



FIR Filter Builder

Moku:Go User Manual

With Moku:Go's FIR Filter Builder, you can design and implement lowpass, highpass, bandpass, and bandstop finite impulse response (FIR) filters with up to 14,819 coefficients at a sampling rate of 30.52 kHz, or 232 coefficients at a sampling rate up to 3.906 MHz. Moku:Go's Windows/macOS interface allows you to fine tune your filter's response in the frequency and time domains to suit your specific application. Select between four frequency response shapes, five common impulse responses, and up to eight window functions.





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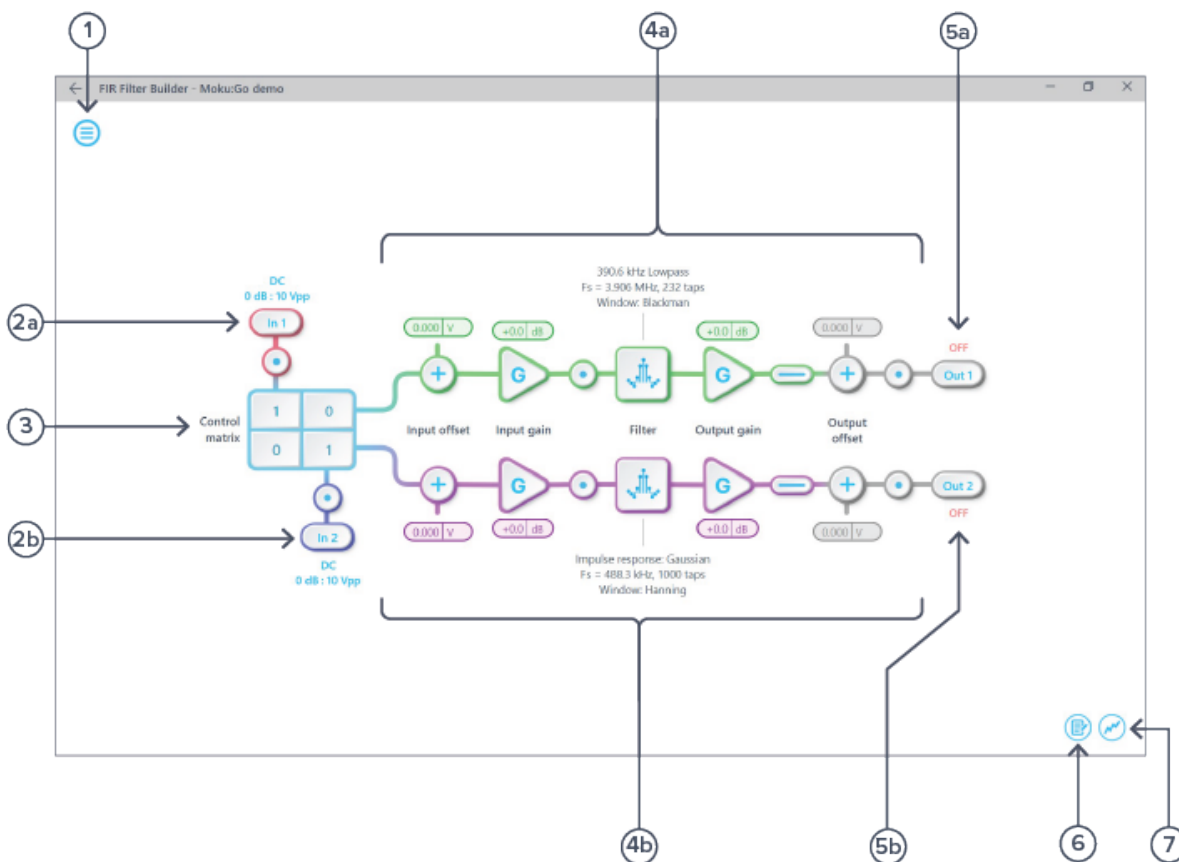


Ensure Moku:Go is fully updated. For the latest information:

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User Interface

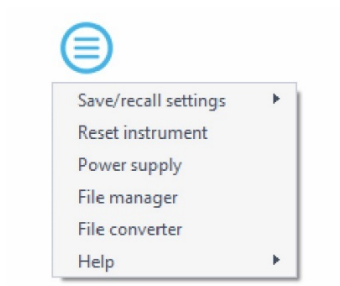


ID	Description
1	Main menu
2a	Input configuration for Channel 1
2b	Input configuration for Channel 2
3	Control matrix
4a	Configuration for FIR filter 1
4b	Configuration for FIR filter 2
5a	Output switch for FIR filter 1
5b	Output switch for FIR filter 2
6	Enable the data logger
7	Enable the oscilloscope



Main Menu

The **main menu** can be accessed by clicking the  icon in 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 state		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

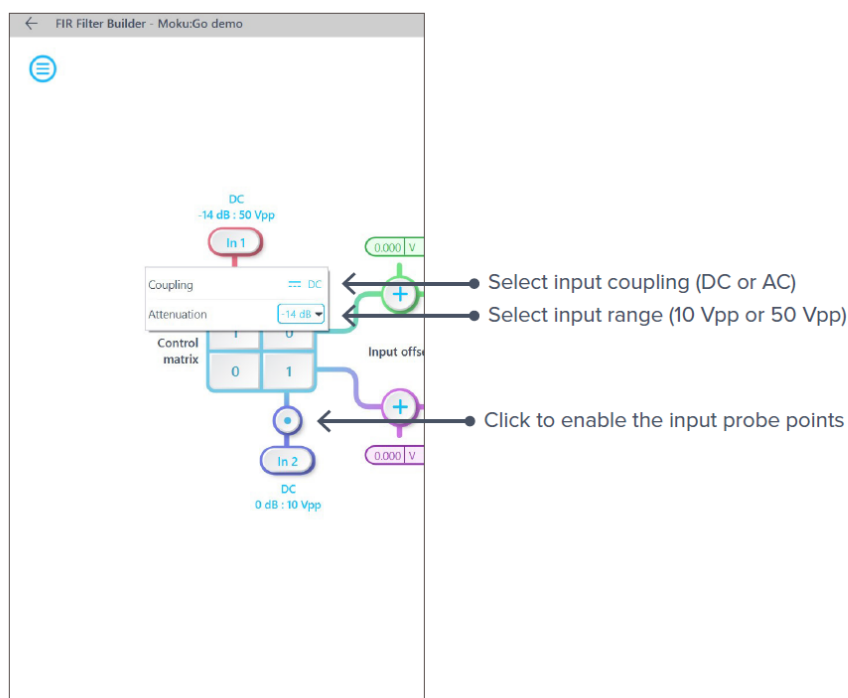
*Power supply is available on Moku:Go M1 and M2 models. Detailed information about the power supply can be found in Moku:Go power supply manual.

