LIQUID INSTRUMENTS Moku:Go FIR Filter Builder User Manual

**LIQUID INSTRUMENTS Moku:Go FIR Filter Builder**

With the Moku:Go FIR Filter Builder, you can design and implement lowpass, high pass, bandpass, and band stop 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. The Moku:Go 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.

Contents

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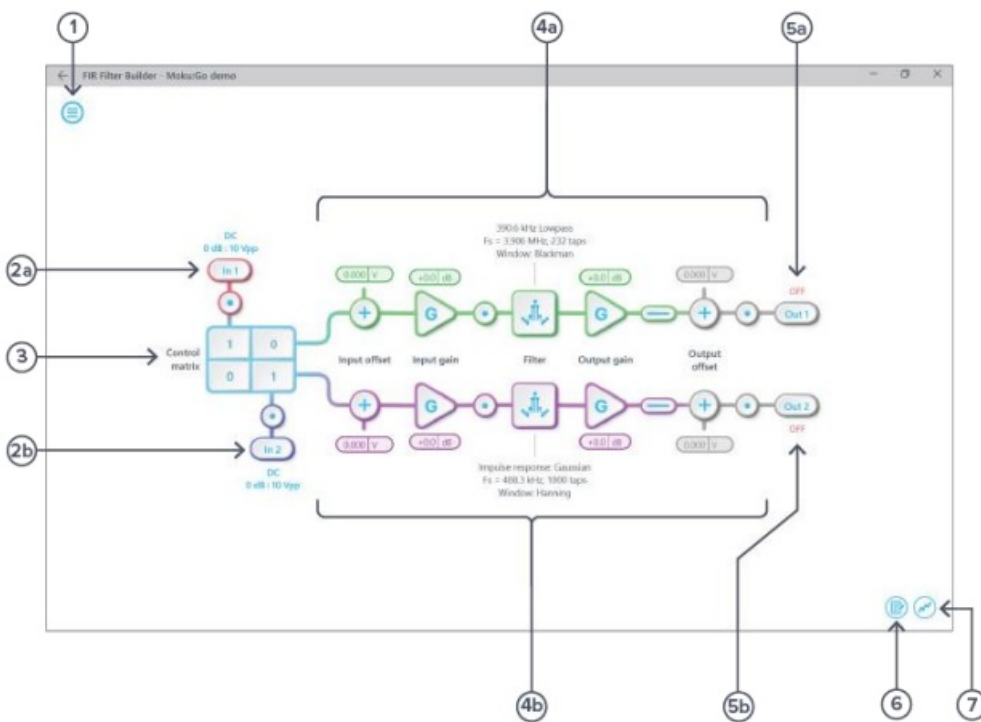
ID	Description
1	Main menu
2a	Input configuration for Channel 1
2b	Input configuration for Channel 2
3	Control matrix
4a	Configuration for FIR filter 1
4b	Configuration for FIR filter 2
5a	Output switch for FIR filter 1
5b	Output switch for FIR filter 2
6	Enable the data logger
7	Enable the oscilloscope

Main menu

The main menu can be accessed by clicking the icon ⊜ in the top-left corner.
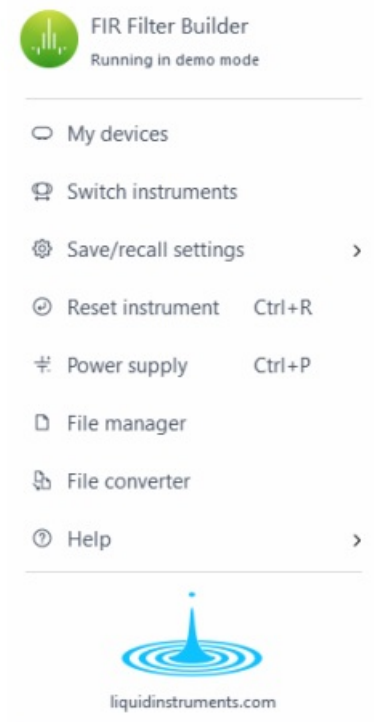
This menu provides the following options:

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

*Power Supply is available on the Moku:Go M1 and M2 models. Detailed information about the Power Supply can be found on page 22 of this user manual.
**Detailed information about the file manager and file converter can be found on page 21 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.
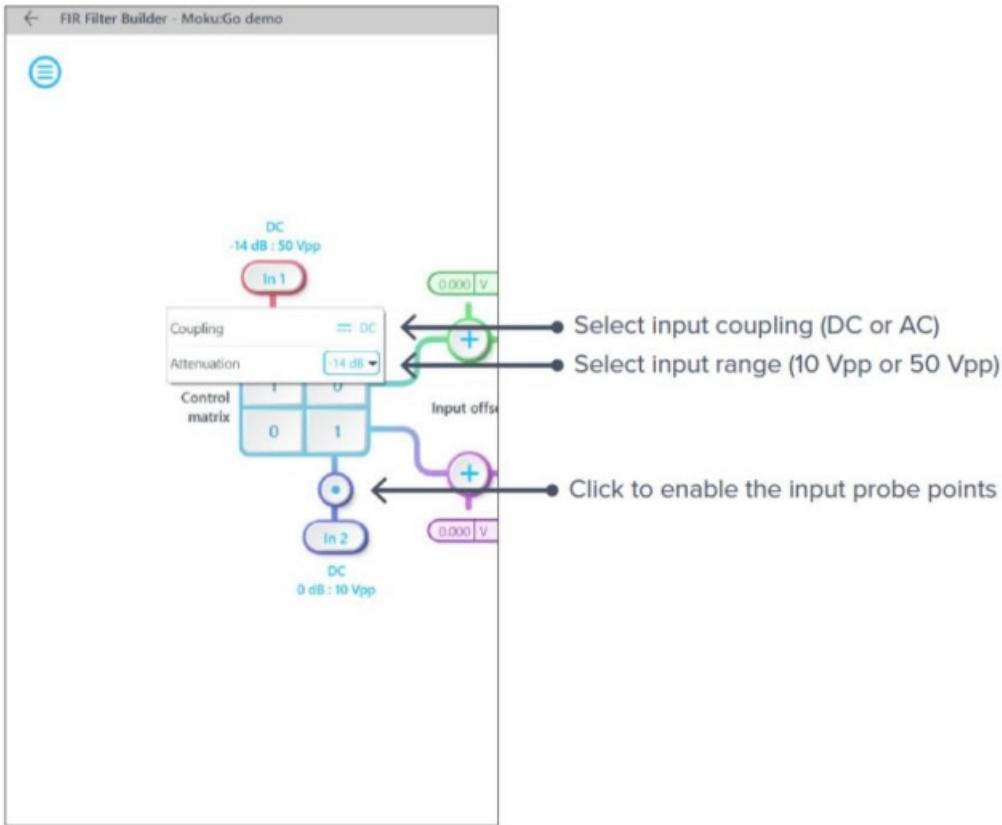
Details about the probe points can be found in the **Probe Points** section.

