Oscilloscope / Voltmeter

Moku:Go User Manual

Moku:Go's Oscilloscope instrument can be used to observe, analyze, measure, and record signals over time on 2 channels, with an analogue bandwidth of 30 MHz and sampling to 125 MSa/s.

Oscilloscopes are the most essential item of test equipment in any electronics lab. Moku:Go's user interface makes control and setup of the oscilloscope very efficient.

Additionally, there are a wide range of measurements available together with a computed math channel.

LIQUID INSTRUMENTS

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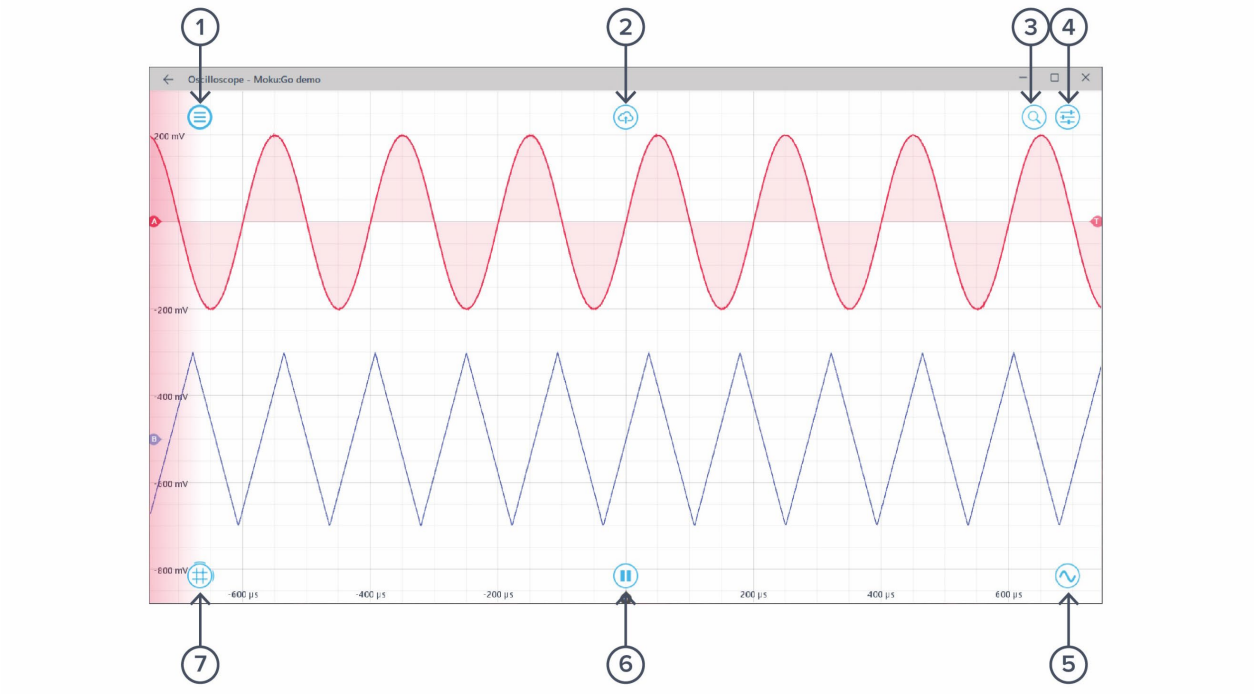
User Interface



ID	Description	ID	Description
1	Main menu	5	Waveform generator
2	Save data	6	Play/Pause
3	Signal display navigation	7	Cursors
4	Settings		

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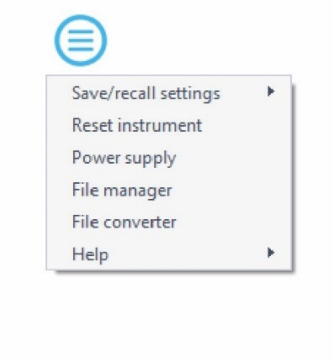
Main Menu

The **main menu** can be accessed by clicking the icon on the top-left corner.



This menu provides the following options:

Options	Shortcuts	Description
Save/recall settings:		
• **Save instrument state**	Ctrl+S	Save the current instrument settings.
• **Load instrument state**	Ctrl+O	Load last saved instrument settings.
• **Show current sate**		Show the current instrument settings.
Reset instrument	Ctrl+R	Reset the instrument to its default state.
Power supply		Access power supply control window.*
File manager		Open file manager tool.**
File converter		Open file converter tool.**
Help		
• **Liquid Instruments website**		Access Liquid Instruments website.
• **Shortcuts list**	Ctrl+H	Show Moku:Go app shortcuts list.
• **Manual**	F1	Access instrument manual.
• **Report an issue**		Report bug to Liquid Instruments.
• **About**		Show app version, check update, or license information.

* Power supply is available on Moku:Go M1 and M2 models. Detailed information about the power supply can be found in Moku:Go power supply manual.

**Detailed information about the file manager and file converter can be found at the end of this user manual.

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Signal Display Navigation

Signal display position

The displayed siganl can be moved around the screen by clicking anywhere on the signal display window and dragging to a new position. The cursor will turn into a icon once clicked, drag horizontally to shift along the time axis and drag vertically to shift along the voltage axis.

