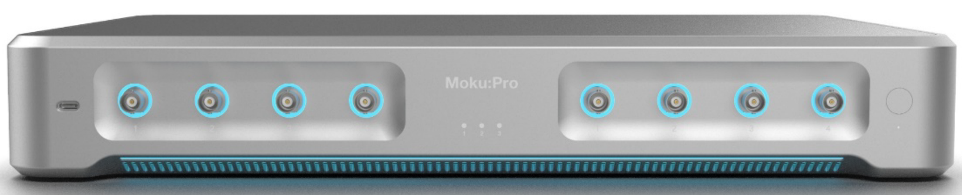
Moku:Pro

Specifications



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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_{pp} into 1 MΩ [1]
Input impedance	50 Ω / 1 MΩ
Input coupling	AC / DC
AC coupling corner (-3 dB) [2]	160 kHz into 50 Ω 16 Hz into 1 MΩ
Input referred noise	30 nV/√Hz at 100 Hz 20 nV/√Hz at 10 MHz (1.25 GSa/s acquisition rate) 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_{pp} into 50 Ω), 100 MHz (10 V_{pp} into 50 Ω)
Sampling rate	1.25 GSa/s per channel
Resolution	16-bit
Voltage range	10 V_{pp} into 50 Ω
Output impedance	50 Ω
Output coupling	DC
Connector	BNC

[1] 50 Ω front-end impedance can only support input voltages up to 4 V_{pp}.
[2] For Moku:Pro devices shipped prior to April 2022, corners are 16 kHz into 50 Ω and 1.6 Hz into 1 MΩ.

Clock reference

Onboard clock

Frequency	10 MHz
Stability	< 300 ppb

10 MHz reference input

Expected waveforms	Sine / square
Input frequency	10 MHz ± 20 kHz
Input range	300 mV_{pp} to 2 V_{pp}
Input impedance	1 kΩ
Input coupling	AC coupled
Connector	BNC

10 MHz reference output

Waveform type	Square
Output frequency	10 MHz
Output level	1.4 V_{PP}
Output impedance	50 Ω
Output coupling	AC coupled
Connector	BNC

Storage

Internal SSD drive	240 GB

General characteristics

General and environmental characteristics

Power consumption	115 W typical
Power voltage range	100 - 240 V~ +/- 10%, 50/60 Hz The equipment shall be plugged into a socket outlet with reliable protective earthing contact.
Temperature	Operating: 0 to +45 °C Non-operating: -10 to +60 °C 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.) Depth: 330 mm (13.0 in.) Height: 65 mm (2.56 in.)
Weight	6.7 kg (14.77 lb)

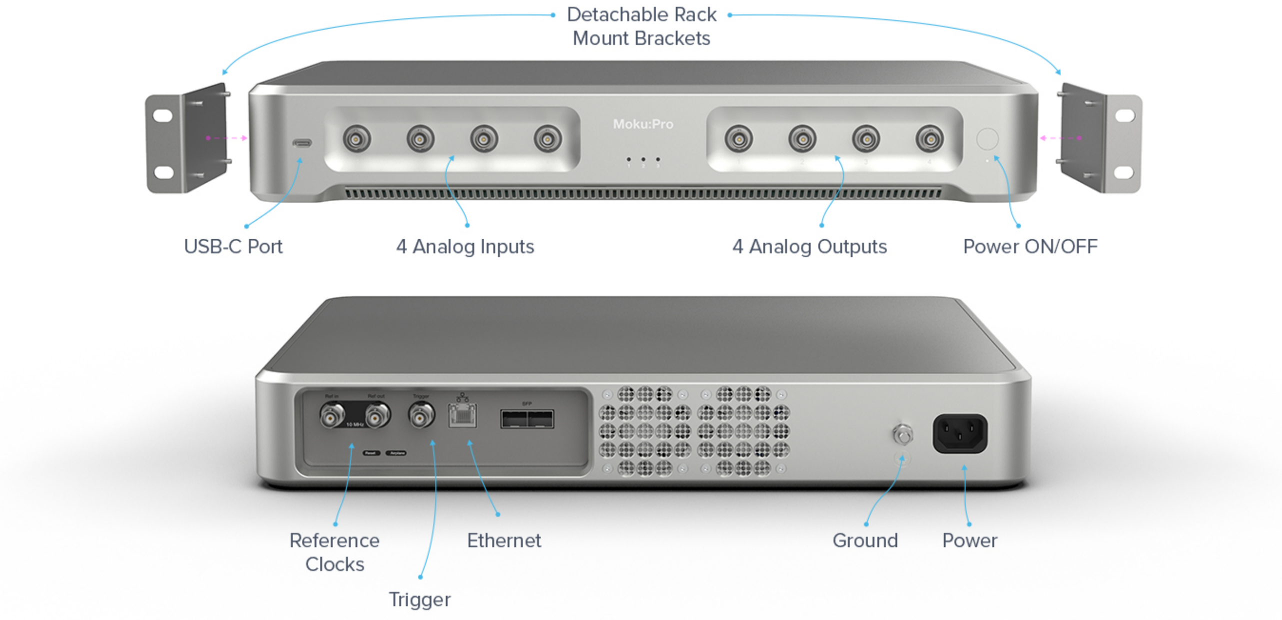
General connectivity

Connectivity

Analog inputs	4 x BNC
Analog outputs	4 x BNC
Network	Ethernet (10/100/1000 Base-T) 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. Please contact the manufacturer/representative office if a replacement mains power supply cord is needed.

Symbols

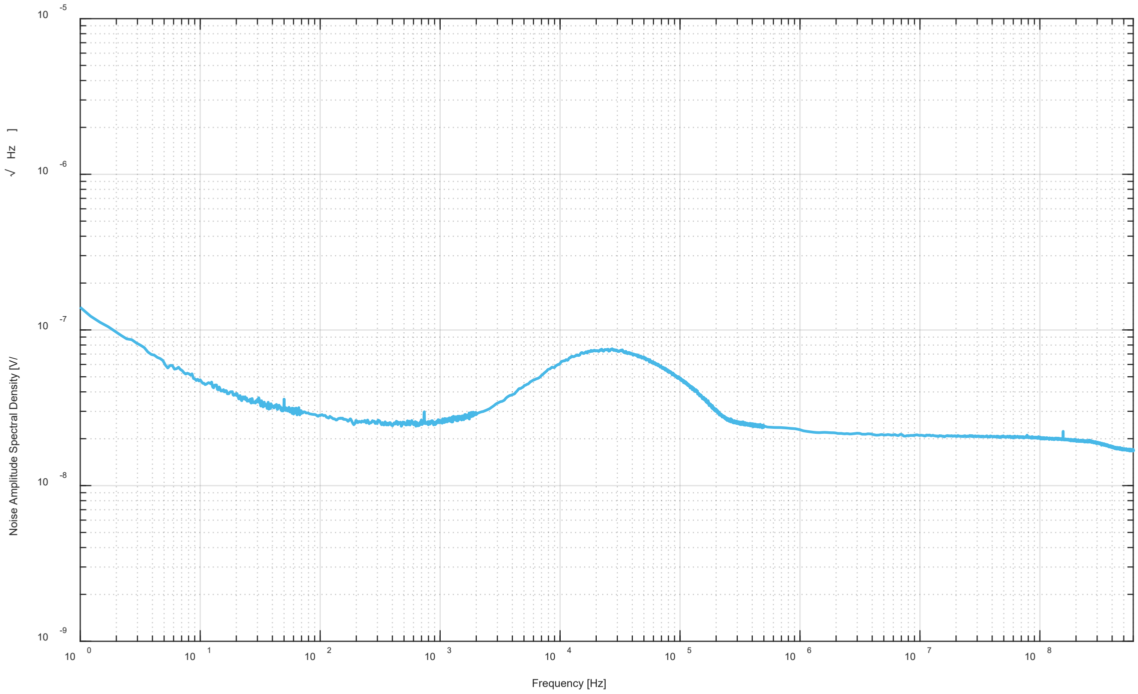
	Caution: Consult accompanying documents
	Warning: Risk of electric shock