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



Input Configuration

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



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



Control Matrix

The **control matrix** combines, rescales, and redistributes the input signals to the two independent FIR filters. The output vector is the product of the control matrix multiplied by the input vector.

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

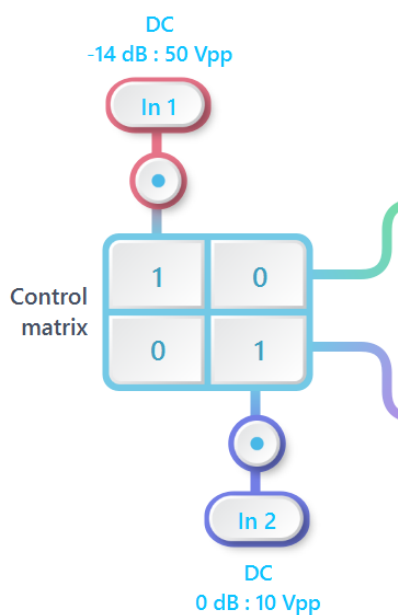
where

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

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

For example, a control matrix of $\begin{bmatrix} 1 & 1 \\ 0 & 2 \end{bmatrix}$ adds **Input 1** and **Input 2** and routes to the top **Path1** (FIR Filter 1), multiplies **Input 2** by a factor of two, and then routes it to the bottom **Path2** (FIR Filter 2).

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

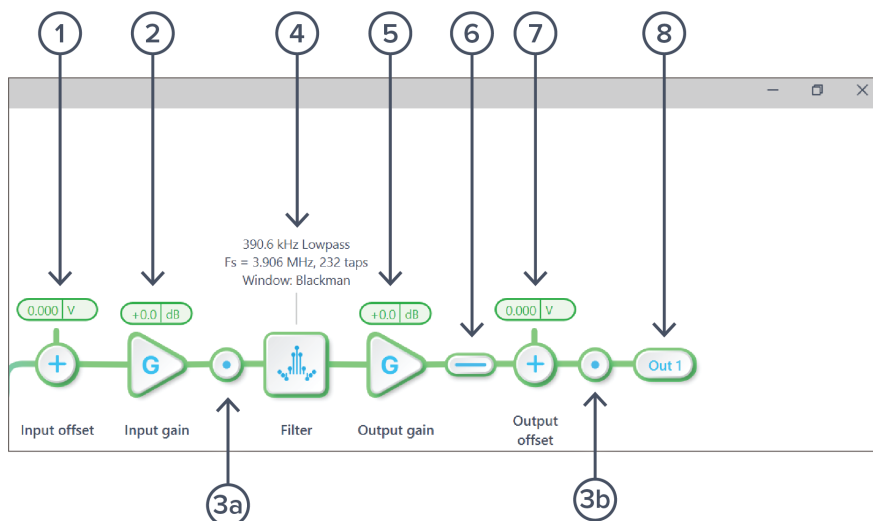




FIR Filter

The two independent, fully real-time configurable FIR filter paths follow the control matrix in the block diagram, represented in green and purple for filter 1 and 2, respectively.

User Interface



ID	Parameter	Description
1	Input offset	Click to adjust the input offset (-2.5 to +2.5 V)
2	Input gain	Click to adjust the input gain (-40 to 40 dB)
3a	Pre-filter probe	Click to enable/disable the pre-filter probe point. See Probe Points section for details.
3b	Output probe	Click to enable/disable the output probe point. See Probe Points section for details.
4	FIR filter	Click to open view and configure the FIR filter builder
5	Output gain	Click to adjust the input gain (-40 to 40 dB)
7	Output switch	Click to zero the filter output
7	Output offset	Click to adjust the input offset (-2.5 to +2.5 V)
8	DAC switch	Click to enable/disable Moku:Go's DAC output

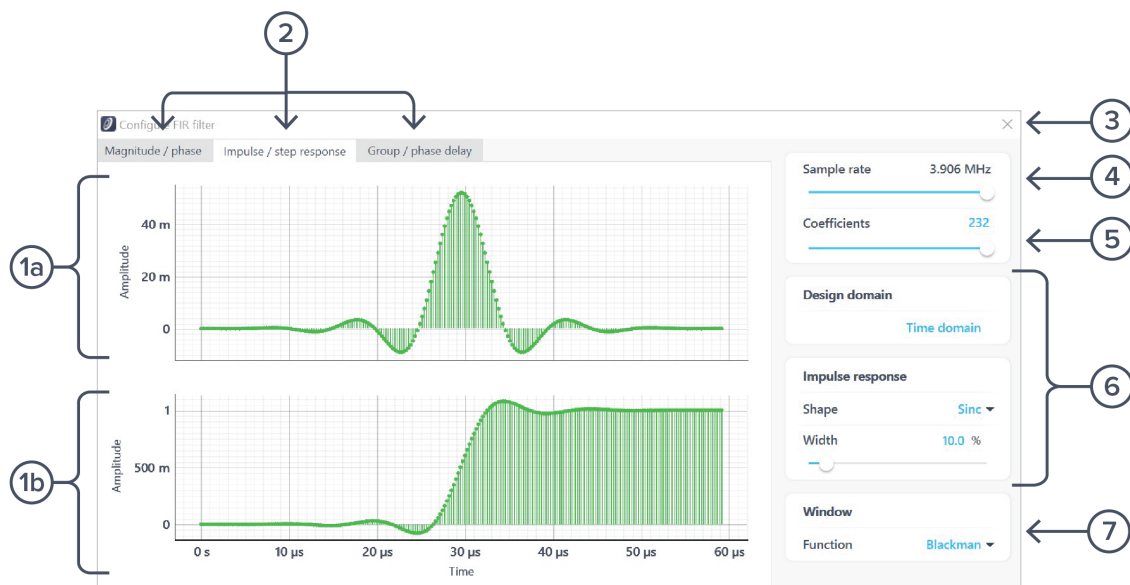


FIR Filter Builder

Builder Interface




Click the icon to open the full **FIR Filter Builder** view.