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.

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

where

$$Path1 = a \times In1 + b \times In2$$

$$Path2 = c \times In1 + d \times In2$$

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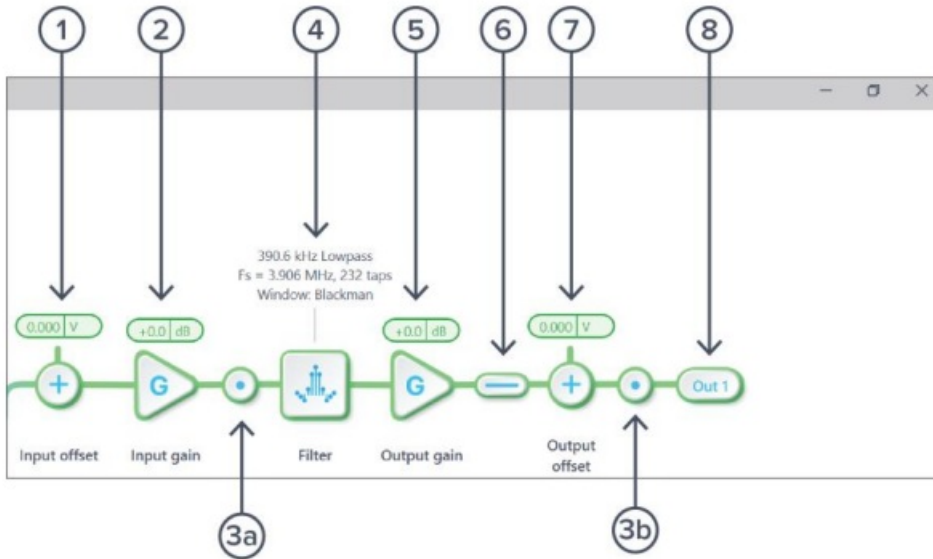The value of each element in the control matrix can be set between -20 to +20 with 0.1 increments when the absolute value is less than 10, or 1 increment when the absolute value is between 10 and 20. Adjust the value by clicking on the element.

