

# Moku:Pro

## Specifications



# Table of contents

|                                              |           |
|----------------------------------------------|-----------|
| <b>Moku:Pro Hardware</b>                     | <b>6</b>  |
| Specifications.....                          | 6         |
| Analog I/O .....                             | 6         |
| External trigger input .....                 | 7         |
| Clock reference.....                         | 7         |
| Internal Storage.....                        | 7         |
| General characteristics.....                 | 8         |
| General connectivity.....                    | 9         |
| Safety Information .....                     | 10        |
| Hardware measurements .....                  | 11        |
| ADC input noise .....                        | 11        |
| Compound Crosstalk (ADC-ADC & DAC-ADC).....  | 12        |
| Analog output noise .....                    | 16        |
| <b>Moku:Pro Arbitrary Waveform Generator</b> | <b>17</b> |
| Description.....                             | 17        |
| Specifications.....                          | 18        |
| Common .....                                 | 18        |
| Waveform .....                               | 18        |
| <b>Moku:Pro Frequency Response Analyzer</b>  | <b>19</b> |
| Description.....                             | 19        |
| Specifications.....                          | 20        |
| Source .....                                 | 20        |
| Input .....                                  | 20        |
| Measurement.....                             | 20        |
| Saving Data.....                             | 21        |
| <b>Moku:Pro Data Logger</b>                  | <b>22</b> |
| Description.....                             | 22        |
| Specifications.....                          | 23        |
| Input .....                                  | 23        |
| Logging .....                                | 23        |
| <b>Moku:Pro Digital Filter Box</b>           | <b>24</b> |
| Description.....                             | 24        |
| Specifications.....                          | 25        |
| Inputs .....                                 | 25        |
| Filter characteristics .....                 | 25        |
| Selecting the right IIR filter .....         | 27        |
| <b>Moku:Pro FIR Filter Builder</b>           | <b>28</b> |

|                                                               |           |
|---------------------------------------------------------------|-----------|
| Description.....                                              | 28        |
| Specifications.....                                           | 29        |
| Inputs .....                                                  | 29        |
| Filter characteristics .....                                  | 29        |
| <b>Moku:Pro Laser Lock Box</b> .....                          | <b>31</b> |
| Description.....                                              | 31        |
| Specifications.....                                           | 32        |
| Signal input.....                                             | 32        |
| Internal demodulation local oscillator .....                  | 32        |
| External demodulation reference.....                          | 33        |
| Lowpass filter .....                                          | 33        |
| Auxiliary oscillator.....                                     | 34        |
| Scan waveform.....                                            | 34        |
| PID Controllers.....                                          | 34        |
| <b>Moku:Pro Lock-In Amplifier</b> .....                       | <b>36</b> |
| Description.....                                              | 36        |
| Specifications.....                                           | 37        |
| Signal channel .....                                          | 37        |
| External reference .....                                      | 37        |
| Internal reference .....                                      | 38        |
| Demodulator .....                                             | 38        |
| Signal output .....                                           | 39        |
| <b>Moku:Pro Logic Analyzer (Multi-instrument Mode)</b> .....  | <b>40</b> |
| Description.....                                              | 40        |
| Specifications.....                                           | 41        |
| Digital I/O .....                                             | 41        |
| Horizontal characteristics.....                               | 41        |
| Trigger .....                                                 | 41        |
| Measurements .....                                            | 42        |
| Protocol Decoder .....                                        | 42        |
| Saving data .....                                             | 43        |
| <b>Moku:Pro Logic Analyzer (Single-instrument Mode)</b> ..... | <b>44</b> |
| Description.....                                              | 44        |
| Specifications.....                                           | 45        |
| Analog Inputs .....                                           | 45        |
| Horizontal characteristics.....                               | 45        |
| Trigger .....                                                 | 45        |
| Measurements .....                                            | 45        |
| Protocol Decoder .....                                        | 46        |
| Saving data .....                                             | 47        |

|                                               |           |
|-----------------------------------------------|-----------|
| <b>Moku:Pro Neural Network</b>                | <b>48</b> |
| Description.....                              | 48        |
| Features.....                                 | 48        |
| Specifications.....                           | 49        |
| <b>Moku:Pro Oscilloscope</b>                  | <b>50</b> |
| Description.....                              | 50        |
| Features.....                                 | 50        |
| Specifications.....                           | 51        |
| Vertical characteristics .....                | 51        |
| Horizontal characteristics.....               | 51        |
| Trigger .....                                 | 52        |
| Measurements .....                            | 52        |
| Integrated waveform synthesizer .....         | 53        |
| <b>Moku:Pro Phasemeter</b>                    | <b>54</b> |
| Description.....                              | 54        |
| Specifications.....                           | 55        |
| Inputs .....                                  | 55        |
| Measurement.....                              | 55        |
| Outputs.....                                  | 55        |
| Saving Data.....                              | 56        |
| Synthesizer .....                             | 56        |
| <b>Moku:Pro PID Controller</b>                | <b>57</b> |
| Description.....                              | 57        |
| Specifications.....                           | 58        |
| Inputs .....                                  | 58        |
| Controller.....                               | 58        |
| <b>Moku:Pro Spectrum Analyzer</b>             | <b>59</b> |
| Description.....                              | 59        |
| Specifications.....                           | 60        |
| Frequency .....                               | 60        |
| Amplitude .....                               | 60        |
| Synthesizer .....                             | 61        |
| <b>Moku:Pro Time &amp; Frequency Analyzer</b> | <b>62</b> |
| Description.....                              | 62        |
| Specifications.....                           | 63        |
| Events .....                                  | 63        |
| Intervals.....                                | 63        |
| Signal output .....                           | 64        |
| <b>Moku:Pro Waveform Generator</b>            | <b>65</b> |



Description..... 65

    Common characteristics..... 66

    Waveform characteristics..... 66

    Modulation .....67

**Moku:Pro Multi-Instrument Mode 70**

Description.....70

    Common characteristics..... 71

# Moku:Pro Hardware

## Specifications

### Analog I/O

#### Analog inputs

|                                         |                                                                                                                            |
|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Channels                                | 4                                                                                                                          |
| Bandwidth (-3 dB)                       | 300 MHz / 600 MHz switchable                                                                                               |
| Sampling rate                           | 5 GSa/s with 1 channel, and 1.25 GSa/s with 4 channels                                                                     |
| Resolution                              | 10 bits (high bandwidth) / 18 bits (low bandwidth)                                                                         |
| Maximum voltage range                   | 40 V <sub>pp</sub> into 1 MΩ <sup>1</sup>                                                                                  |
| Input impedance                         | 50 Ω / 1 MΩ                                                                                                                |
| Input coupling                          | AC / DC                                                                                                                    |
| AC coupling corner (-3 dB) <sup>2</sup> | 160 kHz into 50 Ω<br>16 Hz into 1 MΩ                                                                                       |
| Input referred noise                    | 30 nV/√Hz at 100 Hz<br>20 nV/√Hz at 10 MHz (1.25 GSa/s acquisition rate)<br>13 nV/√Hz at 10 MHz (5 GSa/s acquisition rate) |
| Effective number of bits (ENOB)         | 8.8 bits                                                                                                                   |
| Connector                               | BNC                                                                                                                        |

#### Analog outputs

|                                      |                                                                               |
|--------------------------------------|-------------------------------------------------------------------------------|
| Channels                             | 4                                                                             |
| Bandwidth (maximum output frequency) | 500 MHz (2 V <sub>pp</sub> into 50 Ω), 100 MHz (10 V <sub>pp</sub> into 50 Ω) |
| Sampling rate                        | 1.25 GSa/s per channel                                                        |
| Resolution                           | 16-bit                                                                        |
| Voltage range                        | 10 V <sub>pp</sub> into 50 Ω                                                  |
| Output impedance                     | 50 Ω                                                                          |
| Output coupling                      | DC                                                                            |
| Connector                            | BNC                                                                           |

<sup>1</sup> 50 Ω front-end impedance can only support input voltages up to 4 V<sub>pp</sub>.

<sup>2</sup> For Moku:Pro devices shipped prior to April 2022, corners are 16 kHz into 50 Ω and 1.6 Hz into 1 MΩ.

## External trigger input

### External trigger

|                   |                     |
|-------------------|---------------------|
| Trigger waveform  | TTL compatible      |
| Trigger bandwidth | DC to 100 MHz       |
| Trigger impedance | Hi-Z / 1 M $\Omega$ |
| Min trigger level | 0.7 V               |
| Max trigger level | 20 V                |
| Connector         | BNC                 |

## Clock reference

### Onboard clock

|           |           |
|-----------|-----------|
| Frequency | 10 MHz    |
| Stability | < 300 ppb |

### 10 MHz reference input

|                    |                                           |
|--------------------|-------------------------------------------|
| Expected waveforms | Sine / square                             |
| Input frequency    | 10 MHz $\pm$ 20 kHz                       |
| Input range        | 300 mV <sub>pp</sub> to 2 V <sub>pp</sub> |
| Input impedance    | 1 k $\Omega$                              |
| Input coupling     | AC coupled                                |
| Connector          | BNC                                       |

### 10 MHz reference output

|                  |                     |
|------------------|---------------------|
| Waveform type    | Square              |
| Output frequency | 10 MHz              |
| Output level     | 1.4 V <sub>pp</sub> |
| Output impedance | 50 $\Omega$         |
| Output coupling  | AC coupled          |
| Connector        | BNC                 |

## Internal Storage

### Storage

|                    |        |
|--------------------|--------|
| Internal SSD drive | 240 GB |
|--------------------|--------|

# General characteristics

## General and environmental characteristics

|                      |                                                                                                                                              |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| Power consumption    | 115 W typical                                                                                                                                |
| Power voltage range  | 100 - 240 V <sup>~</sup> +/- 10%, 50/60 Hz<br>The equipment shall be plugged into a socket outlet with reliable protective earthing contact. |
| Temperature          | Operating: 0 to +45 °C<br>Non-operating: -10 to +60 °C<br>Do not obstruct the cooling fan outlets. 20 cm ventilation clearance is required.  |
| Humidity             | R.H. 5% to 95% noncondensing                                                                                                                 |
| Operating Altitude   | Up to 10,000 feet (3000 m)                                                                                                                   |
| Other requirements   | Intended for indoor use only                                                                                                                 |
| Pollution degree     | 2                                                                                                                                            |
| Overvoltage category | OVC II                                                                                                                                       |

## Electromagnetic compliance



## Physical characteristics

|            |                                                                                   |
|------------|-----------------------------------------------------------------------------------|
| Dimensions | Width: 440 mm (17.32 in.)<br>Depth: 330 mm (13.0 in.)<br>Height: 65 mm (2.56 in.) |
| Weight     | 6.7 kg (14.77 lb)                                                                 |

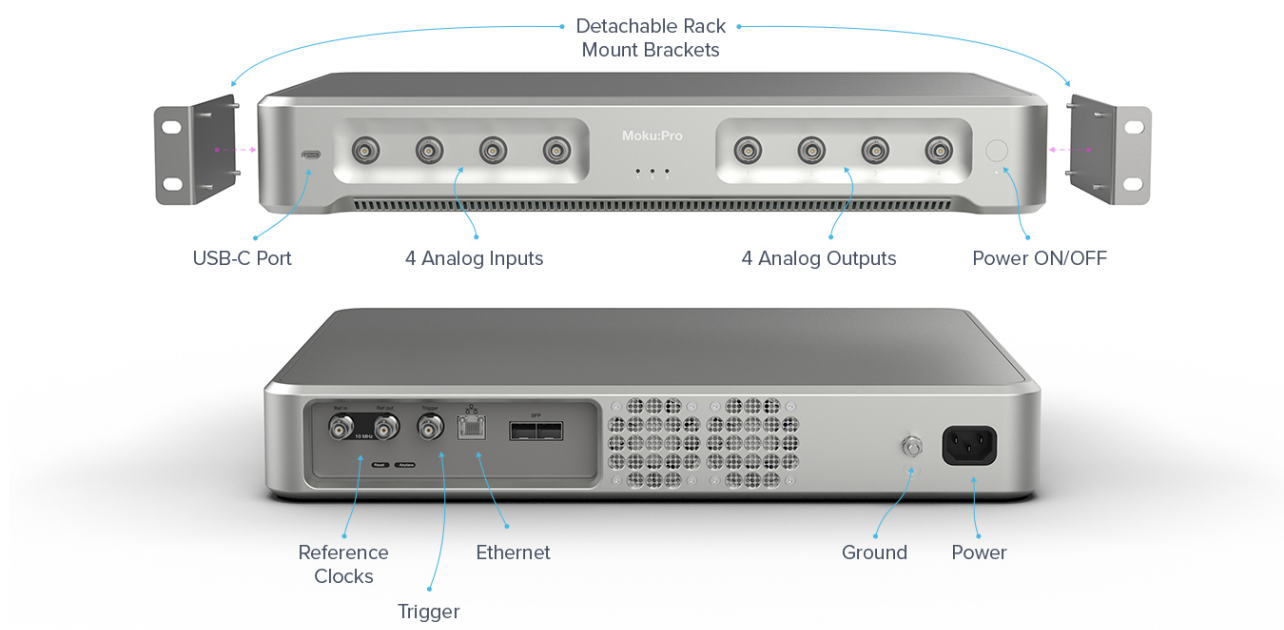
# General connectivity

## Connectivity

|                               |                                                     |
|-------------------------------|-----------------------------------------------------|
| Analog inputs                 | 4 x BNC                                             |
| Analog outputs                | 4 x BNC                                             |
| Network                       | Ethernet (10/100/1000 Base-T)<br>Wi-Fi 802.11 b/g/n |
| USB data port                 | Type-C // For connecting to the Moku:Pro via USB    |
| External trigger input        | BNC                                                 |
| 10 MHz clock reference input  | BNC                                                 |
| 10 MHz clock reference output | BNC                                                 |

## Available accessories

|                     |                                            |
|---------------------|--------------------------------------------|
| Rack mount brackets | x 2 // secured by 4 screws each (supplied) |
| P-500               | 500 MHz 10:1 passive probe (optional)      |



# Safety Information

## Safety

|              |                                                                                                                                                                                                    |
|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Manufacturer | Liquid Instruments Pty Ltd, 243 Northbourne Avenue, Suite 1, Level 1, Lyneham, ACT 2602, Australia                                                                                                 |
| Cleaning     | Clean loose dust on exterior with lint-free, dry cloth.                                                                                                                                            |
| Impairment   | If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.                                                                  |
| Power cable  | Do not use a mains power supply cord other than the one provided by the manufacturer.<br>Please contact the manufacturer/representative office if a replacement mains power supply cord is needed. |

## Symbols

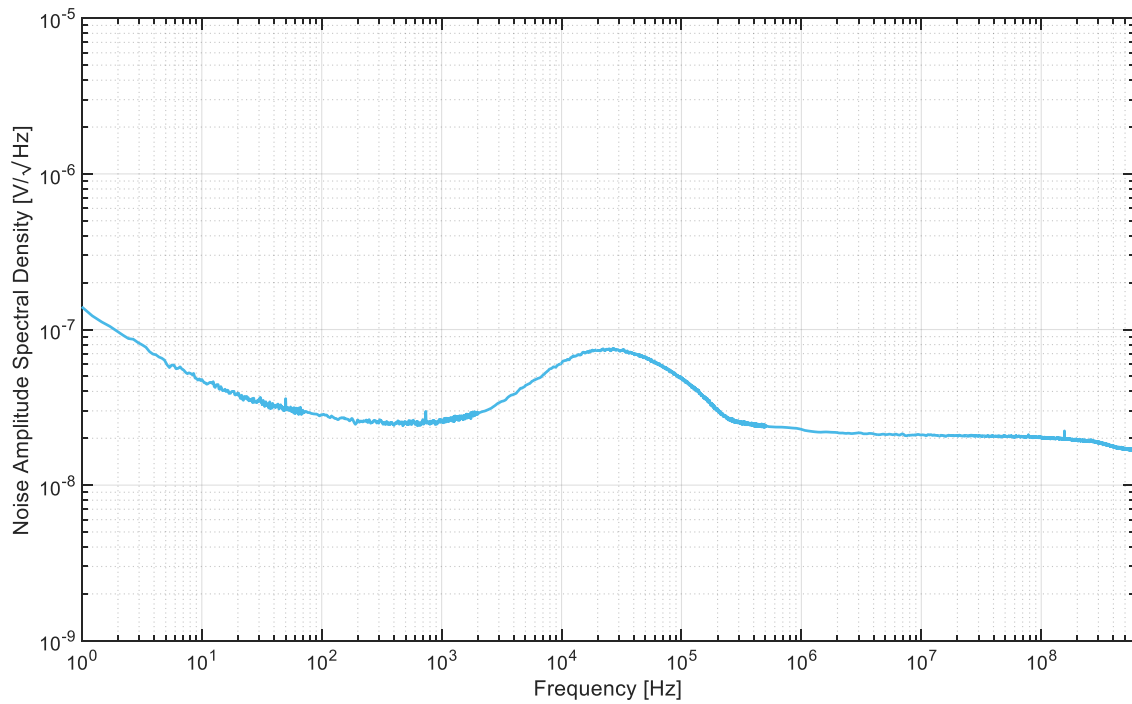
|                                                                                    |                                         |
|------------------------------------------------------------------------------------|-----------------------------------------|
|   | Caution: Consult accompanying documents |
|  | Warning: Risk of electric shock         |