ID	Parameter	Description
1a	Plot 1	Impulse response plot
1b	Plot 2	Step reponse plot
2	Plot set selection	Click to select the set of plots to display in the plot area
3	Save & close	Click to save and close the filter builder view
4	Sampling rate	Adjust the sampling rate for the input. Slide between 30.52 kHz and 3.906 MHz. You may also use the scroll wheel on the slider to adjust it.
5	Number of coefficients	Click the number to enter or slide the slider to adjust the number of coefficients. You may also use the scroll wheel on the slider to adjust it.
6	Filter design	Configure the parameters for the FIR filter. Detailed information can be found in a later section.
7	Window function	Click to select the window function

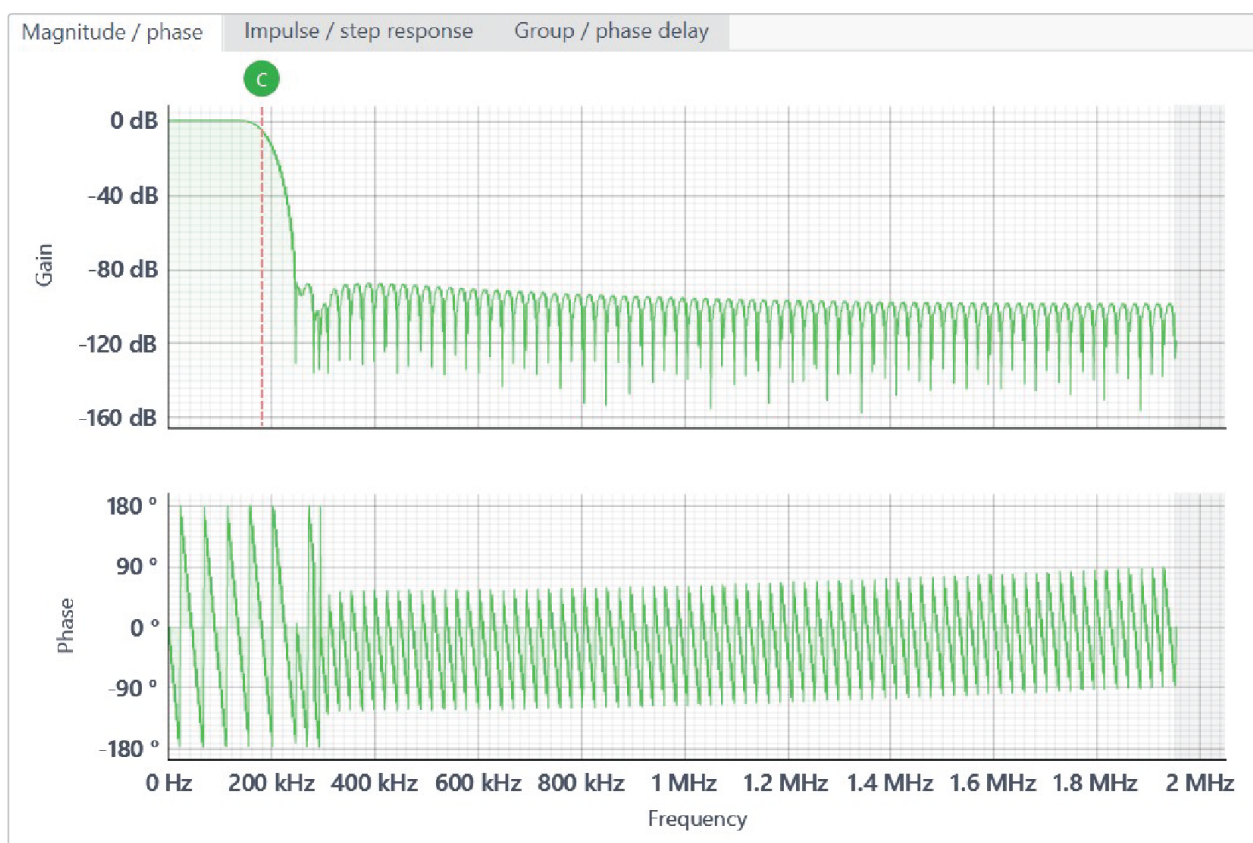


Filter Characteristic Graphs

A set of two real-time filter characteristic plots can be shown at a time in the FIR filter builder. Click the **plot set selection** buttons to select between **Magnitude/phase**, **Impulse/step response**, and **Group/phase delay** plot sets. Click and drag the  icon in the **Magnitude/phase** to adjust the corner frequency in real-time.