DC
-14 dB : 50 Vpp
In 1

Control matrix

| 1 | 0 |
| 0 | 1 |

In 2
DC
0 dB : 10 Vpp
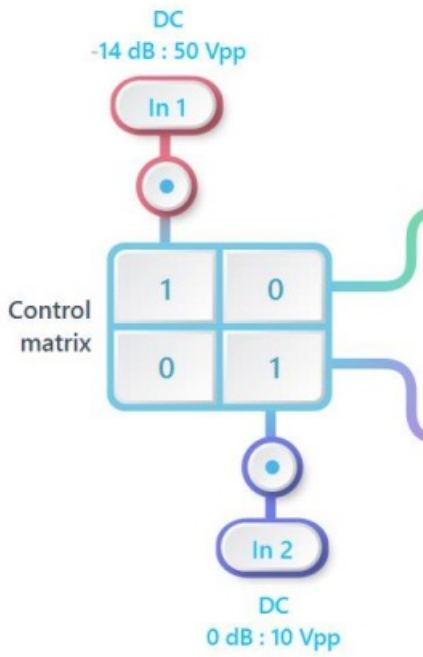
FIR Filter

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

390.6 kHz Lowpass
Fs = 3.906 MHz, 232 taps
Window: Blackman

0.000 V   +0.0 dB   +0.0 dB   0.000 V

Input offset   Input gain   Filter   Output gain   Output offset   Out 1

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).
6	Output switch	Click to zero the filter output.
7	Output offset	Click to adjust the output offset (-2.5 to +2.5 V).
8	DAC switch	Click to enable/disable the Moku:Go 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 on page 13.
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 plot** to adjust the corner frequency in real-time.
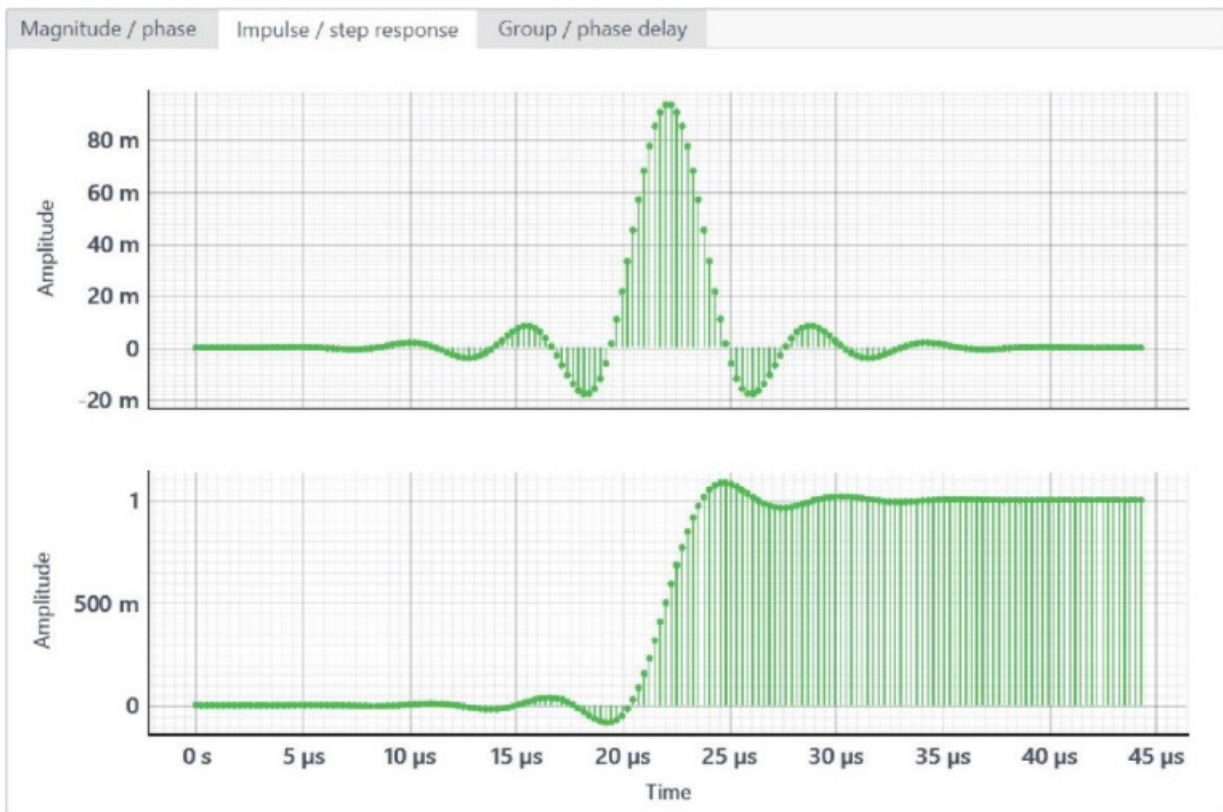
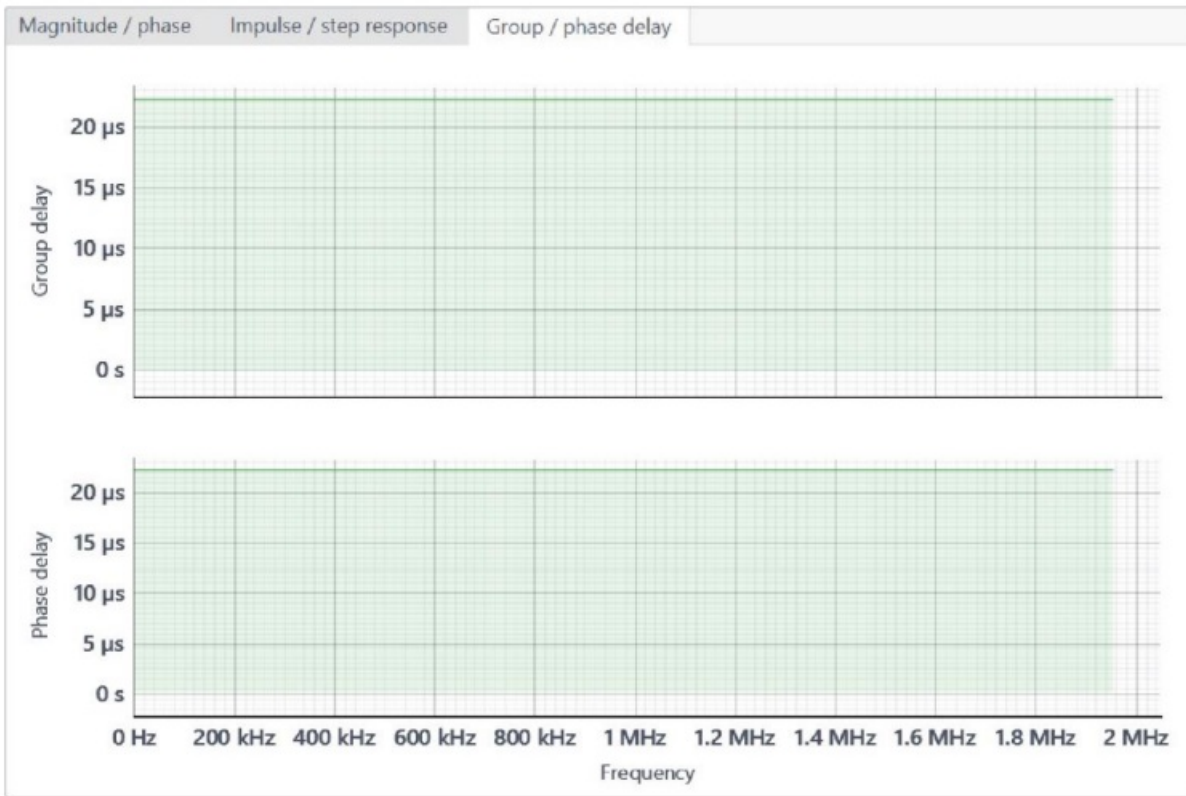|	Magnitude/phase		Impulse/step response		Group/phase delay	
	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
X – axis	Frequency (MHz)		Time (µs)		Frequency (MHz)	
Y – axis	Gain (dB)	Phase (°)	Amplitude (V)		Group/phase Delay (µs)	