# Hardware measurements

## ADC input noise

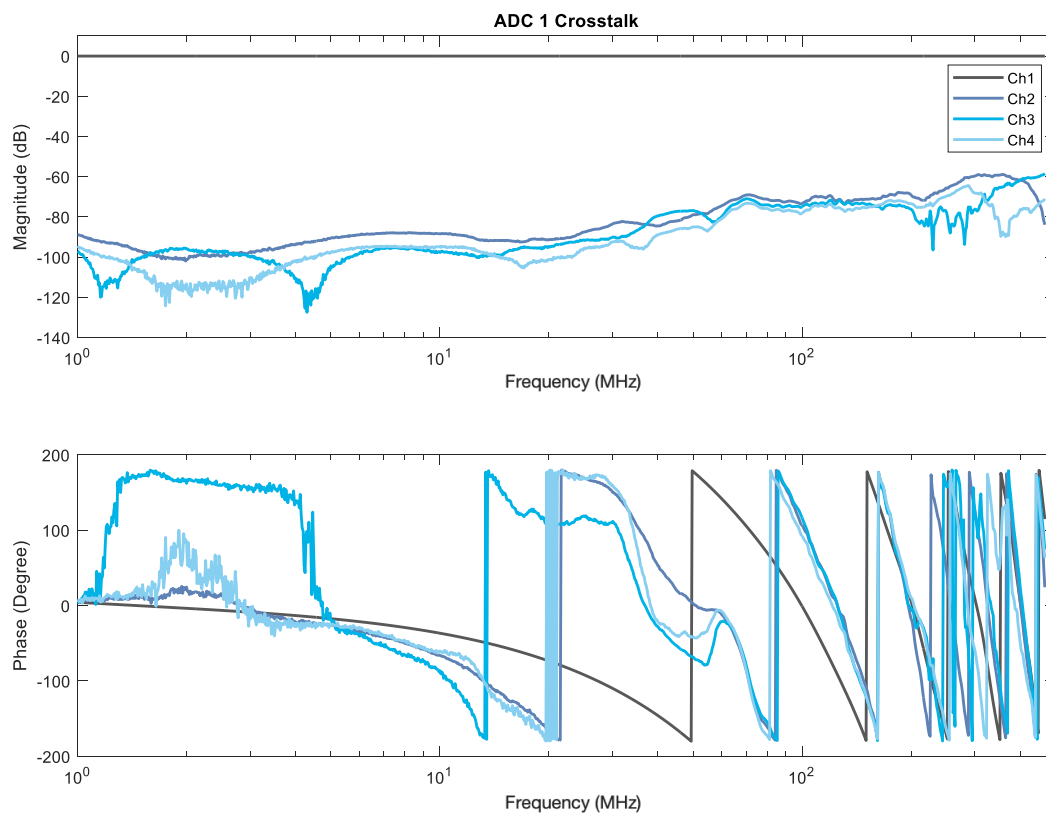
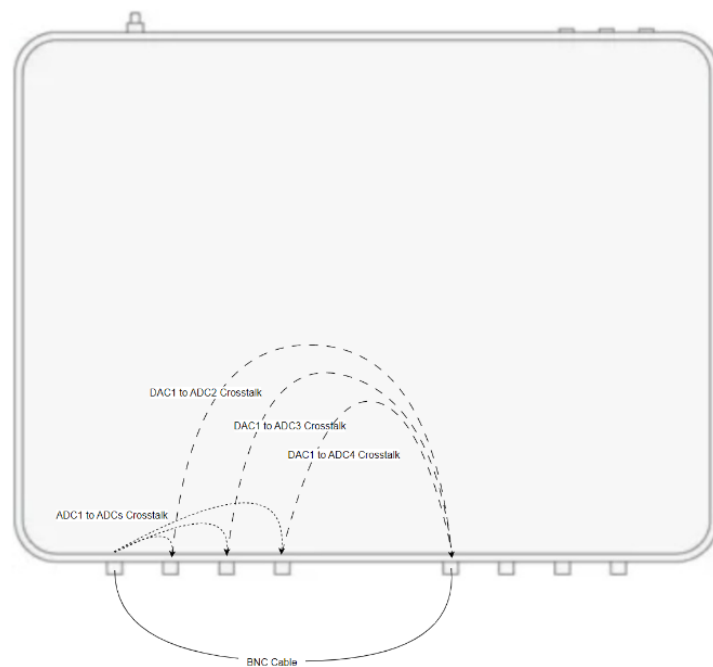
50  $\Omega$  // DC coupled // 0 dB attenuation

Acquisition mode: Precision

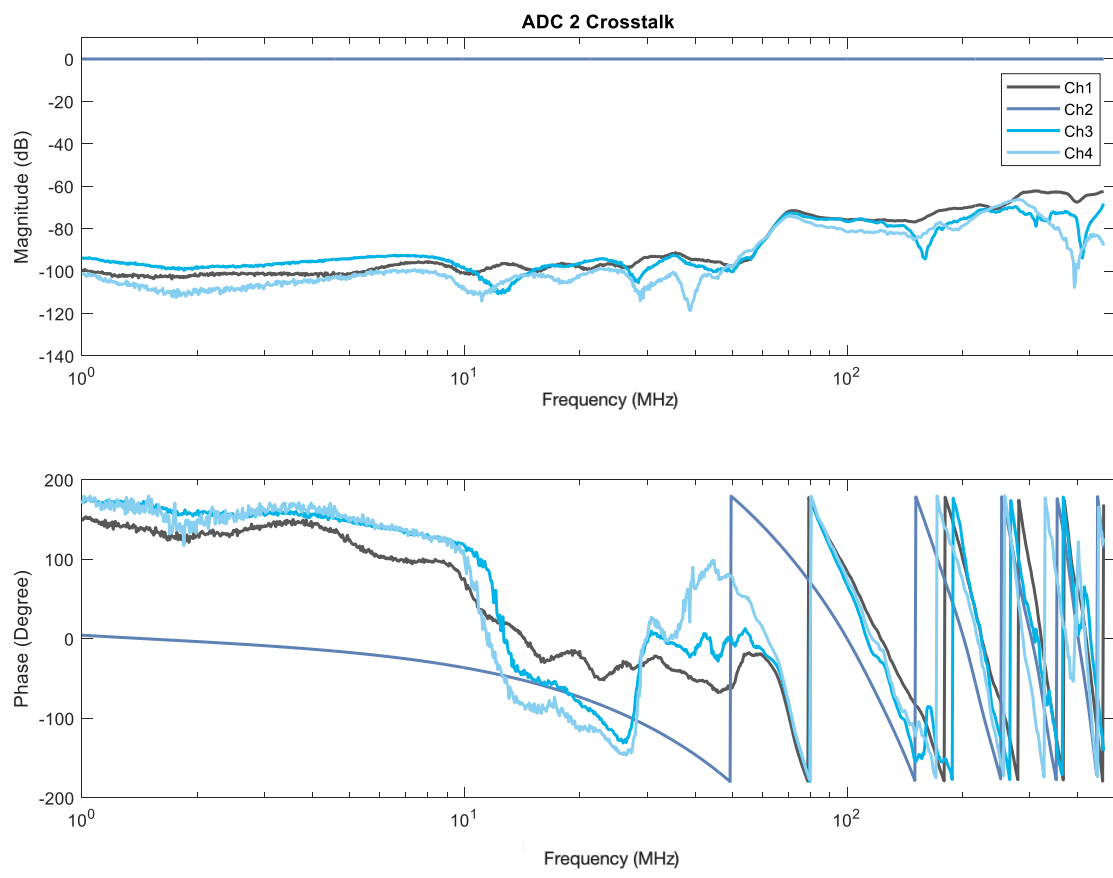
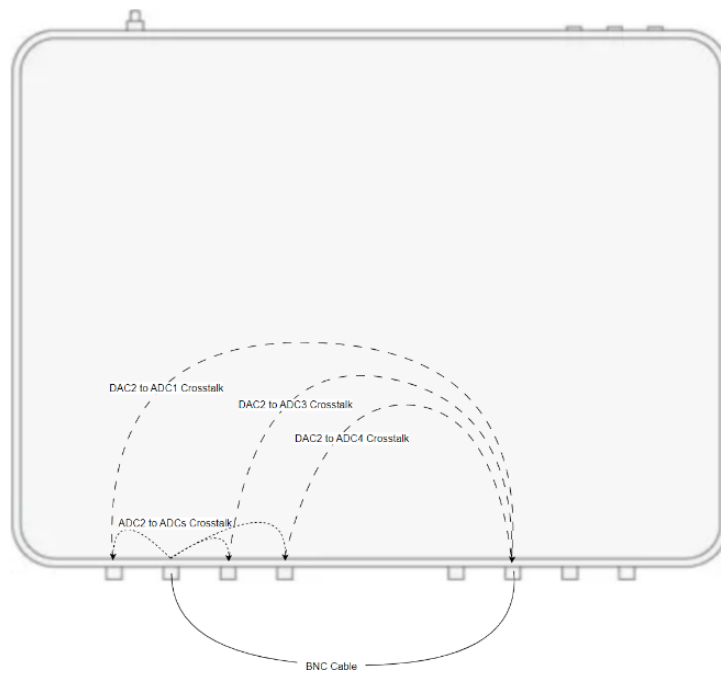


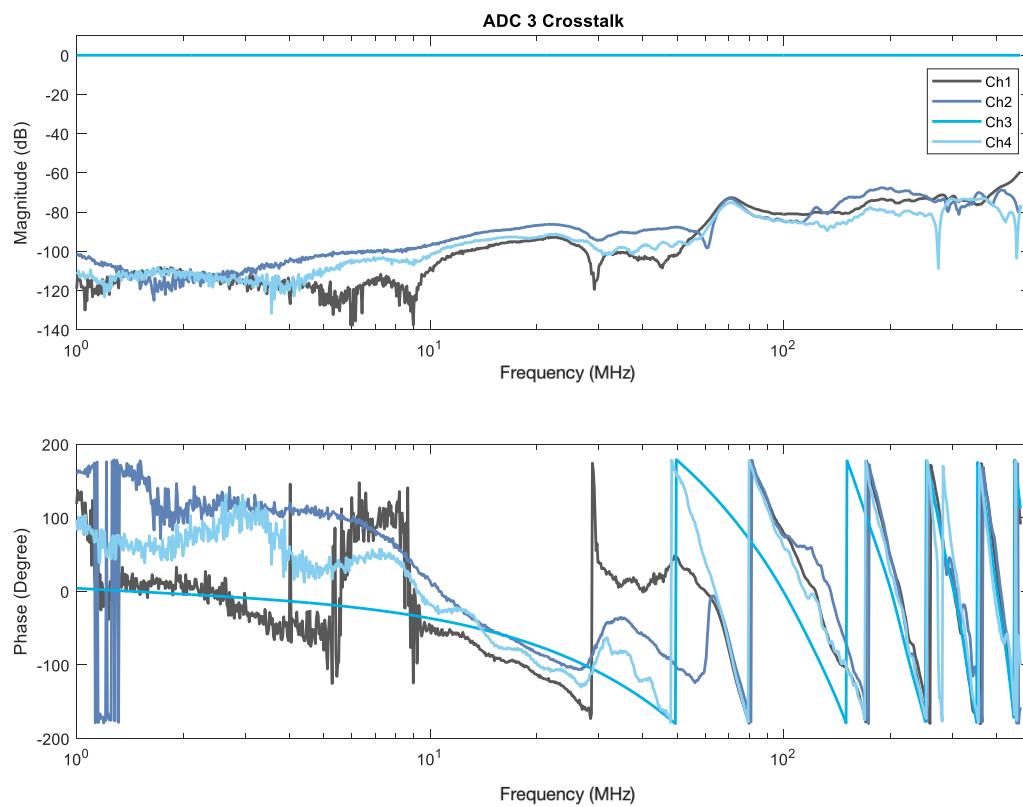
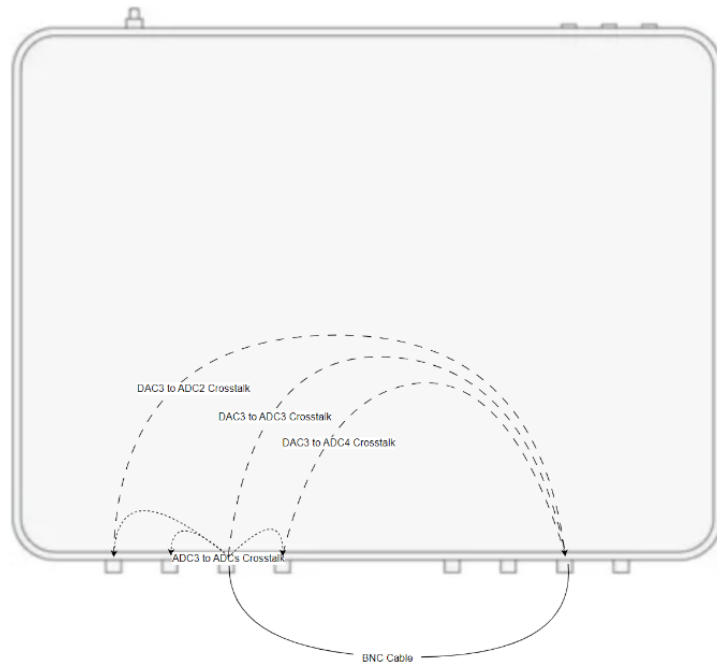
## Compound Crosstalk (ADC-ADC & DAC-ADC)

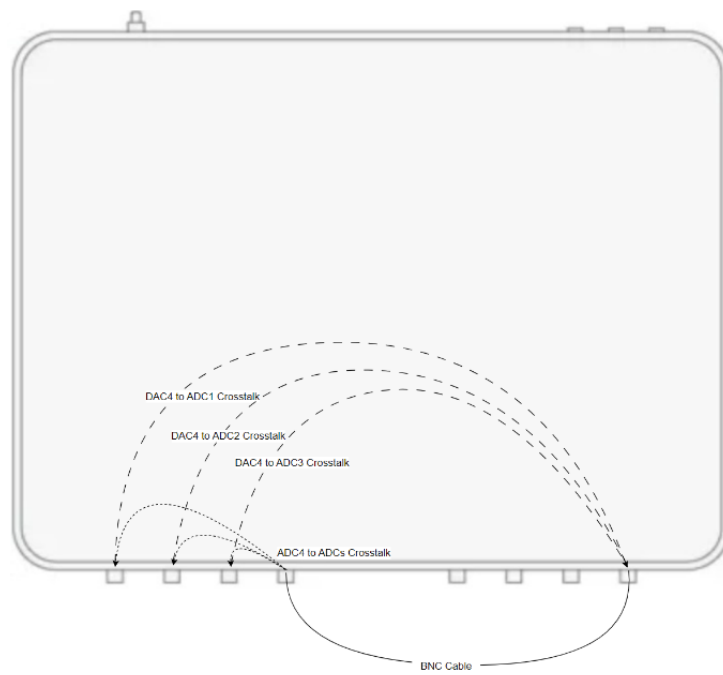
50  $\Omega$  // AC coupled // 0 dB attenuation



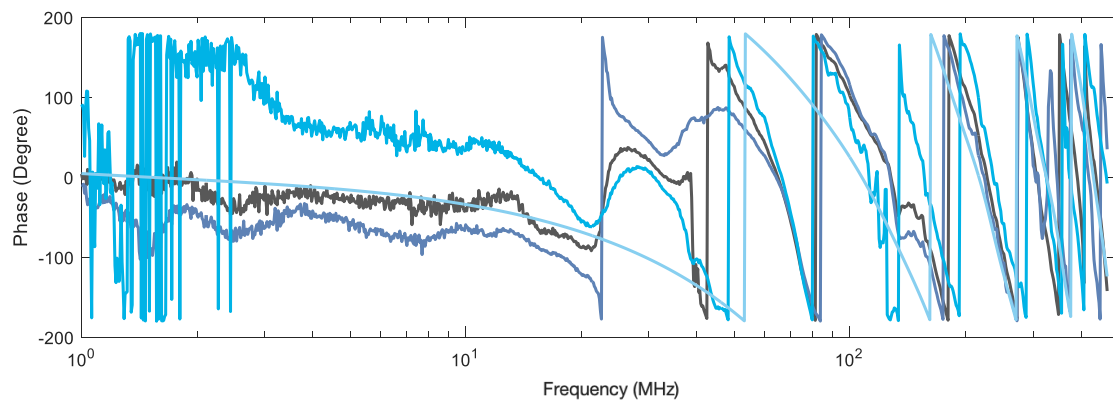
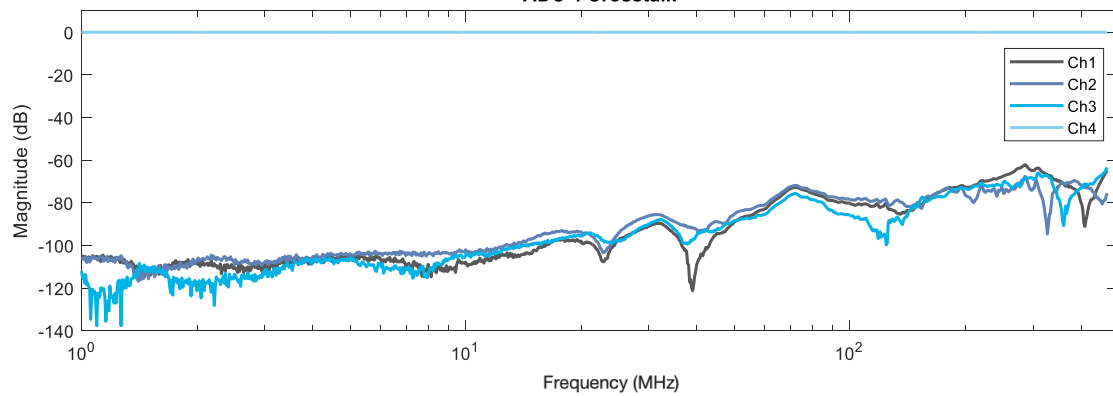






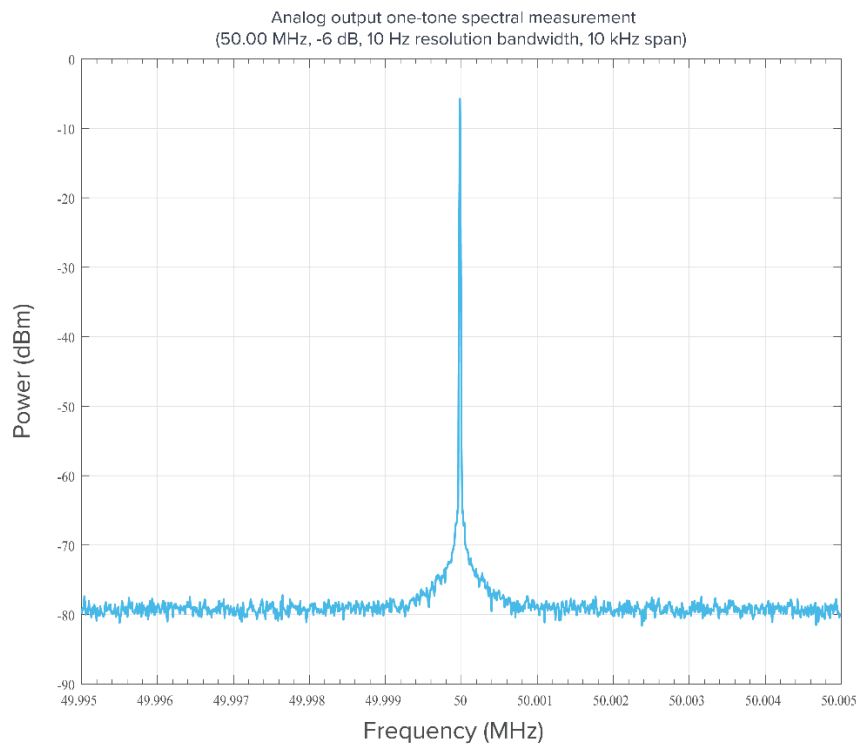


**ADC 4 Crosstalk**

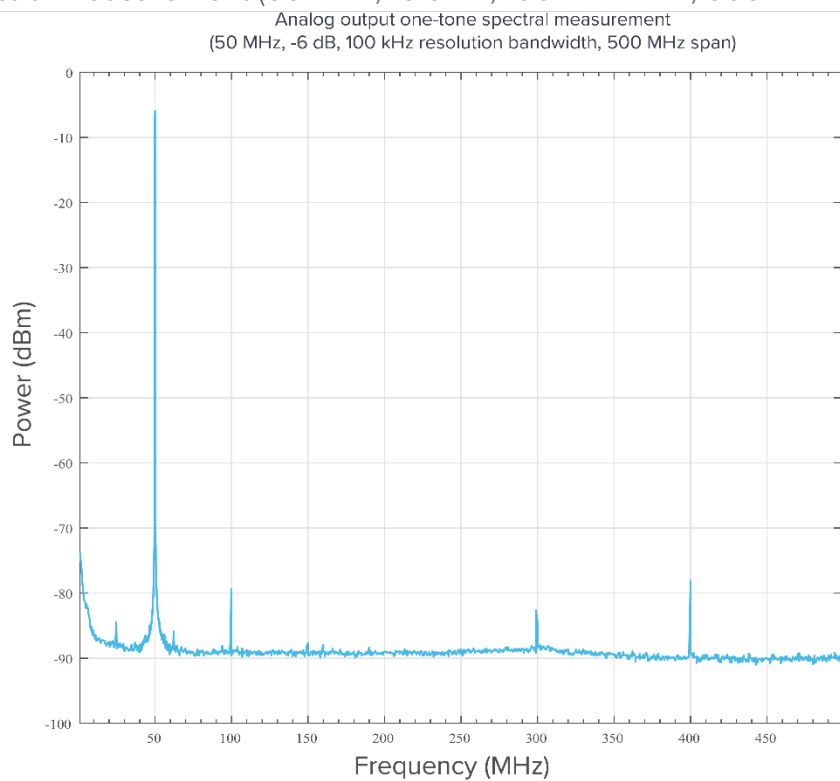


## Analog output noise

One-tone spectral measurement (50 MHz, -6 dBm, 10 Hz RBW, 10 kHz span)