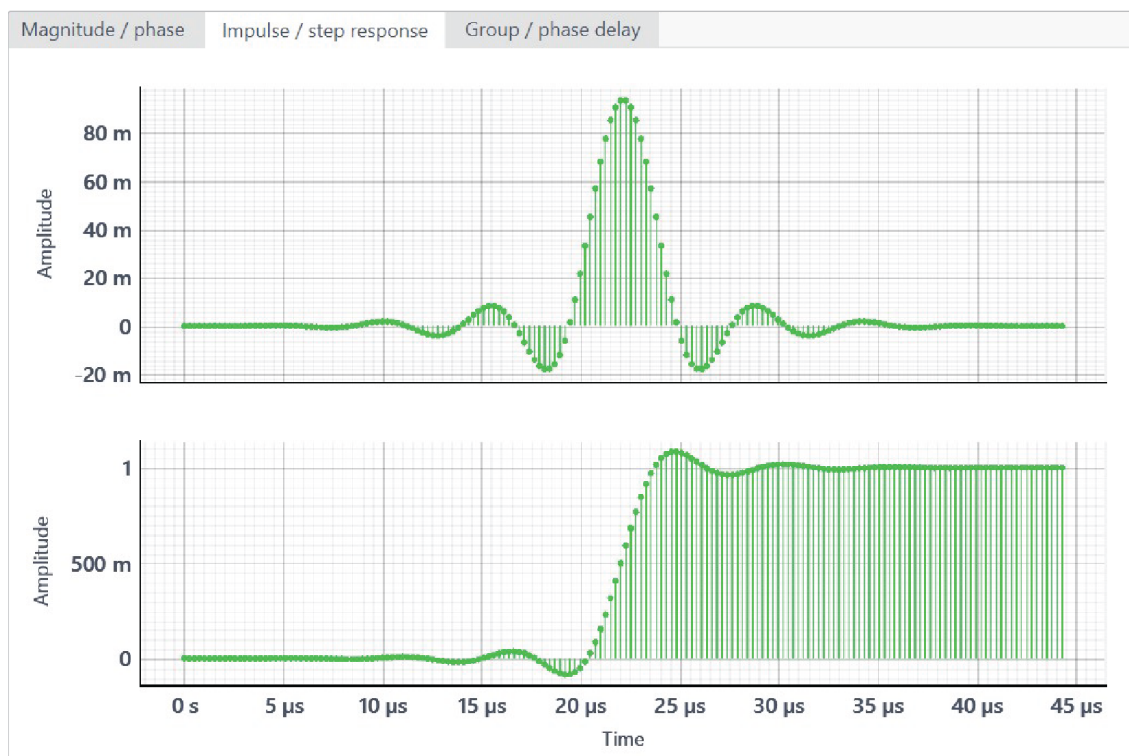
	Magnitude/phase		Impulse/step response		Group/phase delay	
	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
X - axis	Frequency (MHz)		Time (μ s)		Frequency (MHz)	
Y - axis	Gain (dB)	Phase ($^{\circ}$)	Amplitude (V)		Group/phase Delay (μ s)	

Magnitude/Phase plot set:

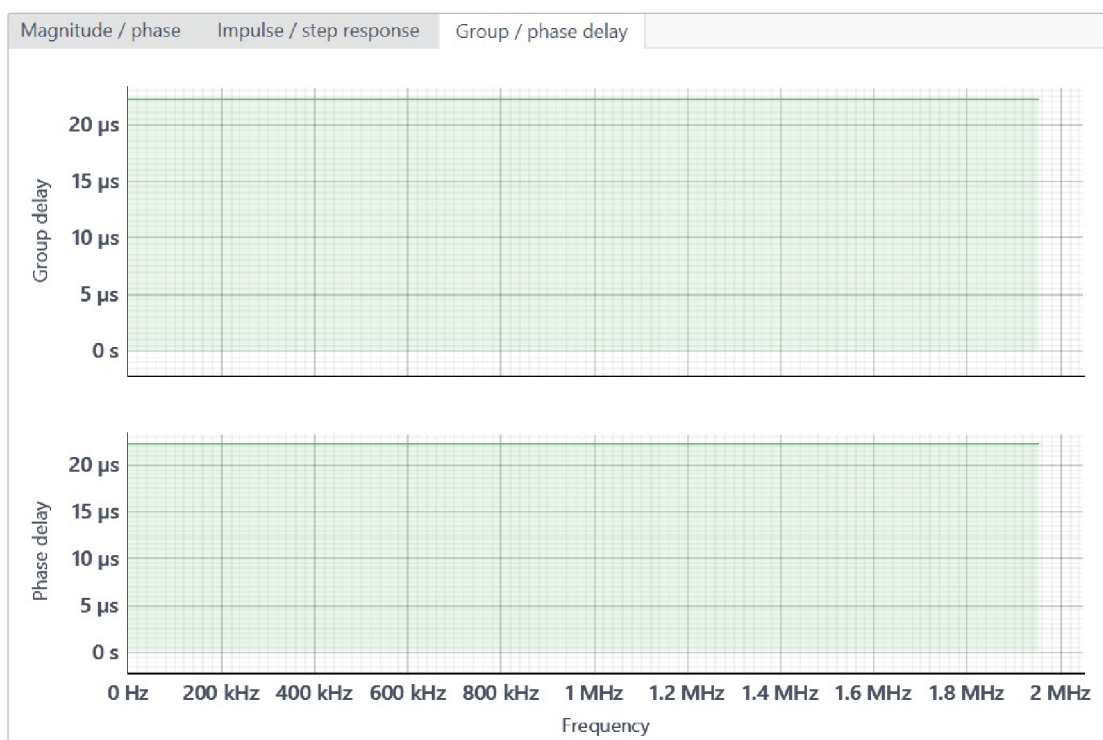




Impulse/step response plot set:



Group/phase delay plot sets:





Sampling Rate/Coefficients

The maximum number of coefficients depends on the chosen sampling rate. Available sampling rates with their corresponding maximum numbers of coefficients are listed in the table below.

