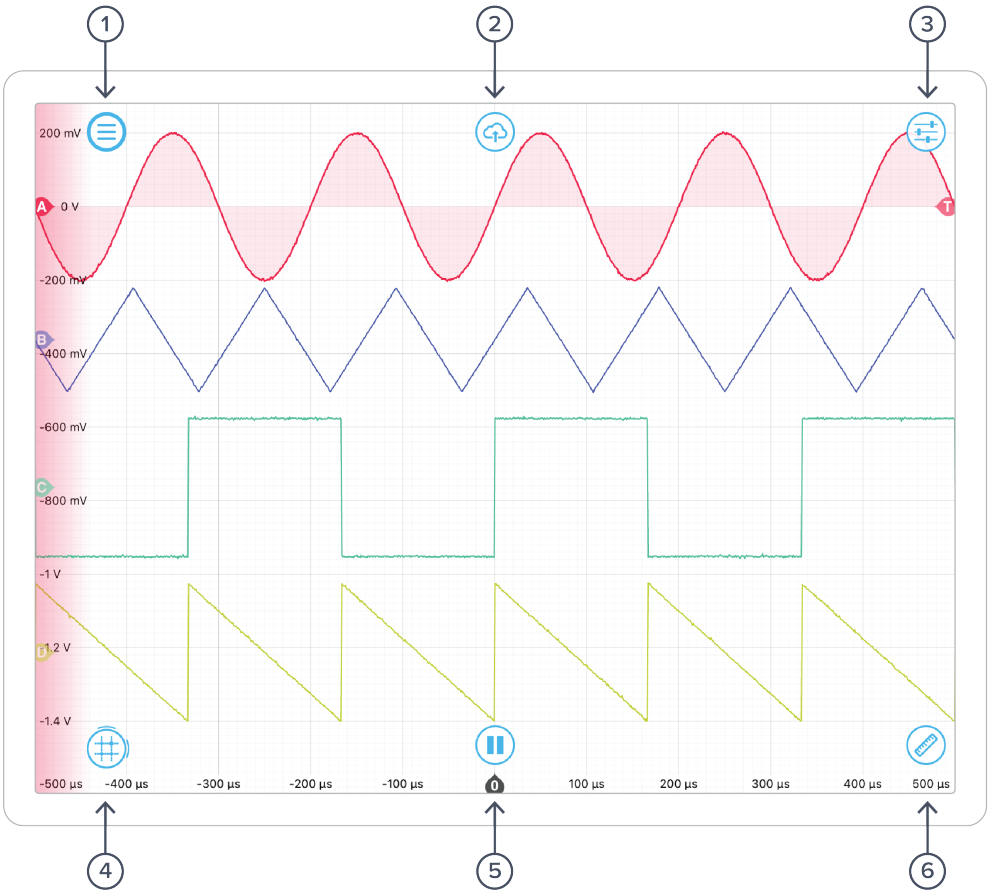
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Ensure Moku:Pro is fully updated. For the latest information:

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User Interface



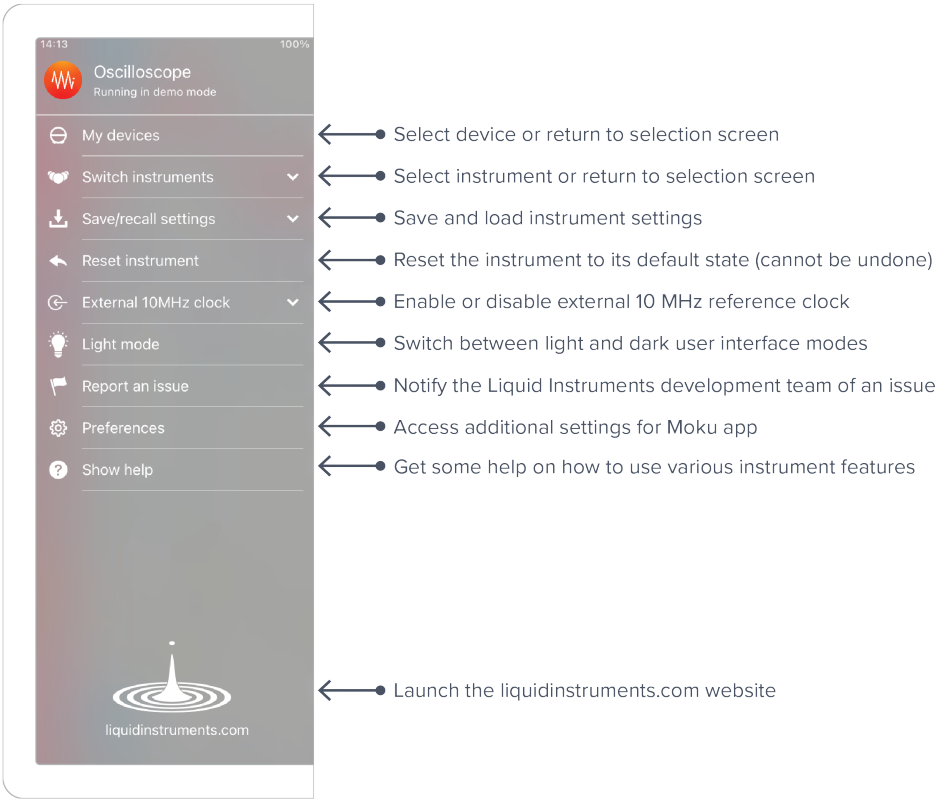
ID	Button	Description
1	Main menu	The main menu contains controls for switching instruments, switching devices, selecting device clock and user interface modes, and more. See Main Menu
2	Share	The sharing button gives access to controls that allow you to save and share your data. See Saving and sharing data
3	Controls	Reveals or hides the control drawer, giving access to all instrument settings. Also available by swiping in from/out to the right-hand side of the screen.
4	Cursors	Tapping brings up the cursor menu, from which you may add or remove cursors. Dragging up/right from this button will quickly create a voltage/time cursor respectively.
5	Play/pause	Pauses or resumes data capture. While paused, you can zoom in on features for more detail, but no new data will be captured. Pressing the “Share” button will also pause capture and must be resumed from this button.