The signal display can also be moved hotizontally and vertically with arrow keys.

Display scale and zoom

Scrolling the mouse wheel zooms in and out along the primary axis. Access the scroll setting by hovering the cursor over the icon.

Icons	Description
	Assign the horizonal axis as the primary axis.
	Assign the vertical axis as the primary axis.
	Rubber band zoom: hold the primary mouse button to draw a region to zoom-in, release the button to execute.

Additional keyboard combinations are also available.

Actions	Description
Ctrl + Scroll Wheel	Zoom secondary axis.
+/-	Zoom primary axis with keyboard.
Ctrl +/-	Zoom secondary axis with keyboard.
Shift + Scroll Wheel	Zoom primary axis towards the center.
Ctrl + Shift + Scroll Wheel	Zoom secondary axis towards the center.
R	Rubber band zoom.

Auto scale

Double click anywhere on the signal display window to auto scale the traces.

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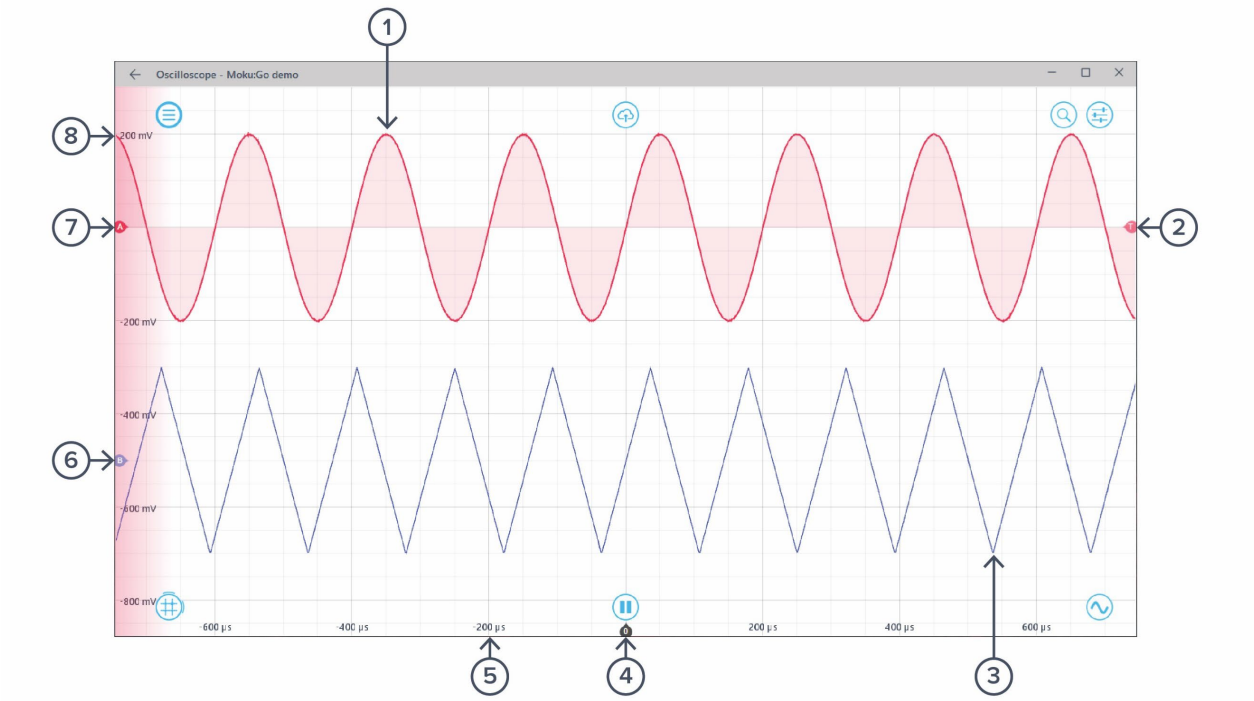
Axes and Traces



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 red 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 either).
3	Channel B Trace	The time/voltage trace for channel B. When channel B is active, the trace will have a light blue fill to the zero-volt level (not shown above).
4	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.
5	Time Axis	Shows the time scale for both channels (the channels always share the same time scale).
6	Channel B Origin Mark	Marks the “zero volt” level for channel B.
7	Channel A Origin Mark	Marks the “zero volt” level for channel A.
8	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.

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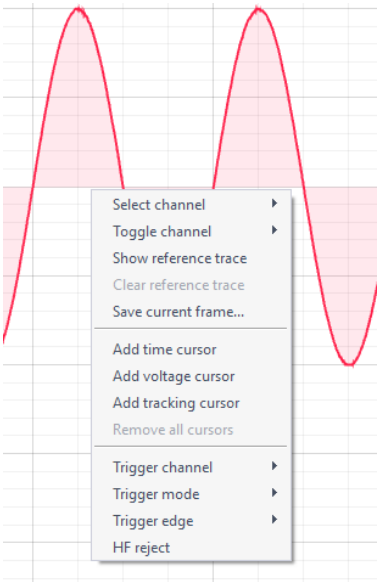
Right-click (secondary click) in the signal display area reveals additional option for the active channel. You can switch active channel, toggle on and off channels, add or remove reference trace, or save the current frame on the display via this menu. Options regarding to cursors and triggers are covered in detail in later sections.