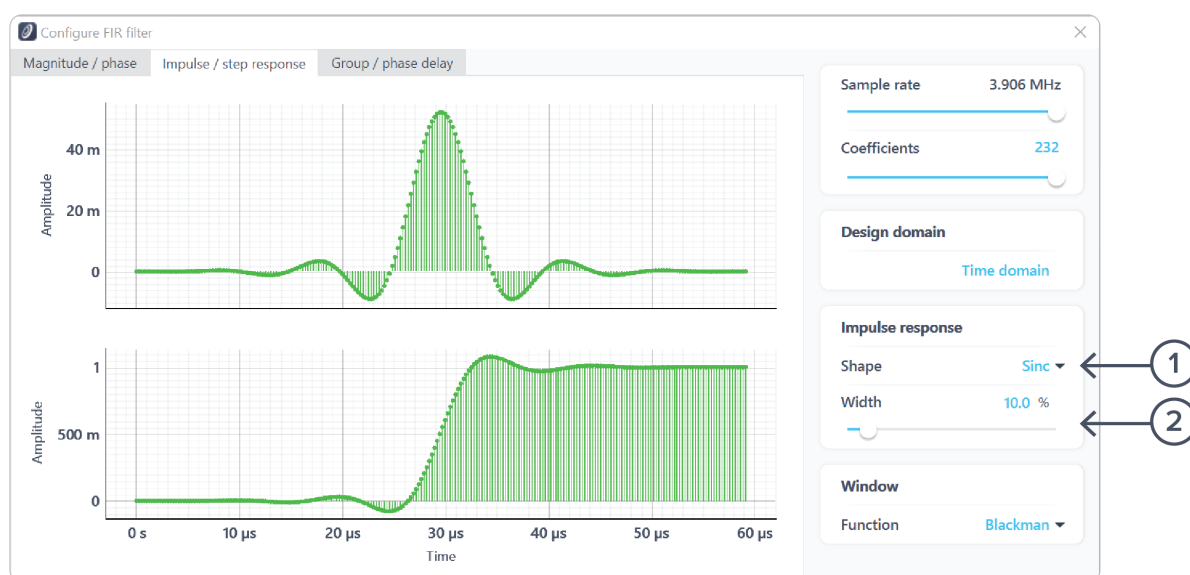
Sampling rate	Maximum number of coefficients
30.52 kHz	14,819
61.04 kHz	14,819
122.1 kHz	7,424
244.1 kHz	3,712
488.3 kHz	1,856
976.6 kHz	928
1.953 MHz	464
3.906 MHz	232



Design Domain

The FIR filter can be designed in either time or frequency domain. In **time domain designer**, an impulse response function builder is accessible. Several predefined functions are available. Users can also enter an equation with the **equation editor** or load their own set of coefficients with the **custom impulse response** option. In **frequency domain designer**, a frequency response builder is accessible. Lowpass, highpass, bandpass, and bandstop filters are available with adjustable cut-off frequencies.

Time Domain Designer



ID	Parameter	Description
1	Impulse shape	Click to select the shape of the impulse response
2	Impulse width	Click the number to enter or slide the slider to adjust the impulse width

List of available shapes

Shape	Note
Rectangular	
Sinc	Width adjustable from 0.1 % to 100 %
Triangular	
Gaussian	Width adjustable from 0.1 % to 100 %
Equation	Click the equation to open the equation editor. Details about the equation editor can be found in the in the Equation Editor section.
Custom	Details about the custom impulse response can be found in Custom Impulse Response section






Coefficient Quantization

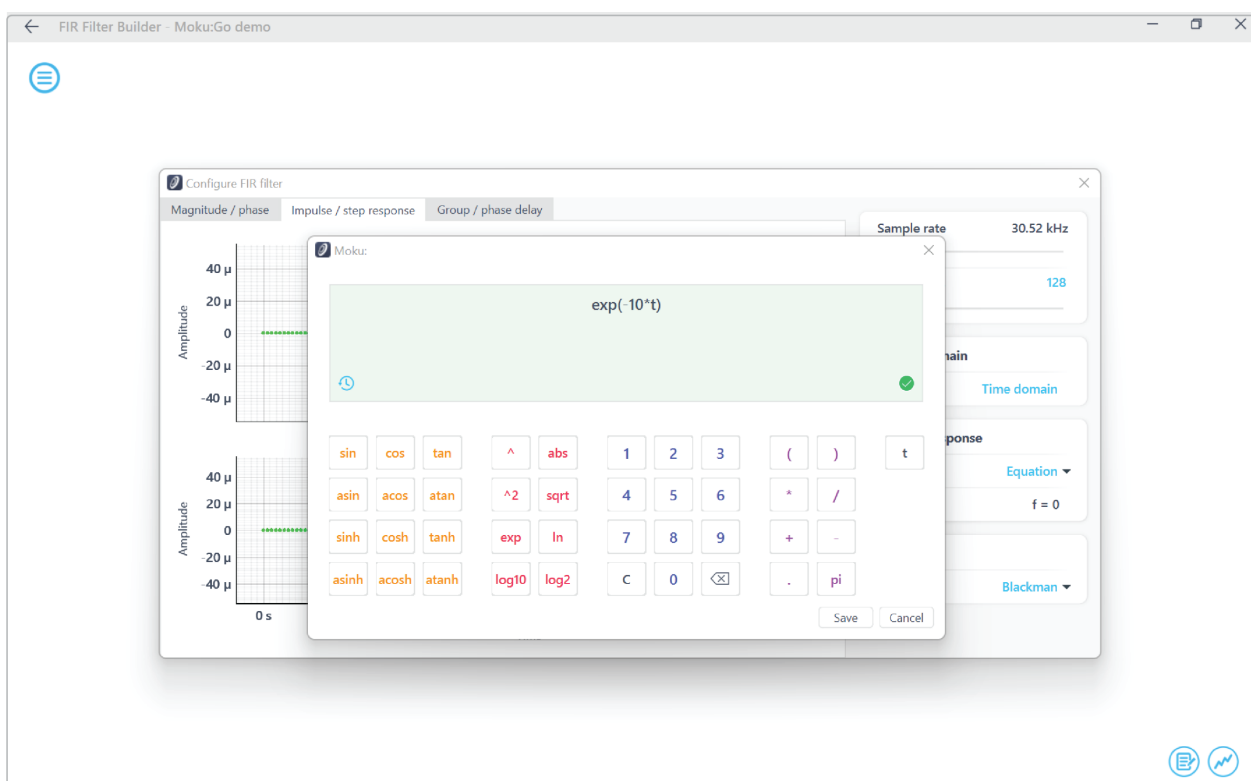
Due to the limit of digitization depth, the quantization error is pronounced at certain FIR filter settings. A red coefficient quantization warning may appear on the top-right corner of the plot, and the actual response curve will be plotted in red.





Equation Editor

- The equation editor allows you to define arbitrary mathematical functions for the impulse response.
- Select from a range of common mathematical expressions including trigonometric, quadratic, exponential, and logarithmic functions.
- The variable **t** represents time in the range from 0 to 1 periods of the total waveform.
- Access recently entered equations by pressing the  icon.
- The validity of the entered equation is indicated by the  and  icons that appear to the right of the equation box.