Hardware measurements

ADC input noise

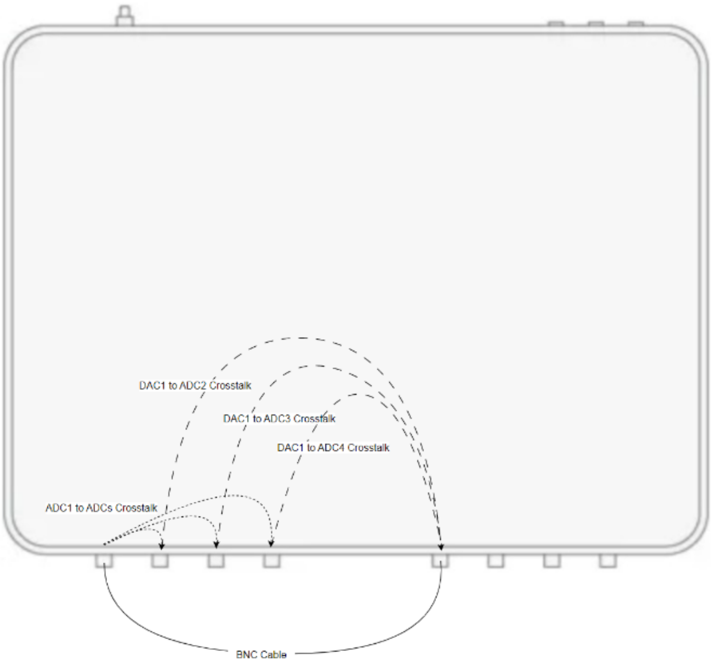
50 Ω // DC coupled // 0 dB attenuation

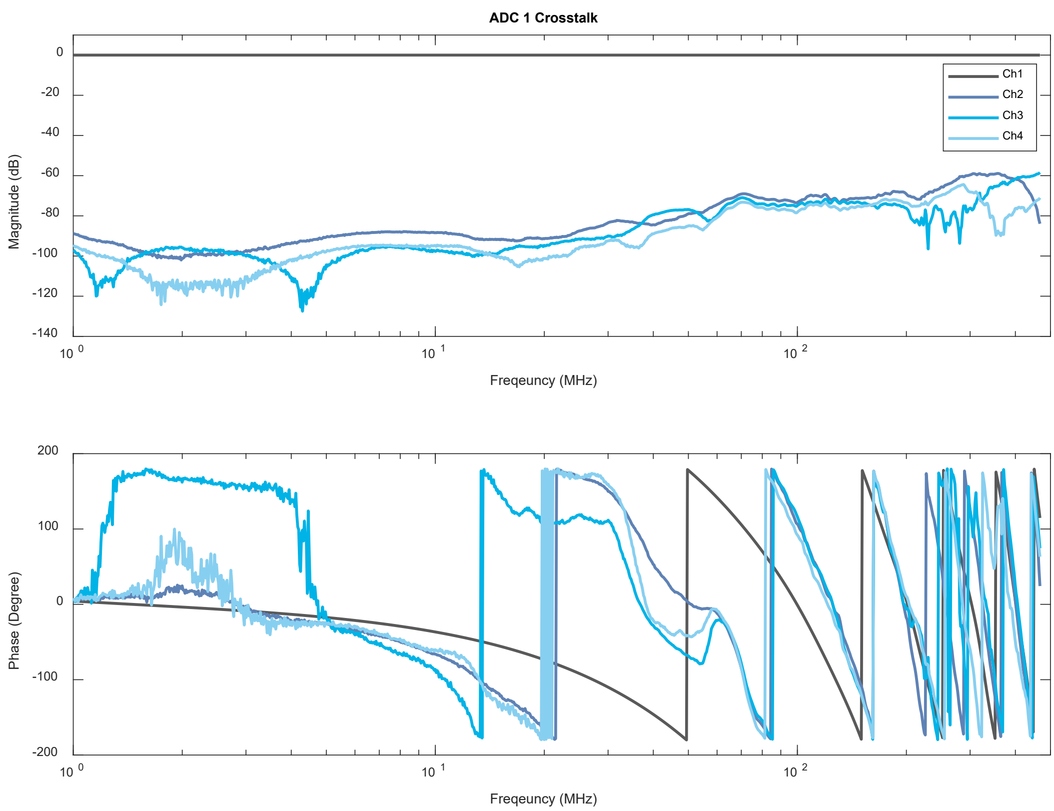
Acquisition mode: Precision

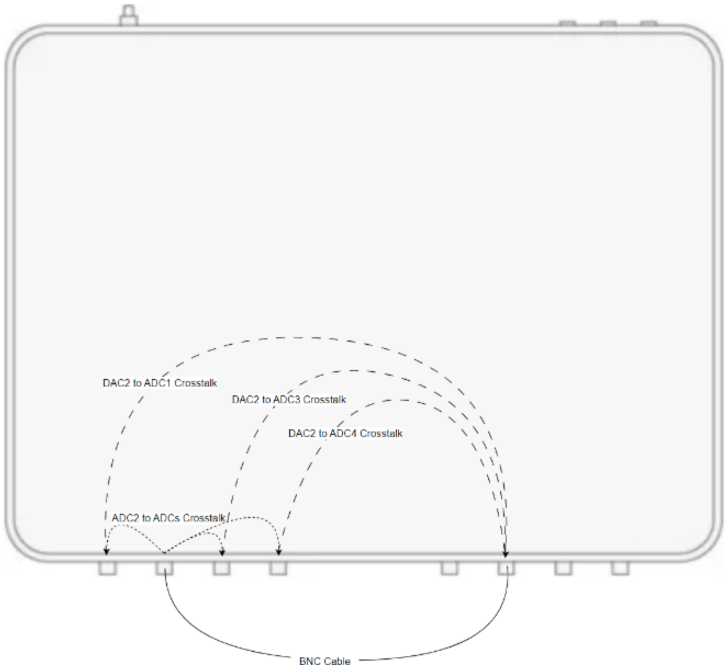


Compound Crosstalk (ADC-ADC & DAC-ADC)

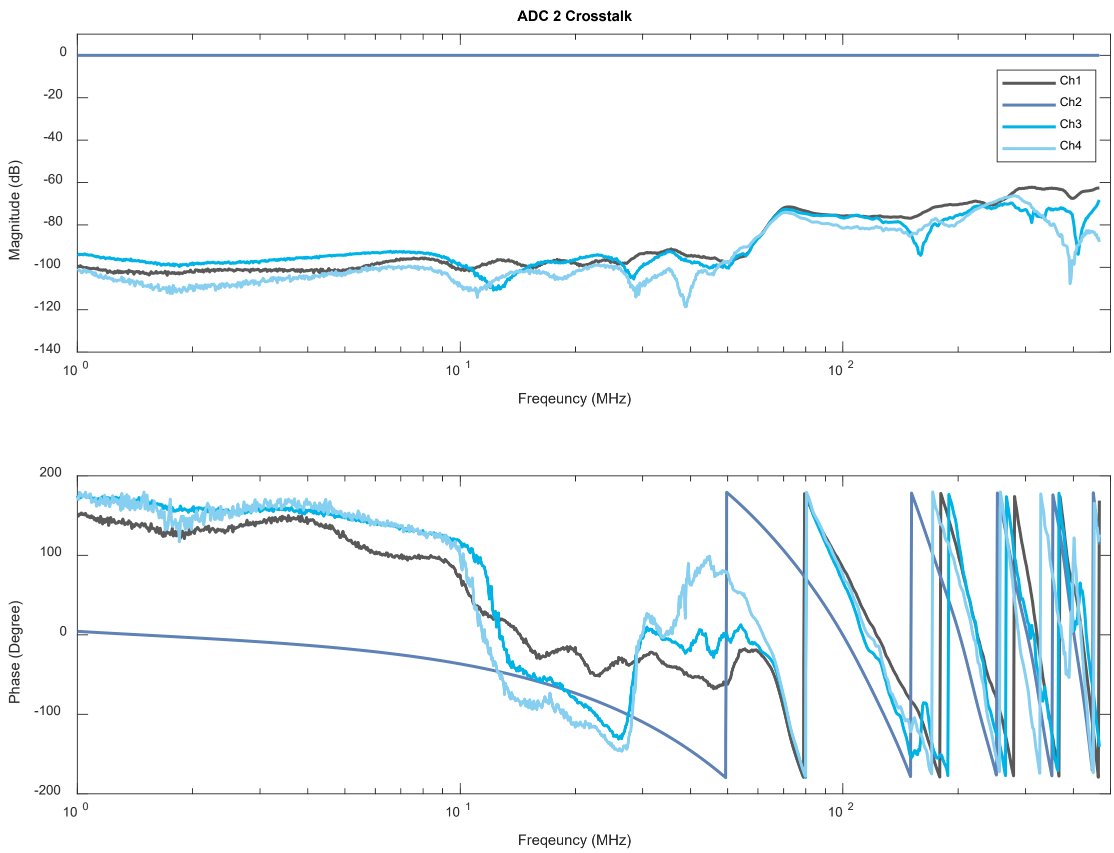
50 Ω // AC coupled // 0 dB attenuation



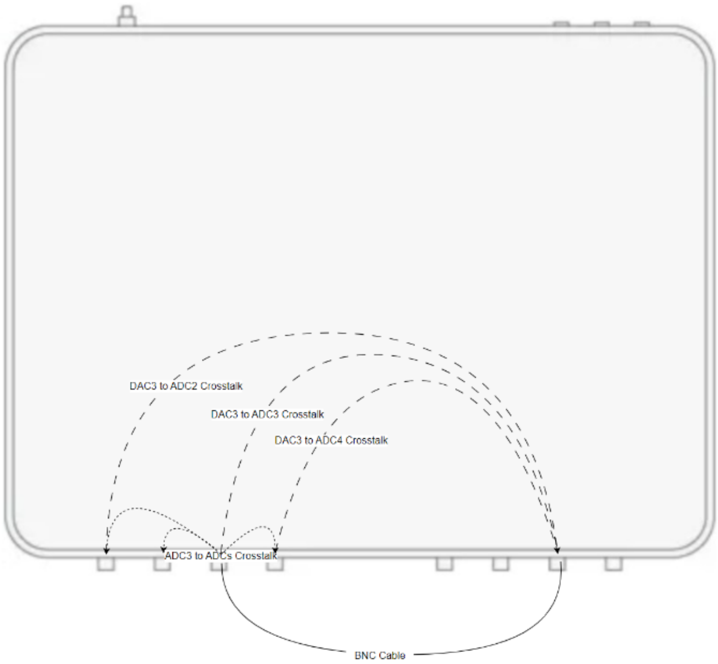


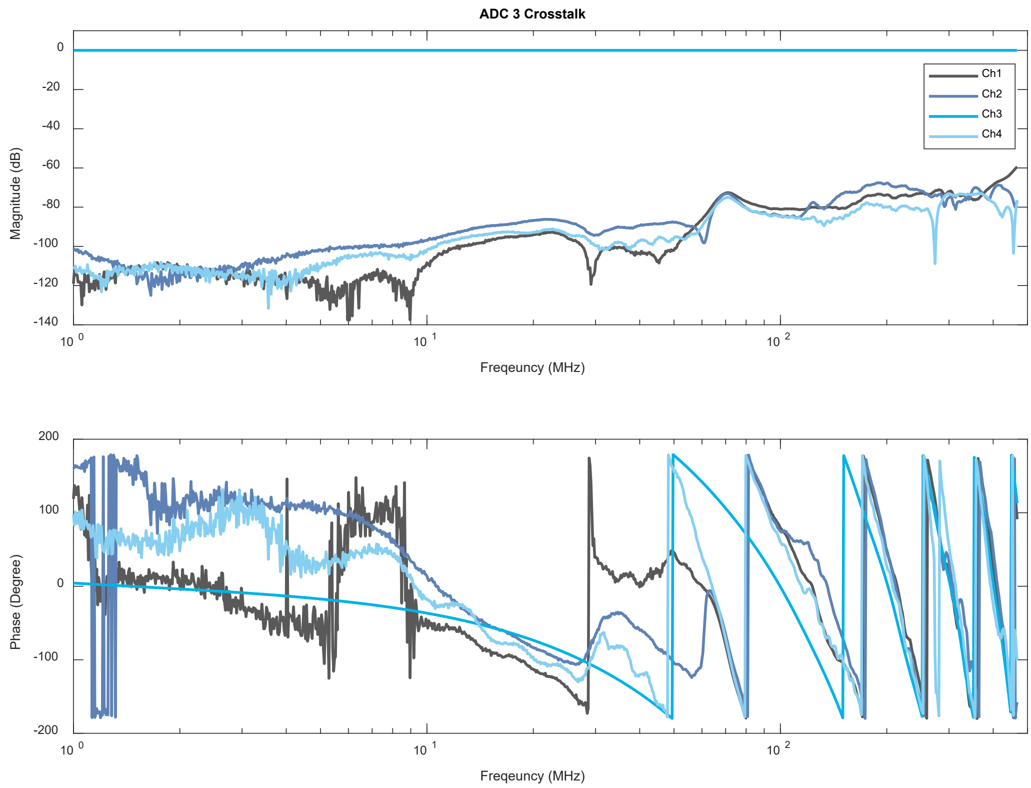


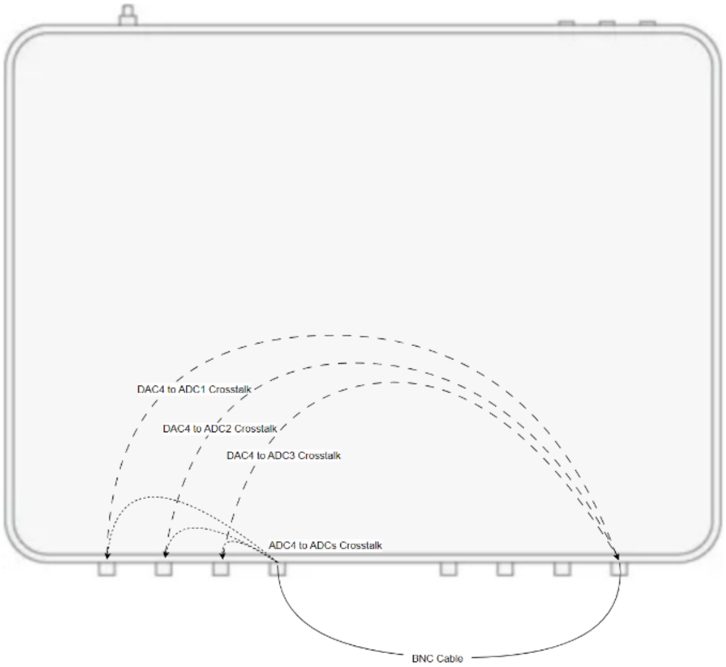
DAC2 to ADC1 Crosstalk
DAC2 to ADC3 Crosstalk
DAC2 to ADC4 Crosstalk
ADC2 to ADCs Crosstalk
BNC Cable