Options	Description
Select channel	Select the active channel.
Toggle channel	Turn a channel on/off.
Show reference trace	Display the current frame as reference trace.
Clear reference trace	Clear the current reference trace.
Save current frame	Open the export data window.

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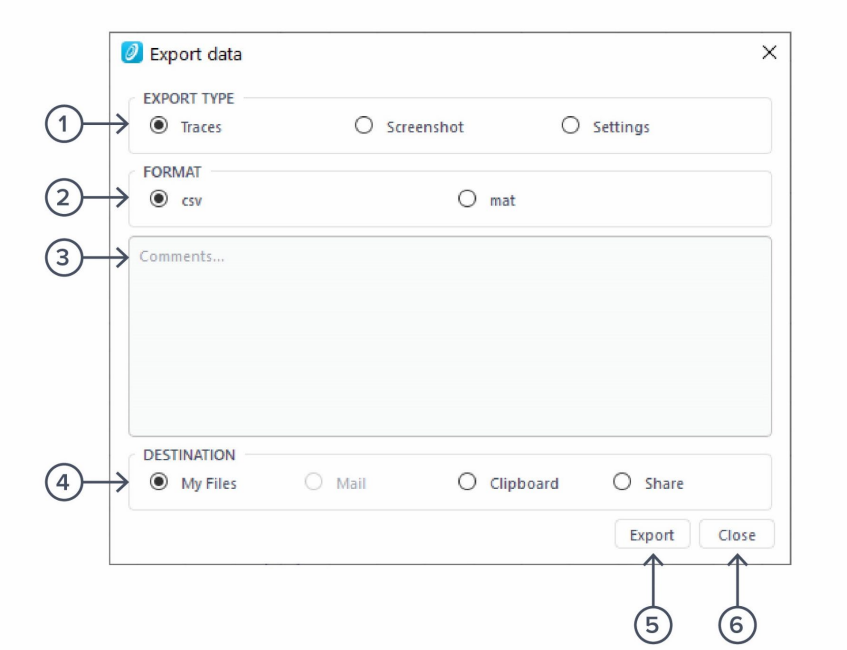
Export data

The **export data** options can be accessed by clicking the icon, allowing you to:



ID	Description
1	Select the type of data to export.
2	Select the exporting format (CSV or MAT).
3	Enter additional comments for the saved file.
4	Select the exporting location on your local computer.
5	Click to execute data export.
6	Click to close the export data window.

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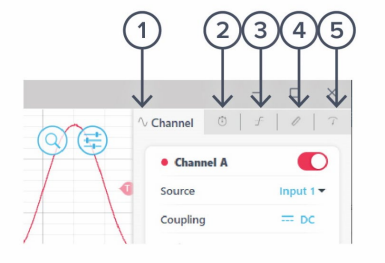
Settings

The **controls** options can be accessed by clicking the icon, allowing you to reveal or hide the control drawer, giving you access to all instrument settings. The controls drawer contains channels, timebase, trigger, measurement, and voltmeter settings.



ID	Description
1	Channel
2	Timebase
3	Trigger
4	Measurement
5	Voltmeter

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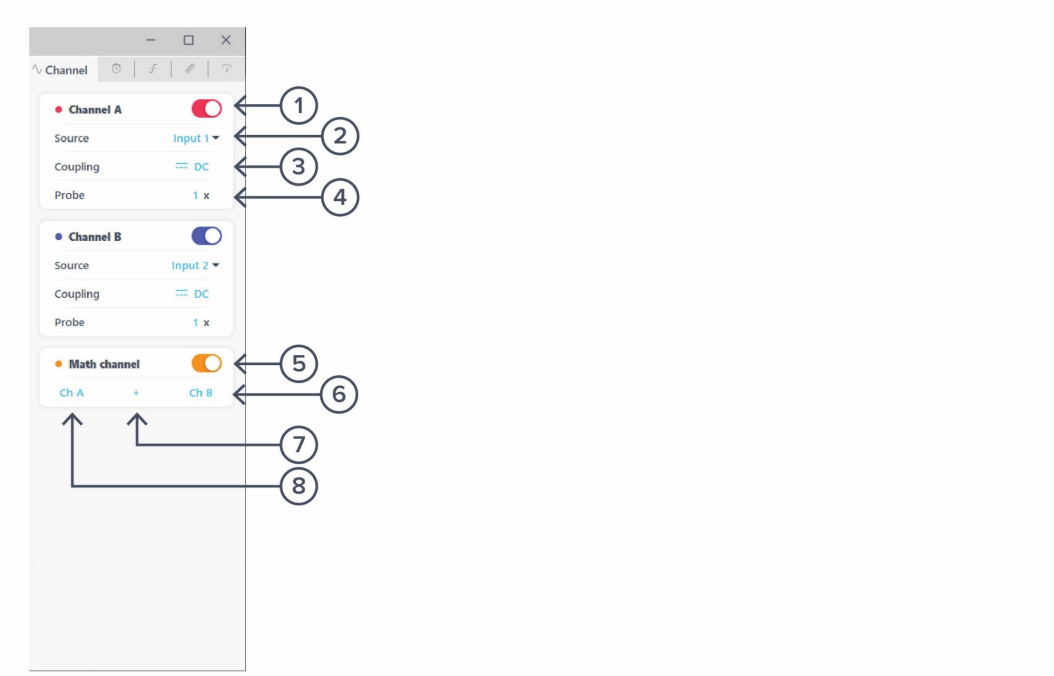
Channels

The **channels** pane allows you to change the input settings for each ADC channel, adjust the input scales and coupling, and enable/disable the math channel.