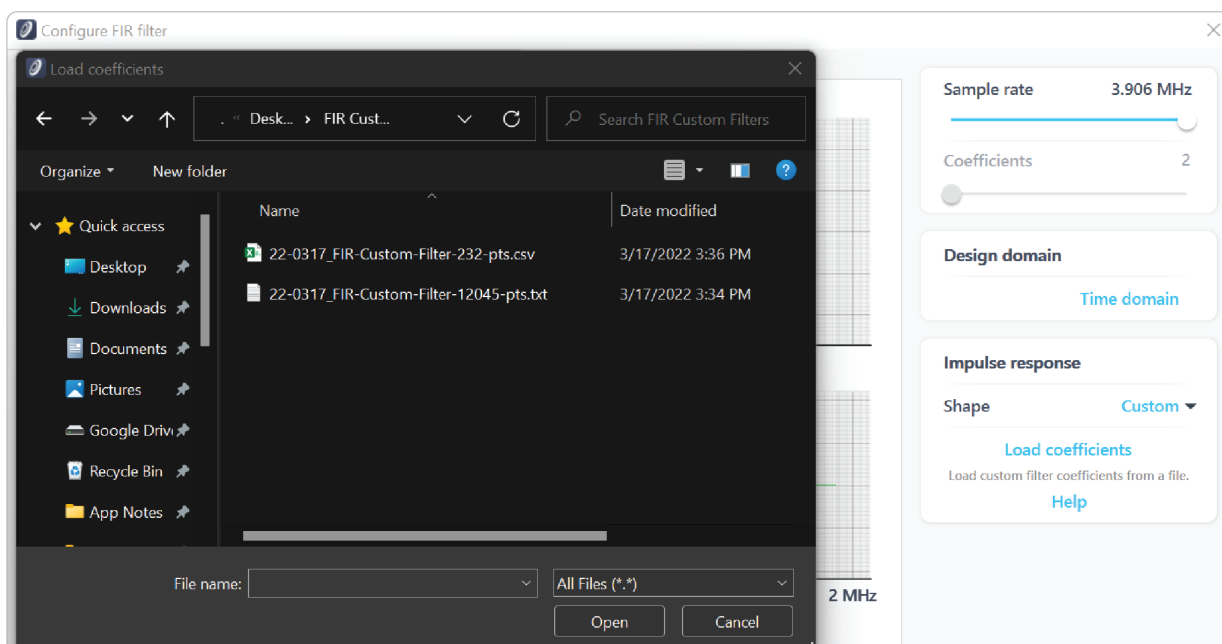
Custom Impulse Response

The output of the FIR filter is a weighted sum of the most recent input values:

$$y[n] = \sum_{i=0}^{N-1} c_i x[n - i]$$

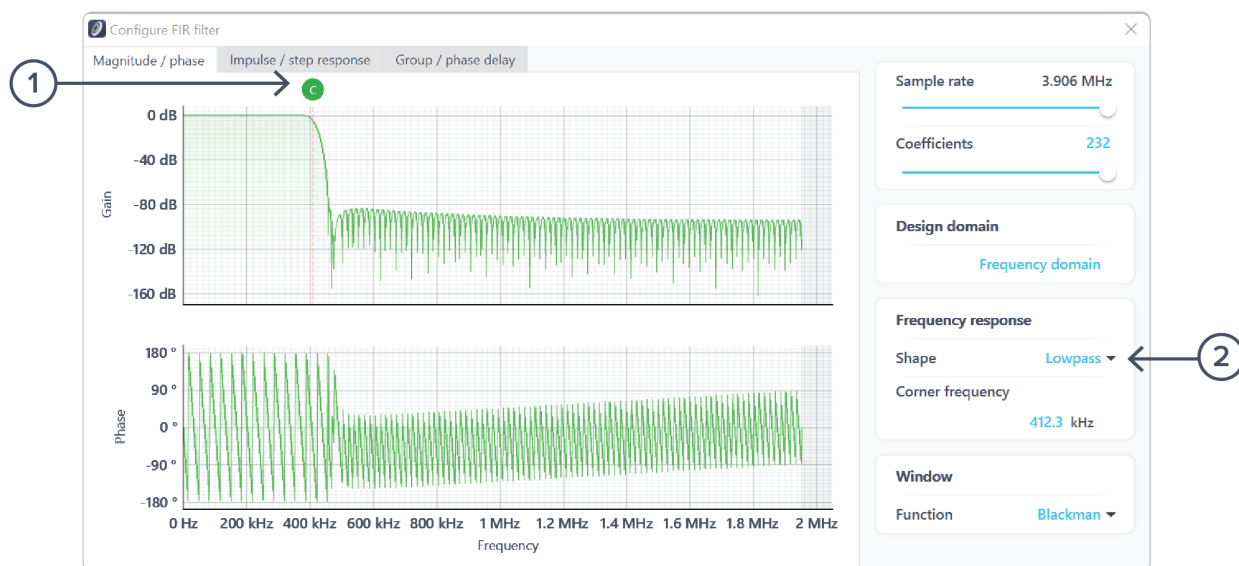
To specify a custom filter, you must supply a text file containing the filter coefficients from your computer that is connected to Moku:Go. The file can contain up to 14,819 coefficients separated by commas or new lines. Each coefficient must be in the range of $[-2.5, +2.5]$. Internally, these are represented as signed 25-bit fixed-point numbers, with 24 fractional bits. Filter coefficients can be computed using signal processing toolboxes in MATLAB, SciPy, etc.

Some coefficients may result in overflow or underflow, which degrade filter performance. Filter responses should be checked prior to use.