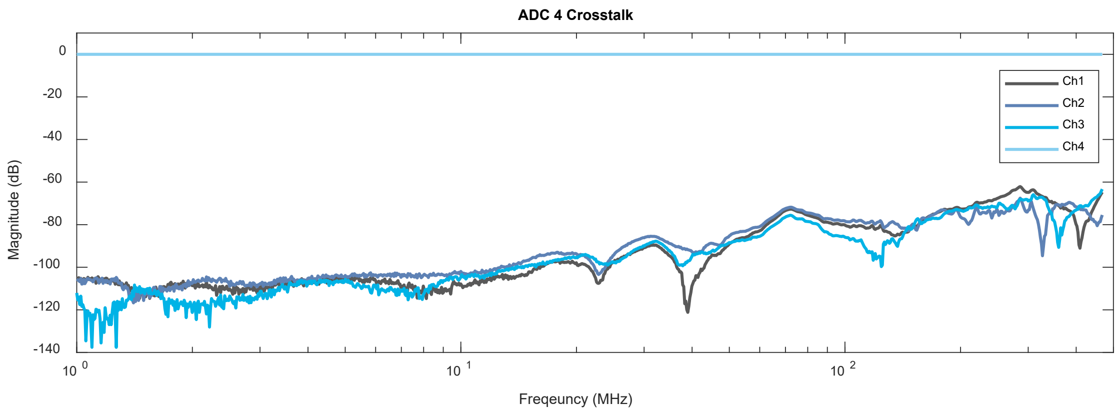


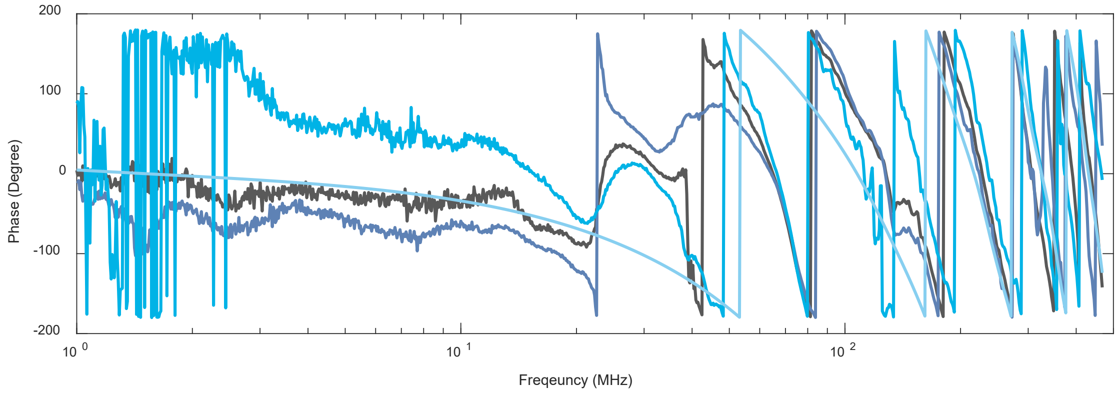
ADC 2 Crosstalk
Magnitude (dB)
0
-20
-40
-60
-80
-100
-120
-140
Ch1
Ch2
Ch3
Ch4
10 0
10 1
10 2
Freqeuncy (MHz)
Phase (Degree)
200
100
0
-100
-200
10 0
10 1
10 2
Freqeuncy (MHz)


DAC3 to ADC2 Crosstalk
DAC3 to ADC3 Crosstalk
DAC3 to ADC4 Crosstalk
ADC3 to ADCs Crosstalk
BNC Cable


ADC 3 Crosstalk
Magnitude (dB)
Freqeuncy (MHz)
Ch1
Ch2
Ch3
Ch4
Phase (Degree)
Freqeuncy (MHz)

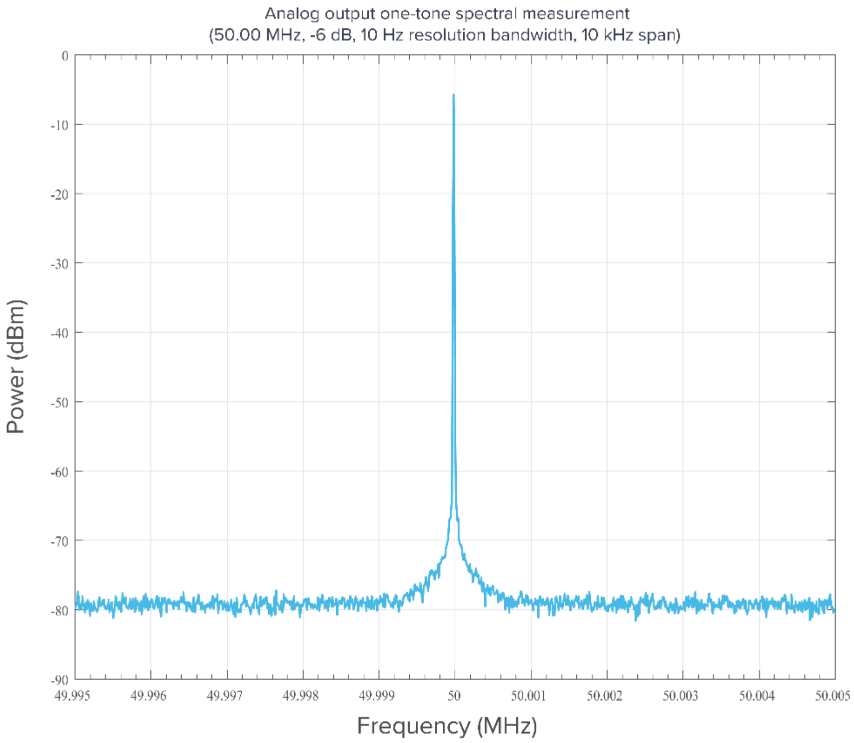

DAC4 to ADC1 Crosstalk
DAC4 to ADC2 Crosstalk
DAC4 to ADC3 Crosstalk
ADC4 to ADCs Crosstalk
BNC Cable


ADC 4 Crosstalk
Magnitude (dB)
0
-20
-40
-60
-80
-100
-120
-140
Ch1
Ch2
Ch3
Ch4
10 0
10 1
10 2
Freqeuncy (MHz)

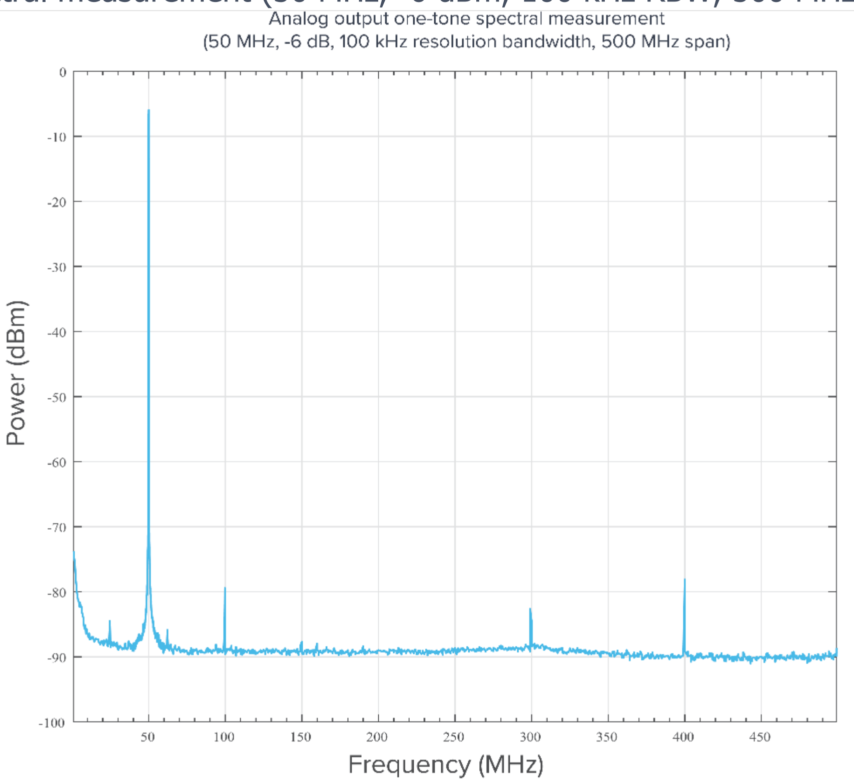

Phase (Degree)
200
100
0
-100
-200
10 0
10 1
10 2
Freqeuncy (MHz)