ID	Button	Description
1	Channel A	Toggles channel A on/off.
2	Channel A source	Changes data source for channel A. The default is to view data from input 1, but channel A may also view input 2, output 1 or output 2.
3	Coupling	Toggles between DC/AC coupling.
4	Probe	Specifies the probe attenuation, if such an attenuating probe is connected.
5	Math	Toggles math channel on/off.
6	Math channel source 2	Second channel in Math channel calculation. It is not available for certain operations, such as FFT.
7	Math operations	Detailed explanation about the math operations can be found in the *Instrument Reference* – *Math Operation* section.
8	Math channel source 1	First channel in Math channel calculation.

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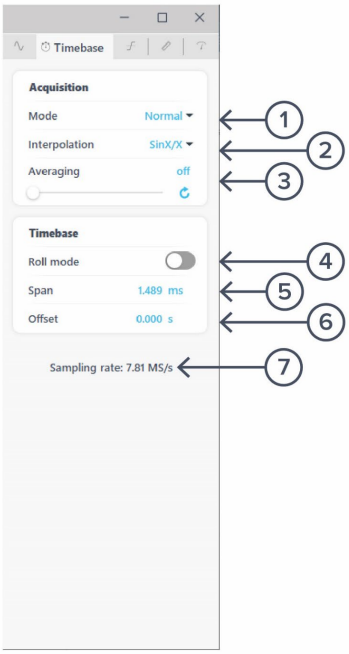
Timebase



ID	Button	Description
1	Acquisition mode	Changes acquisition mode between normal and precision. Detailed information can be found in the *Instrument Reference* - *Acquisition Modes and Sampling* section.
2	Interpolation mode	Change the interpolation mode. Detailed information can be found in the *Instrument Reference* – *Interpolation Mode* section.
3	Averaging	Displays on screen an average trace taken from this many consecutive frames. Click the icon to reset.
4	Roll-mode Toggle	Toggles between roll and sweep modes. See Display Options section.
5	Span	Horizontal screen scale. Changes dynamically when zoom in and out along the horizontal axis.
6	Offset	Horizontal trigger point offset. Changes dynamically when drag along the horizontal axis.
7	Sampling rate	Instant sampling rate at the current timebase setting. Channels dynamically when the span changes.

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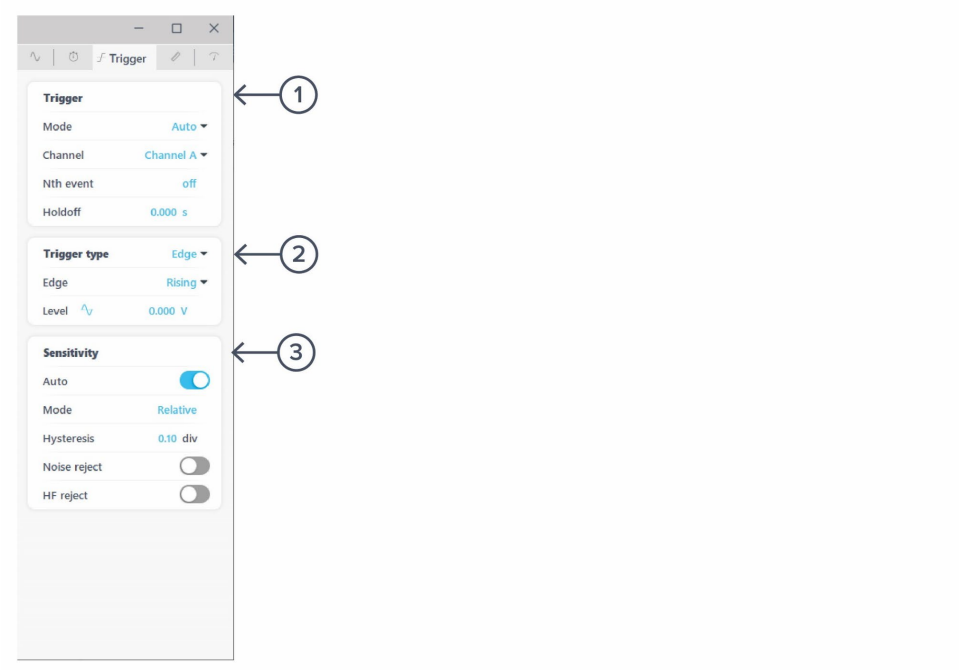
Trigger



ID	Button	Description
1	Trigger Settings Pane	**Mode:** Switches between auto, normal and single trigger modes. See Navigating your Signal section. **Channel:** Select the source for the trigger circuit. This can be one of the Oscilloscope channels, Moku:Go inputs, Moku:Go outputs. **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.
2	Tigger type	Select between edge and pulse triggering with selectable levels, edge types and pulse widths. Click ∿ to zero the trigger level.
3	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.

