



Digital Filter Box

Moku:Go User Manual

With Moku:Go's Digital Filter Box, you can interactively design and generate different types of infinite impulse response filters with sampling rates of 61.035 kHz, 488.28 kHz and 3.9063 MHz. Select between low pass, high pass, band pass, and band stop filter shapes with up to eight fully configurable types including Butterworth, Chebyshev, and Elliptic.





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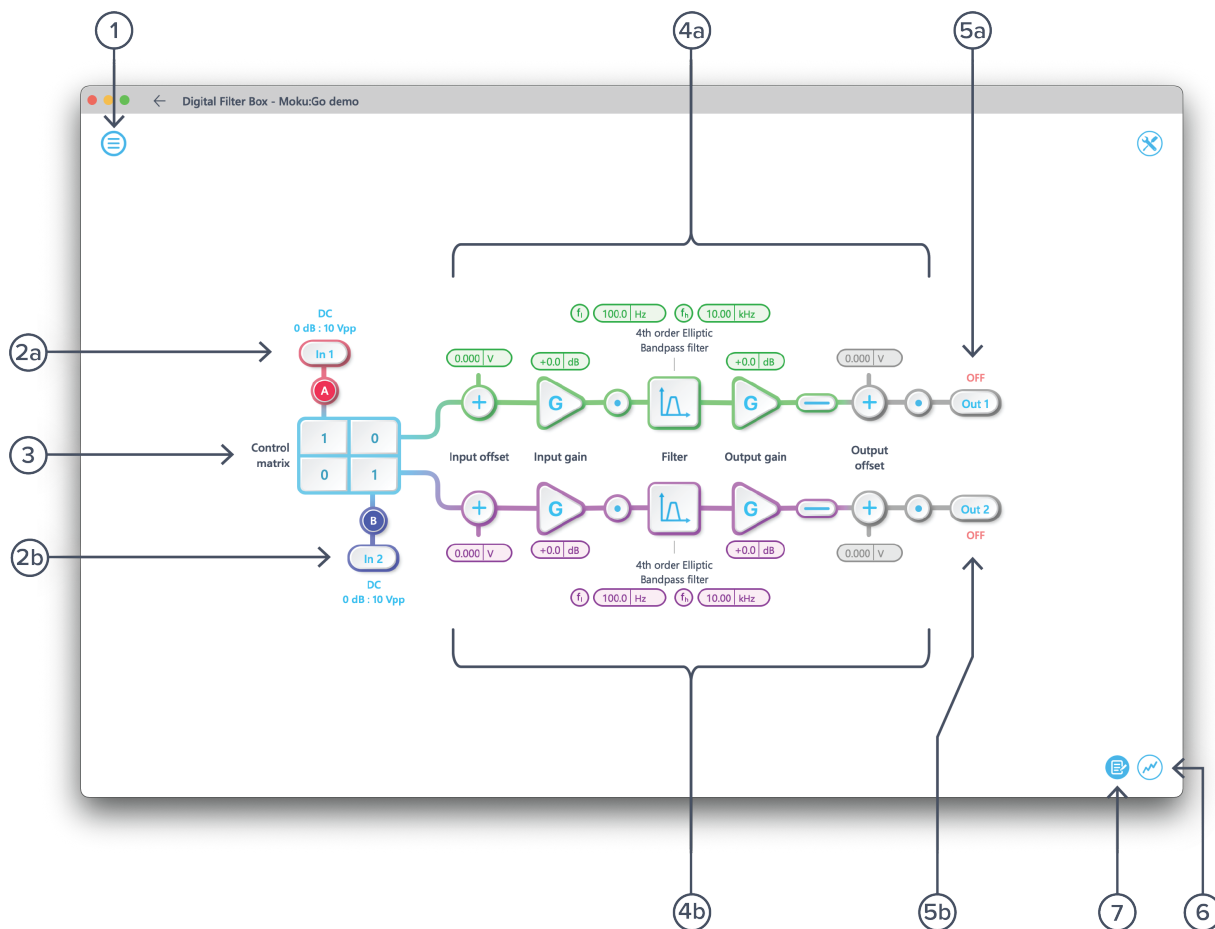