Analog output noise

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



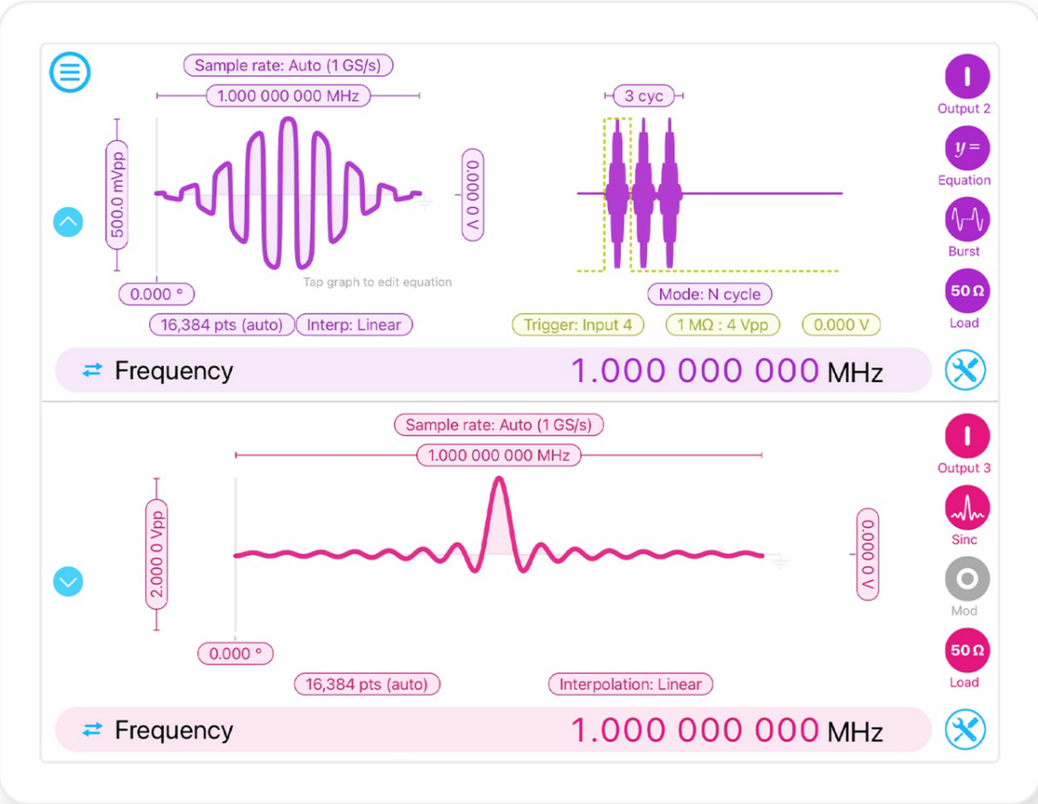
One-tone spectral measurement (50 MHz, -6 dBm, 100 kHz RBW, 500 MHz span)



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 Ω
Output load	50 Ω / 1 MΩ
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 10 Vpp at 312.5 MSa/s
Resolution	100 μV

DC offset

Range (peak AC + DC)	± 5 V into 50 Ω ± 10 V into high impedance
Resolution	100 μV

Phase offset

Range	0º to 360º
Resolution	0.000 001º

Waveform

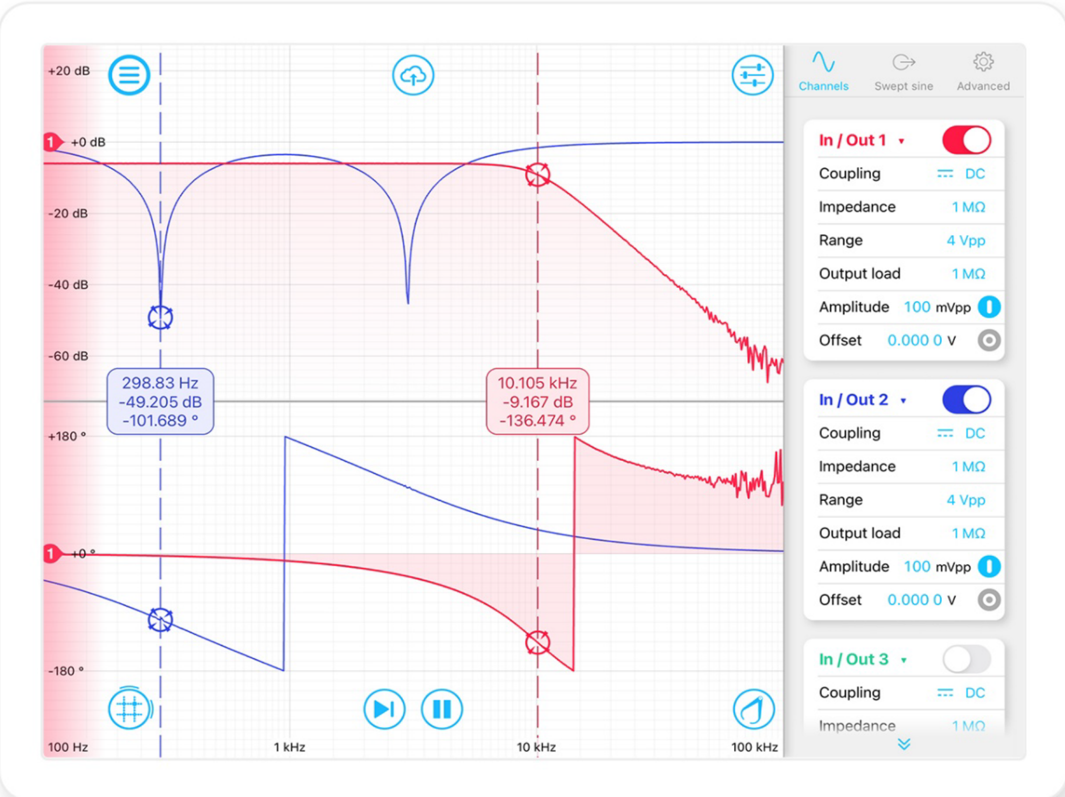
Custom

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	≤ 10% for edge times between 4 ns and 8 ns ≤ 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	±0.5 mV to ±5 V into 50 Ω
Source impedance	50 Ω

Input

Input characteristics

Input impedance	50 Ω / 1 MΩ
Input coupling	AC / DC
Input attenuation	0 dB / 20 dB / 40 dB
Input voltage range	0.4 V_{PP} into 50 Ω with 0 dB attenuation 4 V_{PP} into 50 Ω with 20 dB attenuation 40 V_{PP} into 1 M Ω with 40 dB attenuation
Input noise	30 nV/√Hz @ 100 Hz
Crosstalk	< 60 dB
Noise floor	< 100 kHz: < -125 dBm 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 µs or 1 cycle
	Max.	10.0 seconds
Averaging time	Min.	Greater of 1 µs or 1 cycle
	Max.	10.0 seconds
Normalization	Normalizes magnitude and phase using a reference sweep[3]	
Absolute gain error	< 0.05 dB	
Absolute phase error	< 0.5º	

[3] 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

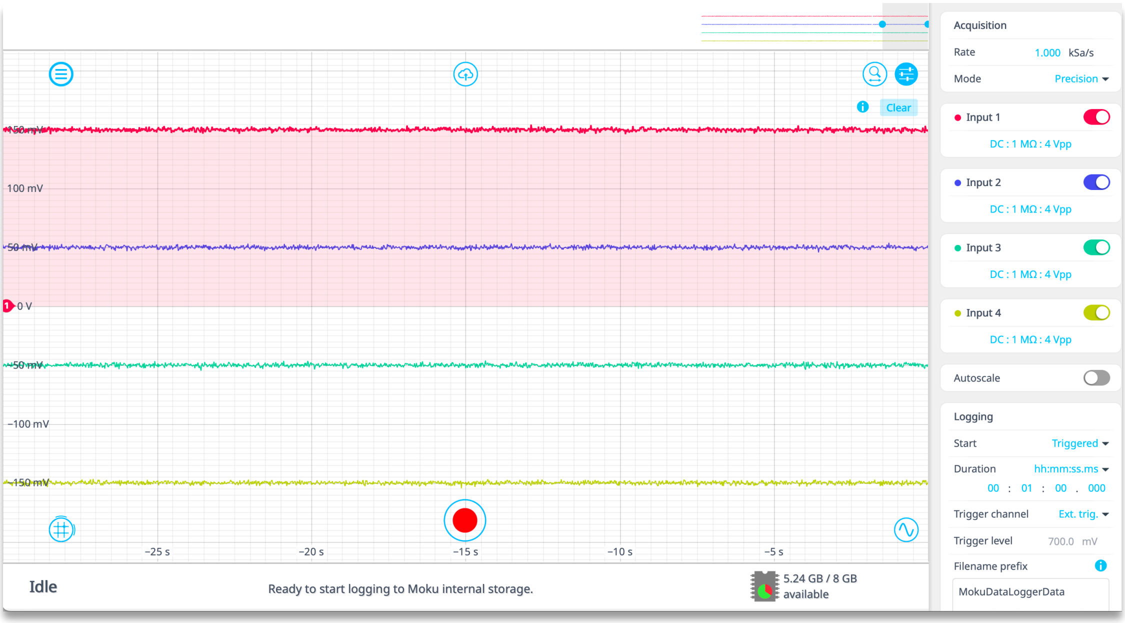
Saving data

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 nV √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_{PP} into 50 Ω with 0 dB attenuation 4 V_{PP} into 50 Ω with 20 dB attenuation 40 V_{PP} into 1 MΩ with 40 dB attenuation
Input impedance	50 Ω / 1 MΩ
Input coupling	AC / DC

Logging

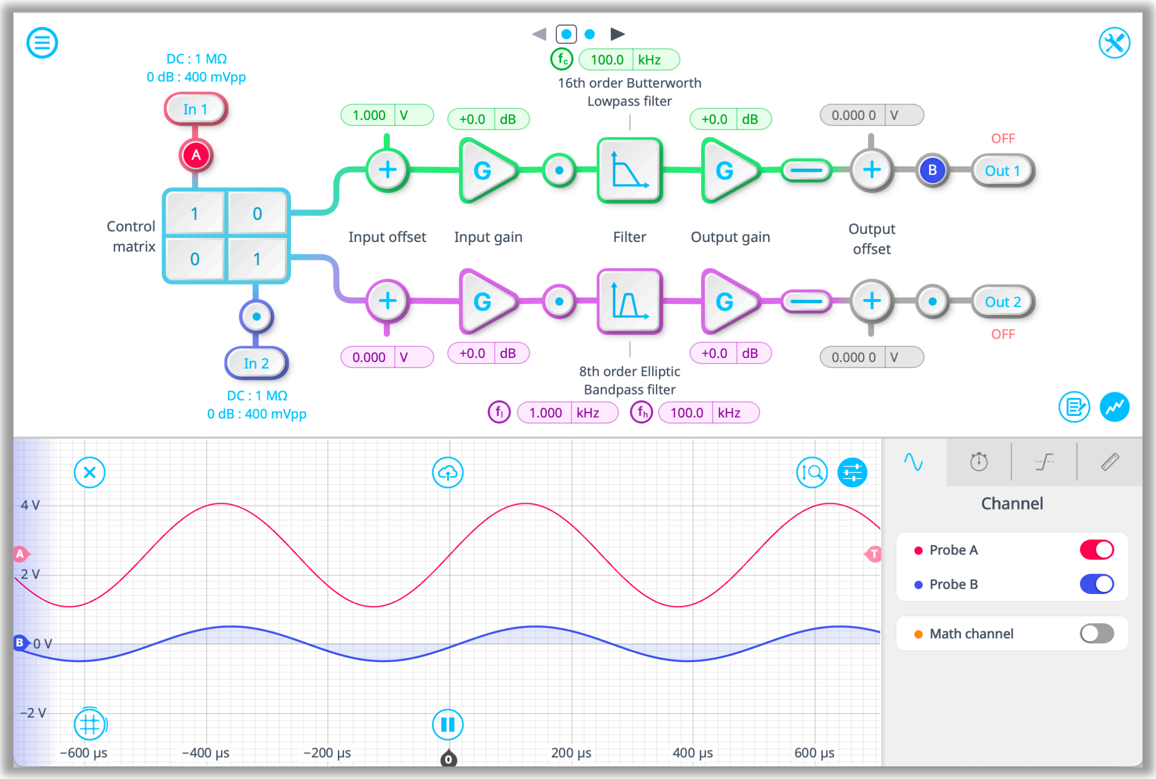
Acquisition

File formats	Binary: Records data using a proprietary LI format for high-speed data logging. 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 5 MSa/s for 2 channels 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[4]
- 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