Frequency Domain Designer




ID	Parameter	Description
1	Cut-off cursor	Click and hold to slide in the frequency axis
2	Impulse width	Click to select the filter shape

List of available shapes:

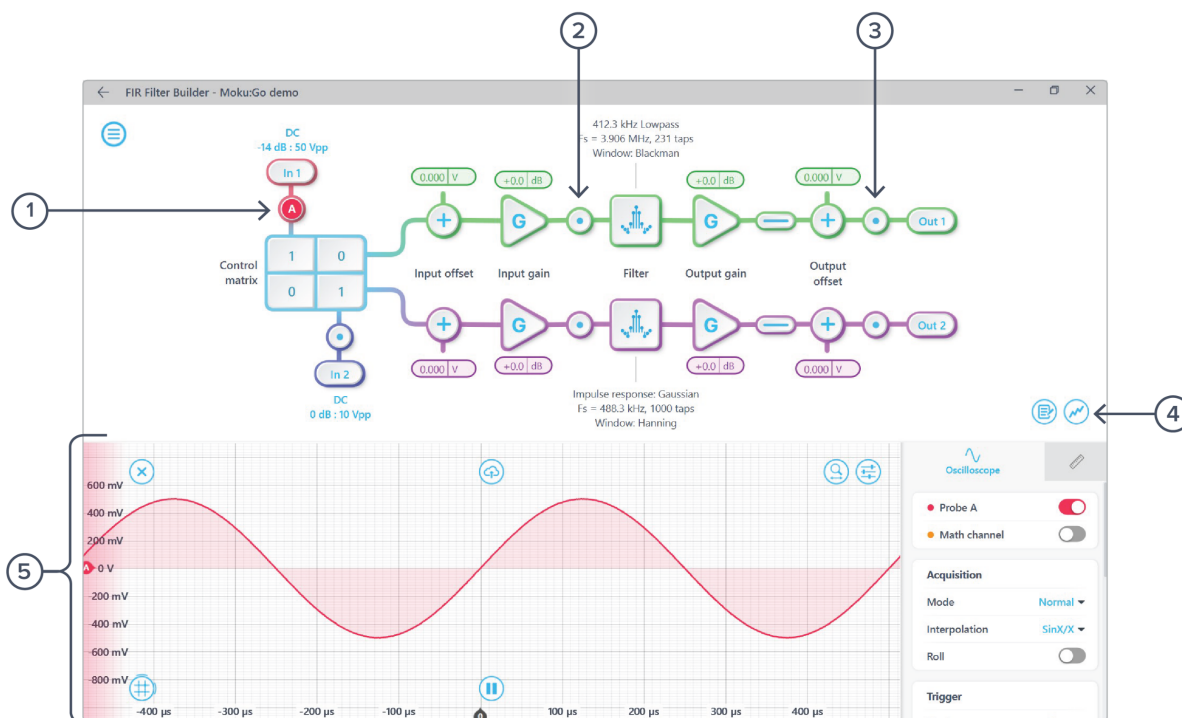
Shape	Note
Lowpass	Single adjustable cursor
Highpass	Single adjustable cursor
Bandpass	Two adjustable cursors
Bandstop	Two adjustable cursors



Probe Points

Moku:Go's FIR Filter Builder has an integrated oscilloscope and data logger that can be used to probe the signal at the input, pre-FIR filter, and output stages. The probe points can be added by clicking the  icon.

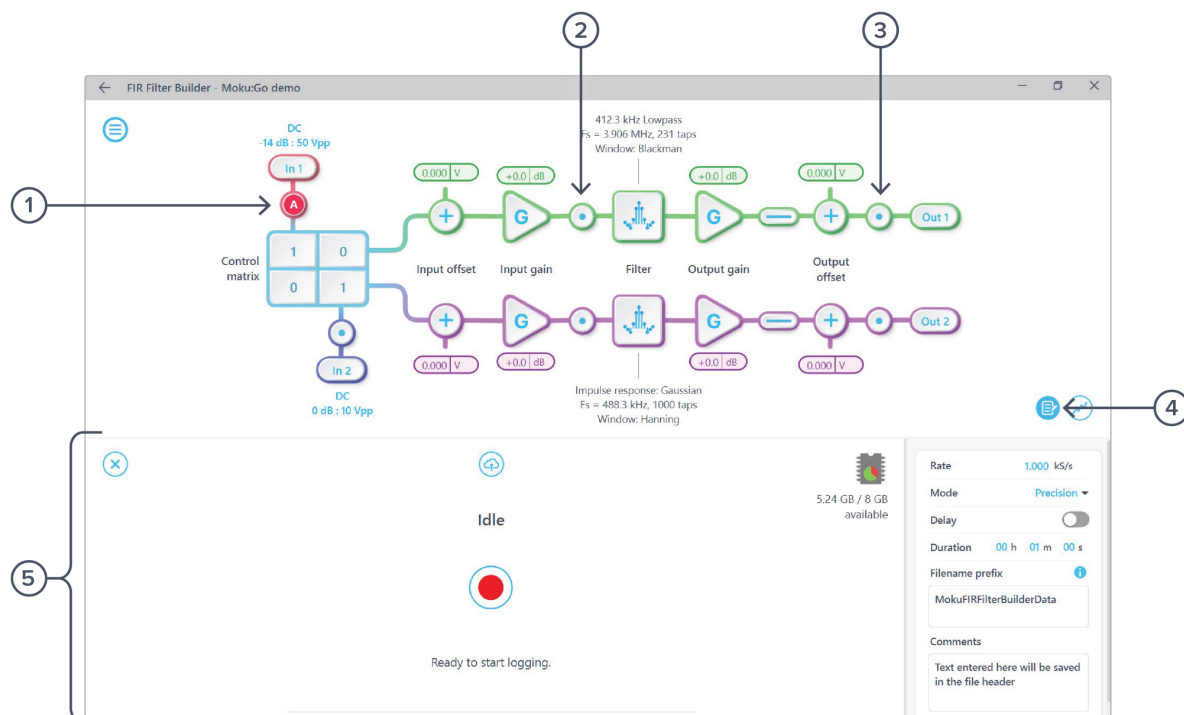
Oscilloscope



ID	Parameter	Description
1	Input probe point	Click to place the probe point at input
2	Pre-FIR probe point	Click to place the probe before the FIR filter
3	Output probe point	Click to place the probe at output
4	Oscilloscope/data logger toggle	Toggle between built-in oscilloscope or data logger
5	Oscilloscope	Refer to Moku:Go's Oscilloscope manual for the details