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6	Measurements	Reveals or hides the measurements drawer. Also available by swiping up from/down to the bottom of the screen. See Making Measurements

Main Menu

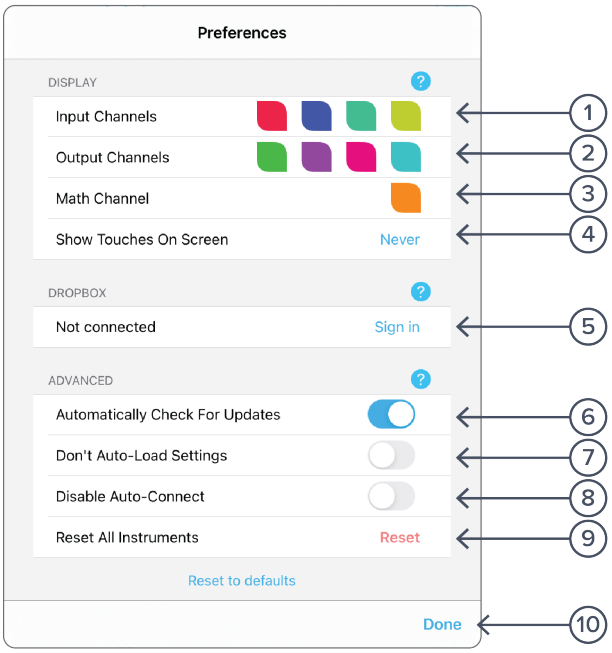
The **main menu** can be accessed by pressing the icon, allowing you to:



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Preferences

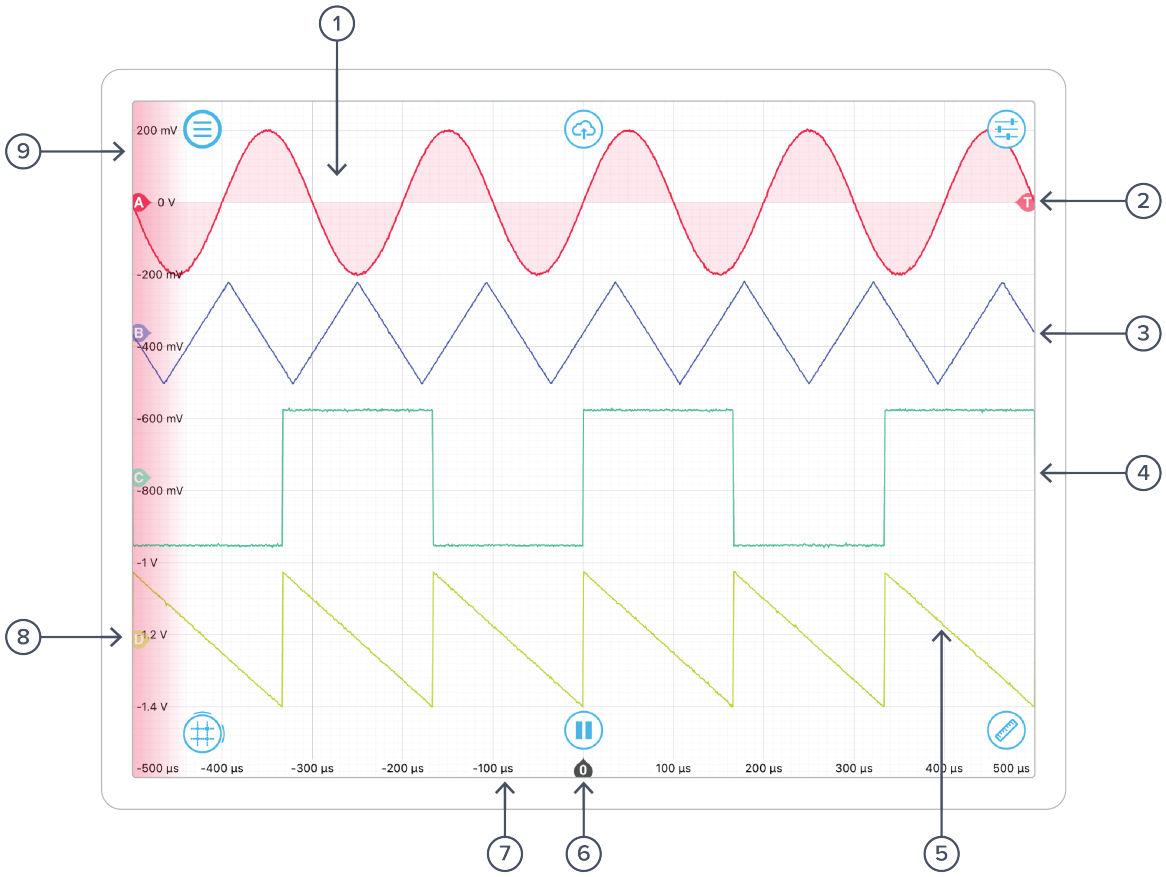
The preferences pane can be accessed via the main menu. In here, you can reassign the color representations for each channel, connect to Dropbox, etc. Throughout the manual, the default colors (shown in the figure below) are used to present instrument features.



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.