Additional information about the trigger type, trigger sensitivity can be found in the Navigating your Signal section.

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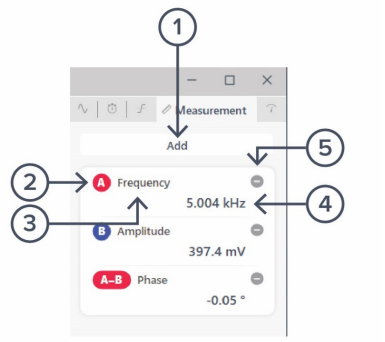
Measurement

The measurement pane allows you to add/remove measurements to measure frequency, amplitude, or other properties of a channel. A measurement can be assigned to a specific input channel, math channel, or difference between any two channels.



ID	Description
1	Click to add additional measurement tile.
2	Measurement source channel. Click to loop through the channels.
3	Measurement type.
4	Measurement value.
5	Click to remove the measurement tile.

Click a measurement tile to open the menu to adjust the measurement. The following options are available:

Options	Description
Type	Select the measurement type. Detailed explanation about the measurements can be found in Making Measurements section.
Channels	Select measurement source.
Difference Channels	Measure the difference between the measurement source to another channel.
Remove	Remove the measurement tile.

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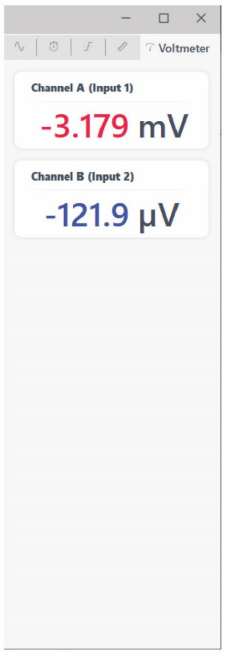
Voltmeter

The voltmeter tiles constantly read the voltage level from input 1 and 2, and display them under this pane.



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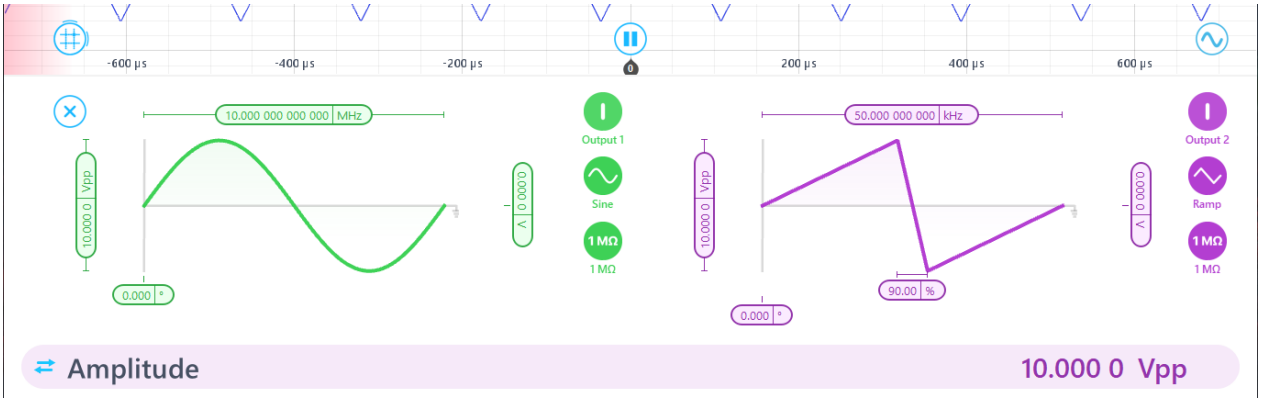
Waveform generator

Moku:Go's Oscilloscope has a built-in waveform generator capable of generating basic waveforms on the two output channels. Detailed instructions for the waveform generator instrument can be found in Moku:Go waveform generator manual.