One-tone spectral measurement (50 MHz, -6 dBm, 100 kHz RBW, 500 MHz span)

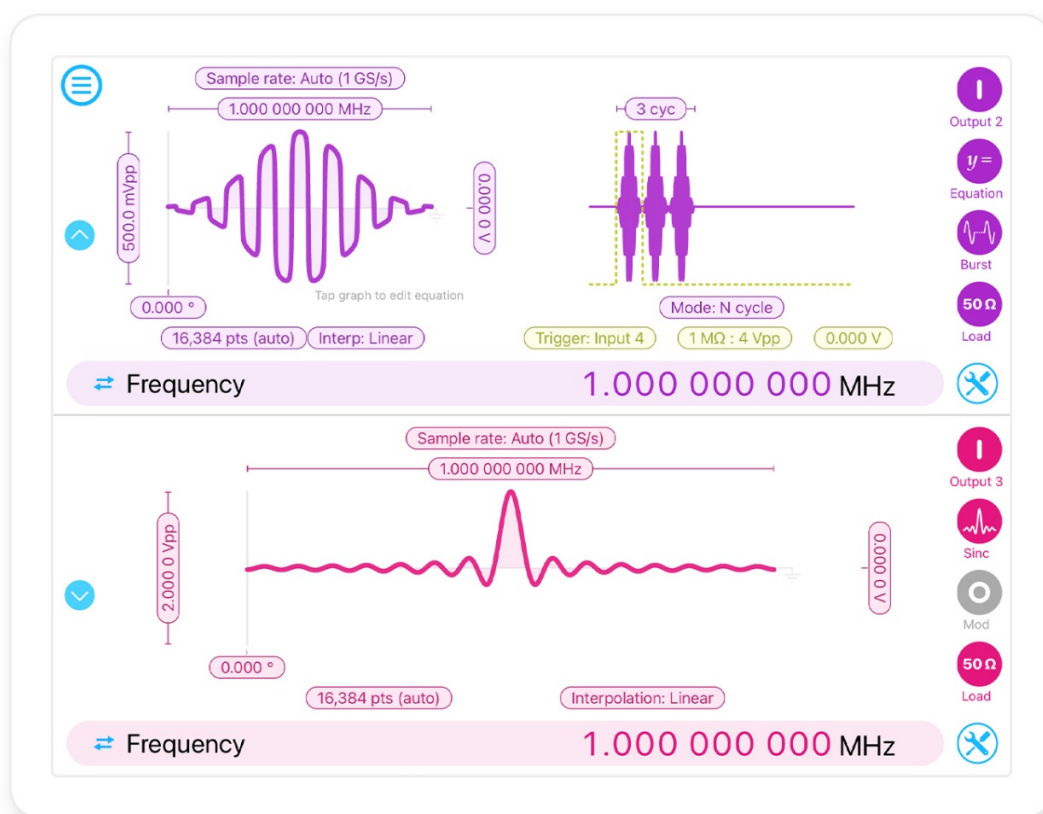




# Moku:Pro Arbitrary Waveform Generator

## Description

Moku:Pro Arbitrary Waveform Generator can generate four custom waveforms with up to 65,536 points and sample rates ranging from 312.5 MSa/s to 1.25 GSa/s. Waveforms can be loaded from a file or input as a piece-wise mathematical function with up to 32 segments, enabling you to generate truly arbitrary waveforms. In burst mode, waveform generation can be triggered from input channels with start or n cycle modes. In pulsed mode, waveforms can be output with more than 262,144 cycles of dead time between pulses.



## Features

- Four independent AWG channels with up to 500 MHz bandwidth
- Choose between preset waveforms, load points from a file, or input an equation directly
- Phase synchronization output between the four channels
- Configure pulsed output with up to 262,144 cycles of dead time between pulses



# Specifications

## Common

### Overview

|                  |                                                                                                 |
|------------------|-------------------------------------------------------------------------------------------------|
| Channels         | 4                                                                                               |
| Sampling rate    | 312.5 MSa/s, 625 MSa/s, 1.25 GSa/s                                                              |
| Source impedance | 50 $\Omega$                                                                                     |
| Output load      | 50 $\Omega$ / 1 M $\Omega$                                                                      |
| Waveforms        | Sine, Gaussian, Exponential Fall, Exponential Rise, Sinc, Equation, Cardiac, Custom (from file) |

### Amplitude

|                      |                                                            |
|----------------------|------------------------------------------------------------|
| Output voltage range | 2 Vpp at 625 MSa/s and 1.25 GSa/s<br>10 Vpp at 312.5 MSa/s |
| Resolution           | 100 $\mu$ V                                                |

### DC offset

|                      |                                                              |
|----------------------|--------------------------------------------------------------|
| Range (peak AC + DC) | $\pm$ 5 V into 50 $\Omega$<br>$\pm$ 10 V into high impedance |
| Resolution           | 100 $\mu$ V                                                  |

### Phase offset

|            |            |
|------------|------------|
| Range      | 0° to 360° |
| Resolution | 0.000 001° |

## Waveform

### Custom

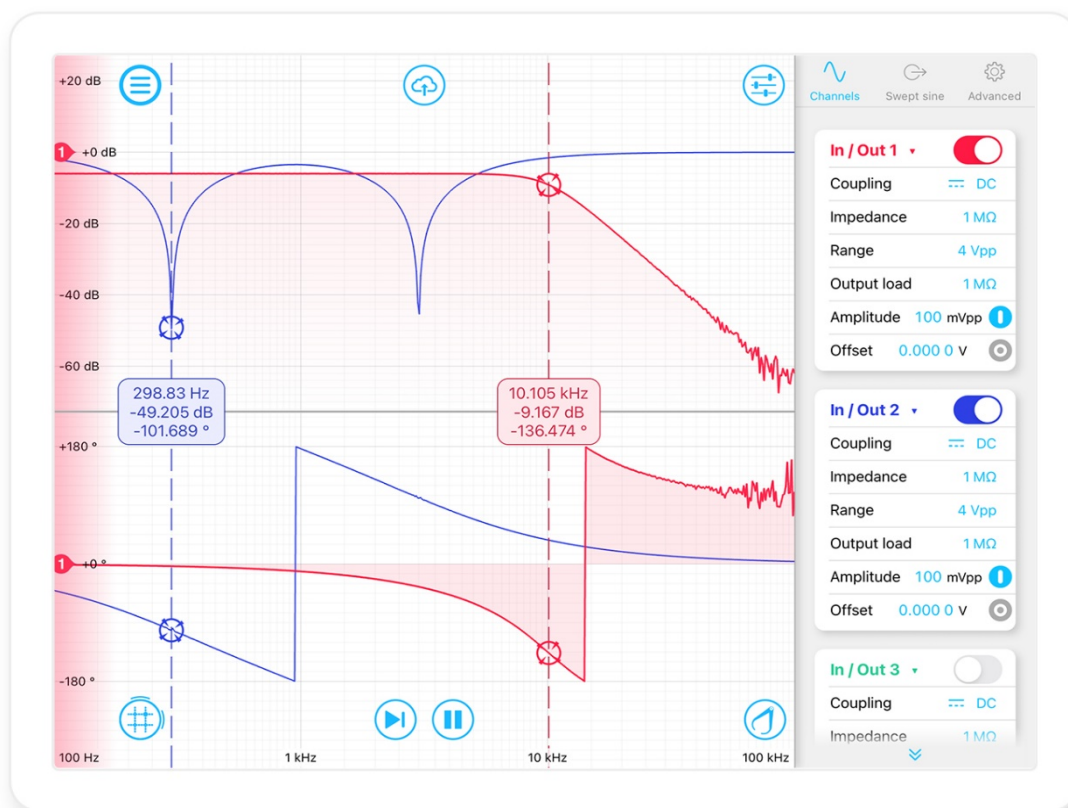
|                     |                                                                                               |               |
|---------------------|-----------------------------------------------------------------------------------------------|---------------|
| Maximum output rate | 312.5 MSa/s                                                                                   | 65,536 points |
|                     | 625 MSa/s                                                                                     | 32,768 points |
|                     | 1.25 GSa/s                                                                                    | 16,384 points |
| Text file type      | Comma- or newline-delimited text                                                              |               |
| File import options | Clipboard, My Files, Desktop file                                                             |               |
| Interpolation       | None, Linear                                                                                  |               |
| Minimum edge time   | 2 ns                                                                                          |               |
| Overshoot           | $\leq$ 10% for edge times between 4 ns and 8 ns<br>$\leq$ 2% for edge times greater than 8 ns |               |
| Period range        | 4 ns to 1 ks                                                                                  |               |



# Moku:Pro Frequency Response Analyzer

## Description

Moku:Pro Frequency Response Analyzer enables you to measure the frequency response of a system in both magnitude and phase using a swept sine output from 10 mHz to 500 MHz with a noise floor as low as -135 dBm. Moku:Pro is equipped with four inputs and four outputs ports, enabling differential or ratio metric measurements. Select up to 8192 points per sweep and configure settling and averaging times to balance total sweep duration and signal-to-noise ratio.



## Features

- Linear or logarithmic swept sine output
- Math channel to add, subtract, multiply, or divide response functions as they are acquired, or calculate arbitrary complex-valued equations
- Saturation detection and dynamic output amplitude control optimizes response detail
- Demodulate up to the 15th harmonic



# Specifications

## Source

### Source

|                        |                                               |
|------------------------|-----------------------------------------------|
| Waveform               | Sine                                          |
| Frequency range        | 10 mHz to 500 MHz                             |
| Sweep type             | Linear / Logarithmic                          |
| Sweep points           | 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192 |
| Output amplitude range | $\pm 0.5$ mV to $\pm 5$ V into 50 $\Omega$    |
| Source impedance       | 50 $\Omega$                                   |

## Input

### Input characteristics

|                     |                                                                                                                                                                                        |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input impedance     | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                             |
| Input coupling      | AC / DC                                                                                                                                                                                |
| Input attenuation   | 0 dB / 20 dB / 40 dB                                                                                                                                                                   |
| Input voltage range | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation |
| Input noise         | 30 nV/ $\sqrt{\text{Hz}}$ @ 100 Hz                                                                                                                                                     |
| Crosstalk           | < 60 dB                                                                                                                                                                                |
| Noise floor         | < 100 kHz: < -125 dBm<br>100 kHz – 500 MHz: < -135 dBm                                                                                                                                 |

## Measurement

### Measurement characteristics

|                      |                                                                     |
|----------------------|---------------------------------------------------------------------|
| Measurement mode     | In/Out (dB), In/In1 (dB) or In (dBm, dBVpp, dBVrms)                 |
| Settling time        | Min. Greater of 1 $\mu\text{s}$ or 1 cycle                          |
|                      | Max. 10.0 seconds                                                   |
| Averaging time       | Min. Greater of 1 $\mu\text{s}$ or 1 cycle                          |
|                      | Max. 10.0 seconds                                                   |
| Normalization        | Normalizes magnitude and phase using a reference sweep <sup>3</sup> |
| Absolute gain error  | < 0.05 dB                                                           |
| Absolute phase error | < 0.5°                                                              |

<sup>3</sup> The normalization feature can be used to isolate the magnitude and phase response of the system under test by compensating for deviations in magnitude and phase caused by delays (e.g., caused by cables) and the frequency response of the Moku:Pro's analog front end. As an alternative the In/In1 mode may also be used, removing the need to take a normalization sweep.





## Saving Data

### Saving data

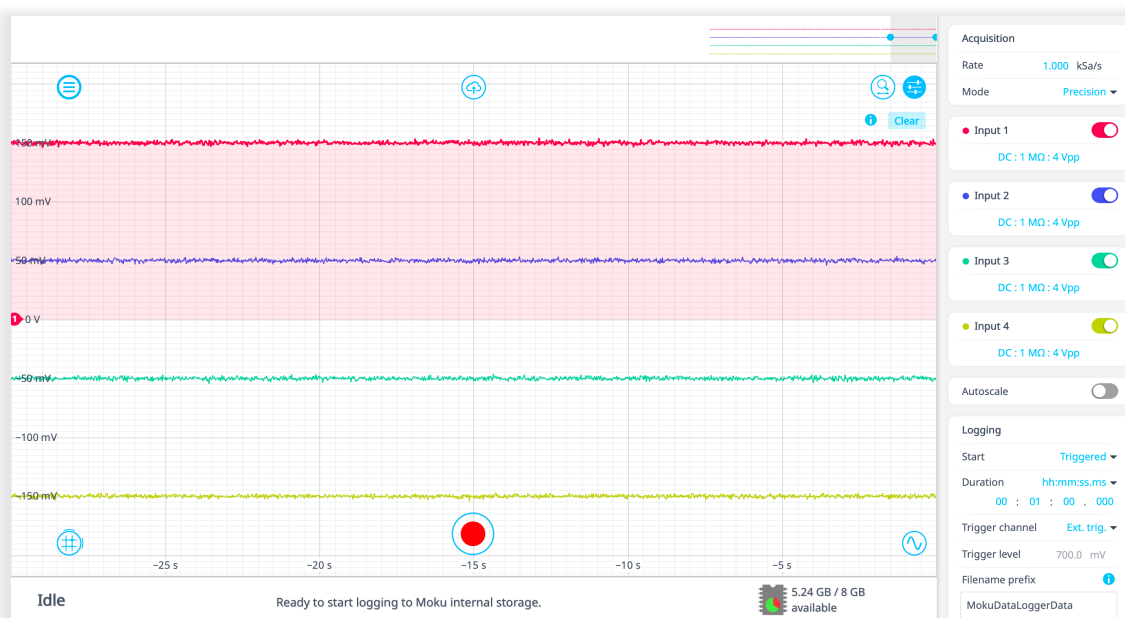
|              |                                                                                     |
|--------------|-------------------------------------------------------------------------------------|
| File formats | Plain text: records data using a standard *.csv format                              |
|              | MATLAB: records data using MathWorks' *.mat format which can be opened using MATLAB |
| Export modes | Dropbox, E-mail, My Files, Desktop, AirDrop and iCloud                              |
| Screenshots  | JPG or PNG                                                                          |



# Moku:Pro Data Logger

## Description

Moku:Pro Data Logger enables you to log data to its 240 GB internal solid-state drive with sampling rates of up to 10 MSa/s. Four inputs are equipped with dual 10-bit and 18-bit ADCs. With blended ADC technology, input noise is down to  $30 \text{ nV} \sqrt{\text{Hz}}$  at 100 Hz, providing ultralow noise data logging from acoustic to RF frequencies. Moku:Pro is also equipped with a 10 MHz clock synchronization I/O, and four 500 MHz outputs, allowing flexible integration with other electronics.



## Features

- Log voltage data on four independent channels to its 240 GB SSD
- Built-in four-channel 500 MHz waveform generator
- 10 MHz clock synchronization ports
- Easily export data to computer, Dropbox, and other cloud-based services
- Schedule your log to start with a delay of up to 10 days, or by external triggered start



# Specifications

## Input

### Voltage

|                     |                                                                                                                                                                                        |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input voltage range | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation |
| Input impedance     | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                             |
| Input coupling      | AC / DC                                                                                                                                                                                |

## Logging

### Acquisition

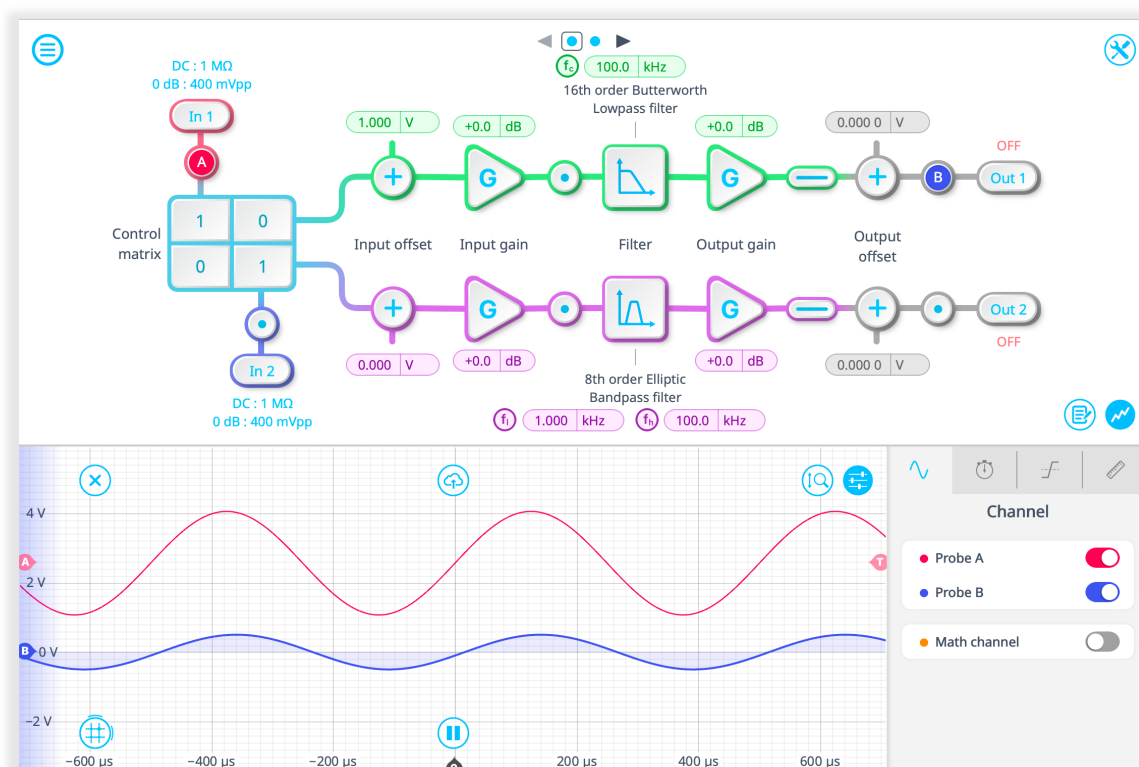
|                        |                                                                                                                                                                                                                                                                                    |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| File formats           | Binary: Records data using a proprietary LI format for high-speed data logging.<br><br>Data saved using the LI format may be converted to other formats when downloading from Moku. iPad can convert to .CSV, MATLAB or NumPy. Desktop can convert to .CSV, MATLAB, NumPy or HDF5. |
| Export modes           | Dropbox, E-mail, My Files, Desktop, and iCloud                                                                                                                                                                                                                                     |
| Maximum sampling rate  | 10 MSa/s for 1 channel<br>5 MSa/s for 2 channels<br>2.5 MSa/s for 4 channels                                                                                                                                                                                                       |
| Delayed log start time | Up to 240 hours                                                                                                                                                                                                                                                                    |
| Trigger start          | External trigger from trigger input, or any of 4 input channels                                                                                                                                                                                                                    |
| Log duration           | 1 millisecond to 10,000 hours                                                                                                                                                                                                                                                      |



# Moku:Pro Digital Filter Box

## Description

With Moku:Pro Digital Filter Box, you can interactively design and generate different types of infinite impulse response filters with output sampling rates of 305.18 kHz, 4.8828 MHz, or 39.063 MHz. Select between lowpass, highpass, bandpass, and bandstop filter shapes with up to eight fully configurable types including Butterworth, Chebyshev, and Elliptic.