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Axes and Traces

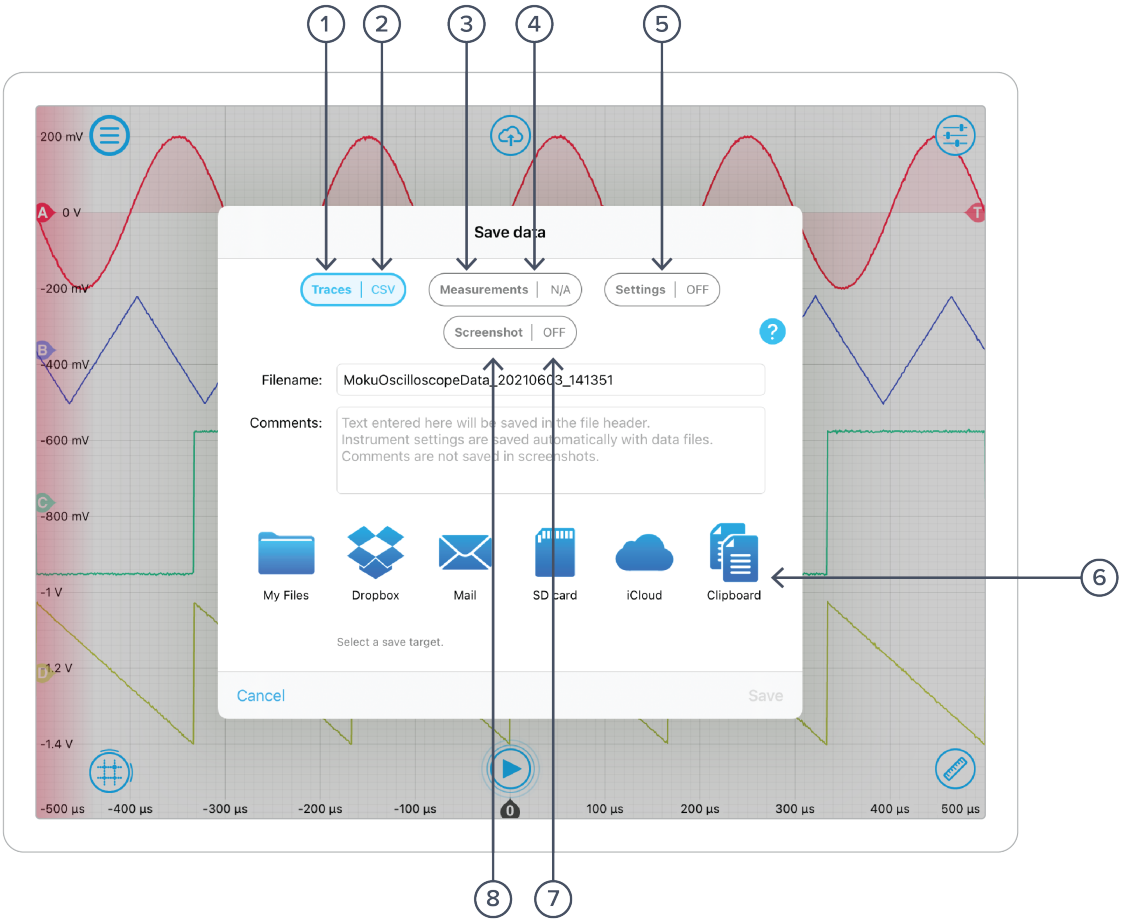


ID	Button	Description
1	Channel A Trace	The time/voltage trace for channel A. When channel A is active, the trace will have a light fill to the zero-volt level (as shown).
2	Trigger Level Mark	Marks the trigger threshold level. Shown against whichever trace is currently set for triggering (if any). Drag to set level or tap for more options. See Navigating your Signal.
3	Channel B Trace	The time/voltage trace for channel B.
4	Channel C Trace	The time/voltage trace for channel C.
5	Channel D Trace	The time/voltage trace for channel D.
6	Time Origin Mark	Marks the “zero second” point on the time scale. This will be the trigger point if the Oscilloscope has triggered, otherwise is undefined.
7	Time Axis	Shows the time scale for both channels (the channels always share a time scale).
8	Origin Mark	Marks the “zero volt” level for channel D. Each channel has its own corresponding origin mark.

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9	Voltage Axis	Shows the voltage scale for the active channel. The active channel is selected by tapping on the waveform and is indicated by the shading of the voltage axis and the trace itself.

Saving and sharing data



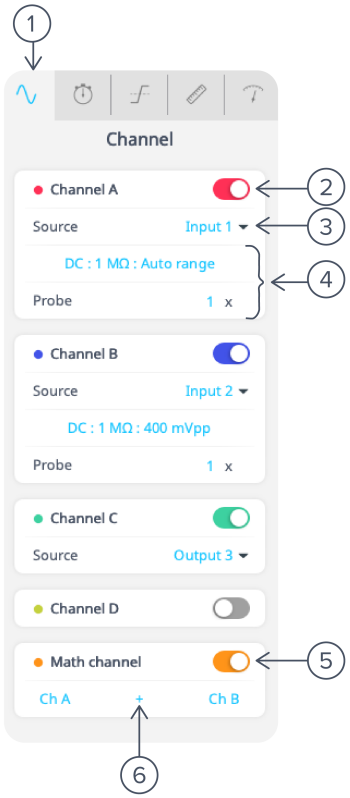
The **save data** options can be accessed by pressing the icon, allowing you to:

ID	Button	Description
1	Traces data	Select to enable saving of trace data
2	Traces format	Tap to select CSV or MATLAB format
3	Measurements trends	Select to enable saving of measurement trends, if a measurements trends drawer is open
4	Measurement trends format	Tap to select CSV or MATLAB format
5	Settings	Save Oscilloscope settings to a file, enables user to quickly setup the Oscilloscope in a known state
6	Save data destination	Select data destination: DropBox, Email, iCloud, or Clipboard
7	Screenshot format	Select PNG or JPG for screenshot
8	Screenshot	Select to save screenshot

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Settings and controls

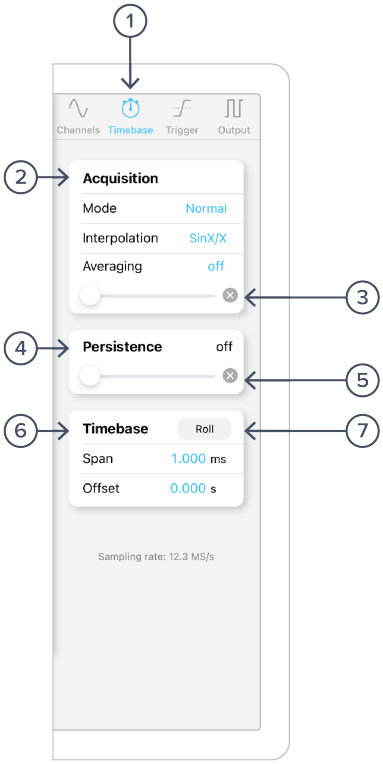
Channel Control Pane



ID	Button	Description
1	Channels Control Pane Selector	Reveals the channels control pane in the controls drawer. Can also be revealed by swiping right from the timebase control pane.
2	Channel A	Toggles channel A on/off
3	Channel A source	Changes Data Source for channel A.
4	Channel A Controls	**Coupling:** Toggles between DC/AC coupling **Impedance:** Toggles between 1 MΩ and 50 Ω impedance **Range:** Manually or Auto set the voltage range **Probe:** Specifies the probe attenuation, if such an attenuating probe is connected.
5	Math Channel On/Off	Toggles the math channel on/off
6	Math Channel Control Pane	**(Operation):** Selects the mathematical operation to perform on the data. Tap the operation symbol and/or channel letters to change behavior.

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Timebase Control Pane

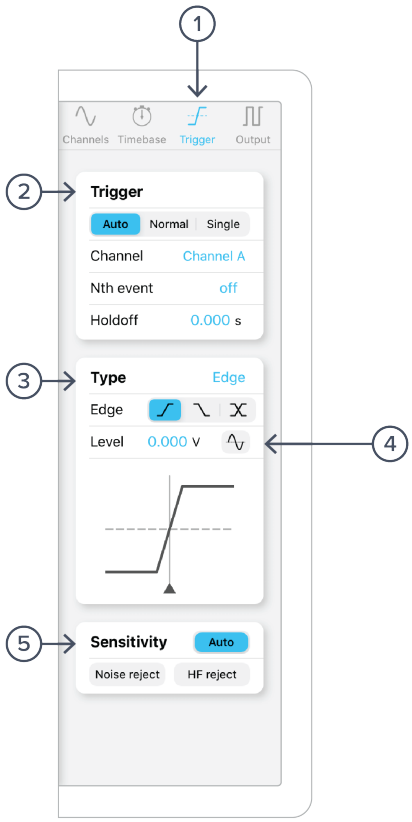


ID	Button	Description
1	Timebase Control Pane Selector	Reveals the timebase control pane in the controls drawer. Also revealed by swiping left from the channels pane or right from the trigger pane.
2	Acquisition Control Pane	**Mode:** Changes acquisition mode between normal and precision. See Acquisition Modes and Sampling **Interpolation:** Changes the on-screen interpolation mode. See Display Options **Averaging:** Displays on screen an average trace taken from this many consecutive waveforms.
3	Averaging Reset	Tap to reset averaging
4	Persistence Control	Keeps a history of the last number of waveforms on the screen.
5	Persistence Reset	Resets the on-screen persistence
6	Timebase Scale Pane	**Scale:** Horizontal screen scale. Changes dynamically when pinch-zooming a trace or can be entered manually by tapping. **Offset:** Horizontal trigger point offset. Changes dynamically when horizontally-dragging a trace or can be set manually by tapping.