[4] 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 Ω / 1 MΩ
Input coupling	AC / DC
Input attenuation	0 dB / 20 dB / 40 dB
Input voltage range	0.4 V_{pp} into 50 Ω with 0 dB attenuation 4 V_{pp} into 50 Ω with 20 dB attenuation 40 V_{pp} into 1 MΩ with 40 dB attenuation

Filter characteristics

Pre-filter

Input offset range	± 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	± 1 V
Output offset resolution	100 uV
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 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 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 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 440.6 Hz to 17.58 MHz at 39.063 MHz sampling rate
Minimum bandwidth	390 mHz at 305.18 kHz sampling rate 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 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 57.5 Hz to 17.58 MHz at 39.063 MHz sampling rate
Minimum bandwidth	390 mHz at 305.18 kHz sampling rate 50 Hz at 39.063 MHz sampling rate

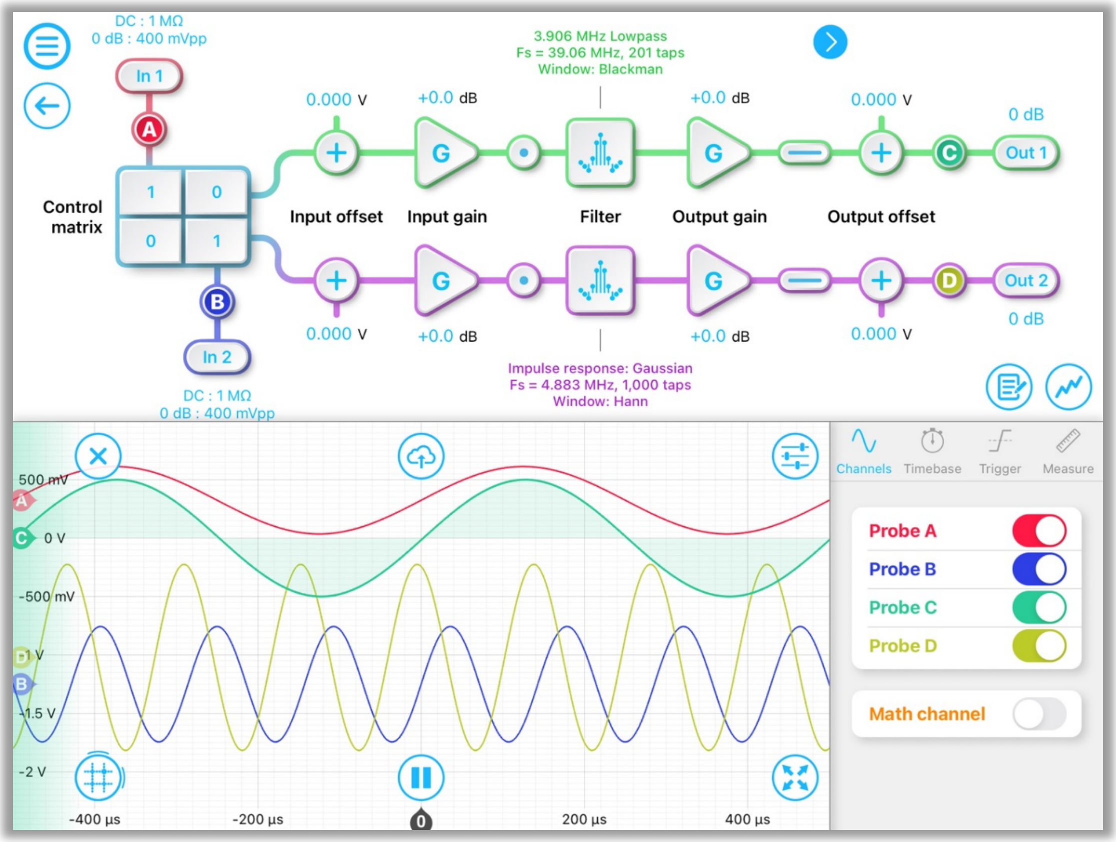
Selecting the right IIR filter

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[5]

Specifications

Inputs

Input characteristics

Channels	4
Input control matrix coefficients	-20 to +20
Input impedance	50 Ω / 1 MΩ
Input coupling	AC / DC
Input attenuation	0 dB / 20 dB / 40 dB
Input voltage range	0.4 V_{pp} into 50 Ω with 0 dB attenuation 4 V_{pp} into 50 Ω with 20 dB attenuation 40 V_{pp} into 1 MΩ with 40 dB attenuation

Filter characteristics

Pre-filter

Input offset range	± 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	± 1 V
Output offset resolution	100 uV
Output gain range	-40 dB to +40 dB
Output gain resolution	0.1 dB

[5] See Moku:Pro Data Logger or Moku:Pro Oscilloscope for specifications on integrated instruments

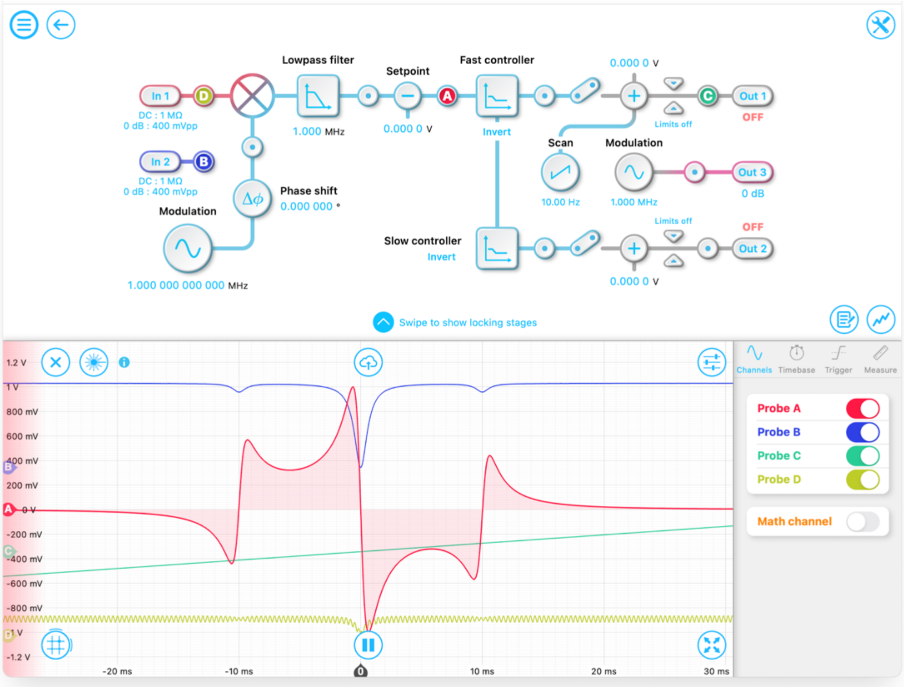
General filter characteristics

Sampling rates	305.18 kHz, 610.4 kHz, 1.221 MHz, 2.441 MHz, 4.883 MHz, 9.766 MHz, 19.53 MHz, 39.06 MHz
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 e.g. 30.52 Hz at sample rate of 305.2 kHz
Maximum filter cut-off frequency	Sampling rate / 2 (approximately) 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 250th 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[6]
- 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

[6] 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 Ω / 1 MΩ
Frequency range	DC to 600 MHz
Input gain[7]	-40 dB / -20 dB / 0 dB / +24 dB / +48 dB
Gain accuracy	± 1%
Input range	40 V_{pp} with -40 dB input gain 4 V_{pp} with -20 dB input gain 0.4 V_{pp} with 0 dB input gain 25 mV_{pp} with +24 dB input gain[7] 1.6 mV with +48 dB input gain[7]
Input noise	< 20 nV/√Hz above 1 MHz at 400 mV_{pp} input range

Internal demodulation local oscillator

Internal reference waveform	
Waveform	Sine
Frequency range	1 mHz to 600 MHz
Frequency resolution	1 μHz
Phase offset range	0 to 360º
Phase offset resolution	0.000 001º
Output impedance	50 Ω
Can be phase-locked to external 10 MHz timebase?	Yes

[7] +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 Ω / 1 MΩ
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 External with phase-locked loop with multiply to 250^{th} harmonic or divide down to $1/8^{th}$ 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 360º
Phase offset resolution	0.000 001º
Orthogonality	90º ± 0.000,002º
PLL multiplier	$1/8^{th}$ 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[8]	0.1 dB to 10 dB
Stopband attenuation[9]	10 dB to 100 dB

[8] Applies to Chebyshev I and Elliptical filter types.
[9] 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 μHz
Amplitude range (AC)	1 mV_{pp} to 10 V_{pp} into 50 Ω
Amplitude resolution	1 mV
Offset range (DC)	± 1 V
Output limit (AC + DC)	± 1 V with 0 dB ± 5 V with 14 dB
Amplitude accuracy	1%
Output impedance	50 Ω
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 μHz
Amplitude range (AC)	1 mV_{pp} to 2 V_{pp} into 50 Ω
Amplitude resolution	1 mV
Offset range (DC)	± 1 V
Output limit (AC + DC)	± 5 V into 50 Ω
Amplitude accuracy	1%
Output impedance	50 Ω

PID Controllers

Set point

Set point range	-1 V to +1 V
Set point resolution	100 μV

Fast controller

Sampling rate	78 MHz
Proportional gain	± 60 dB
Integrator crossover frequency	3.125 Hz to 312.5 kHz. (single integrator) 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