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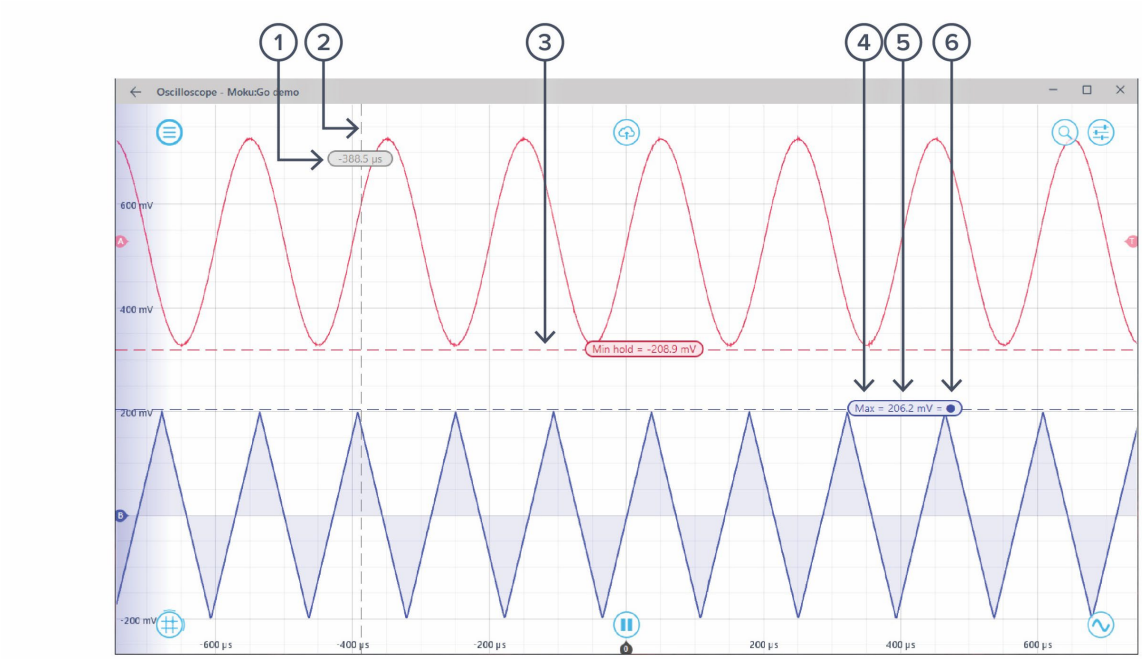
Cursor

The **cursors** can be accessed by clicking the on, allowing you to add voltage or time cursors, or remove all cursors. In addition, you can click and hold the cursors icon, and drag horizontally to add a time cursor, or vertically to add a voltage cursor.

User Interface



ID	Parameter	Description
1	Time reading	Right-click (secondary click) to reveal time cursor options. Drag left or right to set positions.
2	Time cursor	Color represents the channel of the measurement (Gray – Unattached, Red – channel 1, Blue – channel 2).
3	Voltage cursor	Drag up or down to set positions.
4	Cursor function	Indicates the current cursor function (max, min, max hold, etc).
5	Voltage reading	Right-click (secondary click) to reveal voltage cursor options.
6	Reference indicator	Indicates the cursor is set as reference. All other cursors in the same domain and channel measure the offset to the reference cursor.

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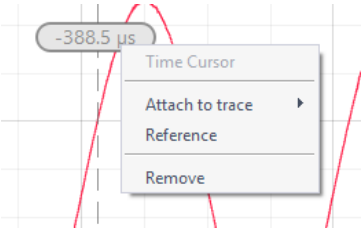
Time Cursor

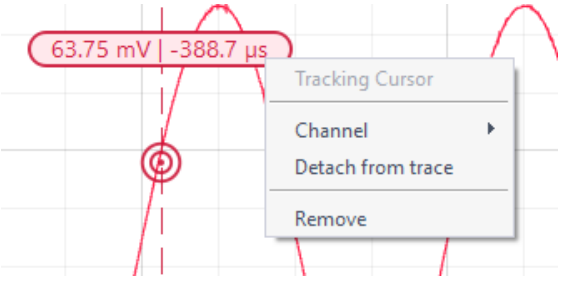
Right-click (secondary click) to reveal time cursor options:



Options	Description
Time Cursor	Cursor type.
Attach to trace	Choose to attach the time cursor to input 1, input 2. Once the cursor is attached to a channel, it becomes to a tracking cursor. The tracking cursor gives continuous voltage reading at the set time position.
Reference	Set the cursor as the reference cursor.
Remove	Remove the time cursor

Tracking Cursor

Right-click (secondary click) to reveal tracking cursor options:



Options	Description
Tracking Cursor	Cursor type.
Channel	Assign the tracking cursor to a specific channel.
Detach from trace	Detach the tracking cursor to a time cursor.
Remove	Remove the time cursor

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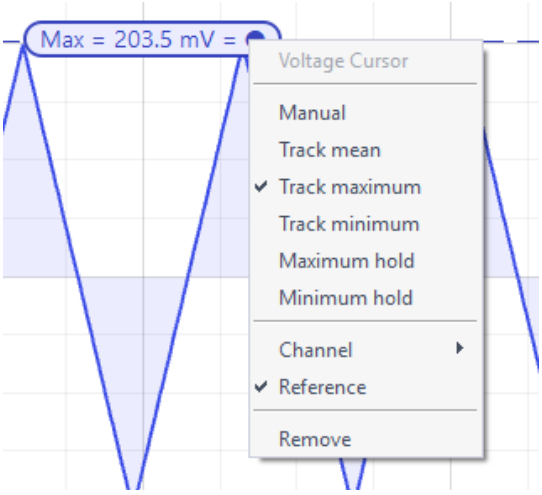
Voltage Cursor

Right-click (secondary click) to reveal voltage cursor options:



Options	Description
Voltage Cursor	Cursor type.
Manual	Manually set the vertical position of the cursor.
Track mean	Track the mean voltage.
Track maximum	Track the maximum voltage.
Track minimum	Track the minimum voltage.
Maximum hold	Set the cursor to hold at the maximum voltage level.
Minimum hold	Set the cursor to hold at minimum voltage level.
Channel	Assign the voltage cursor to a specific channel.
Reference	Set the cursor as the reference cursor.
Remove	Remove the voltage cursor.