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7	Roll-mode Toggle	Toggles between roll and sweep modes. See Display Options

Trigger Control Pane

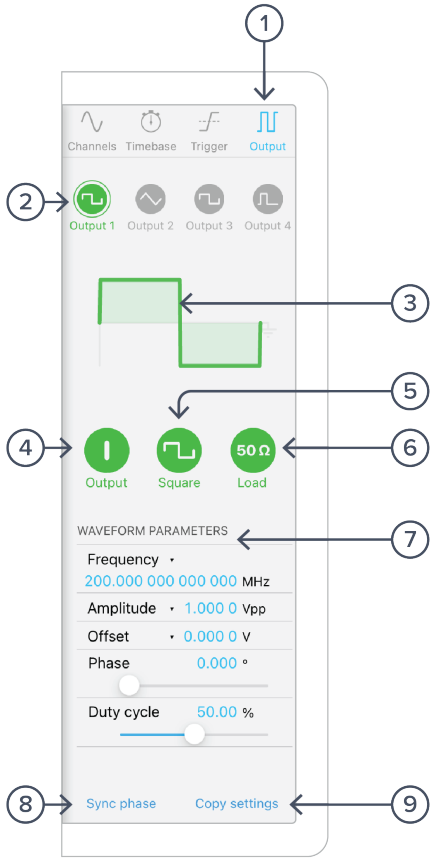


ID	Button	Description
1	Trigger Control Pane Selector	Reveals the trigger control pane in the controls drawer. Can also be revealed by swiping left from the timebase pane or right from the output pane.
2	Trigger Settings Pane	**(Mode):** Switches between auto, normal and single trigger modes. See Navigating your Signal **Channel:** Select the source for the trigger circuit. This can be one of the Oscilloscope channels, Moku:Pro inputs, Moku:Pro outputs, or external trigger input independent of what is displayed on the screen. **Nth event :** Select up to 65,535 trigger events before actually triggering the Oscilloscope **Holdoff :** Select a time to holdoff Oscilloscope trigger post trigger event
3	Trigger type	Select between edge and pulse triggering with selectable levels, edge types and pulse widths
4	Trigger zero	One touch to set trigger level to 0 V

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5	Sensitivity	Configure auto or manual hysteresis for noise rejection. Configure HF reject to enable a low pass filter on the trigger circuit, giving better noise immunity but with a short delay between the trigger event and detection.

Output Control Pane



The output pane of the Oscilloscope allows for generation of various waveforms on Moku:Pro's output channels.

ID	Button	Description
1	Output Control Panel Selector	Reveals the output control pane in the controls drawer. Can also be revealed by swiping left from the trigger pane
2	Output 1 select	Select output 1, 2, 3, or 4.
3	Waveform Preview	Shows a preview of the waveform to be generated
4	Output enable	Toggles the output enable of the selected channel
5	Waveform select	Selects the waveform type to generate
6	Output load select	Selects the output load

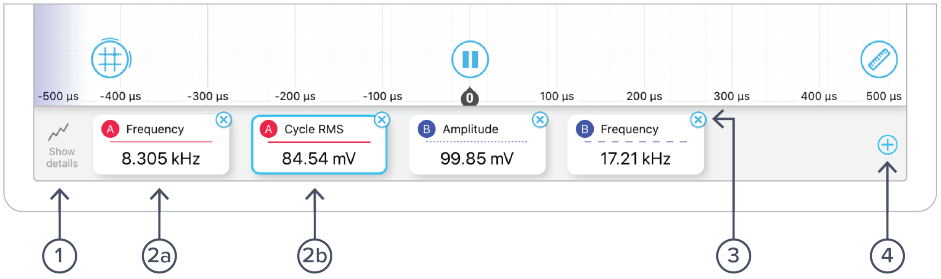
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7	Waveform Parameters	The parameters available in this pane vary for different waveform types. For more information on these parameters, refer to Using the Built-in Waveform Generator. **Amplitude, Frequency:** Basic waveform parameters. **Offset:** DC value to add to the output. Note that setting this non-zero may restrict the maximum amplitude. **Phase:** Phase offset of the waveform with respect to the Moku:Pro's internal clock (and therefore the other output channel). This is not relative to any input signal characteristic. **Symmetry:** For ramp wave, the ratio between rising and falling edge times. **Pulse Width:** For pulse wave, the high-time of the pulse (limited by the frequency). **Edge Time:** For pulse wave, the rise and fall time of the pulse edges. Can be manipulated to provide triangle pulses and other waveforms. **DC Level:** For DC wave, the constant voltage to output.
8	Sync phase	Synchronizes phase with the other channel
9	Copy settings	Copies all waveform settings from one channel to the other

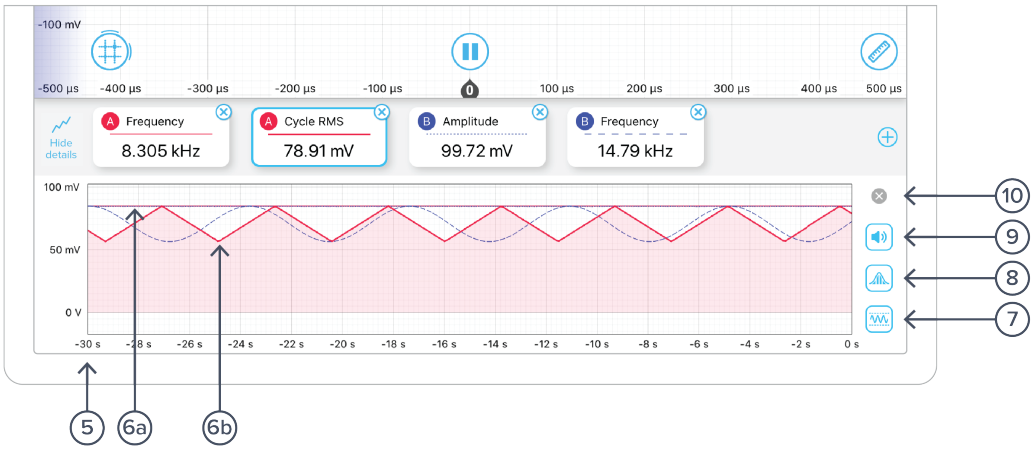
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Measurements drawer

Tap the ruler icon to open the measurements drawer. See Making Measurements for detailed definitions and explanation of the many measurement options.



Show details reveals the measurements trend graph.