## Features

- Design IIR filters using an interactive Bode plot
- Observe and log signals at different stages in the digital signal processing chain using probe points<sup>4</sup>
- View the frequency response of your filter in both magnitude and phase
- Filter up to four channels of data simultaneously with the ability to linearly combine input signals
- Implement custom filters by uploading your own coefficients

<sup>4</sup> See [Moku:Pro Data Logger](#) or [Moku:Pro Oscilloscope](#) for specifications on integrated instruments



# Specifications

## Inputs

### Input characteristics

|                                   |                                                                                                                                                                                        |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Channels                          | 4                                                                                                                                                                                      |
| Input control matrix coefficients | -20 to +20                                                                                                                                                                             |
| Input impedance                   | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                             |
| Input coupling                    | AC / DC                                                                                                                                                                                |
| Input attenuation                 | 0 dB / 20 dB / 40 dB                                                                                                                                                                   |
| Input voltage range               | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation |

## Filter characteristics

### Pre-filter

|                         |                  |
|-------------------------|------------------|
| Input offset range      | $\pm 1$ V        |
| Input offset resolution | 1 mV             |
| Input gain range        | -40 dB to +40 dB |
| Input gain resolution   | 0.1 dB           |

### Post-filter

|                          |                  |
|--------------------------|------------------|
| Output offset range      | $\pm 1$ V        |
| Output offset resolution | 100 $\mu$ V      |
| Output gain range        | -40 dB to +40 dB |
| Output gain resolution   | 0.1 dB           |

### General filter characteristics

|                      |                                                                                        |
|----------------------|----------------------------------------------------------------------------------------|
| Filter shapes        | Lowpass, Highpass, Bandpass, Bandstop, Custom                                          |
| Sampling rates       | 305.18 kHz, 4.8828 MHz, 39.063 MHz                                                     |
| Filter types         | Butterworth, Chebyshev I, Chebyshev II, Elliptic, Cascaded, Bessel, Gaussian, Legendre |
| Passband ripple      | 0.1 dB to 10 dB                                                                        |
| Stopband attenuation | 10 dB to 100 dB                                                                        |
| Zoom view            | Allows you to zoom in on the filter's frequency response                               |



### Lowpass filter

|                          |                                                                                                        |
|--------------------------|--------------------------------------------------------------------------------------------------------|
| Filter order             | 2, 4, 6, 8, 10, 12, 14, 16                                                                             |
| Lowpass corner frequency | 58.63 mHz to 137.3 kHz at 305.18kHz sampling rate<br>7.505 Hz to 17.58 MHz at 39.063 MHz sampling rate |

### Highpass filter

|                            |                                                                                                         |
|----------------------------|---------------------------------------------------------------------------------------------------------|
| Filter order               | 2, 4, 6, 8, 10, 12, 14, 16                                                                              |
| High-pass corner frequency | 723.7 mHz to 137.3 kHz at 305.18 kHz sampling rate<br>92.63 Hz to 17.58 MHz at 39.063 MHz sampling rate |

### Bandpass filter

|                       |                                                                                                        |
|-----------------------|--------------------------------------------------------------------------------------------------------|
| Filter order          | 2, 4, 6, 8                                                                                             |
| Low-corner frequency  | 3.052 Hz to 137.3 kHz at 305.18 kHz sampling rate<br>390.6 Hz to 17.58 MHz at 39.063 MHz sampling rate |
| High-corner frequency | 3.442 Hz to 137.3 kHz at 305.18 kHz sampling rate<br>440.6 Hz to 17.58 MHz at 39.063 MHz sampling rate |
| Minimum bandwidth     | 390 mHz at 305.18 kHz sampling rate<br>50 Hz at 39.063 MHz sampling rate                               |

### Bandstop filter

|                       |                                                                                                         |
|-----------------------|---------------------------------------------------------------------------------------------------------|
| Filter order          | 2, 4, 6, 8                                                                                              |
| Low-corner frequency  | 58.63 mHz to 137.3 kHz at 305.18 kHz sampling rate<br>7.505 Hz to 17.58 MHz at 39.063 MHz sampling rate |
| High-corner frequency | 449.3 mHz to 137.3 kHz at 305.18 kHz sampling rate<br>57.5 Hz to 17.58 MHz at 39.063 MHz sampling rate  |
| Minimum bandwidth     | 390 mHz at 305.18 kHz sampling rate<br>50 Hz at 39.063 MHz sampling rate                                |



## Selecting the right IIR filter

### Filter type

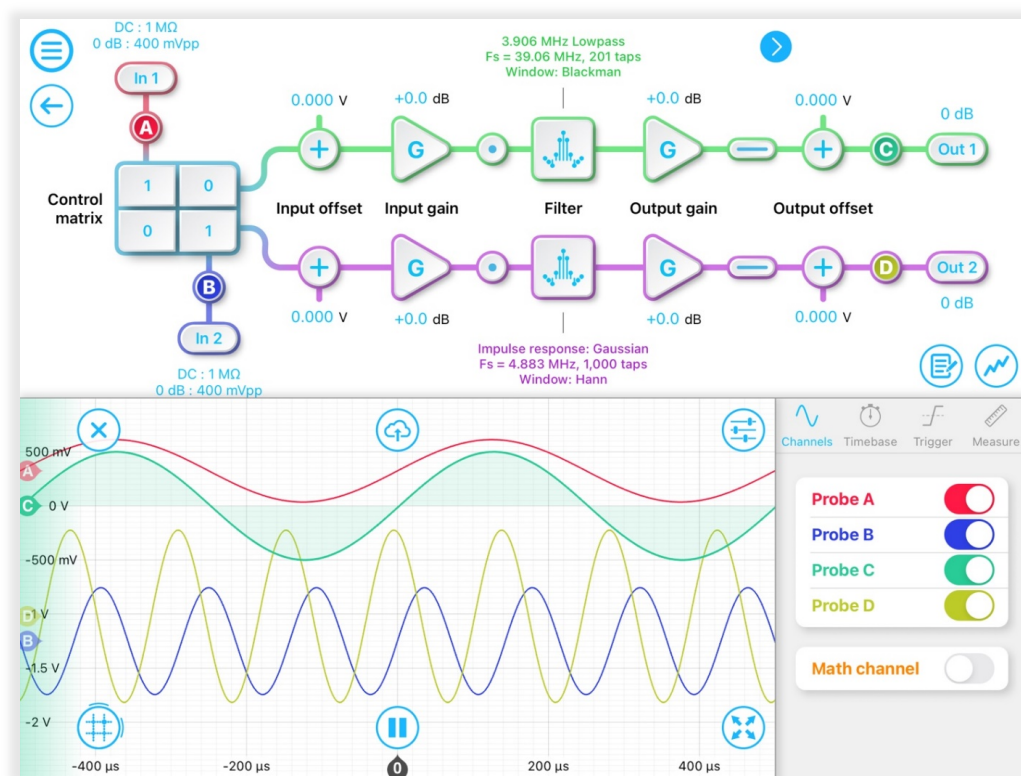
|              |                                                                                                                                                                                                                                             |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Butterworth  | Butterworth filters have a maximally flat passband and a monotonic frequency response, making them a good all-around filter type suitable for most applications.                                                                            |
| Chebyshev I  | Chebyshev I filters have ripple in the passband but a sharper transition than Butterworth filters, making them useful for applications requiring aggressive stopband attenuation but can tolerate passband ripple between 0.1 dB and 10 dB. |
| Chebyshev II | Chebyshev II filters have ripple in the stopband but a sharper transition than Butterworth filters, making them useful in applications requiring flat passbands and aggressive stopband attenuation.                                        |
| Elliptic     | Elliptic (Cauer) filters have ripple in both the passband and stopband, but also have the sharpest possible transition. Elliptic filters are useful in applications requiring extremely aggressive stopband attenuation.                    |
| Cascaded     | Cascaded first-order filters have zero overshoot in the time domain.                                                                                                                                                                        |
| Bessel       | Bessel filters have maximally flat group and phase delay in the passband, thus preserving the wave shape of passband signals.                                                                                                               |
| Gaussian     | Gaussian filters have the minimum possible group delay, 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.                                                                                                                        |



# Moku:Pro FIR Filter Builder

## Description

With the Moku:Pro FIR Filter Builder, you can design and implement lowpass, highpass, bandpass, and bandstop finite impulse response (FIR) filters with up to 14,819 coefficients and sample rate up to 39.06 MHz. Select between four frequency response shapes, four common impulse responses, and seven windows functions; or define the impulse response by equation or custom coefficients.



## Features

- Design filters in the time or frequency domain using common impulse responses & window functions
- Upload your own filter coefficients, or define a custom impulse response in the equation editor
- View your filter's complex transfer function, impulse and step response, or group and phase delay
- Filter up to four channels of data simultaneously with the ability to linearly combine input signals
- Observe and log signals at different stages in the digital signal processing chain using probe points<sup>5</sup>

<sup>5</sup> See [Moku:Pro Data Logger](#) or [Moku:Pro Oscilloscope](#) for specifications on integrated instruments





# Specifications

## Inputs

### Input characteristics

|                                   |                                                                                                                                                                                        |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Channels                          | 4                                                                                                                                                                                      |
| Input control matrix coefficients | -20 to +20                                                                                                                                                                             |
| Input impedance                   | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                             |
| Input coupling                    | AC / DC                                                                                                                                                                                |
| Input attenuation                 | 0 dB / 20 dB / 40 dB                                                                                                                                                                   |
| Input voltage range               | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation |

## Filter characteristics

### Pre-filter

|                         |                  |
|-------------------------|------------------|
| Input offset range      | $\pm 1$ V        |
| Input offset resolution | 1 mV             |
| Input gain range        | -40 dB to +40 dB |
| Input gain resolution   | 0.1 dB           |

### Post-filter

|                          |                  |
|--------------------------|------------------|
| Output offset range      | $\pm 1$ V        |
| Output offset resolution | 100 $\mu$ V      |
| Output gain range        | -40 dB to +40 dB |
| Output gain resolution   | 0.1 dB           |

### General filter characteristics

|                |                                                                                            |
|----------------|--------------------------------------------------------------------------------------------|
| Sampling rates | 305.18 kHz, 610.4 kHz, 1.221 MHz, 2.441 MHz, 4.883 MHz, 9.766 MHz,<br>19.53 MHz, 39.06 MHz |
|----------------|--------------------------------------------------------------------------------------------|



## General filter characteristics

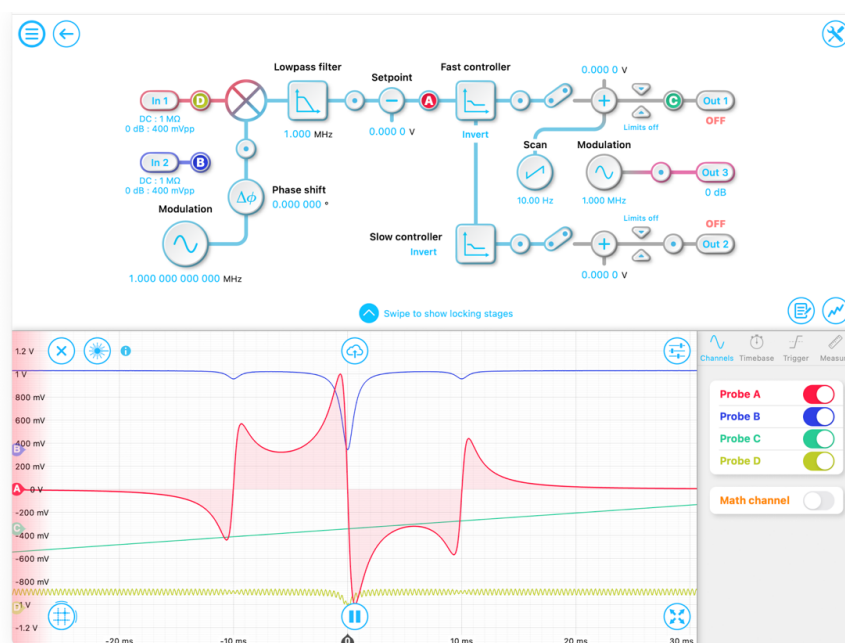
|                                  |                                                                                   |
|----------------------------------|-----------------------------------------------------------------------------------|
| Number of coefficients           | 2 to 14819 @ 305.18 kHz                                                           |
|                                  | 2 to 14819 @ 610.4 kHz                                                            |
|                                  | 2 to 7424 @ 1.221 MHz                                                             |
|                                  | 2 to 3712 @ 2.441 MHz                                                             |
|                                  | 2 to 1856 @ 4.883 MHz                                                             |
|                                  | 2 to 928 @ 9.766 MHz                                                              |
|                                  | 2 to 464 @ 19.53 MHz                                                              |
|                                  | 2 to 232 @ 39.06 MHz                                                              |
| Design domains                   | Time (impulse)                                                                    |
|                                  | Frequency (frequency))                                                            |
| Display options                  | Magnitude / Phase                                                                 |
|                                  | Impulse / Step Response                                                           |
|                                  | Group / Phase Delay                                                               |
| Frequency response               | Lowpass, highpass, bandpass, bandstop                                             |
| Impulse response                 | Rectangular, Sinc, Triangular, Gaussian, Equation, Custom                         |
| Window                           | None, Bartlett, Hann, Hamming, Blackman, Nuttall, Tukey, Kaiser                   |
| Minimum filter cut-off frequency | Sampling rate / 10,000<br>e.g. 30.52 Hz at sample rate of 305.2 kHz               |
| Maximum filter cut-off frequency | Sampling rate / 2 (approximately)<br>e.g. 149.5 kHz at sampling rate of 305.2 kHz |



# Moku:Pro Laser Lock Box

## Description

Moku:Pro Laser Lock Box enables you to lock a laser's frequency to a reference cavity or atomic transition using high-performance modulation locking techniques. The Laser Lock Box includes a “Lock Assist” feature, enabling you to quickly lock to any zero-crossing on the demodulated error signal. With Multi-instrument Mode (MiM), you can deploy up to four laser lock modules simultaneously on a single Moku:Pro. Each module shares the same clock base from the internal or external source. This is an ideal solution for multi-laser stabilization systems.



## Features

- Generate modulation signals at up to 600 MHz
- Demodulate signals with an internal local oscillator, or external local oscillator at the fundamental or up to the 250<sup>th</sup> harmonic
- Scan resonances with sawtooth or triangle waveforms at up to 10 MHz
- Observe and log signals at different stages in the signal processing chain with probe points<sup>6</sup>
- Quickly lock to any zero-crossing in the error signal using the “Lock Assist” feature
- Filter demodulated signals with up to fourth order infinite impulse response filters
- Individually configure high- and low-bandwidth PID controllers for fast and slow feedback

<sup>6</sup> See [Moku:Pro Data Logger](#) or [Moku:Pro Oscilloscope](#) for specifications on integrated instruments



# Specifications

## Signal input

### Signal input

|                         |                                                                                                                                                                                                                                            |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input coupling          | AC / DC                                                                                                                                                                                                                                    |
| Input impedance         | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                                                                                 |
| Frequency range         | DC to 600 MHz                                                                                                                                                                                                                              |
| Input gain <sup>7</sup> | -40 dB / -20 dB / 0 dB / +24 dB / +48 dB                                                                                                                                                                                                   |
| Gain accuracy           | $\pm 1\%$                                                                                                                                                                                                                                  |
| Input range             | 40 V <sub>pp</sub> with -40 dB input gain<br>4 V <sub>pp</sub> with -20 dB input gain<br>0.4 V <sub>pp</sub> with 0 dB input gain<br>25 mV <sub>pp</sub> with +24 dB input gain <sup>7</sup><br>1.6 mV with +48 dB input gain <sup>7</sup> |
| Input noise             | < 20 nV/ $\sqrt{\text{Hz}}$ above 1 MHz at 400 mV <sub>pp</sub> input range                                                                                                                                                                |

## Internal demodulation local oscillator

### Internal reference waveform

|                                                  |                  |
|--------------------------------------------------|------------------|
| Waveform                                         | Sine             |
| Frequency range                                  | 1 mHz to 600 MHz |
| Frequency resolution                             | 1 $\mu\text{Hz}$ |
| Phase offset range                               | 0 to 360°        |
| Phase offset resolution                          | 0.000 001°       |
| Output impedance                                 | 50 $\Omega$      |
| Can be phase-locked to external 10 MHz timebase? | Yes              |

<sup>7</sup> +24 dB and +48 dB input gains are applied digitally and can be used to maximize the Laser Lock Box's dynamic range for weak input signals



## External demodulation reference

### Demodulation reference input

|                          |                                                                                                                                                                                                                   |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input coupling           | AC / DC                                                                                                                                                                                                           |
| Input impedance          | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                                                        |
| Frequency range          | DC to 600 MHz                                                                                                                                                                                                     |
| Input attenuation        | 40 dB / 20 dB / 0 dB                                                                                                                                                                                              |
| External reference modes | Internal reference oscillator, external direct, external with phase-locked loop<br>External with phase-locked loop with multiply to 250 <sup>th</sup> harmonic or divide down to 1/8 <sup>th</sup> of fundamental |

### Phase-locked loop

|                         |                                              |
|-------------------------|----------------------------------------------|
| PLL frequency range     | 10 Hz to 600 MHz                             |
| PLL tracking bandwidth  | 1Hz, 10Hz, 100Hz, 1kHz, 10kHz, 100kHz, 1MHz  |
| Phase offset range      | 0 to 360°                                    |
| Phase offset resolution | 0.000 001°                                   |
| Orthogonality           | 90° $\pm$ 0.000,002°                         |
| PLL multiplier          | 1/8 <sup>th</sup> to 250x of the fundamental |

## Lowpass filter

### Lowpass filter

|                                   |                                                                                        |
|-----------------------------------|----------------------------------------------------------------------------------------|
| Filter architecture               | Infinite Impulse Response (IIR)                                                        |
| Filter shape                      | Lowpass, Bandstop, or Custom                                                           |
| Sampling rate                     | 78.125 MHz                                                                             |
| Filter types                      | Butterworth, Chebyshev I, Chebyshev II, Elliptic, Cascaded, Bessel, Gaussian, Legendre |
| Filter order                      | 2, 4                                                                                   |
| Min. corner frequency             | 2.601 kHz                                                                              |
| Max. corner frequency             | 35.16 MHz                                                                              |
| Passband ripple <sup>8</sup>      | 0.1 dB to 10 dB                                                                        |
| Stopband attenuation <sup>9</sup> | 10 dB to 100 dB                                                                        |

<sup>8</sup> Applies to Chebyshev I and Elliptical filter types.