Magnitude/phase plot set:
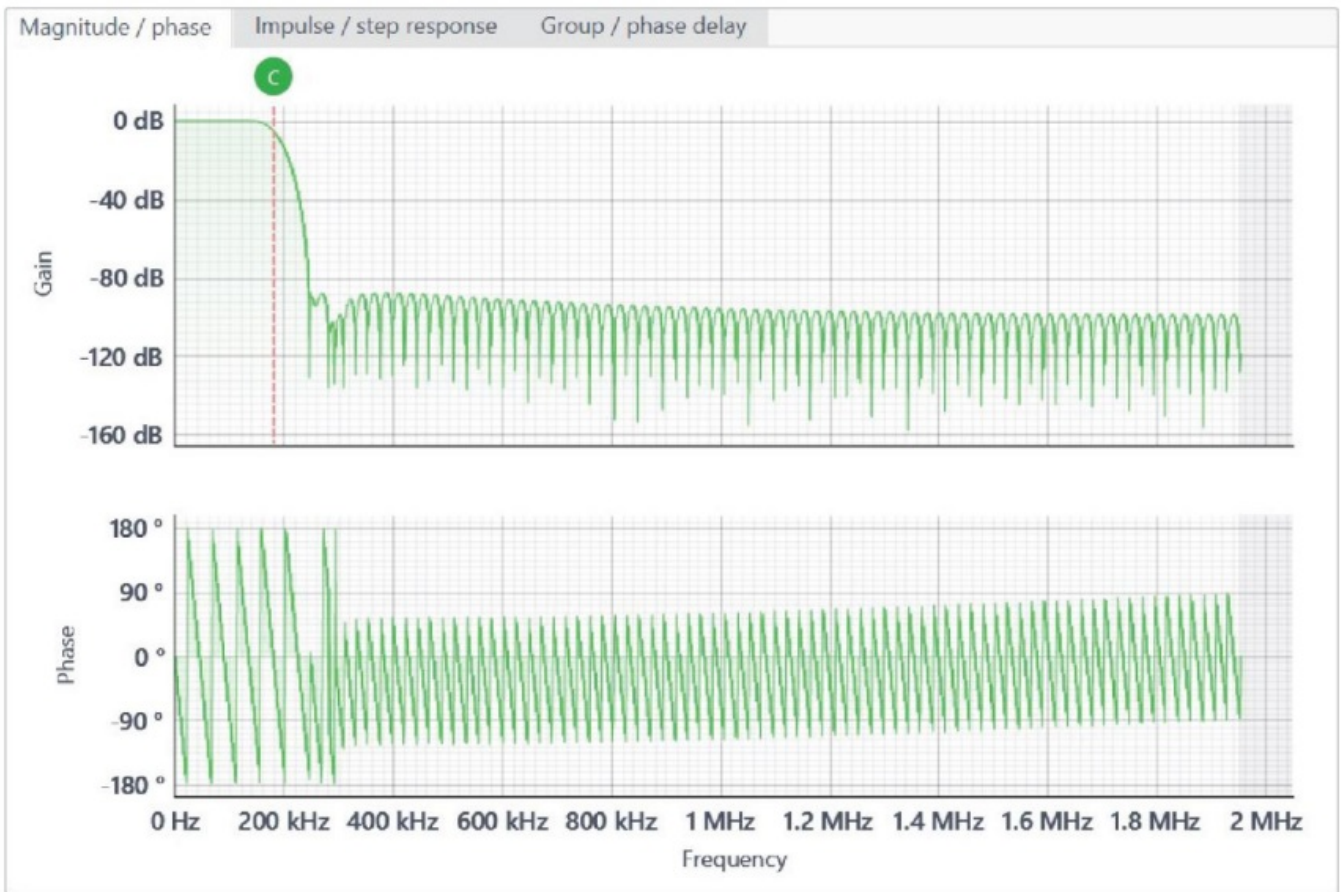
Impulse/step reponse plot set:

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 the **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 the **frequency domain designer**, a frequency response builder is accessible. Lowpass, high pass, bandpass, and band stop filters are available with adjustable cut-off frequencies.

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 the **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.
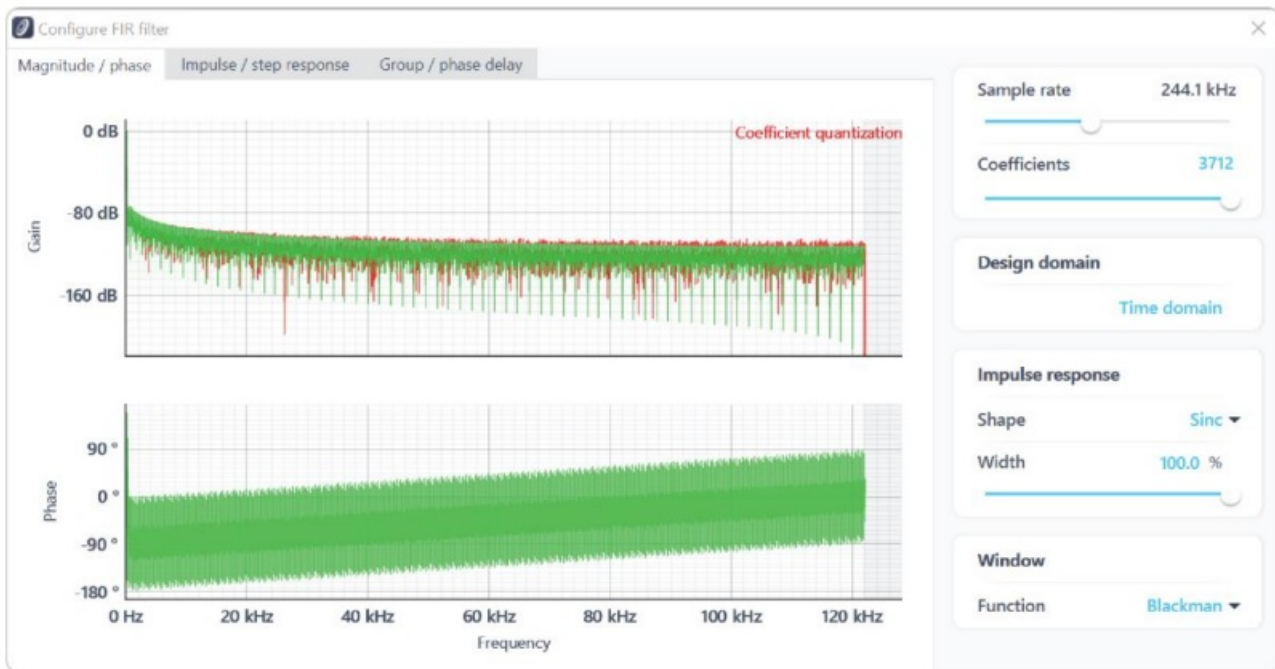
Equation editor