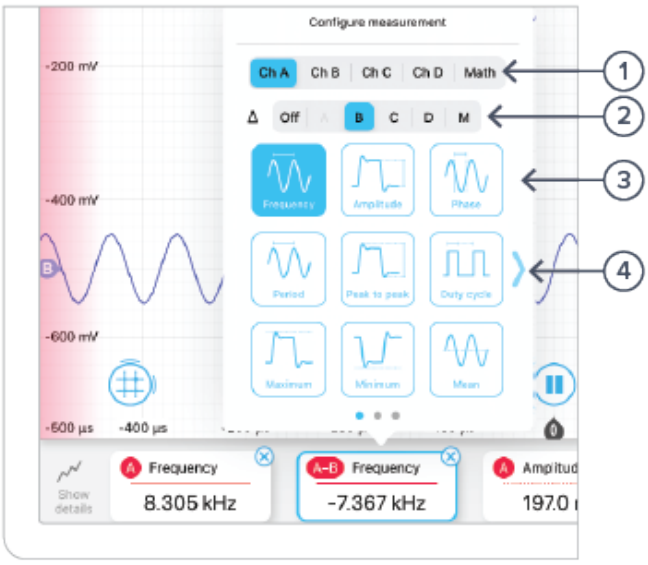


ID	Button	Description
1	Show/Hide Trends	Tap to reveal/hide the measurement trend draw. May also be revealed by swiping up/down on the measurement bar.
2a,b	Measurement Tablets	Measurement results color-coded to the source channel. Line style is matched to the trend window. Tap to change measurement.
3	Remove Measurement	Remove this measurement.
4	Add Measurement	Add new measurement to the currently active channel.
5	Trend History Length	Tap to change trend history length from 30s to 300s,
6a,b	Trend plot	Solid and dashed plots representing trends of the respective measurements.
7	Autoscale	Scale the vertical axis of the history plot.
8	Statistics	Switch to statistics view of the measurements.
9	Audio	Enable audible representation of selected measurement. This can be very helpful when working on an experimental adjustment when you do not have immediate sight of the oscilloscope
10	Close	Close the measurements details

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Configure measurement

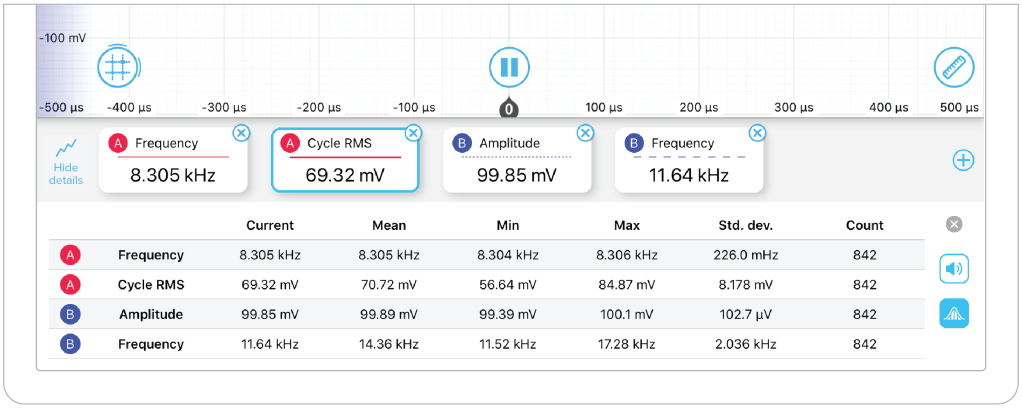
Tap any measurement tab to configure the measurement



ID	Button	Description
1	Channel selection	Select channel A, B, C, D, or Math for measurement.
2	Delta measurement	Select a delta measurement. The screenshot shows frequency difference between channels, together with measurements of channel A amplitude and frequency.
3	Measurement	See Making Measurements for full details
4	Next tab	Select next tab of measurements.

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Measurements drawer with detailed statistics



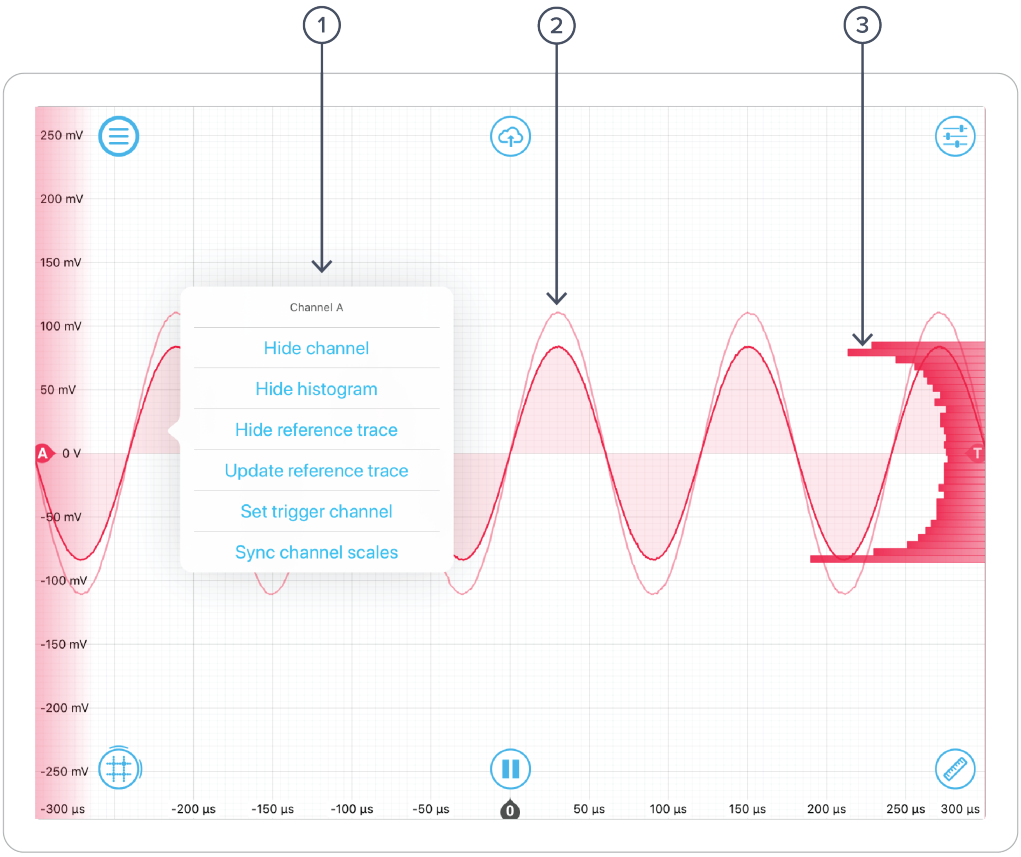
Cursors button

The cursor button allows time and voltage cursors to be readily displayed. Drag up from the cursor button to create a voltage cursor. Drag right from the cursor button to create a time cursor.

Tapping the cursor button allows all cursors to be removed while tapping individual cursors allows specific time or voltage levels and configuration as a reference.

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Trace Context menu



ID	Button	Description
1	Trace Context Menu	Long-press on the trace to reveal: **Hide Channel:** Removes channel trace from the screen. **Show/Hide Histogram:** Histogram shows the count of points at a particular voltage value for that waveform. **Show/Hide/Update Reference Trace:** Reference trace takes a snapshot of the channel trace at the time the reference is created. The reference trace is displayed in the active channel's color with transparency. **Set Trigger channel:** Set trigger to channel selected channel **Sync channel scale:** Make scale of all visible channels the same as the selected channel scale.
2	Reference Trace	An example reference trace for channel A.
3	Histogram	An example histogram for channel A.