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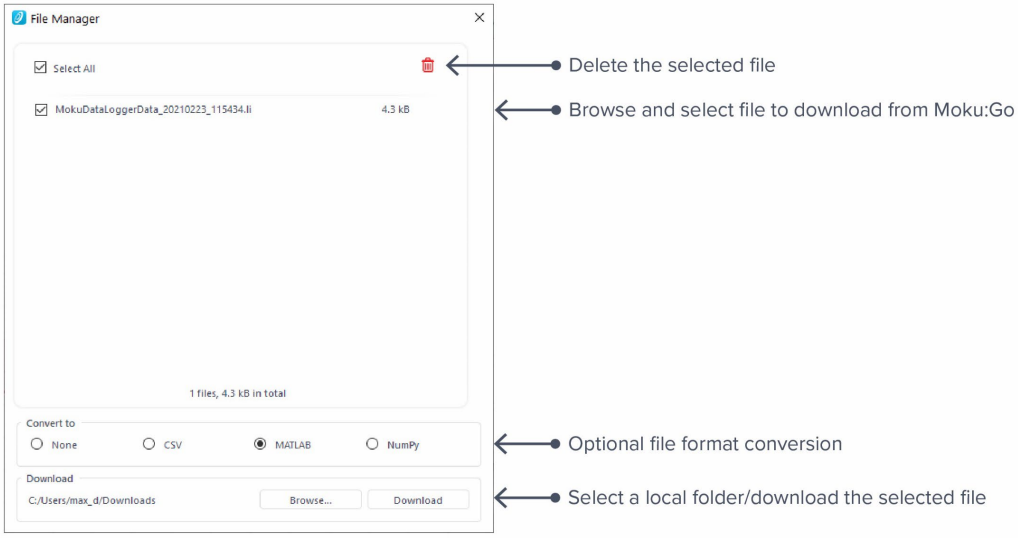
Additional Tools

Moku:Go app has two built-in file management tools: file manager and file converter. The file manager allows user to download the saved data from Moku:Go to local computer, with optional file format conversion. The file converter converts the Moku:Go's binary (.li) format on the local computer to either .csv, .mat, or .npy format.

File Manager



Once a file is transferred to the local computer, a icon shows up next to the file.

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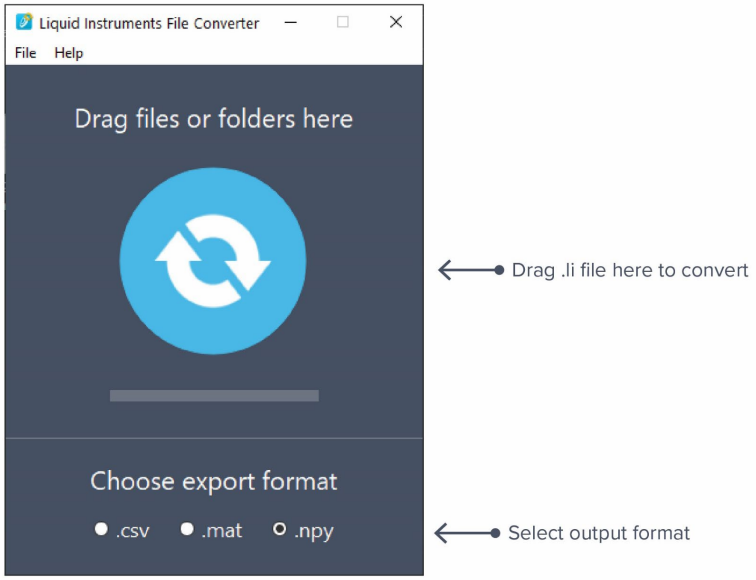
File Converter



The converted file is saved in the same folder as the original file.

Liquid Instruments File Converter has the following menu options:

Options	Shortcut	Description
File		
• **Open file**	Ctrl+O	Select a .li file to convert
• **Open folder**	Ctrl+Shift+O	Select a folder to convert
• **Exit**		Close the file converter window
Help		
• **Liquid Instruments website**		Access Liquid Instruments website
• **Report an issue**		Report bug to Liquid Instruments
• **About**		Show app version, check update, or license information

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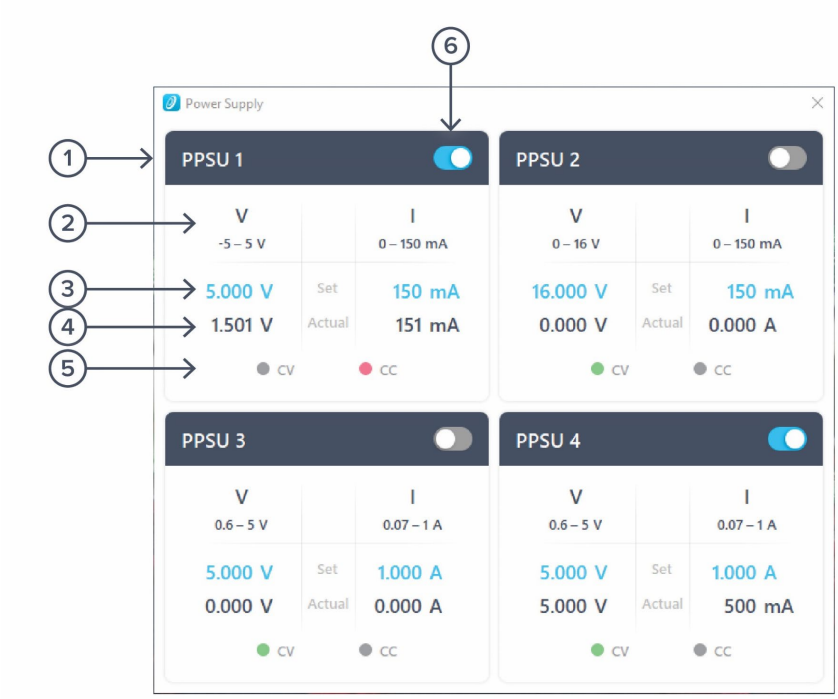
Power Supply