<sup>9</sup> Applies to Chebyshev II and Elliptical filter types.



## Auxiliary oscillator

### Auxiliary oscillator waveform

|                                                       |                                                           |
|-------------------------------------------------------|-----------------------------------------------------------|
| Waveform                                              | Sine                                                      |
| Frequency range                                       | 1 mHz to 500 MHz                                          |
| Frequency resolution                                  | 1 $\mu$ Hz                                                |
| Amplitude range (AC)                                  | 1 mV <sub>pp</sub> to 10 V <sub>pp</sub> into 50 $\Omega$ |
| Amplitude resolution                                  | 1 mV                                                      |
| Offset range (DC)                                     | $\pm 1$ V                                                 |
| Output limit (AC + DC)                                | $\pm 1$ V with 0 dB<br>$\pm 5$ V with 14 dB               |
| Amplitude accuracy                                    | 1%                                                        |
| Output impedance                                      | 50 $\Omega$                                               |
| Can be phase-locked to demodulation local oscillator? | Yes                                                       |

## Scan waveform

### Scanning waveform

|                        |                                                          |
|------------------------|----------------------------------------------------------|
| Waveform               | Positive ramp, Negative ramp, Triangle                   |
| Frequency range        | 1 mHz to 10 MHz                                          |
| Frequency resolution   | 1 $\mu$ Hz                                               |
| Amplitude range (AC)   | 1 mV <sub>pp</sub> to 2 V <sub>pp</sub> into 50 $\Omega$ |
| Amplitude resolution   | 1 mV                                                     |
| Offset range (DC)      | $\pm 1$ V                                                |
| Output limit (AC + DC) | $\pm 5$ V into 50 $\Omega$                               |
| Amplitude accuracy     | 1%                                                       |
| Output impedance       | 50 $\Omega$                                              |

## PID Controllers

### Set point

|                      |              |
|----------------------|--------------|
| Set point range      | -1 V to +1 V |
| Set point resolution | 100 $\mu$ V  |



### Fast controller

|                                      |                                                                                                                     |
|--------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Sampling rate                        | 78 MHz                                                                                                              |
| Proportional gain                    | $\pm 60$ dB                                                                                                         |
| Integrator crossover frequency       | 3.125 Hz to 312.5 kHz. (single integrator)<br>3.125 Hz to single integrator crossover frequency (double integrator) |
| Int. saturation crossover frequency  | 3.125 Hz to integrator crossover frequency                                                                          |
| Integrator gain range                | Proportional gain to +80 dB                                                                                         |
| Differentiator crossover frequency   | 31.25 Hz to 3.125 MHz                                                                                               |
| Diff. saturation crossover frequency | Differentiator crossover frequency to 3.125 MHz                                                                     |
| Differentiator gain range            | Proportional gain to +80 dB                                                                                         |

### Slow controller

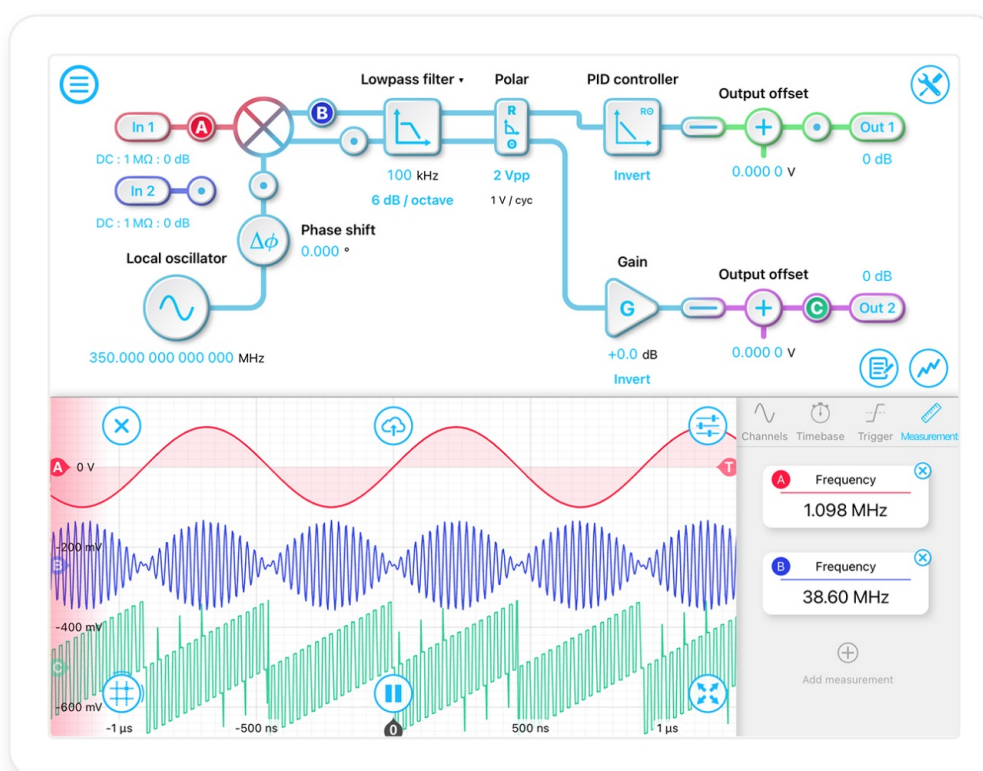
|                                      |                                                 |
|--------------------------------------|-------------------------------------------------|
| Sampling rate                        | 1.22 MHz                                        |
| Proportional gain                    | $\pm 60$ dB                                     |
| Integrator crossover frequency       | 48.83 mHz to 4.883 kHz                          |
| Int. saturation crossover frequency  | 48.83 mHz to integrator crossover frequency     |
| Integrator gain range                | Proportional gain to +80 dB                     |
| Differentiator crossover frequency   | 488.3 mHz to 48.83 kHz                          |
| Diff. saturation crossover frequency | Differentiator crossover frequency to 48.83 kHz |
| Differentiator gain range            | Proportional gain to +80 dB                     |



# Moku:Pro Lock-In Amplifier

## Description

Moku:Pro Lock-in Amplifier supports dual-phase demodulation (XY/R $\theta$ ) from 1 mHz to 600 MHz, at up to the 250<sup>th</sup> harmonic of an externally applied reference, with more than 120 dB dynamic reserve. A PID controller can be placed after the demodulation stage for phase-locked loop applications. An integrated four-channel Oscilloscope and Data Logger lets you observe signals at up to 1.25 GSa/s and log data at up to 10 MSa/s.



## Features

- Measure signals obscured by noise with more than 120 dB dynamic reserve
- Block diagram view of the digital signal processing chain
- Observe and log signals at different stages in the digital signal processing chain<sup>10</sup>
- Demodulate signals with an internal local oscillator, or external local oscillator at the fundamental or up to 250<sup>th</sup> harmonic
- Toggle between rectangular (X/Y mode) or polar coordinates (R/ $\theta$  mode)

<sup>10</sup> See [Moku:Pro Data Logger](#) or [Moku:Pro Oscilloscope](#) for specifications on integrated instruments





# Specifications

## Signal channel

### Signal input

|                                          |                                                                                                                                                                                                                                              |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input coupling                           | AC / DC                                                                                                                                                                                                                                      |
| Input impedance                          | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                                                                                   |
| AC coupling corner (-3 dB) <sup>11</sup> | 160 kHz into 50 $\Omega$<br>16 Hz into 1 M $\Omega$                                                                                                                                                                                          |
| Frequency range                          | DC to 600 MHz                                                                                                                                                                                                                                |
| Input attenuation                        | 0 dB / 20 dB / 40 dB                                                                                                                                                                                                                         |
| Input range                              | 0.4 V <sub>pp</sub> with 0 dB input attenuation<br>4 V <sub>pp</sub> with 20 dB input attenuation<br>40 V <sub>pp</sub> with 40 dB input attenuation                                                                                         |
| Input noise                              | < 30 nV/ $\sqrt{\text{Hz}}$ above 100 Hz at 400 mV <sub>pp</sub> input range<br>< 200 nV/ $\sqrt{\text{Hz}}$ above 10 kHz at 400 mV <sub>pp</sub> input range<br>< 20 nV/ $\sqrt{\text{Hz}}$ above 1 MHz at 400 mV <sub>pp</sub> input range |

## External reference

### Reference input

|                          |                            |
|--------------------------|----------------------------|
| Input coupling           | AC / DC                    |
| Input impedance          | 50 $\Omega$ / 1 M $\Omega$ |
| Frequency range          | DC to 600 MHz              |
| Input attenuation        | 0 dB / 20 dB / 40 dB       |
| External reference modes | Direct, phase-locked       |
| Direct demodulation      | $X = R \cos \theta$        |

### Phase-locked loop

|                        |                                                    |
|------------------------|----------------------------------------------------|
| PLL frequency range    | 10 Hz to 600 MHz                                   |
| PLL tracking bandwidth | 1 MHz, 100 kHz, 10 kHz, 1 kHz, 100 Hz, 10 Hz, 1 Hz |
| Phase range            | 0 to 360°                                          |
| Phase resolution       | 0.000 001°                                         |
| Demodulation           | XY / R $\theta$                                    |
| PLL multiplier         | 1/8 <sup>th</sup> to 250x of the fundamental       |

<sup>11</sup> For Moku:Pro devices shipped prior to April 2022, corners are 16 kHz into 50  $\Omega$  and 1.6 Hz into 1 M $\Omega$ .



## Internal reference

### Internal reference waveforms

|                      |                  |
|----------------------|------------------|
| Waveform             | Sine             |
| Frequency range      | 1 mHz to 600 MHz |
| Frequency resolution | 1 $\mu$ Hz       |
| Phase range          | 0 to 360°        |
| Phase resolution     | 0.000 001°       |
| Demodulation         | XY / R $\theta$  |

### Internal reference auxiliary output

|                                                   |                                                           |
|---------------------------------------------------|-----------------------------------------------------------|
| Amplitude range                                   | 1 mV <sub>pp</sub> to 10 V <sub>pp</sub> into 50 $\Omega$ |
| Amplitude resolution                              | 1 mV                                                      |
| Frequency range                                   | 1 mHz to 500 MHz                                          |
| Offset range                                      | $\pm 1$ V                                                 |
| Output limit (AC + DC)                            | $\pm 1$ V with 0 dB<br>$\pm 5$ V with 14 dB               |
| Amplitude accuracy                                | 1%                                                        |
| Output impedance                                  | 50 $\Omega$                                               |
| Can be phase-locked to external 10 MHz time base? | Yes                                                       |

## Demodulator

### Demodulator characteristics

|                                |                                                                                                                                                                                                                   |
|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sources                        | Internal reference oscillator, external direct, external with phase-locked loop<br>External with phase-locked loop with multiply to 250 <sup>th</sup> harmonic or divide down to 1/8 <sup>th</sup> of fundamental |
| Types                          | Internal: XY / R $\theta$<br>External direct: $X = R\cos\theta$<br>External with PLL: XY / R $\theta$                                                                                                             |
| Filter mode                    | Lowpass filter                                                                                                                                                                                                    |
| Filter cutoff frequency (-3dB) | 700 mHz to 12.4 MHz                                                                                                                                                                                               |
| Filter time constant           | 12.8 ns to 0.215 s                                                                                                                                                                                                |
| Filter slope                   | 6, 12, 18, 24 dB per octave                                                                                                                                                                                       |
| Phase shift precision          | 0.000 001°                                                                                                                                                                                                        |
| Dynamic reserve                | > 120 dB                                                                                                                                                                                                          |



## Signal output

### Output characteristics

|                                |                                                                    |
|--------------------------------|--------------------------------------------------------------------|
| Modes                          | XY (cartesian mode); R $\theta$ (polar mode); Auxiliary Oscillator |
| Number of output channels      | 2                                                                  |
| Channel 1 output               | X/R                                                                |
| Channel 2 output               | Y/ $\theta$ , auxiliary oscillator, or local oscillator            |
| Output gain mode               | Direct, PID <sup>12</sup>                                          |
| Gain range (direct)            | -80 dB to +160 dB                                                  |
| Phase scale (R $\theta$ mode)  | 1 V/cycle                                                          |
| Output voltage offset          | $\pm 1$ V into 50 $\Omega$                                         |
| Output voltage range (AC + DC) | $\pm 5$ V into 50 $\Omega$                                         |
| Output impedance               | 50 $\Omega$                                                        |
| D/A conversion                 | 16-bits, 1.25 GSa/s, 500 MHz analog bandwidth                      |

### PID controller

|                                      |                                                                  |
|--------------------------------------|------------------------------------------------------------------|
| Controller frequency range           | DC to 40 MHz                                                     |
| Proportional gain                    | $\pm 120$ dB (XY mode), $\pm 60$ dB (R $\theta$ mode)            |
| Integrator crossover frequency       | 3.125 Hz to 312.5 kHz                                            |
| Int. saturation crossover frequency  | 3.125 Hz to integrator crossover frequency                       |
| Integrator gain range                | Proportional gain to +120 dB (XY mode), +80 dB (R $\theta$ mode) |
| Differentiator crossover frequency   | 31.25 Hz to 3.125 MHz                                            |
| Diff. saturation crossover frequency | Differentiator crossover frequency to 3.125 MHz                  |
| Differentiator gain range            | Proportional gain to +120 dB (XY mode), +80 dB (R $\theta$ mode) |

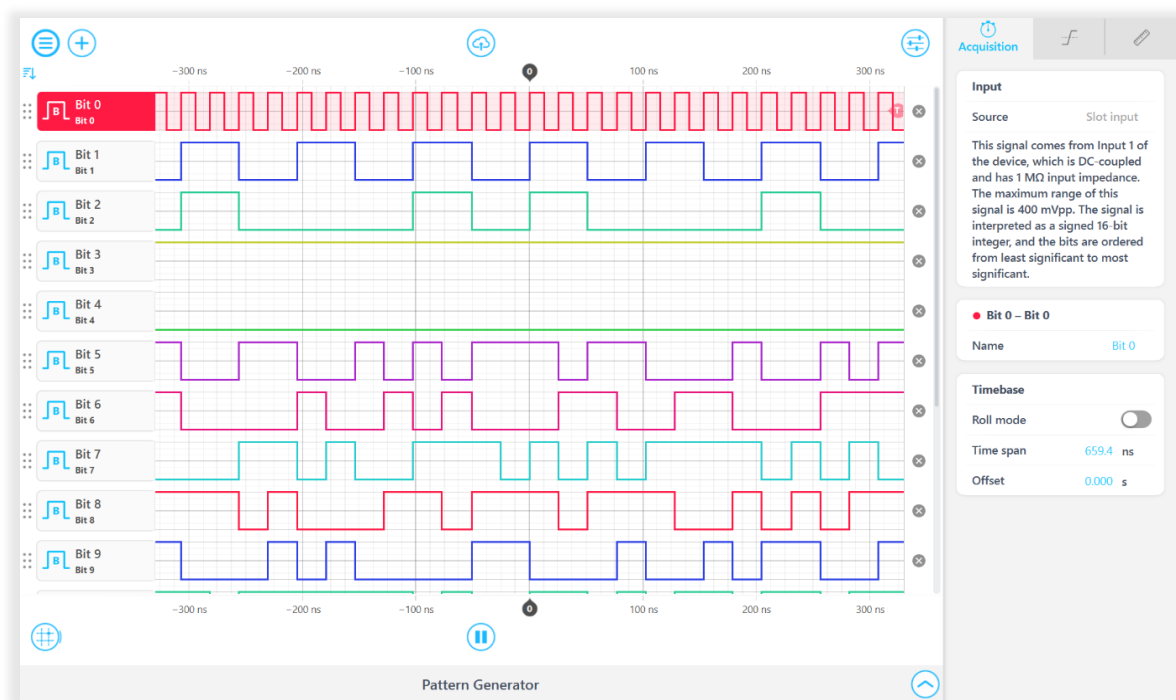
<sup>12</sup> Only one output may have a PID controller enabled at a time



# Moku:Pro Logic Analyzer (Multi-instrument Mode)

## Description

Moku:Pro Logic Analyzer<sup>13</sup> is equipped with one digital input and two digital outputs with sampling rates up to 1.25 GSa/s. It supports  $262k \times 16$  input sample depth and up to  $32,764 \times 16$  output sample depth. Data, screenshots, and instrument settings can be captured and downloaded to the computer.



## Features

- 16-bit single channel<sup>14</sup> digital input with a sampling rate up to 1.25 GSa/s.
- Two outputs that include selectable clock, pulse, and random patterns, or upload a custom file.
- Ultra deep  $262k \times 16$  points input memory depth,  $32,764 \times 16$  points output memory depth.
- Decode up to two protocols at a time, including UART, SPI, I<sup>2</sup>C, I<sup>2</sup>S, CAN, and Parallel bus
- Powerful, intuitive graphical user interface with Python, and MATLAB API support.