Ensure Moku:Go is fully updated. For the latest information:

www.liquidinstruments.com



User Interface



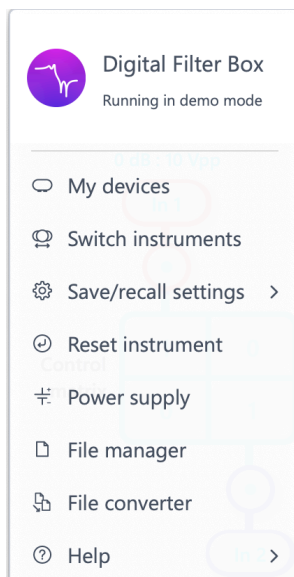
ID Description

| | |
|----|--------------------------------------|
| 1 | Main menu |
| 2a | Input configuration for Channel 1 |
| 2b | Input configuration for Channel 2 |
| 3 | Control matrix |
| 4a | Configuration for filter 1 |
| 4b | Configuration for filter 2 |
| 5a | Output switch for Channel 1 |
| 5b | Output switch for Channel 2 |
| 6 | Enable/disable the oscilloscope view |
| 7 | Enable/disable the data logger view |



Main Menu

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



| Options | Shortcuts | Description |
|-------------------------------------|-----------|--|
| My devices | | Search for Moku devices |
| Switch instruments | | Switch instruments on this Moku:Go |
| 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 for updates, or show license information |

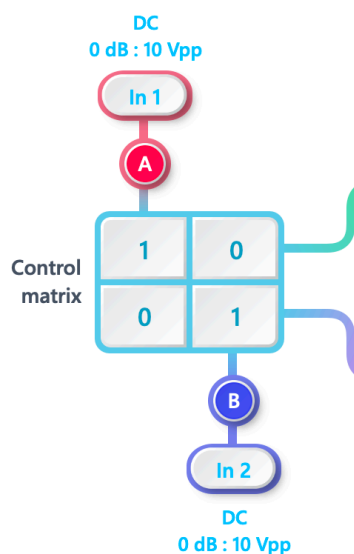
*Power supply is available on Moku:Go M1 and M2 models. Detailed information about power supply can be found in Moku:Go's power supply manual.

**Detailed information about the file manager and file converter can be found toward 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 attenuation (and therefore voltage 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 signal to the two independent 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

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

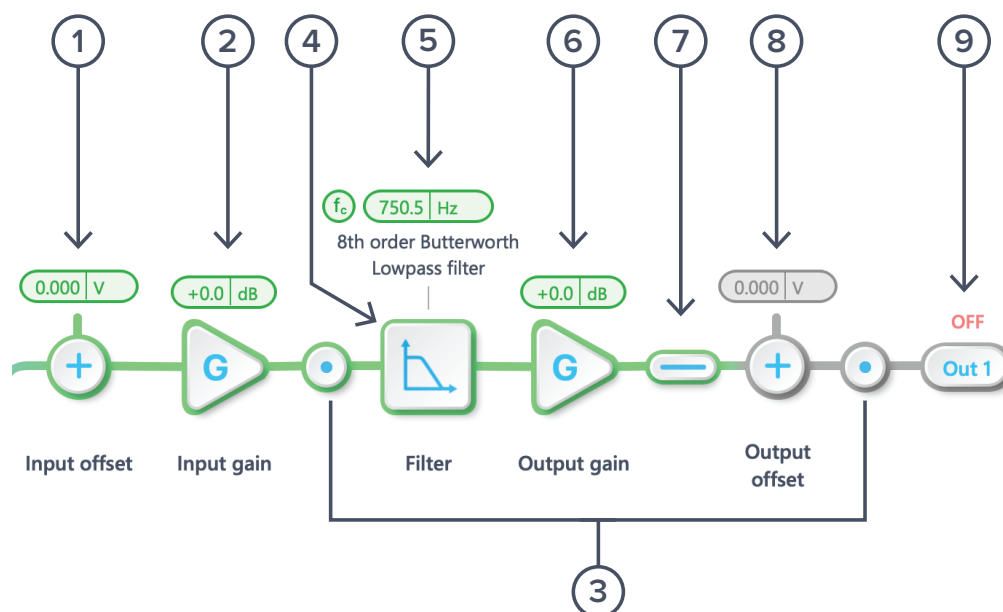
$$\text{Path2} = c \times \text{In1} + d \times \text{In2}$$

For example, a control matrix of $\begin{bmatrix} 1 & 1 \\ 0 & 2 \end{bmatrix}$ equally combines the **Input 1** and **Input 2** to the top **Path1** (filter 1), multiples **Input 2** by a factor of two, and then sends it to the bottom **Path2** (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. Click the element to adjust the value.