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. You can 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.
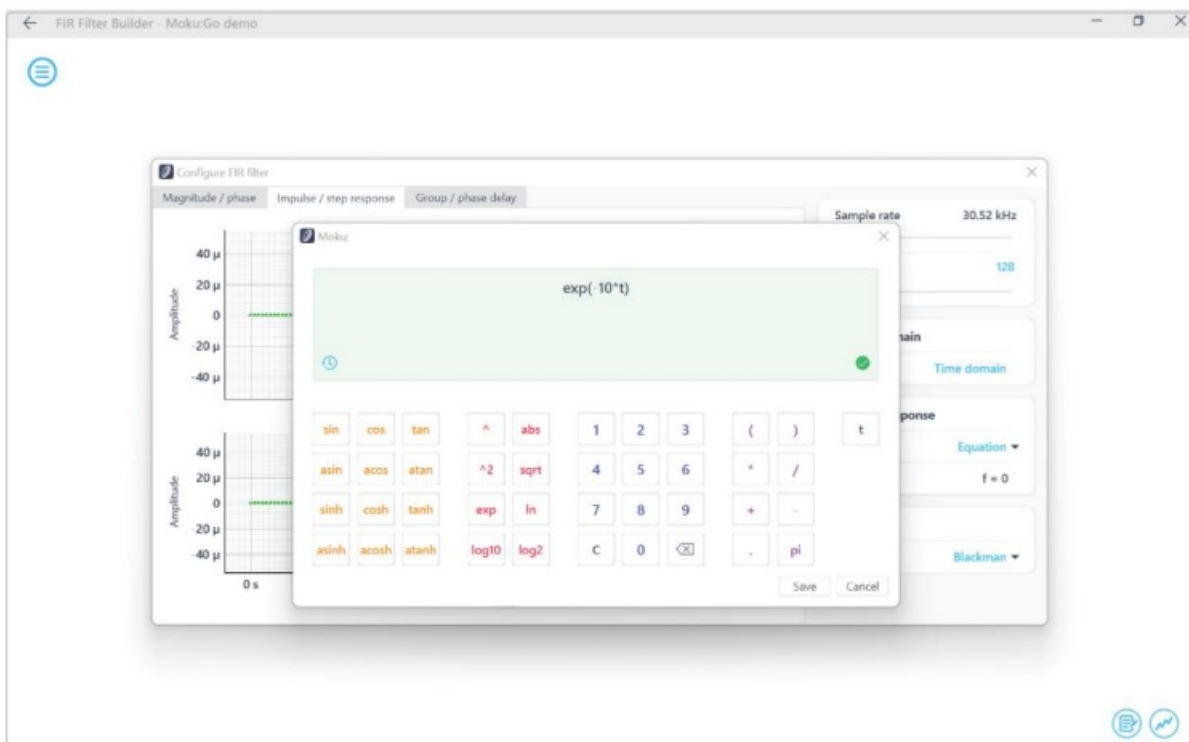
Custom impulse response