Data Logger



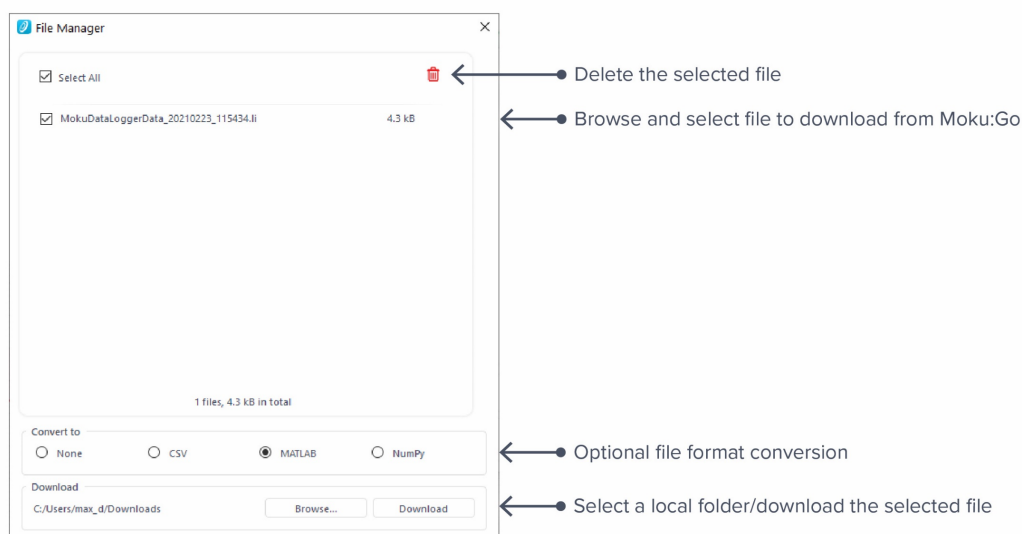
ID	Parameter	Description
1	Input probe point	Click to place the probe point at input
2	Pre-FIR probe point	Click to place the probe before the FIR filter
3	Output probe point	Click to place the probe at output
4	Oscilloscope/data logger toggle	Toggle between built-in oscilloscope or data logger
5	Data Logger	Refer to the Moku:Go's Data Logger manual for the details



Additional Tools

Moku:Go's app has two built-in file management tools: file manager and file converter. The file manager allows users to download the saved data from Moku:Go to a 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.

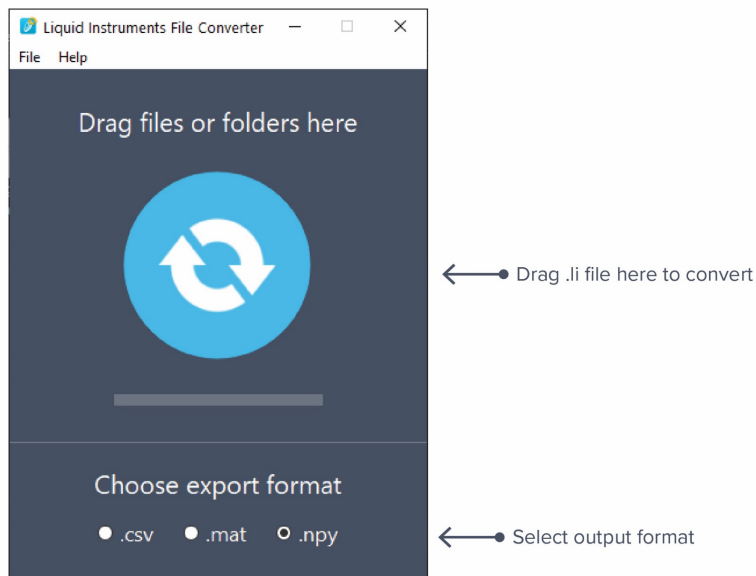
File Manager



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



File Converter



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

Liquid Instruments File Converter has the following menu options:

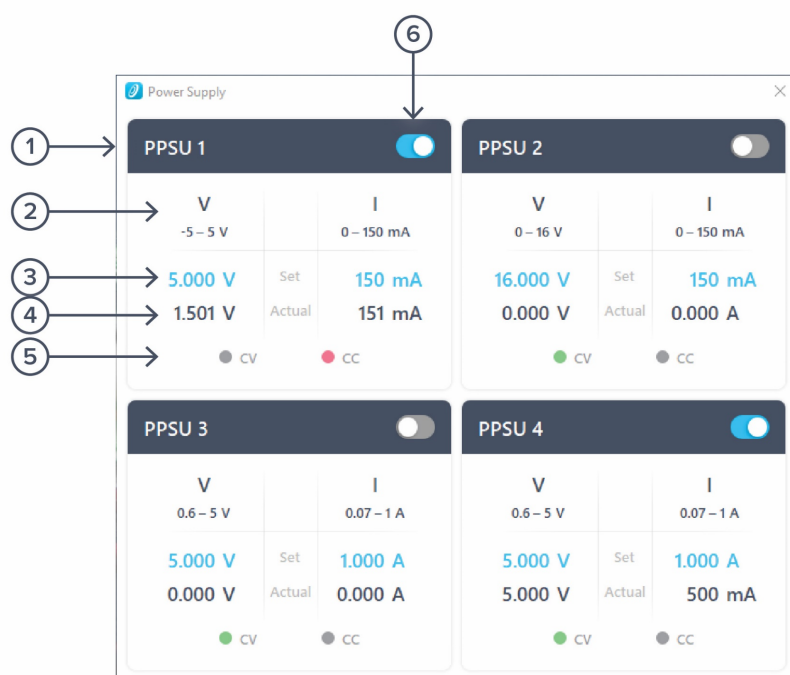
Options	Shortcut	Description
File		
• Open file	Ctrl+O	Select a .li file to convert
• Open folder	Ctrl+Shift+O	Select a folder to convert
• Exit		Close the file converter window
Help		
• Liquid Instruments website		Access Liquid Instruments website
• Report an issue		Report bug to Liquid Instruments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



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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