Digital Filters



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


User Interface

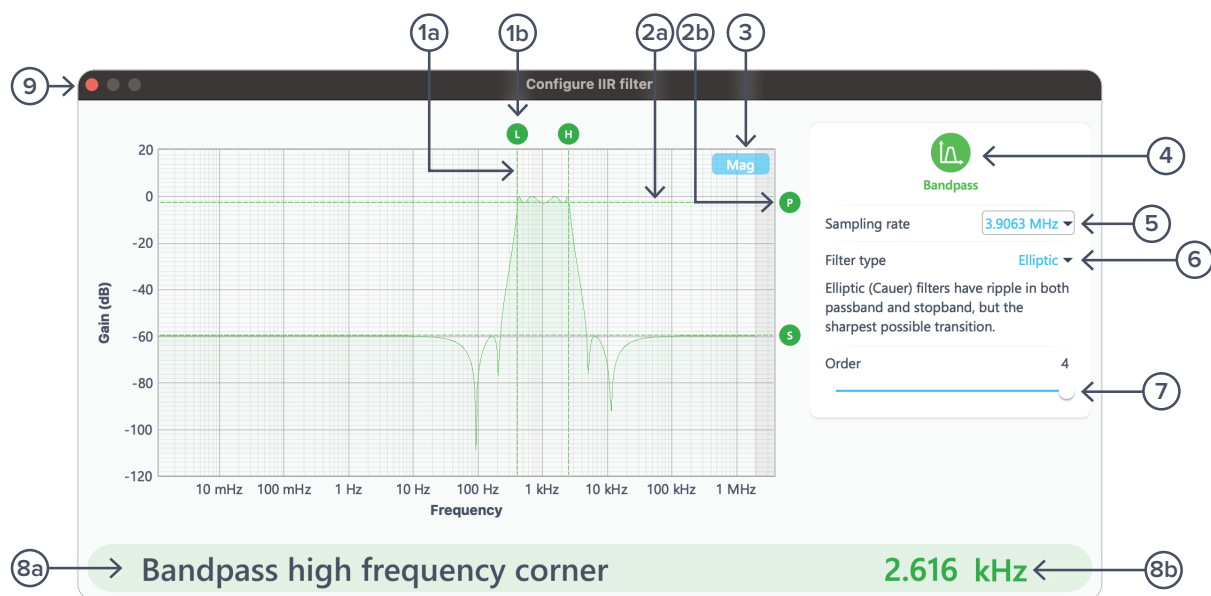
| ID | Parameter | Description |
|----|----------------------|---|
| 1 | Input offset | Click to adjust the input offset (-2.5 to +2.5 V). |
| 2 | Input gain | Click to adjust the input gain (-40 to 40 dB). |
| 3 | Probe points | Click to enable/disable the probe points. See Probe Points section for details. |
| 4 | Digital filter | Click to view and configure the digital filter builder. |
| 5 | Quick filter control | Click or slide to quickly adjust the filter settings |
| 6 | Output gain | Click to adjust the output gain (-40 to 40 dB). |
| 7 | Output switch | Click to zero the filter output. |
| 8 | Output offset | Click to adjust the output offset (-2.5 to +2.5 V). |
| 9 | DAC switch | Click to enable/disable Moku:Go's DAC output. |



Configure IIR filter characteristics

Detailed filter interface

Click the  icon to open the full filter view.





| ID | Parameter | Description |
|----|-------------------------------|---|
| 1a | Frequency (horizontal) cursor | Cursor for corner frequency. |
| 1b | Cursor reading | Reading for frequency cursor. Drag to adjust the corner frequency. Click to select and manually enter the corner frequency in 8b. |
| 2a | Gain (vertical) cursor | Cursor for ripple/gain/attenuation level. |
| 2b | Cursor handle | Short name and handle for gain cursor. Drag to adjust the gain/ripple level. Click to select and manually enter passband ripple in 8b. |
| 3 | Display toggle | Toggle between magnitude and phase response curve. |
| 4 | Filter shape selection | Click to select between lowpass, high pass, band pass, band stop, and custom filters. |
| 5 | Sampling rate | Click to select between 3.9063 MHz, 488.28 kHz, or 61.035 kHz. |
| 6 | Filter type selection | Click to select between Butterworth, Chebyshev I/II, Elliptic, Bessel, Gaussian, Cascaded or Legendre filters. When selected, a short description of the filter type will be given below. |
| 7 | Filter order | Slide to adjust filter orders. |
| 8a | Active configurable parameter | Name of the active configurable parameter. |
| 8b | Parameter value | Click to manually enter the active configurable parameter value. |
| 9 | Save and close | Click to save and close the filter builder. |