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Instrument Reference

Configuring Inputs

Input Impedance

Moku:Pro's inputs have a selectable impedance of either 1 MΩ or 50 Ω. This is effectively the resistance from the signal line to ground. For high-frequency measurements, it is important that Moku:Pro's impedance matches that of the device under measurement. If the impedance is mismatched, some signal power will reflect off Moku:Pro's input, thus interfering with the measurement.

The input impedance also forms a resistive divider with the signal's source impedance, reducing the apparent voltage. The ratio should be a half; however, the impedances have a tolerance that may affect the accuracy of the measurement.

High-impedance mode (1 MΩ) is used where Moku:Pro is observing a signal that is externally-terminated (e.g. between two high-speed devices), or where absolute voltage measurement accuracy is required and the signal is low-enough frequency that reflections from the measurement equipment do not significantly interfere with the original signal.

High-impedance is the default setting for many oscilloscopes that are not targeted at RF frequencies, while 50 Ω is most common for RF devices and signal generators.

Gain Ranges

Moku:Pro contains a front-end attenuator that divides the signal by 10x or 100x increasing the range of voltages that can be measured. In Moku:Pro's Oscilloscope, this attenuator is automatically activated whenever the screen includes voltages outside of the range ±0.5 volts; that is, whenever you zoom out or scroll up/down to reveal voltages outside of this range.

Further input voltage range can be achieved by using an attenuating probe. A "10x" probe is common in test and measurement, meaning the probe will present 1/10th of the input voltage to Moku:Pro. To correct for this on the Oscilloscope's voltage scale, the probe factor can be entered on the channels tab.

Overvoltage Protection

Moku:Pro's input will disconnect automatically when the input voltage on the BNC connector exceeds its limit. At this time, the Oscilloscope will show a flat line at zero volts.

If you're having trouble viewing your signal, ensure the signal is within this range, e.g. by using an attenuating probe.

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Coupling

Moku:Pro includes a switchable AC/DC coupling circuit on each input. This is activated from the channels tab.

For most applications, DC-coupled is the preferred option; this does not filter or modify the signal in any way.

AC-coupled acts as a high pass filter, removing the DC component of the incoming signal (and attenuating other components with a frequency below the coupling corner). This is useful when you're looking for a small signal on top of a large DC offset. Doing so can give better precision than simply scrolling the trace up the screen, as it may avoid Moku:Pro activating its internal attenuator (see Gain Ranges).

Navigating your Signal

Trace Selection

Moku:Pro's Oscilloscope can display up to four signal traces, plus a math trace. Each signal trace may either be the analog input (default) or a preview of the analog output if the waveform generator is active.

To turn a trace on and off, tap the slider on that trace's box on the channels tab.

Triggering

The triggering circuit of the Oscilloscope allows you to indicate what kind of signal event you're interested in. This event will then be aligned to the "zero second" mark of the time axis. Common events that can be triggered are simply times when the signal rises or falls past a particular voltage. These are "rising edge" and "falling edge" triggers respectively, and the voltage past which the signal must move is called the "trigger level".

Data to be displayed before the trigger point (negative values on the time axis) is called "pre-trigger" data and data after, "post-trigger" data. Moku:Pro's Oscilloscope can record and display a maximum of 16,384 points of pre-trigger data but as many as 2^{32} points of post-trigger. In practice, this limits the distance that you may scroll to the left and right.

In the Oscilloscope, the trigger level is set from the trigger tab, or by dragging the trigger marker on the screen. Other trigger parameters such as the event to be triggered upon and the channel to be monitored are also on this tab.

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Trigger Modes

Trigger modes describe how the Oscilloscope responds to several trigger events. The options are “Auto”, “Normal”, and “Single” triggering.

“Normal” trigger mode will only trigger, and therefore update the display, when a trigger event is detected. This is very useful if you genuinely only care about the signal around the trigger event, but you cannot view the signal in real-time without a stream of triggers (e.g. for a DC signal or while setting up the trigger in the first place).

“Auto” trigger mode acts like “Normal”; however if no trigger event has been detected in a short while, it will generate a fake event, causing the display to update. The delay from a real trigger to a fake one is longer than that between fake events, so the signal can be viewed in real-time without triggers while still giving time to view events around a trigger if one does arrive.

“Single” trigger simply captures the first trigger event then stops acquisition until the user starts it again. This is useful when you need time to study your signal in detail or to capture a specific signal event for sharing or saving.

Trigger Filtering

Often a signal will be noisy and setting a simple trigger event such as “rising edge” may cause a trigger event due to noise rather than due to the underlying signal. Moku:Pro’s Oscilloscope has two features to help reliably trigger on noisy data: noise reject and high-frequency (HF) reject.

Noise reject adds a small amount of hysteresis to the trigger event. This stops the trigger firing several times as noise repeatedly crosses the trigger threshold; the rising and falling events happen at different levels.

High-frequency (HF) reject passes the trigger signal through a low pass filter before looking for the trigger event. This smooths out the noise, allowing the trigger circuit to observe just the underlying signal. The trade-off is that this filter introduces some delay in the signal, offsetting the trigger event from the actual data.

Pan and Zoom

The signal on the Oscilloscope will always align a trigger event to the “zero second” mark on the time axis (including fake trigger events injected in auto-trigger mode). To move the signal and view different times and voltages, the Oscilloscope provides a number of gestures:

Single-finger drag: Move the signal left and right (different times) and up and down (different voltage offsets).

Two-finger pinch: Zoom the signal in and out in time and/or voltage (horizontal and vertical pinch respectively).

Two-finger drag: Quickly zoom the signal in and out in time and/or voltage, maintaining current voltage and time offsets. This mode is good for changing scales by orders of magnitude without repeatedly pinch-zooming.

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Screen Update Modes

As you zoom out, you will come to a point where the displayed time span is longer than the time between screen updates. In this case, the Oscilloscope will enter one of two update modes: sweep or roll.

Sweep Mode

Sweep mode is the default if roll is not active. In sweep mode, the screen will only update once a trigger event is received. At this time, all the currently-captured data (all the data before the trigger point) will be updated on the screen at once. New data will be shown on the screen as it arrives, with the new data progressively “sweeping” across the screen.

This mode is useful when you still require trigger events despite the low data rate.

Roll Mode

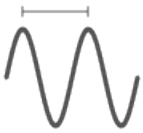
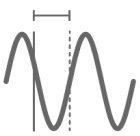
If roll mode is active, trigger events are completely ignored. Instead, all new data is displayed on the screen in real time with the most recent data on the right of screen. This causes the trace to roll from right to left continuously.

Use this mode if you want to view all your data in real time and no longer care about aligning the data by trigger.