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

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

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 [-1, +1]. 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. Check filter responses prior to use.
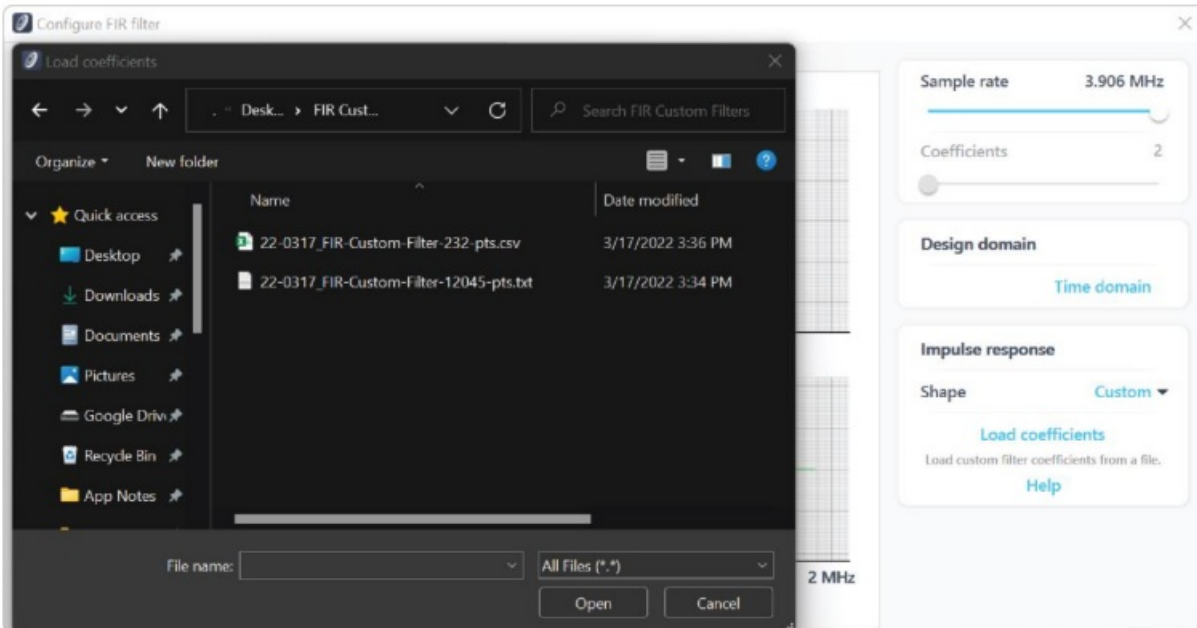
Frequency domain designer
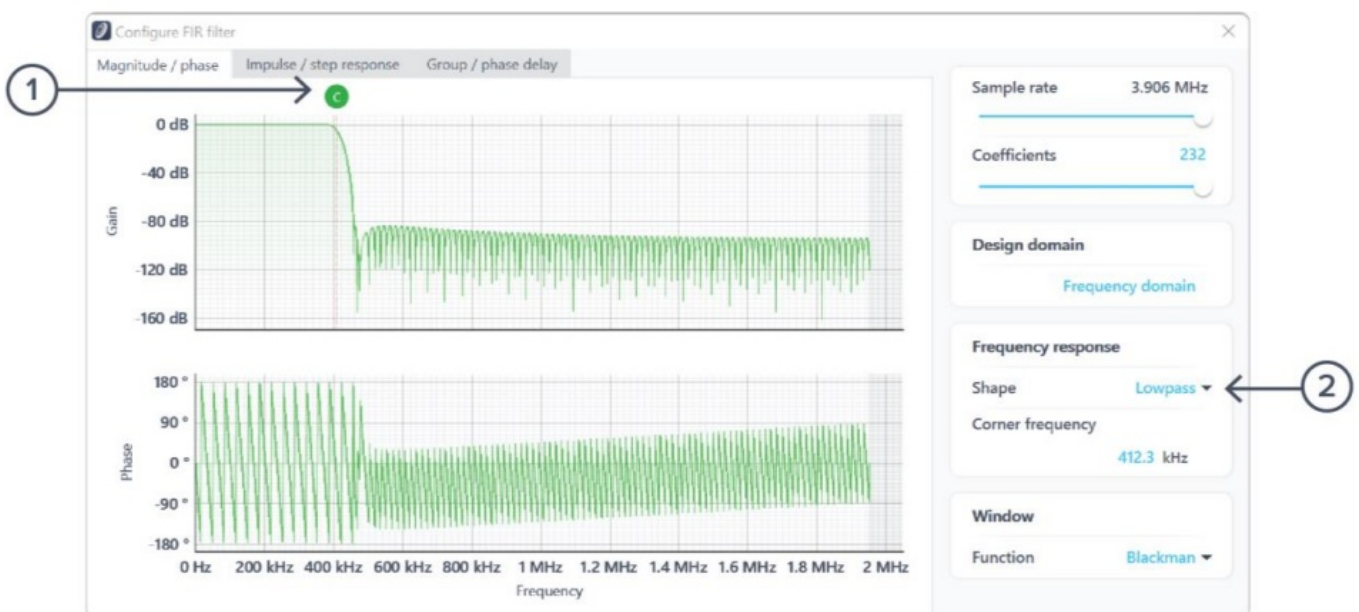
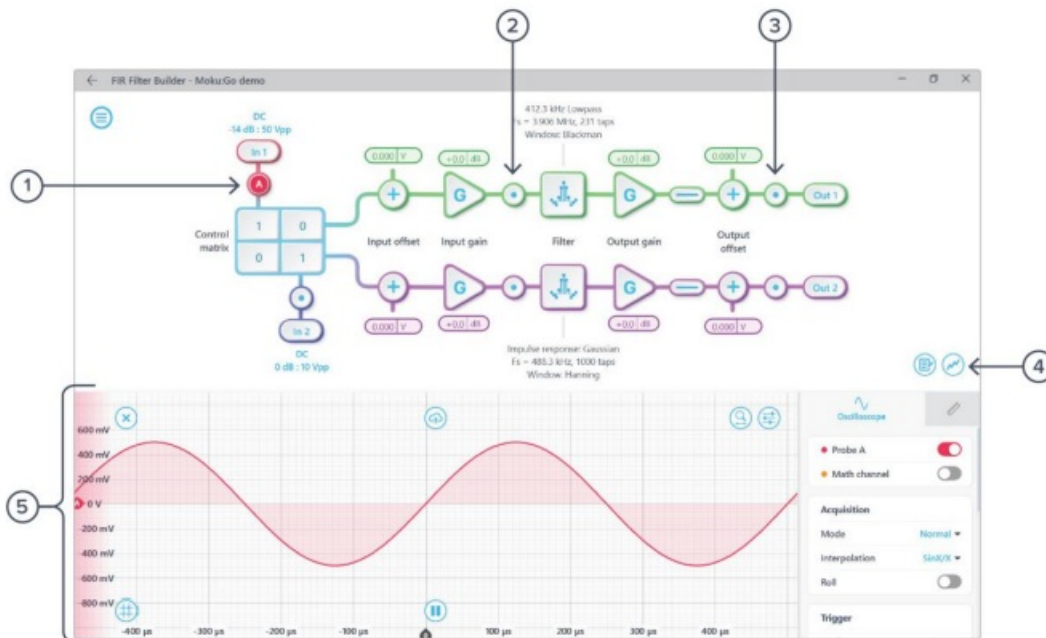| ID	Parameter	Description
1	Cut-off cursor	Click and hold to slide in the frequency axis.
2	Frequency response design parameters	Click to select the filter shape and the corner frequencies.