Filter Shapes

The shape of the filter can be selected by clicking the ④ button (on page 7). There are four pre-defined filter shapes and a fully customizable filter option.



Sampling Rates

Users can select between 3.9063 MHz, 488.28 kHz, or 61.035 kHz of output sampling rate based on the desired corner frequencies. The following table summarizes the lower and upper bounds for each shape of pre-defined filters with different sampling rates:

| Shape | Sampling Rate | Minimum corner frequency | Maximum corner frequency |
|----------|---------------|--------------------------|--------------------------|
| Lowpass | 61.035 kHz | 11.73 mHz | 27.47 kHz |
| | 488.28 kHz | 93.81 mHz | 219.7 kHz |
| | 3.9063 MHz | 750.5 mHz | 1.758 MHz |
| Highpass | 61.035 kHz | 144.7 mHz | 27.47 kHz |
| | 488.28 kHz | 1.158 Hz | 219.7 kHz |
| | 3.9063 MHz | 9.263 Hz | 1.758 MHz |
| Bandpass | 61.035 kHz | 610.4 mHz | 27.47 kHz |
| | 488.28 kHz | 4.883 Hz | 219.7 kHz |
| | 3.9063 MHz | 39.06 Hz | 1.758 MHz |
| Bandstop | 61.035 kHz | 11.73 mHz | 27.47 kHz |
| | 488.28 kHz | 93.81 mHz | 219.7 kHz |
| | 3.9063 MHz | 750.5 mHz | 1.758 MHz |



Filter types

The type of filter can be selected by pressing the ⑥ button (on Page 9). There are seven pre-defined filter types with user-selectable filter orders from 2 up to 8, depending on the filter shapes.

| Filter Types | Description |
|---------------------|---|
| Butterworth | Butterworth filters have a maximally flat passband and a monotonic frequency response. |
| Chebyshev I | Chebyshev I filters have ripple in the passband but a sharper transition than Butterworth filters. |
| Chebyshev II | Chebyshev II filters have ripple in the stopband but a sharper transition than Butterworth filters. |
| Elliptic | Elliptic (Cauer) filters have ripple in both passband and stopband, but the sharpest possible transition. |
| Cascaded | Cascaded first-order filters have zero overshoot in the time domain. |
| Bessel | Bessel filters have a maximally flat group and phase delay in the passband, thus preserving the wave shape of passed signals. |
| Gaussian | Gaussian filters have the minimum possible group delay, and a step response with no overshoot and minimum rise and fall time. |
| Legendre | Legendre (Optimum L) filters have the sharpest possible transition while maintaining a monotonic frequency response. |

Filter Orders

For single sided filters, the order of the filter can be set to 2, 4, 6, or 8. For double sided filters, the order of the filter can be 2 or 4.

Ripples

Chebyshev I, II, and Elliptic filters have ripples on either passband, stopband or both. The following table summarize the adjustable range for the passband and stopband ripples for these filter types.