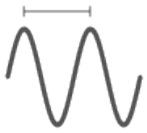
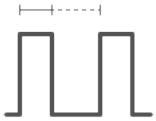
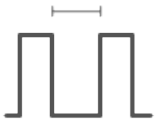
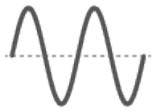
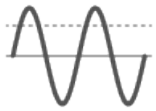
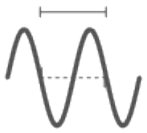
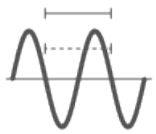
Making Measurements

Automatic Measurements

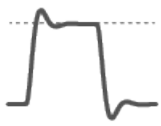
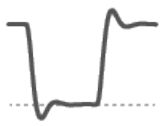
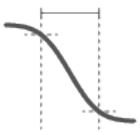
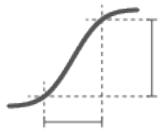
The Oscilloscope can automatically make a number of measurements on your data in real time. To open the measurements pane, swipe up from the bottom or tap the ruler icon. Add a new measurement by tapping the plus button or configure an existing measurement by tapping the measurement itself. The available measurements are described below.

Name (unit)	Icon	Description
Frequency (Hz)		Frequency of the signal as determined by the time between rising or falling edges.
Phase		Phase of strongest frequency component with respect to a perfect sine wave.

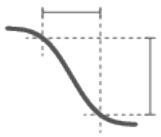
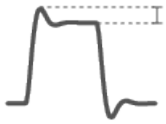
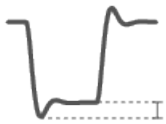
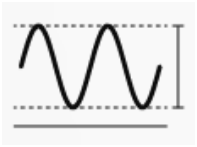
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Period (s)		Time between pairs of rising or falling edges.
Duty Cycle (%)		Ratio of the time spent above the median to that spent below it.
Pulse Width (s)		Time the signal spends above the median.
Negative Width (s)		Time the signal spends below the median.
Mean (V)		Average value of the signal
RMS (V)		Root-Mean-Square value of the signal
Cycle Mean (V)		Average value of the signal, discounting partial cycles at the beginning and end of the frame.
Cycle RMS (V)		Root-Mean-Square value of the signal, discounting partial cycles at the beginning and edge of the frame.
Standard Deviation (V)		Mathematical description of the spread of the points in the signal

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Peak to Peak (V)		Difference between the highest and lowest voltage in the signal.
Amplitude (V)		Difference between the high- and low-level voltage, excluding over- and undershoot.
Maximum (V)		Highest voltage in the signal
Minimum (V)		Lowest voltage in the signal
High Level (V)		Highest voltage in the signal, excluding overshoot.
Low Level (V)		Lowest voltage in the signal, excluding undershoot
Rise Time (s)		Time taken for the signal to transition from 10% to 90% of the way from minimum to maximum.
Fall Time (s)		Time taken for the signal to transition from 90% to 10% from maximum to minimum.
Rise Rate (V/s)		Rate at which the signal transitions from 10% to 90% of the way from minimum to maximum

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Fall Rate (V/s)		Rate at which the signal transitions from 90% to 10% of the way from minimum to maximum
Overshoot (V)		Distance the signal shoots above the maximum level before settling
Undershoot (V)		Distance the signal shoots below minimum level before settling
Fringe visibility (%)		Measurement of interference

Measurement Trends

The Oscilloscope can keep a time-history of any of the above measurements and graph the trends in those measurements.

To reveal the measurement trends tray, swipe up from the measurements tray or tap the “Show Trends” button on the left of that tray. The history of all configured trends will be shown. This window doesn’t define a Y-axis, it’s designed to provide trend information only, not precise readouts of prior measurements.

To configure the length of the history, tap the left-most time value on the X-axis (which is highlighted blue). The range is from 30 seconds to 300 seconds.

Manual Measurements

Measurements of voltage and time between points can also be made manually by placing cursors. A cursor can measure either voltage or time and is linked to a specific channel.

To place a cursor, tap the cursor icon in the bottom-left, or touch and drag out from this icon. Dragging up will give a voltage cursor on the current channel, dragging right will give a time cursor. To remove a single cursor, tap that cursor’s readout box to reveal its cursor menu and select "remove”. To remove all cursors, tap the cursor icon in the bottom-left and select “remove all cursors”.

Voltage Cursors

By default, a voltage cursor will stay at the location you drag it to and display the voltage at that level. Tap the cursor to reveal the cursor menu, from which you can lock the cursor on to specific

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aspects of the signal; current maximum or minimum, or all-time maximum or minimum (max/min hold).

If you have multiple voltage cursors, one can be set as the reference cursor from its cursor menu. If there is a reference cursor, then all other cursor voltages will be displayed with respect to this reference.

Time Cursors

A time cursor must be placed at a specific location and cannot be locked to a signal. It will display the time at which it is placed, relative to the trigger point (see Triggering above).

When two cursors are placed, the difference between them is automatically displayed towards the bottom of the screen, as is the frequency corresponding to this period.

If more than two cursors are placed, one can be selected as the reference cursor and all other time and frequency measurements will then be shown with respect to that. Like voltage cursors, setting a reference is done by tapping the cursor's reading to reveal its cursor menu, and selecting "reference".

Acquisition Modes and Sampling

The Oscilloscope processes data in two stages. First, data is acquired from the analogue-to-digital converters (ADCs), down-sampled, and stored in memory. From there, the data is aligned relative to the trigger point and displayed on the screen.

Both of these operations require down- or up-sampling of the data (reducing or increasing the total number of data points) and the method for doing this can provide increased precision and different aliasing behaviour.

Acquisition Modes

The acquisition mode refers to the process of capturing the data and storing it in Moku:Pro's internal memory. This is always down-sampled.

Normal Mode: Extra data is simply removed from the memory (direct down-sampled). For example, the ADC is running at 1.25 GSPS and the selected time span on the Moku oscilloscope requires 1MSPS, then 1249 out of 1250 points will be ignored.

This causes the signal to alias and doesn't increase the precision of the measurement. It does however provide a view-able signal at all timespans and all input frequencies.

Precision Mode: Extra data is averaged to the memory (decimation). For example, if the ADC is running at 1.25 GSa/s and the selected time span on the Oscilloscope requires 1 MSa/s, then 1250 consecutive samples will be averaged to produce one data point in the memory.

This increases precision and prevents aliasing, however if you have the wrong time span selected for the signal then all points can average to zero (or close to it), making it appear like no signal is present.

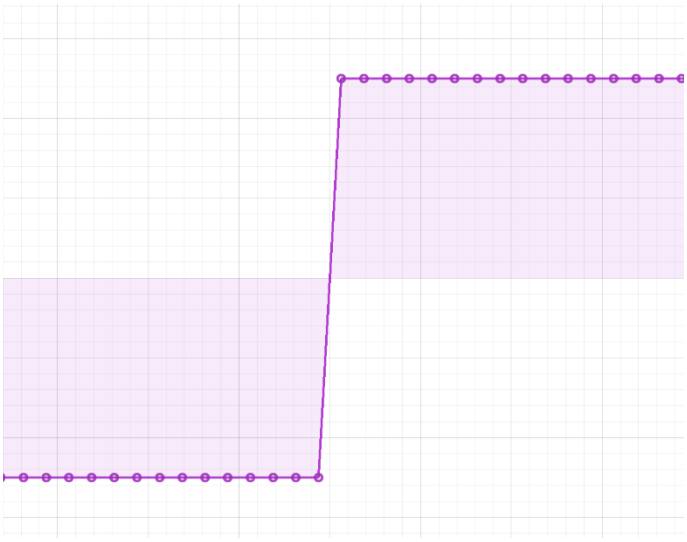
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A common workflow would be to use normal mode to find the signal and align it as you want, then switch to precision mode to improve the signal quality for measurement.