<sup>13</sup> The Moku:Pro Logic Analyzer Pattern Generator is currently only supported in Multi-instrument Mode. These specifications are for a single Logic Analyzer instrument slot. Each Logic Analyzer instrument slot will add another input and two outputs.

<sup>14</sup> The Logic Analyzer input and output channels show 16 bits. The bits are ordered from least significant (Bit 0) to most significant (Bit 15). Each bit is added together to create the waveform for that input or output, they are not individual channels.



# Specifications

## Digital I/O<sup>15</sup>

### Interface

|               |                             |
|---------------|-----------------------------|
| Number of I/O | 3                           |
| I/O sources   | Input A, Output A, Output B |

## Horizontal characteristics

### Acquisition

|                                |                         |
|--------------------------------|-------------------------|
| Sampling rate                  | 1.25 GSa/s              |
| Memory depth                   | 262k points per channel |
| Maximum clock signal frequency | 1.25 GHz                |

### Generation

|                                |                           |
|--------------------------------|---------------------------|
| Sampling rate                  | 1.25 GSa/s                |
| Memory depth                   | 32,764 points per channel |
| Maximum clock signal frequency | 1.25 GHz                  |
| Clock divider                  | 1 to 1,000,000            |

## Trigger

### Trigger

|                 |                                                              |                                                                                                 |
|-----------------|--------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Trigger modes   | Auto:                                                        | Triggers automatically after timeout (1 second if previously triggered, 0.05 seconds otherwise) |
|                 | Normal:                                                      | Triggers only on trigger event                                                                  |
|                 | Single:                                                      | Triggers once on a trigger event. Press the 'play' button to re-trigger                         |
| Trigger sources | An input bit                                                 |                                                                                                 |
| Nth event       | Trigger on the 1 <sup>st</sup> to 65,535 <sup>th</sup> event |                                                                                                 |
| Holdoff         | up to 10 seconds                                             |                                                                                                 |
| Trigger types   | Edge or pulse                                                |                                                                                                 |

<sup>15</sup> The Moku:Pro does not have a dedicated Digital I/O header like the Moku:Go does. Instead, it uses the BNC analog inputs and then converts the analog signal to a 16-bit digital signal or inter-slot 16-bit digital signals.



## Measurements

### Measurements

|                   |                                                                                  |
|-------------------|----------------------------------------------------------------------------------|
| Time measurements | Frequency, phase, period, duty cycle, positive pulse width, negative pulse width |
| Math              | AND, OR, XOR, NAND, NOR, XNOR                                                    |

## Protocol Decoder

### UART

|                        |                      |
|------------------------|----------------------|
| Data width             | 5 bits to 9 bits     |
| Stop width             | 1 bit to 2 bits      |
| Parity                 | None, Even, Odd      |
| Baud rate              | 1 to 2,000,000       |
| Bit order              | LSB first, MSB first |
| Max standard baud rate | 921,600              |

### SPI

|                       |                                       |
|-----------------------|---------------------------------------|
| CLK                   | Serial Clock bit                      |
| CS                    | Chip Select bit                       |
| DATA                  | Serial Data bit                       |
| Data width            | 5 bits to 9 bits                      |
| Bit order             | LSB first, MSB first                  |
| Clock polarity        | Idle low, Idle high                   |
| Clock phase           | Sample on leading, Sample on trailing |
| Max decoder frequency | 30 MHz                                |

### I<sup>2</sup>C

|                       |                  |
|-----------------------|------------------|
| Address size          | 7 bits           |
| SCL <sup>16</sup>     | Serial clock bit |
| SDA                   | Serial data bit  |
| Max decoder frequency | > 1 MHz          |

<sup>16</sup> Some protocols like I<sup>2</sup>C and I<sup>2</sup>S require the user to select a bit for their input data to the protocol decoder. Ensure the bits labelled on the interface match the bits you set for your input data.



## I<sup>2</sup>S

|                       |                                                                                   |
|-----------------------|-----------------------------------------------------------------------------------|
| SCK                   | Serial clock bit                                                                  |
| WS                    | Word select bit                                                                   |
| SD                    | Serial data bit                                                                   |
| Bit order             | LSB first, MSB first                                                              |
| Offset                | Number of clock cycle to wait after WS transition before data transmission starts |
| Data Width            | 2 bits to 32 bits                                                                 |
| Max decoder frequency | 40 MHz                                                                            |

## CAN

|                |                  |
|----------------|------------------|
| Baud rate      | Up to 1 Mbps     |
| Data bit order | MSB or LSB first |

## Parallel bus

|             |                                       |
|-------------|---------------------------------------|
| Sample mode | Rising edge, falling edge, both edges |
| Data width  | 1-12 bits                             |
| Clock       | Any input bit                         |

# Saving data

## Exporting data

|              |                                                                                                                                       |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------|
| File formats | Binary: records data using a proprietary LI format for high-speed data logging. Can be converted to .csv, .txt, .mat, .npy, and HDF5. |
| Export modes | Dropbox, email, iCloud, and My Files                                                                                                  |
| Screenshot   | JPG, PNG                                                                                                                              |

## Export types

|               |                                                                               |
|---------------|-------------------------------------------------------------------------------|
| Traces        | Save 1024 points of data from each visible input bit in the current time span |
| Protocol data | Save protocol decoder states and data as comma-separated values               |
| Screenshots   | Save the app window as a PNG or JPG                                           |
| Settings      | Save the current instruments settings to a text file                          |
| Measurements  | Save all active measurements as comma-separated values                        |
| High-res data | Save up to 262k points per active bit                                         |



# Moku:Pro Logic Analyzer (Single-instrument Mode)

## Description

Moku:Pro Logic Analyzer<sup>17</sup> is equipped with five digital inputs with sampling rates up to 1.25 GSa/s. It supports 262k × 3 input sample depth. Data, screenshots, and instrument settings can be captured and downloaded to the computer.



## Features

- 16-bit single channel<sup>18</sup> digital input with a sampling rate up to 1.25 GSa/s.
- Ultra deep 262k × 3 points input memory depth.
- Decode up to two protocols at a time, including UART, SPI, I<sup>2</sup>C, I<sup>2</sup>S, CAN, and Parallel bus
- Powerful, intuitive graphical user interface with Python, and MATLAB API support.

<sup>17</sup> The Moku:Pro Logic Analyzer Pattern Generator is currently only supported in Multi-instrument Mode. These specifications are for a Single-instrument Mode Logic Analyzer.

<sup>18</sup> The Logic Analyzer input and output channels show 16 bits. The bits are ordered from least significant (Bit 0) to most significant (Bit 15). Each bit is added together to create the waveform for that input or output, they are not individual channels.





# Specifications

## Analog Inputs<sup>19</sup>

### Interface

|                         |                                                      |
|-------------------------|------------------------------------------------------|
| Number of Inputs        | 5                                                    |
| Input sources           | Input 1, Input 2, Input 3, Input 4, External Trigger |
| Threshold voltage range | -20 V to 20 V                                        |

## Horizontal characteristics

### Acquisition

|                                |                         |
|--------------------------------|-------------------------|
| Sampling rate                  | 1.25 GSa/s              |
| Memory depth                   | 262k points per channel |
| Maximum clock signal frequency | 1.25 GHz                |

## Trigger

### Trigger

|                 |                                                              |                                                                                                 |
|-----------------|--------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Trigger modes   | Auto:                                                        | Triggers automatically after timeout (1 second if previously triggered, 0.05 seconds otherwise) |
|                 | Normal:                                                      | Triggers only on trigger event                                                                  |
|                 | Single:                                                      | Triggers once on a trigger event. Press the 'play' button to re-trigger                         |
| Trigger sources | Input 1, Input 2, Input 3, Input 4, Ext. trig.               |                                                                                                 |
| Nth event       | Trigger on the 1 <sup>st</sup> to 65,535 <sup>th</sup> event |                                                                                                 |
| Holdoff         | up to 10 seconds                                             |                                                                                                 |
| Trigger types   | Edge or pulse                                                |                                                                                                 |

## Measurements

### Measurements

|                   |                                                                                  |
|-------------------|----------------------------------------------------------------------------------|
| Time measurements | Frequency, phase, period, duty cycle, positive pulse width, negative pulse width |
| Math              | AND, OR, XOR, NAND, NOR, XNOR                                                    |

<sup>19</sup> The Moku:Pro does not have a dedicated Digital I/O header like the Moku:Go does. Instead, it uses the BNC analog inputs and then converts the analog signal to a digital signal using the user provided threshold range.



## Protocol Decoder

### UART

|                        |                      |
|------------------------|----------------------|
| Data width             | 5 bits to 9 bits     |
| Stop width             | 1 bit to 2 bits      |
| Parity                 | None, Even, Odd      |
| Baud rate              | 1 to 2,000,000       |
| Bit order              | LSB first, MSB first |
| Max standard baud rate | 921,600              |

### SPI

|                       |                                       |
|-----------------------|---------------------------------------|
| CLK                   | Serial clock bit                      |
| CS                    | Chip select bit                       |
| DATA                  | Serial data bit                       |
| Data width            | 5 bits to 9 bits                      |
| Bit order             | LSB first, MSB first                  |
| Clock polarity        | Idle low, Idle high                   |
| Clock phase           | Sample on leading, Sample on trailing |
| Max decoder frequency | 30 MHz                                |

### I<sup>2</sup>C

|                       |                  |
|-----------------------|------------------|
| Address size          | 7 bits           |
| SCL <sup>20</sup>     | Serial clock bit |
| SDA                   | Serial data bit  |
| Max decoder frequency | > 1 MHz          |

### I<sup>2</sup>S

|                       |                                                                                   |
|-----------------------|-----------------------------------------------------------------------------------|
| SCK                   | Serial clock bit                                                                  |
| WS                    | Word select bit                                                                   |
| SD                    | Serial data bit                                                                   |
| Bit order             | LSB first, MSB first                                                              |
| Offset                | Number of clock cycle to wait after WS transition before data transmission starts |
| Data Width            | 2 bits to 32 bits                                                                 |
| Max decoder frequency | 40 MHz                                                                            |

<sup>20</sup> Some protocols like I<sup>2</sup>C and I<sup>2</sup>S require the user to select a bit for their input data to the protocol decoder. Ensure the bits labelled on the interface match the bits you set for your input data.



## CAN

|                |                  |
|----------------|------------------|
| Baud rate      | Up to 1 Mbps     |
| Data bit order | MSB or LSB first |

## Parallel bus

|             |                                       |
|-------------|---------------------------------------|
| Sample mode | Rising edge, falling edge, both edges |
| Data width  | 1-5 bits                              |
| Clock       | Any input or trigger input            |

# Saving data

## Exporting data

|              |                                                                                                                                       |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------|
| File formats | Binary: records data using a proprietary LI format for high-speed data logging. Can be converted to .csv, .txt, .mat, .npy, and HDF5. |
| Export modes | Dropbox, email, iCloud, and My Files                                                                                                  |

## Export types

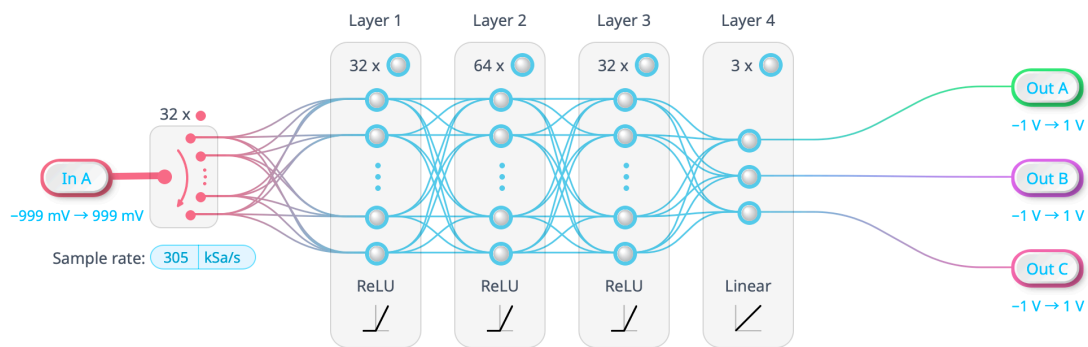
|               |                                                                               |
|---------------|-------------------------------------------------------------------------------|
| Traces        | Save 1024 points of data from each visible input bit in the current time span |
| Protocol data | Save protocol decoder states and data as comma-separated values               |
| Screenshots   | Save the app window as a PNG or JPG                                           |
| Settings      | Save the current instruments settings to a text file                          |
| Measurements  | Save all active measurements as comma-separated values                        |
| High-res data | Save up to 262k points per active bit                                         |



# Moku:Pro Neural Network

## Description

Moku:Pro Neural Network<sup>21</sup> enables fast, agile implementation and evaluation of user-defined neural networks utilizing Multi-instrument Mode. Design and train your network configuration offline in a Python supported environment, then upload it to the Moku app for real-time Neural Network operation.



[Load network configuration...](#) [?](#)

## Features

- Training: collect training data on any Moku; or simulate a desired complex process offline
- 5 activations functions
- Upload network configuration
- Data log Neural Network outputs with the Moku Data Logger, Oscilloscope, or other Moku instruments

<sup>21</sup> Moku Neural Network is only available in Multi-instrument Mode.



# Specifications

|                            |                                       |
|----------------------------|---------------------------------------|
| Input channels (parallel)  | Up to 4                               |
| Input channels (serial)    | 1 to 100                              |
| Output channels (parallel) | Up to 4                               |
| Output channels (serial)   | 1 to 100                              |
| Layers                     | Up to 4                               |
| Neurons per layer          | Up to 100                             |
| Sample rate                | 1 SA/s to 305 kSA/s                   |
| Activation functions       | ReLU, Softsign, Tanh, Sigmoid, Linear |
| Precision                  | 18-bit fixed point                    |



# Moku:Pro Oscilloscope

## Description

Moku:Pro Oscilloscope features four high-speed, ultra-low noise input channels with 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 at  $30\text{ nV}/\sqrt{\text{Hz}}$  at 100Hz with large dynamic range. The built-in four-channel waveform generators can produce waveforms with a bandwidth of up to 500 MHz.



## Features

- Four analog inputs with 600 MHz bandwidth
- Exceptional low-frequency noise performance:  $30\text{ nV}/\sqrt{\text{Hz}}$  at 100 Hz
- Dual-ADC design with blended ADC technology
- Ultra-stable 0.3 ppm onboard oscillator with 10 MHz synchronization in and out
- Integrated high-speed waveform generator channels with analog bandwidths up to 500 MHz



- Deep memory captures > 60 million samples

## Specifications

### Vertical characteristics

#### Voltage

|                              |                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Channels                     | 4                                                                                                                                                                                                                                                                                                                                                                                    |
| Input coupling               | AC / DC                                                                                                                                                                                                                                                                                                                                                                              |
| Input impedance              | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                                                                                                                                                                                                                           |
| Input bandwidth (-3 dB)      | 300 MHz / 600 MHz switchable                                                                                                                                                                                                                                                                                                                                                         |
| Input voltage range          | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation                                                                                                                                                                                               |
| Input voltage noise          | < 30 nV/ $\sqrt{\text{Hz}}$ above 10 Hz at 400 mV <sub>pp</sub> input range<br>< 200 nV/ $\sqrt{\text{Hz}}$ above 1 kHz at 400 mV <sub>pp</sub> input range<br>< 20 nV/ $\sqrt{\text{Hz}}$ above 10 MHz at 400 mV <sub>pp</sub> input range (1.25 GSa/s acquisition rate)<br>< 13 nV/ $\sqrt{\text{Hz}}$ above 10 MHz at 400 mV <sub>pp</sub> input range (5 GSa/s acquisition rate) |
| Channel-to-channel isolation | > 40 dB                                                                                                                                                                                                                                                                                                                                                                              |

### Horizontal characteristics

#### Time

|                 |               |
|-----------------|---------------|
| Time mode       | Normal, Roll  |
| Horizontal span | 4 ns to 100 s |

#### Acquisition

|                       |                                                                                  |
|-----------------------|----------------------------------------------------------------------------------|
| Acquisition mode      | Normal, Precision <sup>22</sup> , Peak Detect, Deep memory (> 60 million points) |
| Maximum sampling rate | 5 GSa/s                                                                          |
| ENOB                  | 8.8                                                                              |
| Averaging (linear)    | Off, 2 to 100 waveforms                                                          |
| Persistence           | Off, 100 ms to 10 s, infinite                                                    |
| Interpolation         | Linear, SinX/X, Gaussian                                                         |

<sup>22</sup> Precision mode samples the waveform at the full rate and applies a finite impulse response (FIR) lowpass filter to attenuate noise above the usable bandwidth of the measurement sampling rate and prevent aliasing.