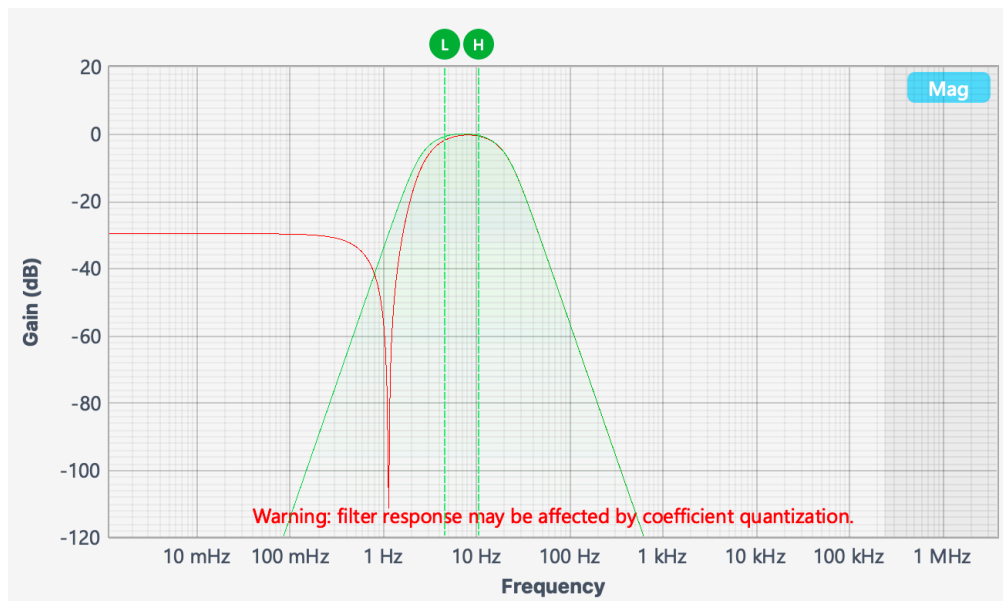
| Filter Types | Passband Ripple | Stopband Ripple |
|---------------------|---|---|
| Chebyshev I | 0.1 dB to 10.0 dB with 0.1 dB increment | N/A |
| Chebyshev II | N/A | 10.0 dB to 100.0 dB with 1 dB increment |
| Elliptic | 0.1 dB to 10.0 dB with 0.1 dB increment | 10.0 dB to 100.0 dB with 1 dB increment |

Coefficient Quantization



Due to the limited precision with which a coefficient can be digitally represented, quantization error is pronounced at certain IIR filter settings. A red coefficient quantization warning may appear on the




bottom of the response plot and a red trace in the transfer function showing the closest achievable filter response to the ideal value in green.



Custom filter


Additionally, a custom filter type allows for their filter coefficients to be uploaded from the clipboard or a local file. Click the  icon to  explanation of the coefficients and file format.


Custom

Sampling rate 3.9063 MHz ▼

Load from clipboard

Load from file





Custom filter details

About IIR filter coefficients

Moku:DigitalFilterBox implements infinite impulse response (IIR) filters using 4 cascaded Direct Form I second-order stages with a final output gain stage. The total transfer function can be written:

$$H(z) = g \prod_{k=1}^4 s_k \frac{b_{0k} + b_{1k}z^{-1} + b_{2k}z^{-2}}{1 + a_{1k}z^{-1} + a_{2k}z^{-2}}$$

To specify a filter, you must supply a text file containing the filter coefficients. The file should have six coefficients per line, with each line representing a single stage. If output scaling is required, this should be given on the first line:

| | | | | | | |
|---------------------|---------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <i>g</i> (optional) | 7.8357416974, | | | | | |
| Stage 1 | 1.0000000000, | 0.0044157497, | 0.0088314994, | 0.0044157497, | -1.6692917152, | 0.9692269375 |
| Stage 2 | 1.0000000000, | 0.0472217267, | 0.0944434535, | 0.0472217267, | -1.8988580275, | 0.9341904809 |
| Stage 3 | 1.0000000000, | 0.0375275838, | 0.0750551677, | 0.0375275838, | -1.9259771042, | 0.9311308010 |
| ⋮ | <i>s</i> | <i>b</i> ₀ | <i>b</i> ₁ | <i>b</i> ₂ | <i>a</i> ₁ | <i>a</i> ₂ |

Each coefficient must be in the range [-4.0, +4.0). Internally, these are represented as signed 48-bit fixed-point numbers, with 45 fractional bits. The output scaling can be up to 8,000,000. Filter coefficients can be computed using signal processing toolboxes in e.g. MATLAB or SciPy.

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

Close

Each coefficient must be in the range [-4.0,+4.0). Internally, these are represented as signed 48-bit fixed-point numbers, with 45 fractional bits. The output scaling can be up to 8,000,000. Filter coefficients can be computed using signal processing toolboxes in e.g. MATLAB or SciPy.

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



Output Switches

Switches can be used to connect or disconnect the output signal. When a switch is in open state, the output signal will be Output offset voltage.