Interpolation Modes

Once the data is in the memory, it needs to be displayed on the screen. This may be down-sampling or up-sampling, depending on zoom level. Down-sampling is done by Cubic Spline Interpolation and cannot be configured by the user. Up-sampling mode can be selected and is one of Linear, Sin X/X or Gaussian.

Linear



Linear interpolation does not perform any up-sampling. For display, it marks each point in the original data set and draws a straight line between them. This is “ugly” but doesn’t “invent” any new data points.

Sin X/X

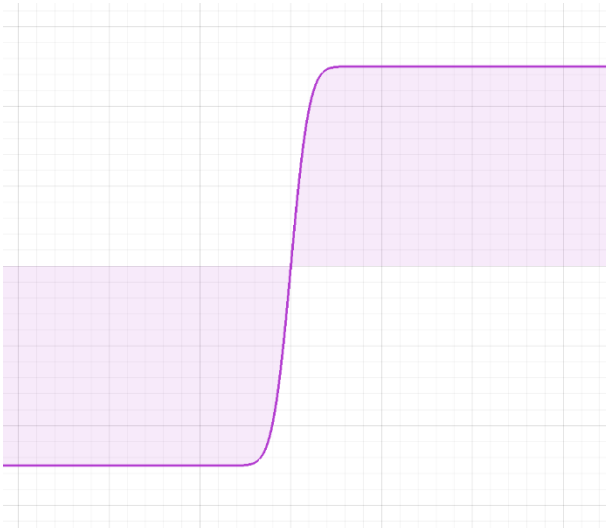


Also called “Sinc” interpolation, this mode preserves the frequency characteristics of the signal. In the time domain though, it can appear that there is over- or under-shoot that is not in fact present in the signal.

Use Sin X/X if your signal is sine-like; it doesn’t include significant frequency components that have been removed by filtering or decimation.

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Gaussian



Gaussian interpolation “smooths” the signal out, preserving the visual characteristics of the signal at the expense of frequency information.

Use this mode if your signal is square-like; it contains harmonics or other signal elements that have been removed by filtering or decimation.

Display Options

When displaying data in the screen, the Oscilloscope can provide waveform averaging to reduce noise and persistence to catch brief events. Averaging and persistence are not exported with either channel or high-res data, see Saving and Sharing Data.

Averaging

Drag the slider to average the given number of waveforms on the screen. If the signal is strictly repetitive then this can give you improved precision and noise performance. If not, this mode should not be used.

Persistence

Drag the slider to keep the given number of old waveforms on the screen, fading out. Dragging the slider all the way right will set infinite persistence, in which waveforms are never erased from the screen.

Persistence is useful for capturing events that would otherwise only be on the screen for one frame.

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Math Operations

The Oscilloscope can perform real time math operations on the incoming data and display it as a third channel. This math channel is different from the measurements above; measurements can be configured to be performed on the math channel rather than on a physical input channel.

Operation	Symbol	Description
Addition	+	Sum of two channels.
Subtraction	-	Difference of two channels.
Multiplication	x	Product of two channels. The two channels can be the same, giving a squaring of the signal values.
Division	÷	Ratio of two channels.
XY	XY	Plots a trace whose horizontal axis is not time, but the voltage of the selected channel.
Integral	∫	Discrete time-integral (running sum) of the trace
Derivative	d / dt	Discrete time-derivative (pointwise difference) of the trace
FFT	FFT	Fast Fourier Transform of a trace, giving the frequency domain representation. This mode is complex and described in more detail below.
Min Hold	Min hold	Minimum hold
Max Hold	Max hold	Maximum hold
User entered function	f()	A user-defined math function

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FFT Function

The FFT math channel gives the user the frequency-domain representation of the input data. This can be useful for quickly checking parameters in that domain. In general, the user should quickly switch to Moku:Pro's Spectrum Analyzer instead, gaining access to advanced features that drastically improve the quality of the measurement.

Limitations of the FFT function of the Oscilloscope include:

- The FFT is subject to aliasing, depending on acquisition mode. Moku:Pro's Spectrum Analyzer instrument has an advanced DSP anti-aliasing chain, minimizing the effect of unwanted signals.
- The FFT is not windowed. The Spectrum Analyzer provides a range of different windows for minimizing harmonics and spurs, improving amplitude accuracy, and so on.
- The FFT has a fixed frequency resolution set by the time span. The Spectrum Analyzer has a fully-configurable Resolution Bandwidth (RBW).
- The FFT has its span completely defined by the time span. The Spectrum Analyzer can have any span, providing much more detail around the signal of interest.

Using the Built-in Waveform Generator

The Oscilloscope has a built-in waveform generator. This resembles Moku:Pro's Waveform Generator instrument, but without modulation and sweep properties.

Waveform	Symbol	Description
Sine		Sinusoid. Configurable parameters are: • Frequency • Amplitude (peak-to-peak) • Offset • Phase (relative to the other channel)
Square		Square wave, variable duty cycle, low jitter. Configurable parameters are: • Frequency • Amplitude (peak-to-peak) • Offset • Phase (relative to the other channel) • Duty cycle
Ramp		Ramp, generalized sawtooth wave. Configurable parameters are: • Frequency • Amplitude (peak-to-peak) • Offset • Phase (relative to the other channel)

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		• Symmetry (ratio of rising- to falling-edge of the ramp; symmetries of 0% or 100% are sawtooth waves).
Pulse		Square wave, configurable edge times, worse jitter than Square option above. Configurable parameters are: • Frequency • Amplitude (peak-to-peak) • Offset • Phase (relative to the other channel) • Pulse width (high-time of the waveform) • Edge time (time taken to transition from the low- to high-level and vice-versa, limiting slew rate).
DC		Fixed DC output voltage. Configurable parameters are: • DC Level (voltage to output)

Saving and Sharing Data

The Oscilloscope can save different data to multiple locations. For full details regarding available locations and set up, see the Saving and sharing data section of this manual.

Data Types

Oscilloscope data can be saved through the “save data” icon in the center-top. The following options are available, corresponding to the two different phases of data acquisition above:

Channel Data: The data as viewed on the screen, including cubic down-sampling and interpolation.

High-res Data: The data directly from Moku:Pro’s internal memory, no interpolation or cubic down-sampling. The data saved in this way is exactly and only data that has been acquired (either by direct down-sampling or decimation depending on acquisition mode above).

In addition to the data itself, the Oscilloscope can save:

Measurement Trends: A CSV file containing the history of the measurements made by the Oscilloscope. See Measurement Trends above.

Settings: A file containing the current settings of the Oscilloscope instrument.

Screenshot: An image of the current screen, including traces and scales. This does not save the view of any settings tabs or the on-screen icons.

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

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