## Trigger

### Trigger

|                 |                                                                                                                                               |                                                                                                 |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Trigger modes   | Auto:                                                                                                                                         | Triggers automatically after timeout (1 second if previously triggered, 0.05 seconds otherwise) |
|                 | Normal:                                                                                                                                       | Triggers only on trigger event                                                                  |
|                 | Single:                                                                                                                                       | Triggers once on a trigger event. Press the play button to retrigger                            |
| Trigger sources | Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, Output 4, External                                                          |                                                                                                 |
| Nth event       | Trigger on the 1 <sup>st</sup> to 65,535 <sup>th</sup> event                                                                                  |                                                                                                 |
| Holdoff         | 3.2 ns to 10 seconds                                                                                                                          |                                                                                                 |
| Trigger types   | Edge: Rising edge, falling edge, both edges                                                                                                   |                                                                                                 |
|                 | Pulse: Positive / negative polarity <ul style="list-style-type: none"><li>10.0 seconds &gt; <b>pulse width</b> &gt; 3.2 nanoseconds</li></ul> |                                                                                                 |

### Trigger sensitivity

|                   |                                 |                                                                                                                                                               |
|-------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sensitivity modes | Auto:                           | Automatically configures trigger sensitivity based on horizontal and vertical scales<br>Select <i>Noise Reject</i> or high-frequency <i>HF Reject</i> options |
|                   | Manual:                         | Manually configure trigger sensitivity                                                                                                                        |
| Manual modes      | Relative, Absolute              |                                                                                                                                                               |
| Hysteresis        | Relative: 0.01 div to 5.00 div  |                                                                                                                                                               |
|                   | Absolute: 100 $\mu$ V to 1.00 V |                                                                                                                                                               |

## Measurements

### Measurements

|                        |                                                                                                                                                                  |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Time measurements      | Frequency, phase, period, duty cycle, positive pulse width, negative pulse width, rise time, fall time, rise rate, fall rate                                     |
| Amplitude measurements | Peak-to-peak, amplitude, maximum, minimum, mean, cycle mean, RMS, cycle RMS, standard deviation, high-level, low-level, overshoot, undershoot, fringe visibility |
| Math                   | Add, subtract, multiply, divide, XY mode, integrate, differentiate, FFT, min hold, max hold, arbitrary equation mode (using equation editor)                     |
| Visualizations         | Histogram, time trend                                                                                                                                            |

### Cursors

|              |                                                                         |
|--------------|-------------------------------------------------------------------------|
| Time cursors | Drag on time axis, or manual select time. Cursor time deltas displayed. |
|--------------|-------------------------------------------------------------------------|





## Cursors

|                        |                                                                                                        |
|------------------------|--------------------------------------------------------------------------------------------------------|
| Voltage cursor options | Manual, track mean, track maximum, track minimum, maximum hold, minimum hold                           |
| User defined reference | A single cursor can be set as a reference for differential measurements using all other active cursors |

## Integrated waveform synthesizer

### Synthesizer

|                         |                                                                                                        |
|-------------------------|--------------------------------------------------------------------------------------------------------|
| Channels                | 4                                                                                                      |
| Output impedance        | 50 $\Omega$                                                                                            |
| Waveforms <sup>23</sup> | Sine, Square, Ramp, Pulse, Noise, DC                                                                   |
| Output frequency range  | 1 mHz to 500 MHz                                                                                       |
| Output voltage range    | > 100 MHz: 2 V <sub>pp</sub> into 50 $\Omega$<br>1 mHz to 100 MHz: 10 V <sub>pp</sub> into 50 $\Omega$ |

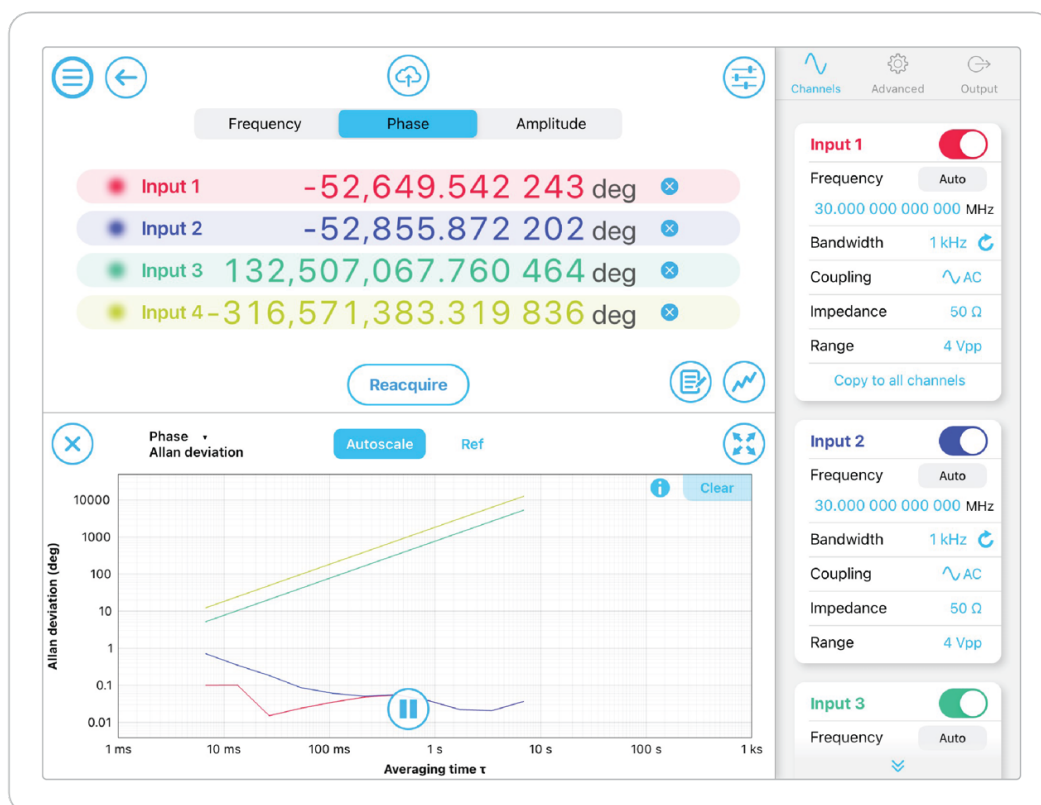
<sup>23</sup> Modulation not available for waveforms synthesized using the oscilloscope instrument.



# Moku:Pro Phasemeter

## Description

Moku:Pro Phasemeter measures phase (relative to a reference clock) of up to four input signals with 1 nrad precision from 1 kHz up to 300 MHz. Based on a digitally implemented phase-locked loop architecture, Moku:Pro's Phasemeter provides exceptional dynamic range, zero deadtime, and measurement precision that exceeds the performance of conventional lock-in amplifiers and frequency counters.



## Features

- Four independent phasemeter channels with output options that track and record the phase, frequency, and amplitude of four independent signals
- Phase-locked output option enables you to generate sine waves that are phase locked to the inputs, with frequency division to  $1/8^{\text{th}}$  or multiplication to 250x.
- Observe measurement data in the frequency domain using the Phasemeter's integrated spectral analysis toolkit
- Phase-locked loop tracking bandwidths from 1 Hz up to 1 MHz
- Drive measured phase to outputs with phase wrapping, or drive frequency offset or amplitude



# Specifications

## Inputs

### Input characteristics

|                       |                                                                                                                                                                                        |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Input frequency range | 1 kHz to 300 MHz                                                                                                                                                                       |
| Input voltage range   | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation |
| Input impedance       | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                             |
| Input coupling        | AC / DC                                                                                                                                                                                |

## Measurement

### Measurement characteristics

|                     |                                                                                                                                                              |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase error         | 0.1 $\mu$ radian/ $\sqrt{\text{Hz}}$ @ 10 Hz                                                                                                                 |
| Phase precision     | 1 nano radian                                                                                                                                                |
| Frequency precision | 1 $\mu$ Hz                                                                                                                                                   |
| Modes of operation  | Auto-acquire      Automatically determines input frequency for signals above 1 MHz<br>Manual              Initializes the phasemeter to a specific frequency |
| Tracking bandwidth  | 1 Hz / 10 Hz / 100 Hz / 1 kHz / 10 kHz / 100 kHz / 1 MHz (user selectable)                                                                                   |
| Advanced option     | Phase wrapping, single input, auto-reset, invert, and user-configurable mV/cycle output scaling                                                              |

### Data visualization

|                |                                                                                                               |
|----------------|---------------------------------------------------------------------------------------------------------------|
| Visualizations | Timeseries, Power Spectral Density, Amplitude Spectral Density, Coherence, Rayleigh Spectrum, Allan Deviation |
|----------------|---------------------------------------------------------------------------------------------------------------|

## Outputs

### Phase, frequency offset or amplitude output

|                    |                                                                                                                                                                          |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Channels           | 4                                                                                                                                                                        |
| Modes of operation | Sine wave (option to phase-lock to the input signal)<br>Drive measured signal phase, frequency offset, or amplitude with user-defined scaling and configurable DC offset |
| Output range       | 2 V <sub>pp</sub> or 10 V <sub>pp</sub>                                                                                                                                  |



## Saving Data

### Saving data

|                        |                                                                                                                                                                                                                                                                                    |
|------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Logging rates          | 37 Sa/s, 150 Sa/s, 596 Sa/s, 2.4 kSa/s, 19.1 kSa/s, 152 kSa/s                                                                                                                                                                                                                      |
| File format            | Binary: Records data using a proprietary LI format for high-speed data logging.<br><br>Data saved using the LI format may be converted to other formats when downloading from Moku. iPad can convert to .CSV, MATLAB or NumPy. Desktop can convert to .CSV, MATLAB, NumPy or HDF5. |
| Export modes           | Dropbox, E-mail, My Files, Desktop, and iCloud                                                                                                                                                                                                                                     |
| Delayed log start time | Up to 240 hours                                                                                                                                                                                                                                                                    |
| Log duration           | 1 millisecond to 10,000 hours                                                                                                                                                                                                                                                      |

## Synthesizer

### Synthesizer<sup>24</sup>

|                  |                                                                                          |
|------------------|------------------------------------------------------------------------------------------|
| Channels         | 4                                                                                        |
| Output impedance | 50 $\Omega$                                                                              |
| Waveform shape   | Sine                                                                                     |
| Output modes     | Manual, phase-locked to input signal, with scaling to 250x harmonic or division to 1/8th |
| Sampling rate    | 1.25 GSa/s per channel                                                                   |
| Voltage range    | $\pm 5$ V into 50 $\Omega$                                                               |

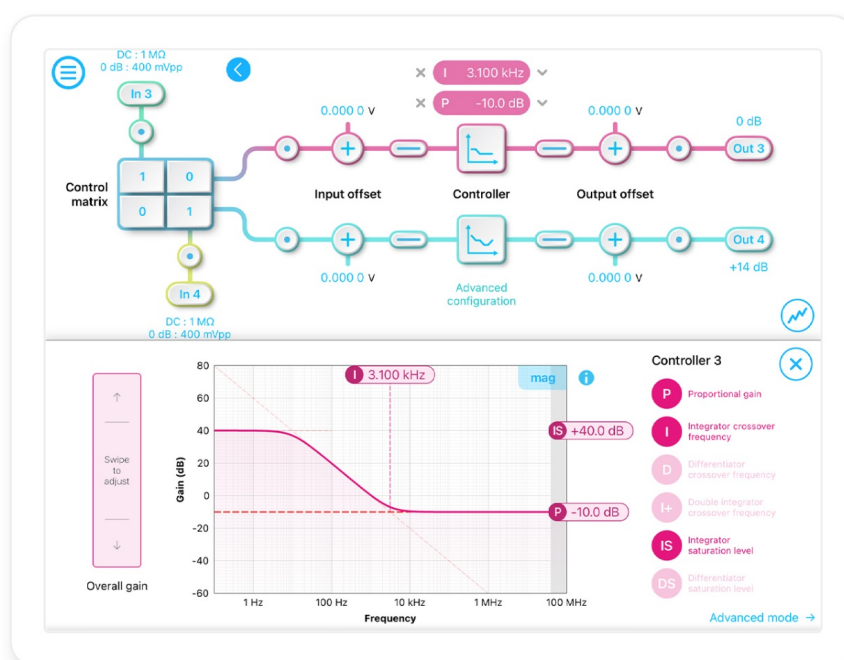
<sup>24</sup> Where not stated, the Phasemeter's synthesizer specifications match those of the [Moku:Pro Waveform Generator](#) instrument.



# Moku:Pro PID Controller

## Description

Moku:Pro PID Controller features four fully configurable PID controllers with an open loop bandwidth of 35.38 MHz. This enables them to be used in applications requiring both low and high feedback bandwidths such as laser temperature and current stabilization. The PID Controller can also be used as a lead-lag compensator by saturating the integral and differential controllers with independent gain settings.



## Features

- Four input channels, four output channels, and four independent PID Controllers with control matrix for MIMO
- Design the control system's frequency response using the interactive Bode plot in real time
- Block diagram view of the digital signal processing with built-in probe points in signal processing chain
- Advanced multi-section PID builder with single or double integrators and differentiators with low- and high-frequency gain saturation
- Integrated probe points for signal monitoring and data logging
- Observe and log signals at different stages in the digital signal processing chain using probe points<sup>25</sup>

<sup>25</sup> See [Moku:Pro Data Logger](#) or [Moku:Pro Oscilloscope](#) for specifications on integrated instruments



# Specifications

## Inputs

### Input characteristics

|                                                 |                                                                                                                                                                                        |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Channels                                        | 4                                                                                                                                                                                      |
| Input control matrix coefficients (linear gain) | -20 to +20                                                                                                                                                                             |
| Input impedance                                 | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                             |
| Input coupling                                  | AC / DC                                                                                                                                                                                |
| Input attenuation                               | 0 dB / 20 dB / 40 dB                                                                                                                                                                   |
| Input voltage range                             | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation |

## Controller

### General characteristics

|                             |                                                                                                                                |
|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Gain profiles               | Proportional (P), integral (I), differential (D), double-integral (I+), integral saturation (IS), differential saturation (DS) |
| Maximum bandwidth           | 150 kHz with a phase delay of 30°                                                                                              |
| Input / output offset range | ± 1 V                                                                                                                          |
| Output limit (AC + DC)      | ± 1 V into 50 $\Omega$                                                                                                         |
| Offset precision            | 100 $\mu$ V                                                                                                                    |

### Gain characteristics

|                                       |                                                                                                                                |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Gain profiles                         | Proportional (P), integral (I), differential (D), double-integral (I+), integral saturation (IS), differential saturation (DS) |
| Controller frequency range            | DC to 40 MHz                                                                                                                   |
| Proportional gain                     | ± 60 dB                                                                                                                        |
| Integrator crossover frequency        | 3.125 Hz to 312.5 kHz                                                                                                          |
| Double integrator crossover frequency | 3.125 Hz to integrator crossover frequency                                                                                     |
| Integral saturation level             | Between proportional gain and +60 dB<br>The integrator saturation crossover frequency cannot be lower than 3.125 Hz            |
| Differentiator crossover frequency    | 31.25 Hz to 3.125 MHz                                                                                                          |
| Differentiator saturation level       | Between proportional gain and +60 dB<br>The differentiator saturation crossover frequency cannot be higher than 3.125 MHz      |



## Description

The screenshot displays the Keysight PNA Network Analyzer software interface. The main plot shows the power spectral density (PSD) in dBm versus frequency in MHz. A red peak is visible at approximately 80 MHz, and a blue peak is at 160.0 MHz. The interface includes various controls for channels, frequency, output, units, and input settings. A measurement summary at the bottom left shows the peak level as -6.94 dBm and the peak frequency as 160.0 MHz.

- Display and record power spectra or power spectral densities in the frequency domain from DC to 300 MHz
- Generate four sine waves up to 500 MHz using Moku:Pro's built-in analog outputs
- Quickly measure important metrics by dragging measurement cursors onto features of interest
- Live measurement functions: peak level, peak frequency, noise level, peak SNR, and occupied bandwidth



# Specifications

## Frequency

### Frequency

|       |                   |
|-------|-------------------|
| Range | DC to 300 MHz     |
| Span  | 100 Hz to 300 MHz |

### Resolution bandwidth (RBW)

|         |                                                                                            |                                                                                                                     |
|---------|--------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Modes   | Auto                                                                                       | Automatically sets the RBW based on the current span and window function                                            |
|         | Manual                                                                                     | Allows the user to manually set the RBW within the limits tolerated by the span and window function                 |
|         | Min                                                                                        | Sets the RBW at the minimum possible value for the current span and window function<br>The minimum RBW is 618.5 mHz |
| Windows | Rectangular, Bartlett, Hamming, Hann, Blackman-Harris. Flat top, Nuttall, Gaussian, Kaiser |                                                                                                                     |

## Amplitude

### Voltage

|                         |                                                                                                                                                                                        |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Channels                | 4                                                                                                                                                                                      |
| Input coupling          | AC / DC                                                                                                                                                                                |
| Input impedance         | 50 $\Omega$ / 1 M $\Omega$                                                                                                                                                             |
| Input attenuation       | 0 dB / 20 dB                                                                                                                                                                           |
| Input bandwidth (-3 dB) | 300 MHz / 600 MHz switchable                                                                                                                                                           |
| Input voltage range     | 0.4 V <sub>pp</sub> into 50 $\Omega$ with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 $\Omega$ with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 M $\Omega$ with 40 dB attenuation |

### Display

|                              |                                      |
|------------------------------|--------------------------------------|
| Scales                       | Vpp, Vrms, dBm, dBV                  |
| Display modes                | Power, Power Spectral Density (PSD)  |
| Video filter bandwidth (VBW) | 580 mHz to 3.1 MHz depending on span |
| Averages                     | 1 to 100                             |
| Persistence                  | Off, 100 ms to 10 s, infinite        |





## Synthesizer

### Synthesizer

|                         |                                                                                                        |
|-------------------------|--------------------------------------------------------------------------------------------------------|
| Channels                | 4                                                                                                      |
| Output impedance        | 50 $\Omega$                                                                                            |
| Waveforms <sup>26</sup> | Sine                                                                                                   |
| Output frequency range  | 1 mHz to 500 MHz                                                                                       |
| Sweep mode              | Sweeps the output frequency across the current span with a fixed sweep period of 5 seconds             |
| Output voltage range    | > 100 MHz: 2 V <sub>pp</sub> into 50 $\Omega$<br>1 mHz to 100 MHz: 10 V <sub>pp</sub> into 50 $\Omega$ |

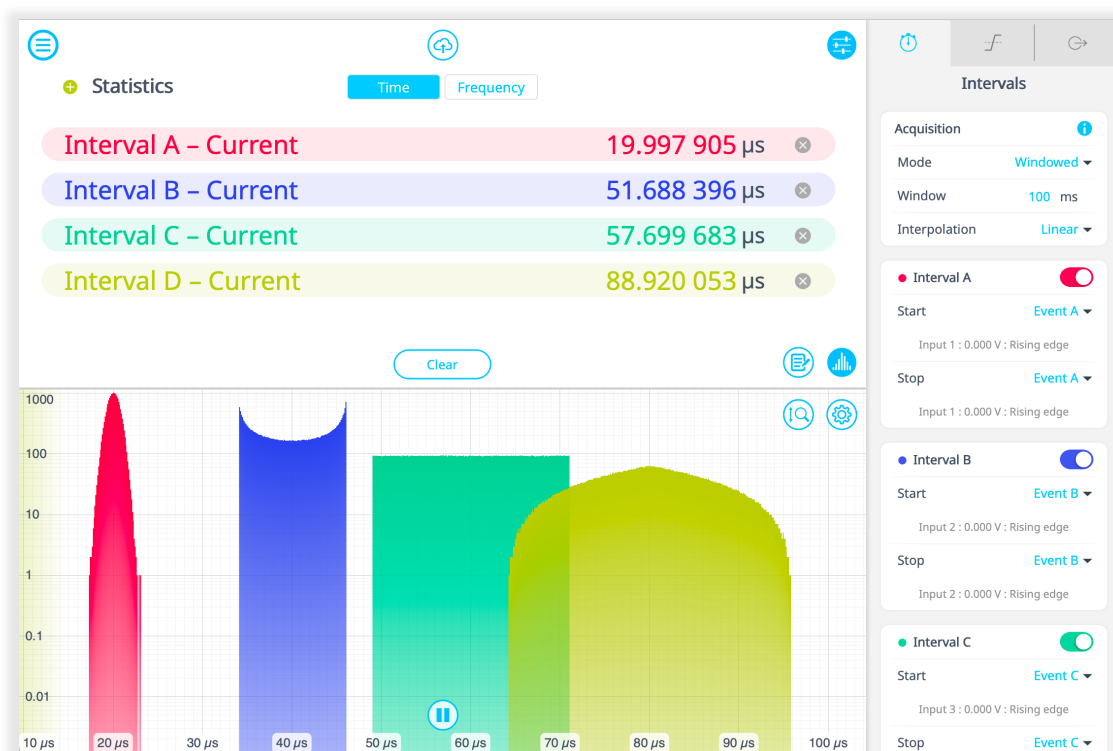
<sup>26</sup> Modulation not available for waveforms synthesized using the oscilloscope instrument.