Closed/Enable



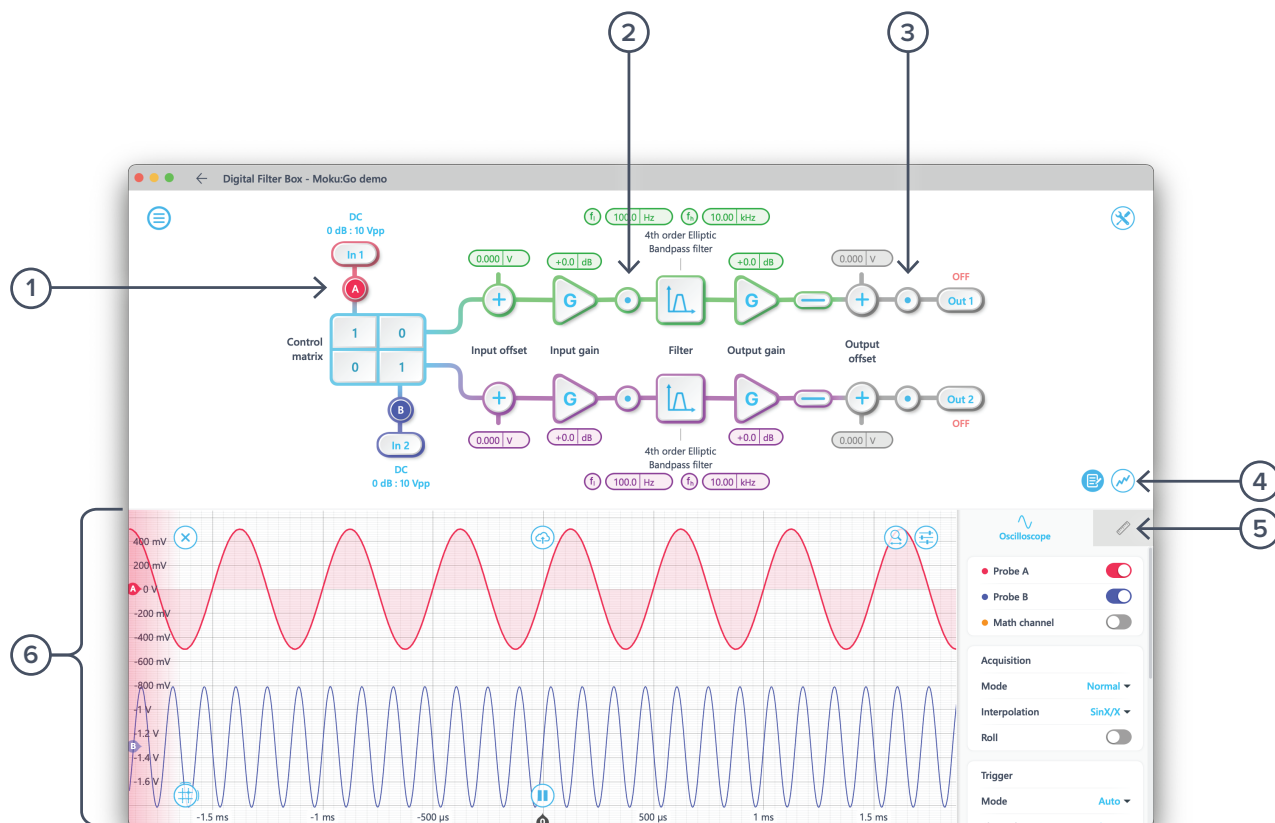
Open/Disable



Probe Points

Moku:Go's Digital Filter Box has an integrated oscilloscope that can be used to probe the signal at the input, pre-filter, and output stages. The probe points can be added by Clicking the .