List of available shapes:

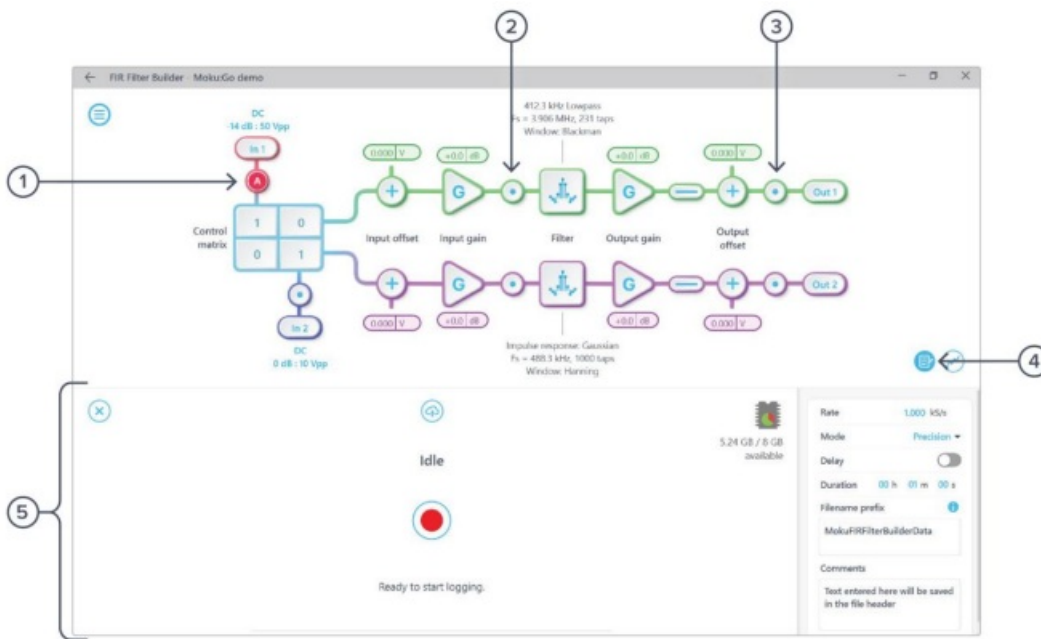| Shape	Note
Lowpass	Single adjustable cursor.
Highpass	Single adjustable cursor.
Bandpass	Two adjustable cursors.
Bandstop	Two adjustable cursors.

Probe points

The Moku:Go 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 the 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 the output.
4	Oscilloscope/Data Logger toggle	Toggle between the integrated Oscilloscope or Data Logger.
5	Oscilloscope	Refer to the **Moku:Go Oscilloscope** manual for the details

Data Logger

ID	Parameter	Description
1	Input probe point	Click to place the probe point at the 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 the output.
4	Oscilloscope/data logger toggle	Toggle between the integrated Oscilloscope or Data Logger.
5	Data Logger	Refer to the **Moku:Go Data Logger** manual for the details.

It is possible to stream data directly from Moku:Go to a computer without the need to save to a .li file using the Python, MATLAB, or LabVIEW APIs. For more information on how this feature works, please refer to our **API documentation site**.

Additional tools

The Moku:Go 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 binary (.li) format on the local computer to either .csv, .mat, or .npy format.

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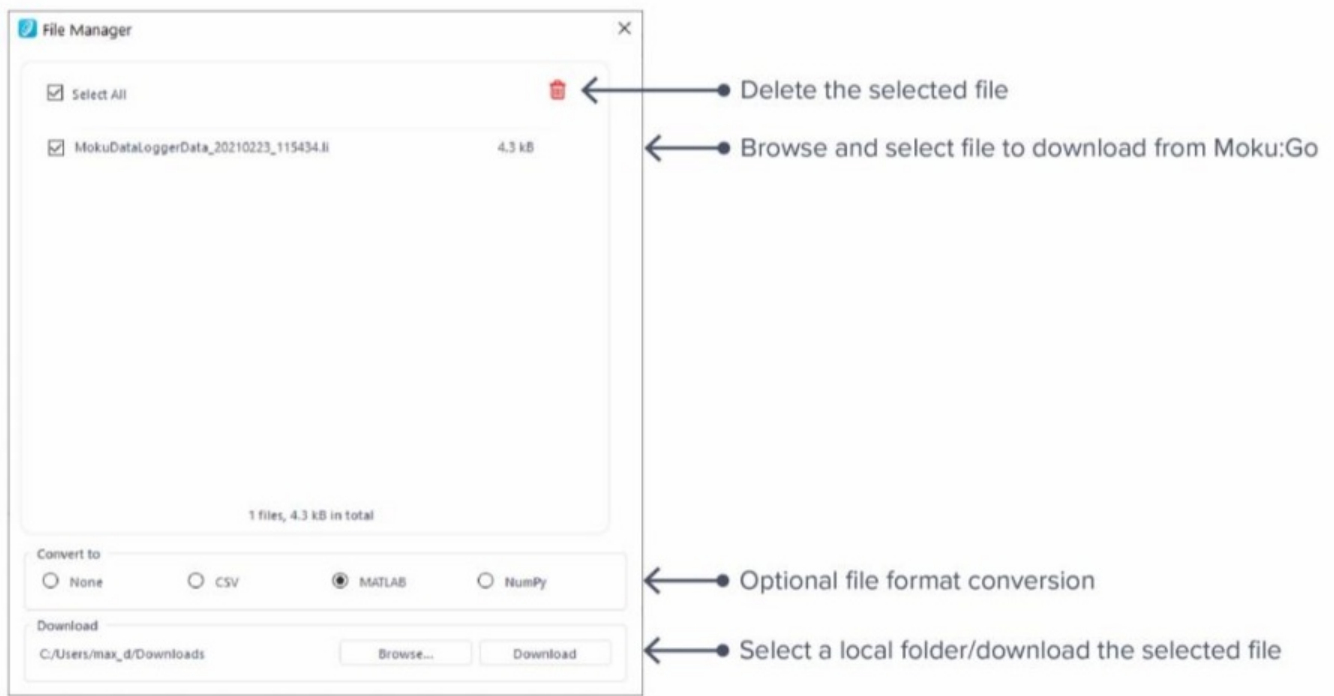
Once a file is transferred to the local computer, a icon 📁 shows up next to the file.