Moku:Go Power supply is available on M1 and M2 models. M1 features a 2-channel power supply, while M2 features a 4-channel power supply. The power supply control window can be accessed in all instruments under the main menu.

The power supply operates in two modes: **constant voltage (CV)** or **constant current (CC)** mode. For each channel, the user can set a current and voltage limit for the output. Once a load is connected, the power supply operates either at the set current or set voltage, whichever comes first. If the power supply is voltage limited, it operates in the CV mode. If the power supply is current limited, it operates in the CC mode.



ID	Function	Description
1	Channel name	Identifies the power supply being controlled.
2	Channel range	Indicates the voltage/current range of the channel.
3	Set value	Click the blue numbers to set the voltage and current limit.
4	Readback numbers	Voltage and current readback from the power supply, the actual voltage and current being supplied to the external load.
5	Mode indicator	Indicates if the power supply is in CV (green) or CC (red) mode.
6	On/Off Toggle	Click to turn the power supply on and off.

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Instrument Reference

Configuring Inputs

Coupling

Moku:Go 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:Go activating its internal attenuator (see Gain Ranges).

Navigating your Signal

Trace Selection

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

To turn a trace on and off, click the slider next to the corresponding trace on the channels tab.

To change the source of a channel, click the Source dropdown box of the channel, then select between the input channels and output channels.

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. The particular voltage which the signal must past 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:Go'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 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:Go'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.

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.

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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. Automatic measurements can be accessed in the measurement tab. Add a new measurement by clicking the “Add” button, you can change a measurement by clicking on the measurement tile. The available measurements are described below.

Name (unit)	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.
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
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

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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
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

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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 behavior.

Acquisition Modes

The acquisition mode refers to the process of capturing the data and storing it in Moku:Go'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 125 MSPS and the selected time span on the Moku:Go's Oscilloscope requires 1 MSPS, then 124 out of 125 points will be ignored.

This can cause 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 125 MSa/s and the selected time span on the Oscilloscope requires 1 MSa/s, then 125 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.

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.

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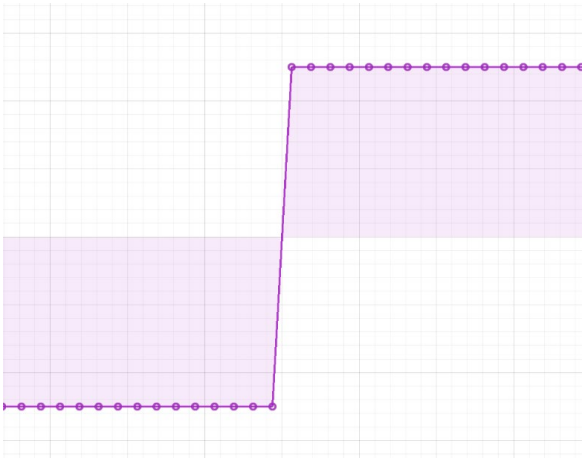
Linear



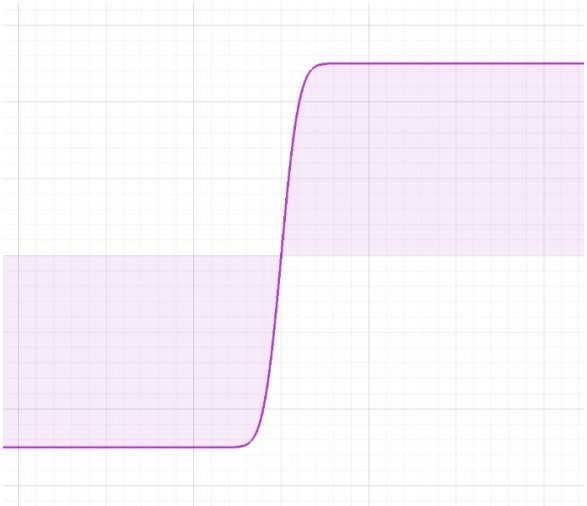
Linear interpolation does not perform any up-sampling. For display, it marks each point in the original data set and draws a straight line between them. This is “ugly” but doesn’t “invent” any new data points.

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 does not include significant frequency components that have been removed by filtering or decimation.

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.

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Display Options

When displaying data on the screen, the Oscilloscope can provide waveform averaging to reduce noise and persistence to catch brief events. Averaging and persistence are not exported for 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 switch to Moku:Go'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:Go'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.

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