Oscilloscope

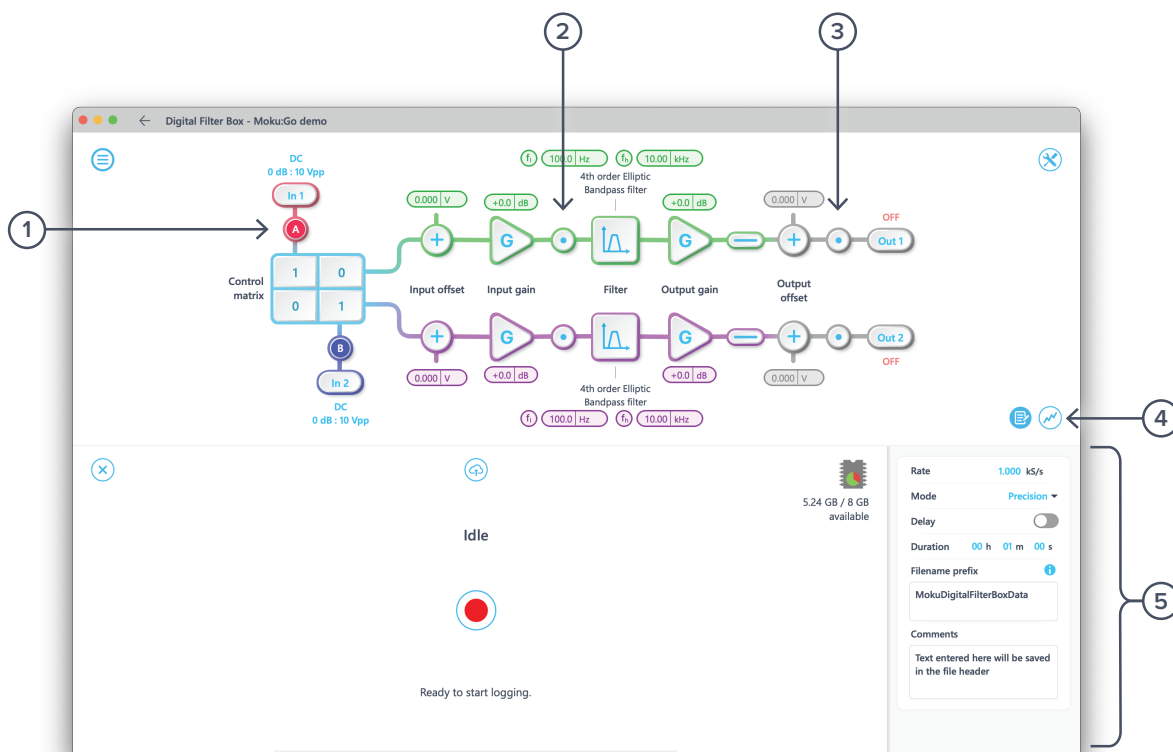


| ID | Parameter | Description |
|----|------------------------|--|
| 1 | Input probe point | Click to place the probe point at input |
| 2 | Pre-filter probe point | Click to place the probe after input gain |
| 3 | Output probe point | Click to place the probe at output |
| 4 | Oscilloscope settings* | Additional settings for built-in oscilloscope |
| 5 | Measurement* | Measurement function for built-in oscilloscope |
| 6 | Oscilloscope* | Signal display area for oscilloscope |

*Detailed instructions for the oscilloscope instrument can be found in Moku:Go's Oscilloscope manual.



Data Logger



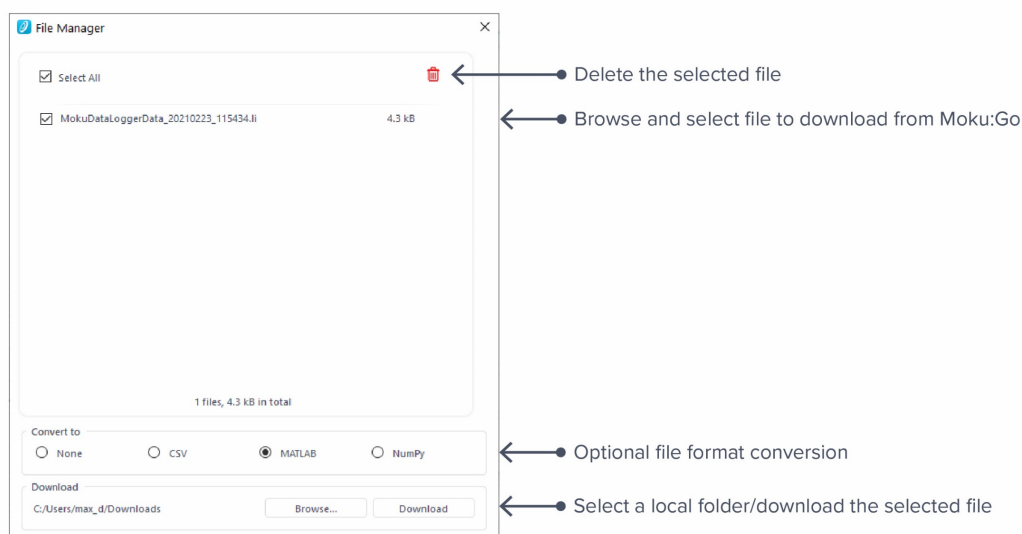
| ID | Parameter | Description |
|----|---------------------------------|---|
| 1 | Input probe point | Click to place the probe point at inputs. |
| 2 | Pre-Filter probe point | Click to place the probe before the filter. |
| 3 | Output probe point | Click to place the probe at outputs. |
| 4 | Oscilloscope/data logger toggle | Toggle between built-in oscilloscope or data logger. |
| 5 | Data Logger | Refer to 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.