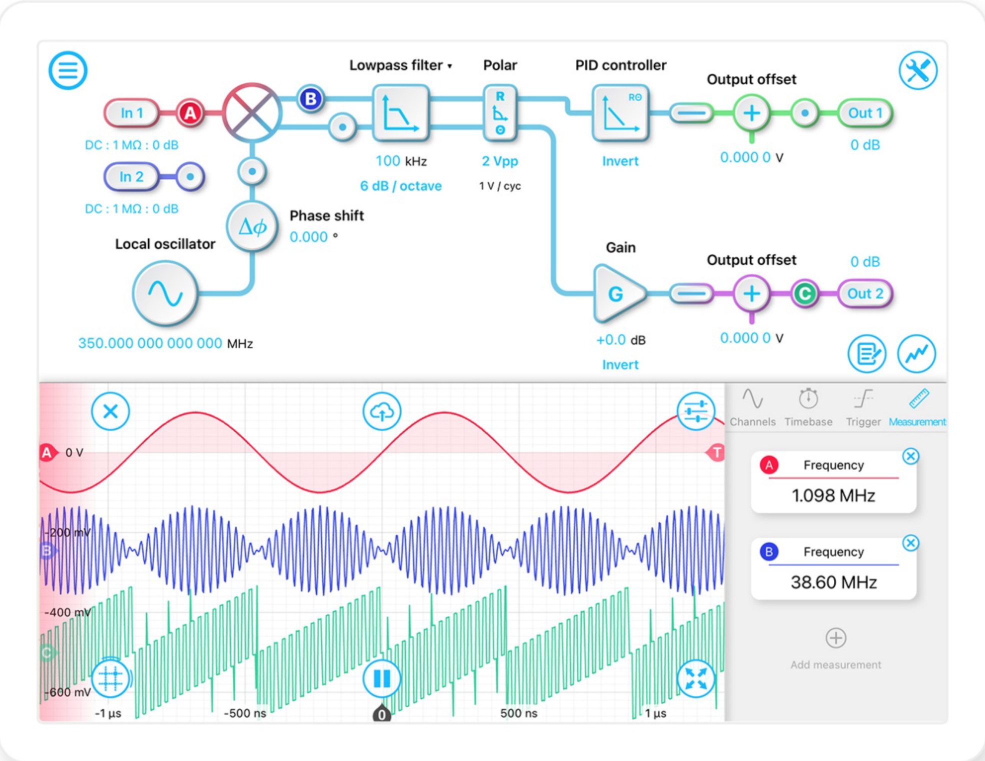
Slow controller

Sampling rate	1.22 MHz
Proportional gain	± 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/Rθ) from 1 mHz to 600 MHz, at up to the 250th 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[10]
- Demodulate signals with an internal local oscillator, or external local oscillator at the fundamental or up to 250th harmonic
- Toggle between rectangular (X/Y mode) or polar coordinates (R/θ mode)

[10] 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 Ω / 1 MΩ
AC coupling corner (-3 dB)[11]	160 kHz into 50 Ω 16 Hz into 1 MΩ
Frequency range	DC to 600 MHz
Input attenuation	0 dB / 20 dB / 40 dB
Input range	0.4 V_{pp} with 0 dB input attenuation 4 V_{pp} with 20 dB input attenuation 40 V_{pp} with 40 dB input attenuation
Input noise	< 30 nV/√Hz above 100 Hz at 400 mV_{pp} input range < 200 nV/√Hz above 10 kHz at 400 mV_{pp} input range < 20 nV/√Hz above 1 MHz at 400 mV_{pp} input range

External reference

Reference input

Input coupling	AC / DC
Input impedance	50 Ω / 1 MΩ
Frequency range	DC to 600 MHz
Input attenuation	0 dB / 20 dB / 40 dB
External reference modes	Direct, phase-locked
Direct demodulation	X = Rcosθ

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 360º
Phase resolution	0.000 001º
Demodulation	XY / Rθ
PLL multiplier	1/8th to 250x of the fundamental

[11] For Moku:Pro devices shipped prior to April 2022, corners are 16 kHz into 50 Ω and 1.6 Hz into 1 MΩ.

Internal reference

Internal reference waveforms

Waveform	Sine
Frequency range	1 mHz to 600 MHz
Frequency resolution	1 μHz
Phase range	0 to 360º
Phase resolution	0.000 001º
Demodulation	XY / Rθ

Internal reference auxiliary output

Amplitude range	1 mV_{pp} to 10 V_{pp} into 50 Ω
Amplitude resolution	1 mV
Frequency range	1 mHz to 500 MHz
Offset range	± 1 V
Output limit (AC + DC)	± 1 V with 0 dB ± 5 V with 14 dB
Amplitude accuracy	1%
Output impedance	50 Ω
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 External with phase-locked loop with multiply to 250^{th} harmonic or divide down to $1/8^{th}$ of fundamental
Types	Internal: XY / Rθ External direct: X = Rcosθ External with PLL: XY / Rθ
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 001º
Dynamic reserve	> 120 dB

Signal output

Output characteristics

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

PID controller

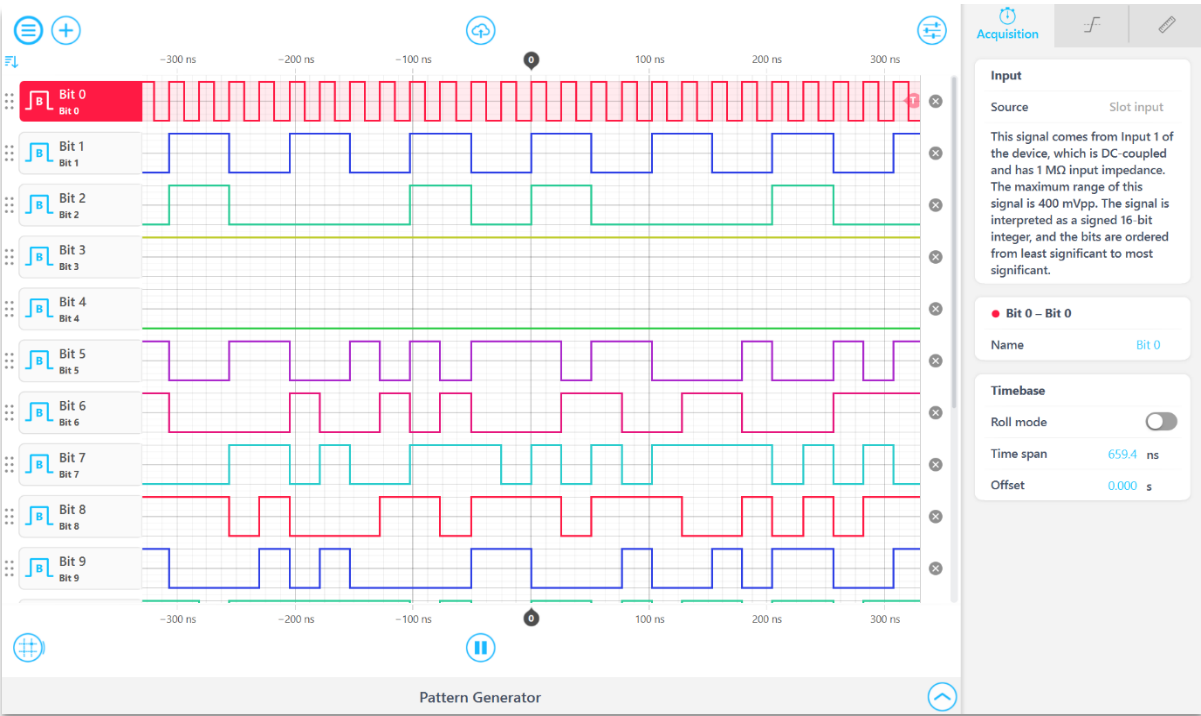
Controller frequency range	DC to 40 MHz
Proportional gain	± 120 dB (XY mode), ± 60 dB (Rθ mode)
Integrator crossover frequency	3.125 Hz to 312.5 kHz
Int. saturation crossover frequency	3.125 Hz to integrator crossover frequency
Integrator gain range	Proportional gain to +120 dB (XY mode), +80 dB (Rθ 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 (Rθ mode)

[12] Only one output may have a PID controller enabled at a time

Moku:Pro Logic Analyzer (Multi-instrument Mode)

Description

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



Features

- 16-bit single channel[14] 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 × 16 points input memory depth, 32,764 × 16 points output memory depth.
- Decode up to two protocols at a time, including UART, SPI, I^2C, I^2S, CAN, and Parallel bus
- Powerful, intuitive graphical user interface with Python, and MATLAB API support.

[13] 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.
[14] 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[15]

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 1st to 65,535th event	
Holdoff	up to 10 seconds	
Trigger types	Edge or pulse	

[15] 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^2C	
Address size	7 bits
SCL[16]	Serial clock bit
SDA	Serial data bit
Max decoder frequency	> 1 MHz

[16] Some protocols like I^2C and I^2S 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.

I²S

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

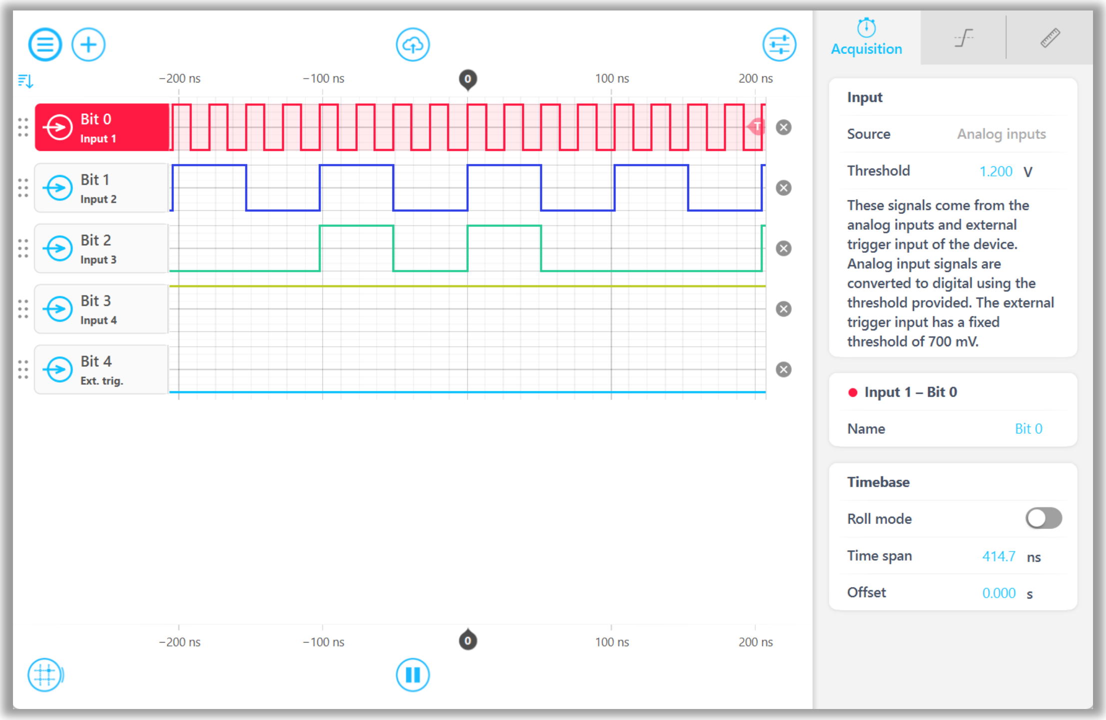
Export types

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[17] 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[18] 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^{2}C, I^{2}S, CAN, and Parallel bus
- Powerful, intuitive graphical user interface with Python, and MATLAB API support.