# Moku:Pro Time & Frequency Analyzer

## Description

Moku:Pro Time & Frequency Analyzer measures intervals between configurable start and stop events with sub-ns precision. Select between continuous, windowed, or gated acquisition mode, compute histograms of interval duration losslessly and in real-time, and log high-resolution event timestamps to on-board storage. Output the measured interval count or current interval to analog output channels for active feedback control.



## Features

- Jitter of < 20 ps for high timing resolution analysis
- Up to four independent event detectors with configurable thresholds on rising edge, falling edge, or both
- Lossless, real-time histograms with a minimum bin width of 0.78 ps
- Output interval count or current interval with adjustable scaling factor
- High resolution raw event timestamp logging to on-board storage for post processing
- Combine with up to three other instruments in Multi-instrument Mode for system level characterization and feedback control



# Specifications

## Events

### Input characteristics

|                              |                                                |
|------------------------------|------------------------------------------------|
| No. of independent analyzers | 4                                              |
| Source                       | Input 1, Input 2, Input 3, Input 4, Ext. trig. |
| Input Coupling               | AC / DC                                        |
| Input Impedance              | 50 $\Omega$ / 1 M $\Omega$                     |
| Input voltage range          | 400 mVpp, 4 Vpp, 40 Vpp                        |
| Frequency range              | DC to 300 MHz                                  |
| Max interval rate            | 156.25 MHz                                     |
| Threshold                    | +/-200 mV, +/-2 V, or +/-20 V                  |
| Edge                         | Rising, Falling, Both                          |
| RMS Jitter                   | < 20 ps                                        |
| Optimum edge time            | 6 ns*                                          |

\*Edge times faster than the optimum edge time can lead to a large bias in the measurement. We recommend adding an analog filter with a 60 MHz bandwidth on the input.

### Histogram

|               |            |
|---------------|------------|
| Bins          | Up to 1024 |
| Min bin width | 0.78 ps    |

### Acquisition

|                  |                                                |
|------------------|------------------------------------------------|
| Acquisition mode | Windowed, Gated, Continuous                    |
| Window length    | 1 ms to 10 s                                   |
| Gate source      | Input 1, Input 2, Input 3, Input 4, Ext. trig. |
| Gate threshold   | -20 V to 20 V                                  |
| Interpolation    | None, Linear                                   |

## Intervals

### Intervals

|                              |                                    |
|------------------------------|------------------------------------|
| No. of independent analyzers | 4                                  |
| Start                        | Event A, Event B, Event C, Event D |
| Stop                         | Event A, Event B, Event C, Event D |



### Real-time statistics

Mean, Minimum, Maximum, Count

## Signal output

### Output characteristics

|                           |                      |
|---------------------------|----------------------|
| Number of output channels | 4                    |
| Modes                     | Interval, Count      |
| Zero point                | 0 s to 1 ks          |
| Scaling (Interval)        | 1 mV/s to 100 MV/s   |
| Scaling (Count)           | 10 nV/cnt to 1 V/cnt |
| Range                     | 2 Vpp, 10 Vpp        |

### Data logger

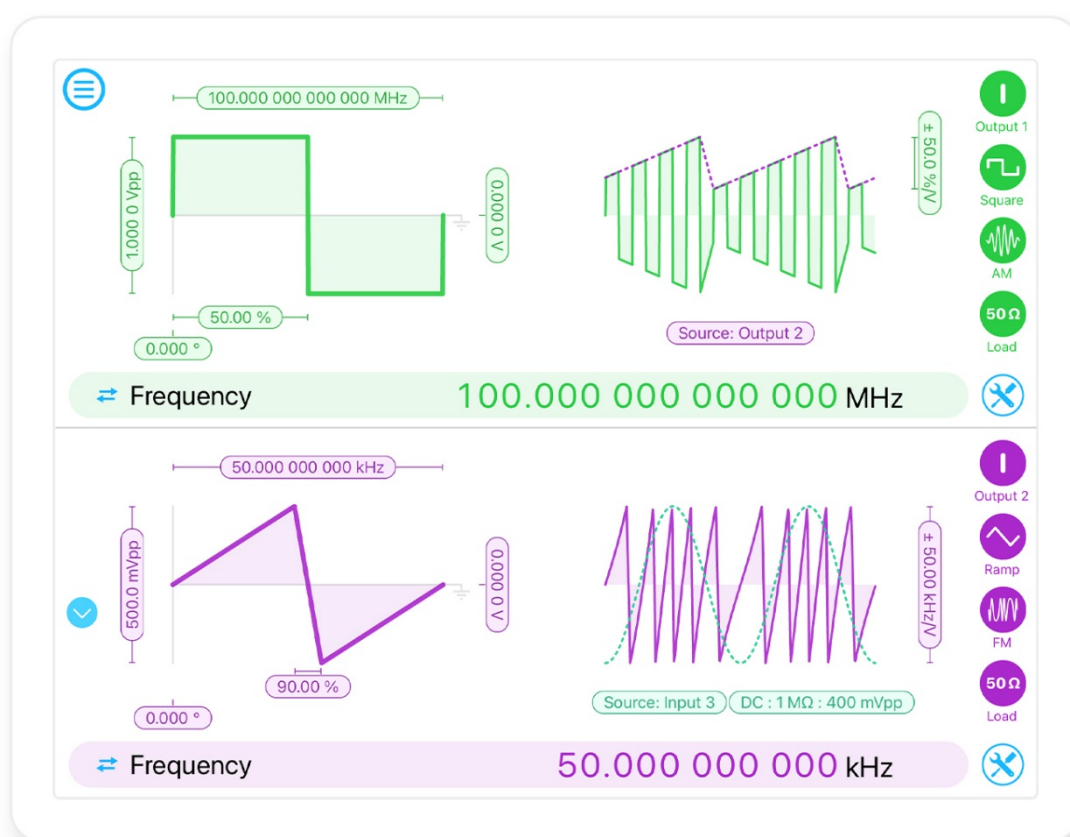
|                  |                                                               |
|------------------|---------------------------------------------------------------|
| Rate             | Up to 156.25 Mevnt/sec burst<br>Up to 10 Mevnt/sec continuous |
| Available memory | 240 GB                                                        |
| Start Mode       | Immediate, Delayed                                            |
| Duration         | 1 ms to 10,000 hours                                          |



# Moku:Pro Waveform Generator

## Description

Moku:Pro Waveform Generator enables you to generate four independent waveforms with a maximum frequency of 500 MHz. Select between sine, square, ramp, pulsed, noise or DC waveform shapes. High-bandwidth modulation of phase, frequency, amplitude, or PWM, or generate triggered bursts or sweeps from an internal or external source.



## Features

- Generate four independent phase coherent waveforms from DC to 500MHz.
- Six built-in waveforms: sine, square, ramp, pulse, noise, and DC.
- Broadband FM, AM, PM, and PWM modulation from internal waveform, cross-channel, or external input sources.
- Versatile trigger options: from input, dedicated TTL trigger port, or another channel.
- 10 MHz reference input and output.



## Common characteristics

### Overview

|                                      |                                                                               |
|--------------------------------------|-------------------------------------------------------------------------------|
| Channels                             | 4                                                                             |
| Bandwidth (maximum output frequency) | 500 MHz (2 V <sub>pp</sub> into 50 Ω), 100 MHz (10 V <sub>pp</sub> into 50 Ω) |
| Sampling rate                        | 1.25 GSa/s per channel                                                        |
| Output impedance                     | 50 Ω                                                                          |
| Waveforms                            | Sine, Square, Ramp, Pulse, Noise, DC                                          |

### Amplitude

|              |                                                    |
|--------------|----------------------------------------------------|
| Range        | 1 mV <sub>pp</sub> to 10 V <sub>pp</sub> into 50 Ω |
| Offset error | < 500 μV into 50 Ω                                 |
| Resolution   | 100 μV                                             |
| Units        | V <sub>pp</sub> , dBm                              |

### DC offset

|                      |                 |
|----------------------|-----------------|
| Range (peak AC + DC) | ± 5 V into 50 Ω |
| Resolution           | 100 μV          |

### Phase offset

|            |            |
|------------|------------|
| Range      | 0° to 360° |
| Resolution | 0.000 001° |

## Waveform characteristics

### Sine

|                 |                  |
|-----------------|------------------|
| Frequency range | 1 mHz to 500 MHz |
|-----------------|------------------|

### Square

|                 |                  |
|-----------------|------------------|
| Frequency range | 1 mHz to 150 MHz |
|-----------------|------------------|

### Ramp

|                 |                  |
|-----------------|------------------|
| Frequency range | 1 mHz to 150 MHz |
|-----------------|------------------|



## Ramp

|                        |                                                                            |
|------------------------|----------------------------------------------------------------------------|
| Symmetry <sup>27</sup> | 16% to 84% at 100 MHz<br>3.2% to 96.8% at 20 MHz<br>0.8% to 99.2% at 5 MHz |
|------------------------|----------------------------------------------------------------------------|

## Pulse

|                      |                              |
|----------------------|------------------------------|
| Frequency range      | 1 mHz to 150 MHz             |
| Period range         | 1 ks to 6.7 ns               |
| Pulse width          | 2 ns to (period – edge time) |
| Edge time            | 2 ns to pulse width          |
| Edge time resolution | 1 ns                         |

## Noise

|            |                            |
|------------|----------------------------|
| Amplitude  | Up to 10 Vpp, minimum 1 mV |
| Resolution | 100 $\mu$ V                |
| DC offset  | Up to 4.998 V              |

# Modulation

## Amplitude

|                     |                                                                                                                                                                                                                                                                                                                                          |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Carrier waveforms   | Sine, Square, Ramp, Pulse, Noise                                                                                                                                                                                                                                                                                                         |
| Source              | Ch1: Input 1, Input 2, Input 3, Input 4, Output 2, Output 3, Output 4, Internal<br>Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal<br>Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal<br>Ch4: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, Internal |
| Internal modulation | Sine                                                                                                                                                                                                                                                                                                                                     |
| Frequency           | 1 mHz to 125 MHz                                                                                                                                                                                                                                                                                                                         |
| Depth               | 0% to 100% (internal)<br>0 - +/- 1000% / V (external)                                                                                                                                                                                                                                                                                    |

<sup>27</sup> Symmetry is limited by the minimum rise time of 2 ns and number of harmonics required to maintain a linearity of more than 99%.



## Frequency

|                                    |                                                                                                                                                                                                                                                                                                                                          |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Carrier waveforms                  | Sine, Square, Ramp, Pulse                                                                                                                                                                                                                                                                                                                |
| Source                             | Ch1: Input 1, Input 2, Input 3, Input 4, Output 2, Output 3, Output 4, Internal<br>Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal<br>Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal<br>Ch4: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, Internal |
| Internal modulation                | Sine                                                                                                                                                                                                                                                                                                                                     |
| Frequency                          | 1 mHz to 125 MHz                                                                                                                                                                                                                                                                                                                         |
| Deviation<br>(carrier + deviation) | 1 mHz to 500 MHz (internal)<br>+/- 2.5 GHz/V (external)                                                                                                                                                                                                                                                                                  |

## Phase

|                     |                                                                                                                                                                                                                                                                                                                                          |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Carrier waveforms   | Sine, Square, Ramp, Pulse                                                                                                                                                                                                                                                                                                                |
| Source              | Ch1: Input 1, Input 2, Input 3, Input 4, Output 2, Output 3, Output 4, Internal<br>Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal<br>Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal<br>Ch4: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, Internal |
| Internal modulation | Sine                                                                                                                                                                                                                                                                                                                                     |
| Frequency           | DC to 125 MHz                                                                                                                                                                                                                                                                                                                            |
| Phase shift         | 0.0° to 3600.0° (internal)<br>0.0 °/V to 3600.0°/V (external)                                                                                                                                                                                                                                                                            |

## Burst

|                    |                                                                                                                                                                                                                                                                                                                                                                                  |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Modes of Operation | Start, N-Cycle, Gated                                                                                                                                                                                                                                                                                                                                                            |
| N-Cycle range      | 1 to 1,000,000                                                                                                                                                                                                                                                                                                                                                                   |
| Trigger Sources    | Ch1: Input 1, Input 2, Input 3, Input 4, Output 2, Output 3, Output 4, Internal, External<br>Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal, External<br>Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal, External<br>Ch4: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, Internal, External |





## Sweep

|                           |                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sweep Frequency Start/End | Sine: 1 mHz to 500 MHz<br>Square, Ramp, Pulse: 1 mHz to 150 MHz                                                                                                                                                                                                                                                                                                                  |
| Sweep Time                | 1 ms to 1 ks                                                                                                                                                                                                                                                                                                                                                                     |
| Trigger Sources           | Ch1: Input 1, Input 2, Input 3, Input 4, Output 2, Output 3, Output 4, External, Internal<br>Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, External, Internal<br>Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, External, Internal<br>Ch4: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, External, Internal |
| Nominal Trigger Level     | Input Channel: configurable<br>Output Channel: configurable<br>External trigger: 1.8 V                                                                                                                                                                                                                                                                                           |

## Pulse Width Modulation

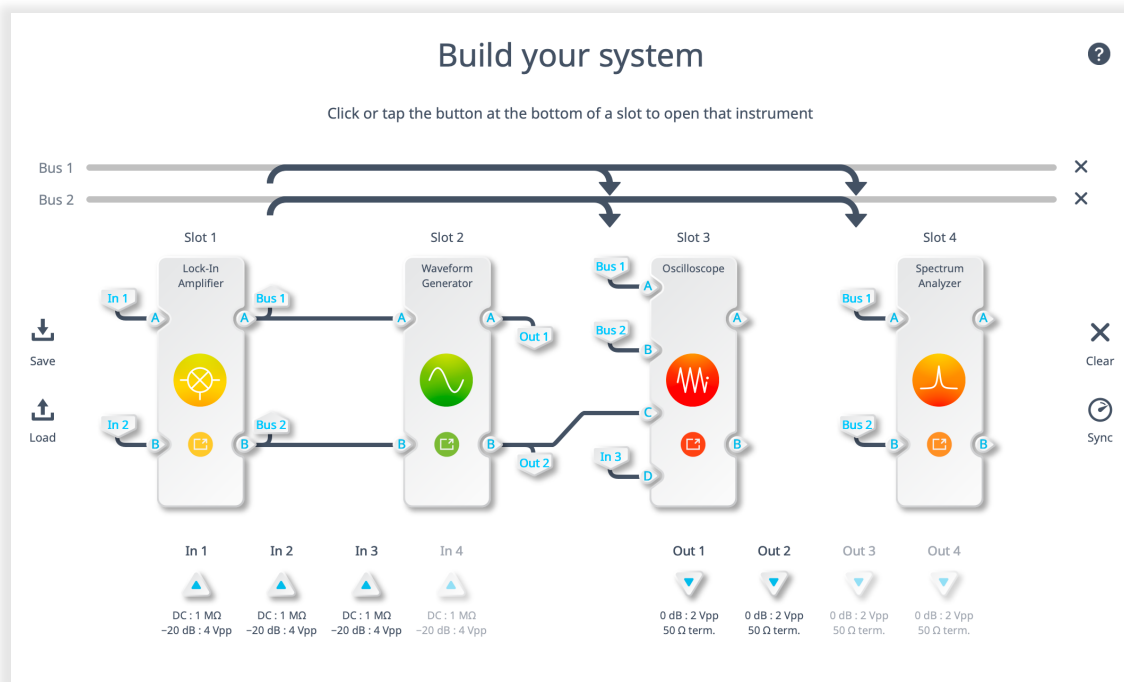
|                       |                                                                                                                                                                                                                                                                                                                                          |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pulse Width Deviation | Programmable pulse width deviation with warnings if pulse width < 0 or exceeds pulse period                                                                                                                                                                                                                                              |
| PWM sources           | Ch1: Input 1, Input 2, Input 3, Input 4, Output 2, Output 3, Output 4, Internal<br>Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal<br>Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal<br>Ch4: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, Internal |



# Moku:Pro Multi-Instrument Mode

## Description

Moku:Pro Multi-Instrument Mode enables you to deploy up to four instruments and operate them simultaneously. These instruments can exchange high-speed, low latency signals between themselves in the digital domain at 5 Gb/s. Source signals from the real world via the blended ADCs and drive signals to the real world via the high-speed digital-to-analog converters. Connect instrument slots to build customized signal processing chains or drop a custom configuration in one slot with Moku Cloud Compile.



## Features

- Configure four independent instruments, operating simultaneously
- Each of the instrument slots has two inputs and two outputs
- Flexible multiplexing allows all four slots to access all four ADC inputs and all four DAC outputs
- High-speed, 5 Gb/s inter-instrument communication with drag and drop setup



- Configurable input and output ranges, one-touch slot synchronization

## Common characteristics

### Overview

|                      |                                                                                                                                                                  |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Instruments          | Up to 4                                                                                                                                                          |
| Inputs / outputs     | 4 analog inputs, 4 analog outputs                                                                                                                                |
| Input ranges         | 0.4 V <sub>pp</sub> into 50 Ω with 0 dB attenuation<br>4 V <sub>pp</sub> into 50 Ω with 20 dB attenuation<br>40 V <sub>pp</sub> into 1 MΩ with 40 dB attenuation |
| Input bandwidth      | 300 MHz                                                                                                                                                          |
| Input sampling rate  | 1.25 GSa/s per channel                                                                                                                                           |
| Input impedance      | 50 Ω / 1 MΩ                                                                                                                                                      |
| Output ranges        | 2 V <sub>pp</sub> , 10 V <sub>pp</sub> into 50 Ω                                                                                                                 |
| Output bandwidth     | 500 MHz at 2 V <sub>pp</sub> , 100 MHz at 10 V <sub>pp</sub>                                                                                                     |
| Output sampling rate | 1.25 GSa/s per channel                                                                                                                                           |
| Output impedance     | 50 Ω                                                                                                                                                             |

### Instrument slot

|                          |                                                                                                                                                                                                                                                                                                                                                 |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Inter-slot communication | 2 channels, each at 16 bits at 312.5 MHz / 5 Gb/s                                                                                                                                                                                                                                                                                               |
| Available instruments    | Arbitrary Waveform Generator<br>Data Logger<br>Digital Filter Box<br>FIR Filter Builder<br>Frequency Response Analyzer<br>Laser Lock Box<br>Lock-in Amplifier<br>Logic Analyzer<br>Neural Network<br>Oscilloscope<br>Phasemeter<br>PID Controller<br>Spectrum Analyzer<br>Time & Frequency Analyzer<br>Waveform Generator<br>Moku Cloud Compile |



This information is subject to change without notice.

© 2025 Liquid Instruments. All rights reserved.



SI Scientific Instruments GmbH  
Roemerstr. 67 | 82205 Gilching

+49 8105 77940  
info@si-gmbh.de

www.si-gmbh.de  
Follow us on: 