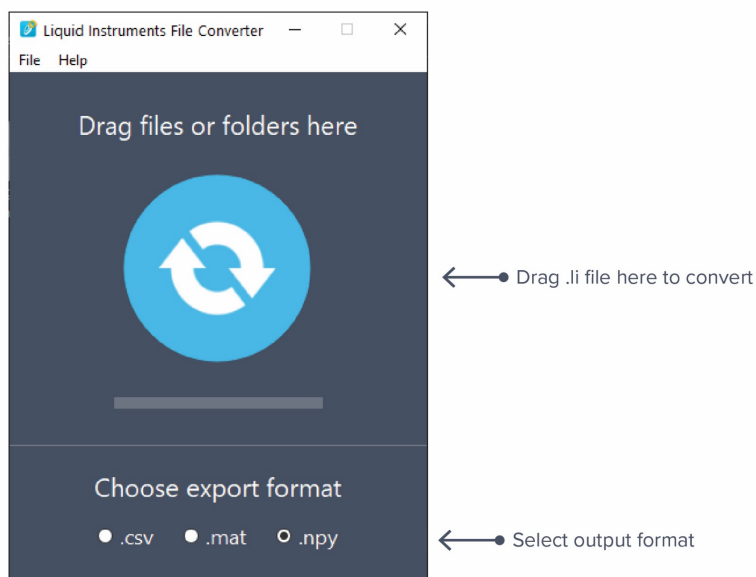
File Manager



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:

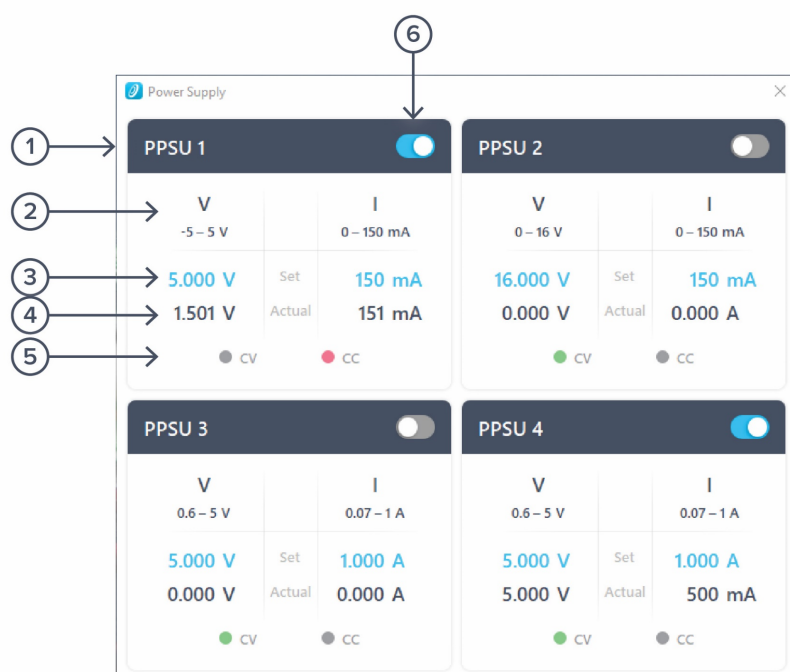
| Options | Shortcut | Description |
|-------------------------------------|--------------|--|
| File | | |
| • Open file | Ctrl+O | Select a .li file to convert |
| • Open folder | Ctrl+Shift+O | Select a folder to convert |
| • Exit | | Close the file converter window |
| Help | | |
| • Liquid Instruments 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's 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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