[17] 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.
[18] 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[19]

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 1st to 65,535th 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

[19] 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

I²C

Address size	7 bits
SCL[20]	Serial clock bit
SDA	Serial data bit
Max decoder frequency	> 1 MHz

I²S

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

[20] Some protocols like I²C and I²S 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

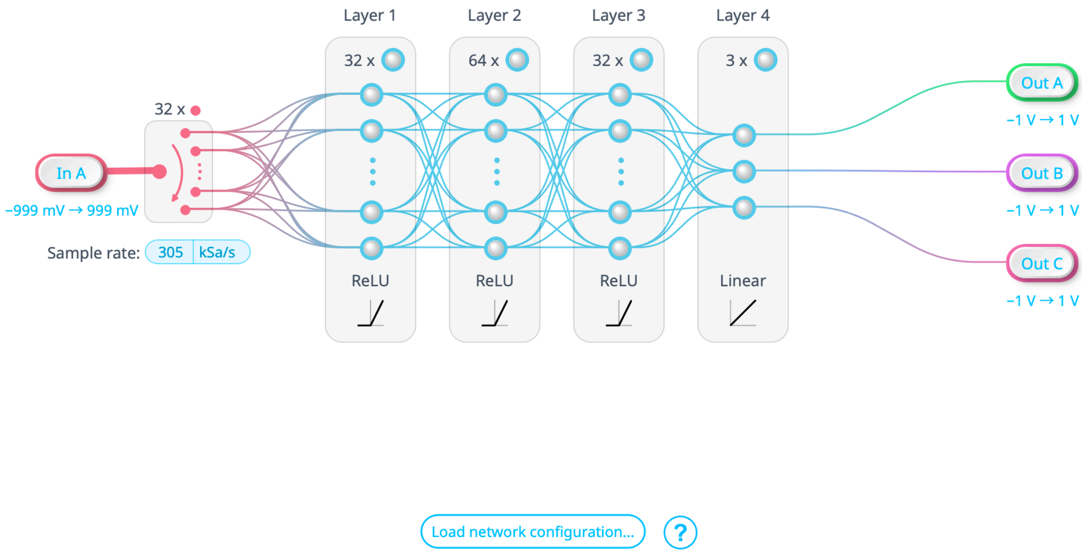
Export types

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[21] 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.



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

[21] 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 30nV/ √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 nV/ √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 Ω / 1 MΩ
Input bandwidth (-3 dB)	300 MHz / 600 MHz switchable
Input voltage range	0.4 V_{pp} into 50 Ω with 0 dB attenuation 4 V_{pp} into 50 Ω with 20 dB attenuation 40 V_{pp} into 1 MΩ with 40 dB attenuation
Input voltage noise	< 30 nV/√Hz above 10 Hz at 400 mV_{pp} input range < 200 nV/√Hz above 1 kHz at 400 mV_{pp} input range < 20 nV/√Hz above 10 MHz at 400 mV_{pp} input range (1.25 GSa/s acquisition rate) < 13 nV/√Hz above 10 MHz at 400 mV_{pp} 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[22], 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

[22] 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^{st} to $65{,}535^{th}$ event	
Holdoff	3.2 ns to 10 seconds	
Trigger types	Edge: Rising edge, falling edge, both edges Pulse: Positive / negative polarity • 10.0 seconds > **pulse width** > 3.2 nanoseconds	

Trigger sensitivity

Sensitivity modes	Auto:	Automatically configures trigger sensitivity based on horizontal and vertical scales Select *Noise Reject* or high-frequency *HF Reject* options
	Manual:	Manually configure trigger sensitivity
Manual modes	Relative, Absolute	
Hysteresis	Relative: 0.01 div to 5.00 div Absolute: 100 μV 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.
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

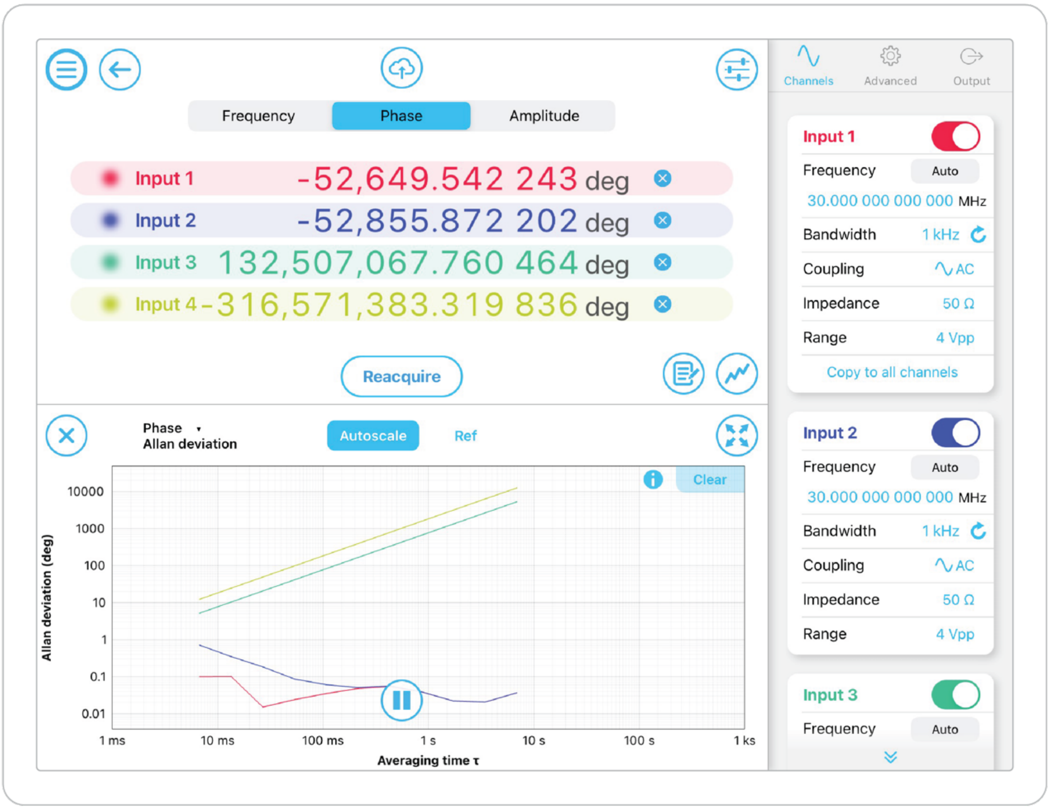
Channels	4
Output impedance	50 Ω
Waveforms[23]	Sine, Square, Ramp, Pulse, Noise, DC
Output frequency range	1 mHz to 500 MHz
Output voltage range	> 100 MHz: 2 V_{pp} into 50 Ω 1 mHz to 100 MHz: 10 V_{pp} into 50 Ω

[23] 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 1/8th 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_{pp} into 50 Ω with 0 dB attenuation 4 V_{pp} into 50 Ω with 20 dB attenuation 40 V_{pp} into 1 MΩ with 40 dB attenuation
Input impedance	50 Ω / 1 MΩ
Input coupling	AC / DC

Measurement

Measurement characteristics

Phase error	0.1 μradian/√Hz @ 10 Hz	
Phase precision	1 nano radian	
Frequency precision	1 μHz	
Modes of operation	Auto-acquire	Automatically determines input frequency for signals above 1 MHz
	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) Drive measured signal phase, frequency offset, or amplitude with user-defined scaling and configurable DC offset
Output range	2 Vpp or 10 Vpp

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. 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[24]

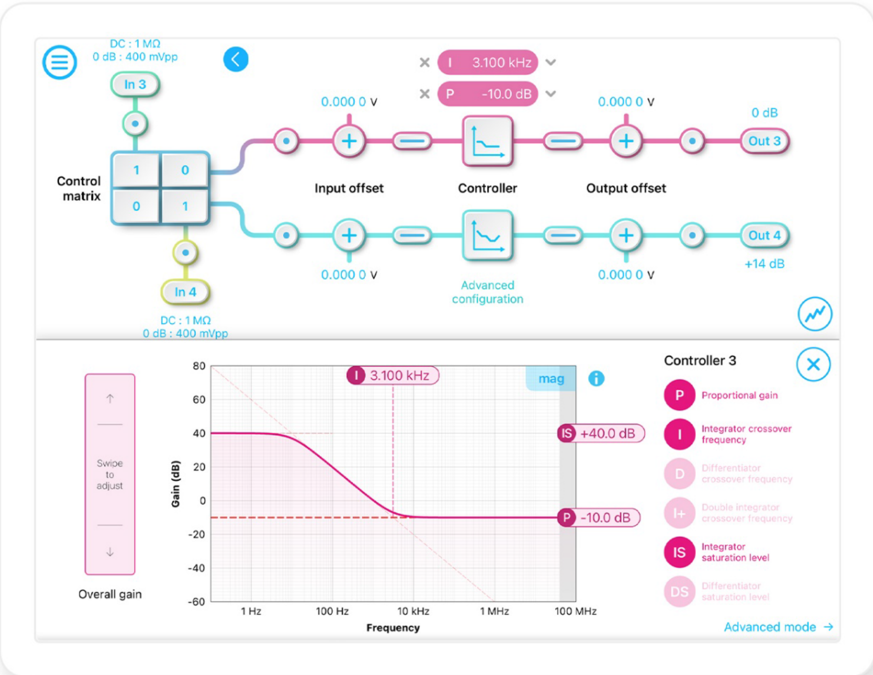
Channels	4
Output impedance	50 Ω
Waveform shape	Sine
Output modes	Manual, phase-locked to input signal, with scaling to 250x harmonic or division to 1/8th
Sampling rate	1.25 GSa/s per channel
Voltage range	± 5 V into 50 Ω

[24] 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[25]

[25] 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 Ω / 1 MΩ
Input coupling	AC / DC
Input attenuation	0 dB / 20 dB / 40 dB
Input voltage range	0.4 V_{pp} into 50 Ω with 0 dB attenuation 4 V_{pp} into 50 Ω with 20 dB attenuation 40 V_{pp} into 1 MΩ 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 Ω
Offset precision	100 µV

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 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 The differentiator saturation crossover frequency cannot be higher than 3.125 MHz

Moku:Pro Spectrum Analyzer

Description

Moku:Pro Spectrum Analyzer allows you to observe input signals in the frequency domain between DC and 300 MHz with an ultralow noise floor. View four channels simultaneously with a resolution bandwidth as low as 618.5 mHz and a minimum span of 100 Hz. The Spectrum Analyzer also features four 500 MHz sinewave generators.