File converter
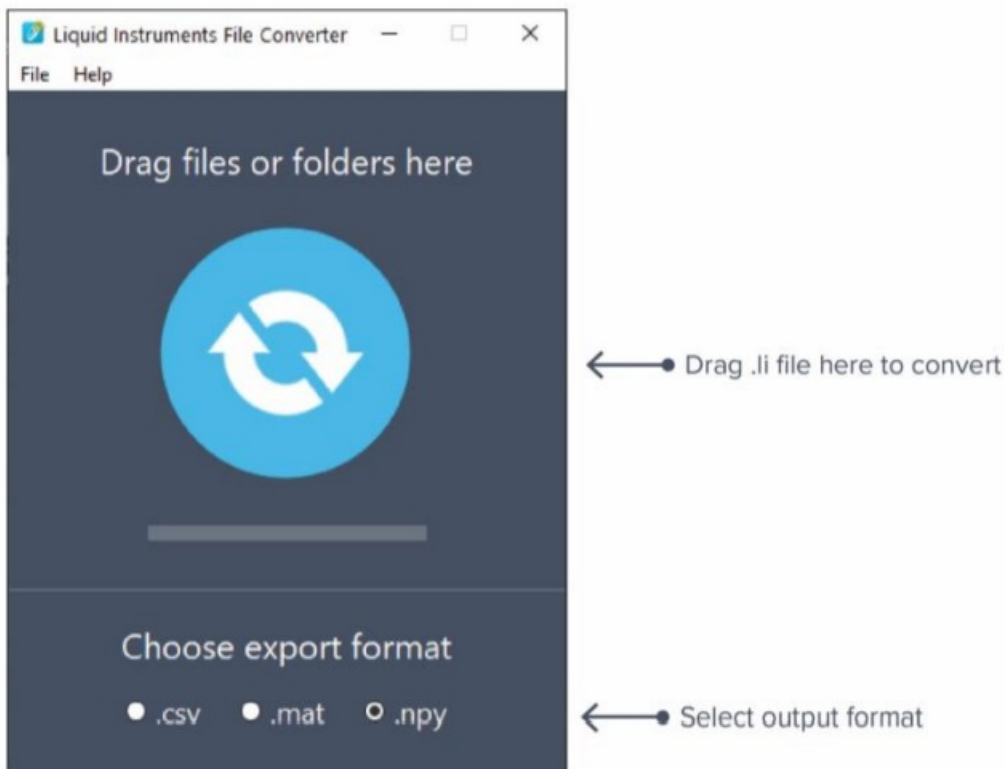
The converted file is saved in the same folder as the original file.
Liquid Instruments File Converter has the following menu options:

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

The Moku:Go Power Supply is available on M1 and M2 models. M1 features a two-channel Power Supply, while M2 features a four-channel Power Supply. Access the Power Supply control window in all instruments under the main menu.

Each Power Supply operates in two modes: **constant voltage (CV)** or **constant current (CC)** mode. For each channel, you 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.
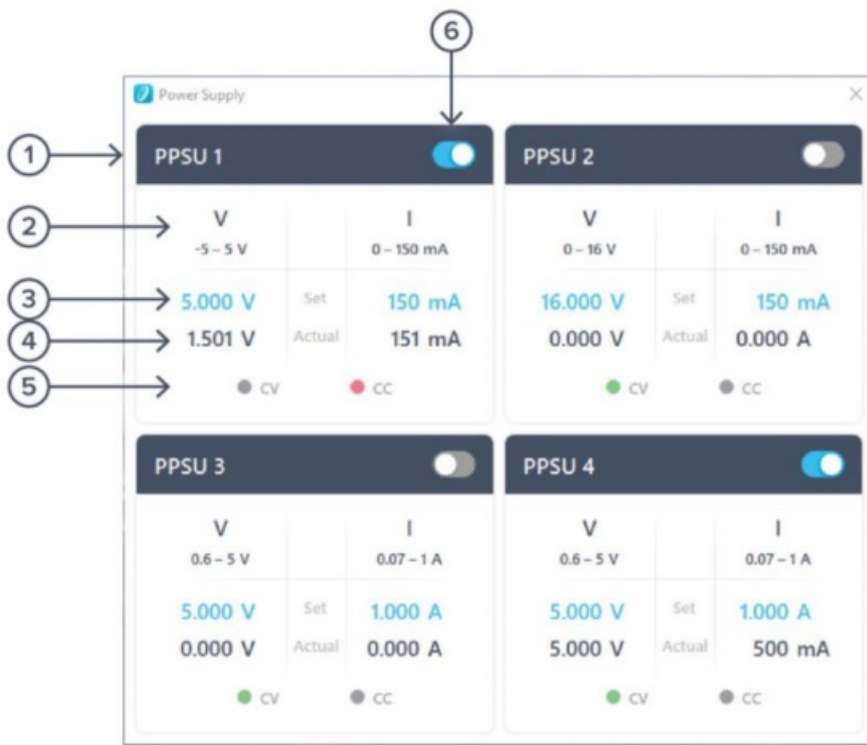
ID	Function	Description
1	Channel name	Identifies the Power Supply being controlled.
2	Channel range	Indicates the voltage/current range of the channel.
3	Set value	Click the blue numbers to set the voltage and current limit.
4	Readback numbers	Voltage and current readback from the Power Supply; the 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.

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

www.liquidinstruments.com
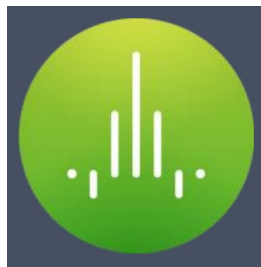
Documents / Resources

LIQUID INSTRUMENTS Moku:Go FIR Filter Builder [pdf] User Manual
V23-0126, Moku Go FIR Filter Builder, Moku Go, FIR Filter Builder, Filter Builder

References

- **Liquid Instruments**
- **Liquid Instruments**
- **Moku API Home | Moku API**