Features

- 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 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 Ω / 1 MΩ
Input attenuation	0 dB / 20 dB
Input bandwidth (-3 dB)	300 MHz / 600 MHz switchable
Input voltage range	0.4 V_{pp} into 50 Ω with 0 dB attenuation 4 V_{pp} into 50 Ω with 20 dB attenuation 40 V_{pp} into 1 MΩ 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

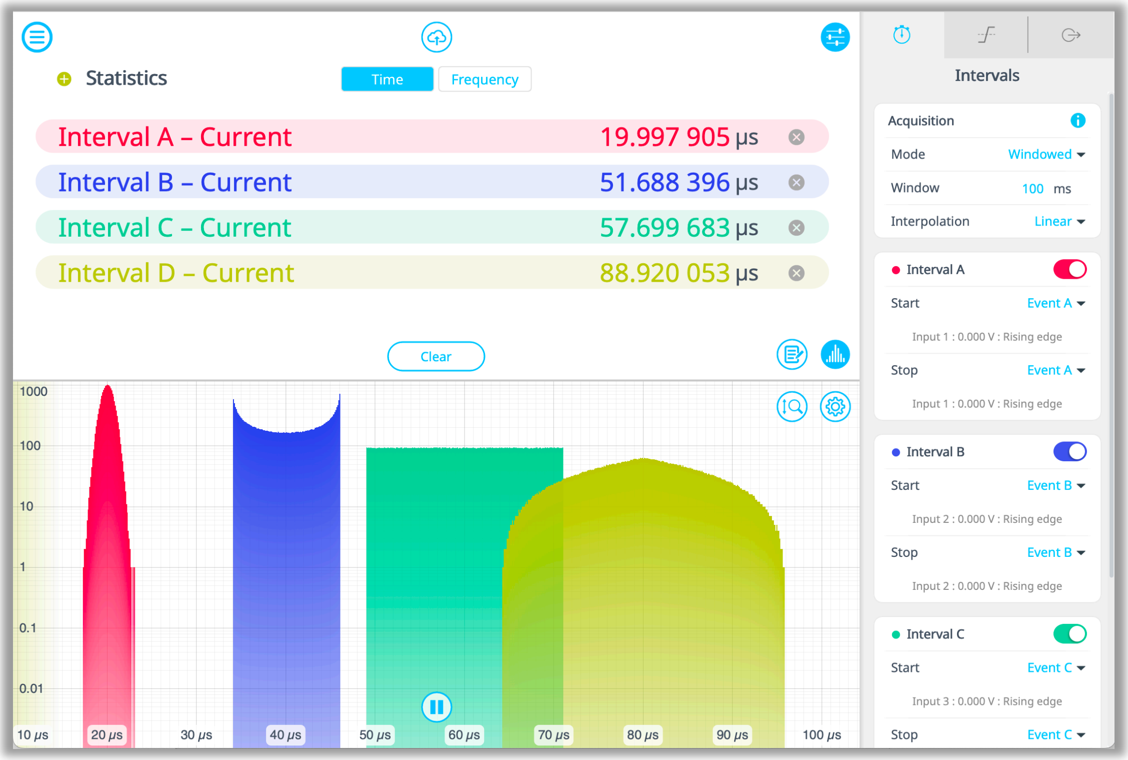
Synthesizer	
Channels	4
Output impedance	50 Ω
Waveforms[26]	Sine
Output frequency range	1 mHz to 500 MHz
Sweep mode	Sweeps the output frequency across the current span with a fixed sweep period of 5 seconds
Output voltage range	> 100 MHz: 2 V_{pp} into 50 Ω 1 mHz to 100 MHz: 10 V_{pp} into 50 Ω

[26] 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 Ω / 1 MΩ
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
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

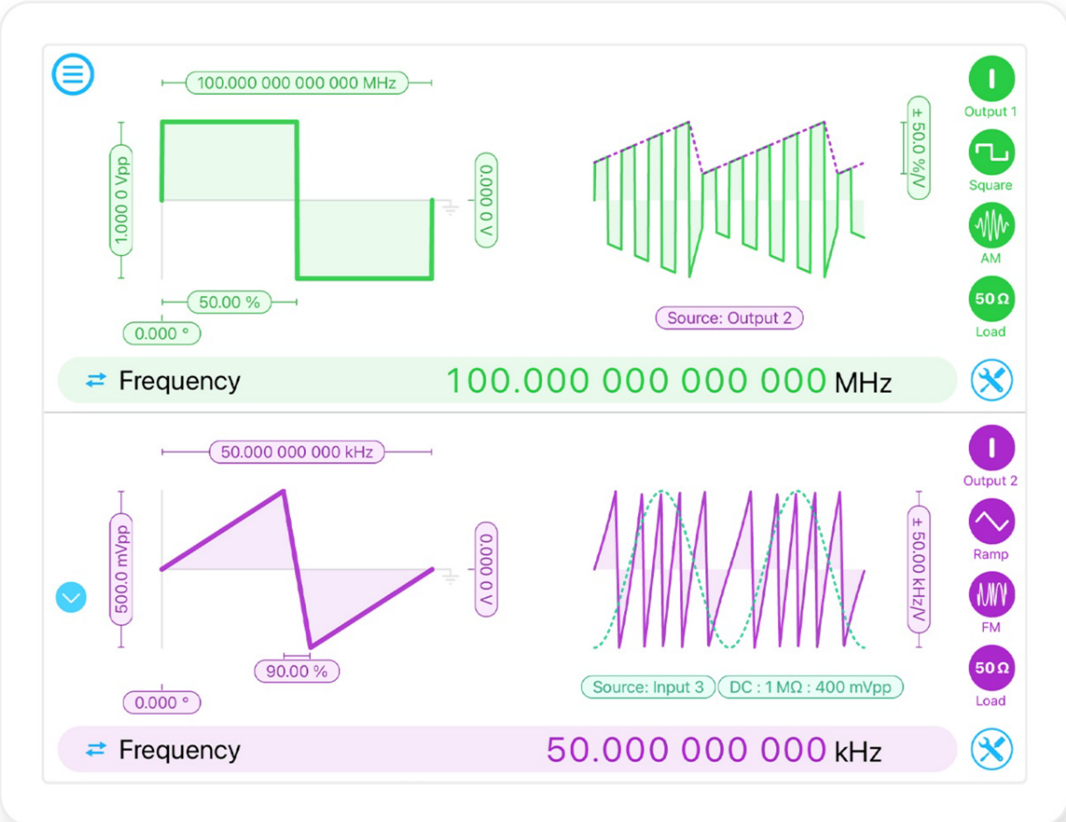
Data logger

Rate	Up to 156.25 Mevnt/sec burst 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_{pp} into 50 Ω), 100 MHz (10 V_{pp} 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_{pp} to 10 V_{pp} into 50 Ω
Offset error	< 500 µV into 50 Ω
Resolution	100 µV
Units	V_{pp}, dBm

DC offset

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

Phase offset

Range	0º to 360º
Resolution	0.000 001º

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
Symmetry[27]	16% to 84% at 100 MHz 3.2% to 96.8% at 20 MHz 0.8% to 99.2% at 5 MHz

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

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 µV
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 Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal 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) 0 - +/- 1000% / V (external)

Frequency

Carrier waveforms	Sine, Square, Ramp, Pulse
Source	Ch1: Input 1, Input 2, Input 3, Input 4, Output 2, Output 3, Output 4, Internal Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal 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 (carrier + deviation)	1 mHz to 500 MHz (internal) +/- 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 Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal 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	0.0º to 3600.0º (internal) 0.0 º/V to 3600.0º/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 Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal, External Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal, External 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 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 Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, External, Internal Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, External, Internal Ch4: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 3, External, Internal
Nominal Trigger Level	Input Channel: configurable Output Channel: configurable External trigger: 1.8 V

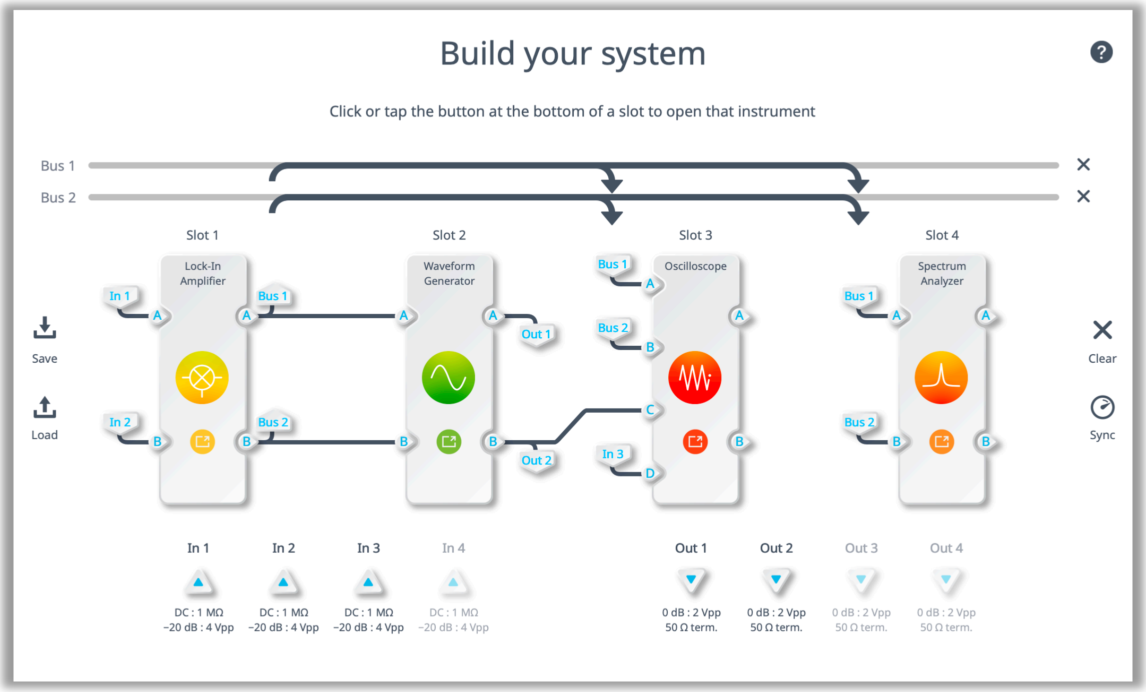
Pulse Width Modulation

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 Ch2: Input 1, Input 2, Input 3, Input 4, Output 1, Output 3, Output 4, Internal Ch3: Input 1, Input 2, Input 3, Input 4, Output 1, Output 2, Output 4, Internal 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 to you 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_{pp} into 50 Ω with 0 dB attenuation 4 V_{pp} into 50 Ω with 20 dB attenuation 40 V_{pp} 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 M Ω
Output ranges	2 V_{pp}, 10 V_{pp} into 50 Ω
Output bandwidth	500 MHz at 2 V_{pp}, 100 MHz at 10 V_{pp}
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 Data Logger Digital Filter Box FIR Filter Builder Frequency Response Analyzer Laser Lock Box Lock-in Amplifier Logic Analyzer Neural Network Oscilloscope Phasemeter PID Controller Spectrum Analyzer Time & Frequency Analyzer Waveform Generator Moku Cloud Compile

This information is subject to change without notice.