Waveform Generator
Moku:Pro User Manual

The Moku:Pro Waveform Generator is designed to generate common signals with high accuracy and configurability across four independent output channels. The outputs are precisely adjustable for frequency, phase, and amplitude. Further, the outputs may be modulated with a variety of internally generated or external signals and triggered from flexible, programmable triggers.

© 2024 Liquid Instruments. All rights reserved.
V24-0609

Table of Contents

User Interface **4**

Main Menu **5**

Output Configuration **6**

Enable / disable outputs 6

Termination 6

- Selecting the correct termination 6

Phase synchronization 6

Waveform types 7

- Sine wave 7
- Square wave 8
- Ramp wave 9
- Pulse wave 10
- Noise 11
- DC wave 12

Modulation types 13

- Amplitude modulation 13
- Frequency modulation 14
- Phase modulation 15
- Pulse-width modulation 16
- Triggered modulation modes 17

Instrument Reference **19**

Waveform types 19

- Sine wave 19
- Square wave 19
- Ramp wave 19
- Pulse wave 19
- Noise 19
- DC 19

Waveform parameters 20

- Amplitude 20
- Frequency 20
- Offset 20
- Phase 20
- Symmetry 20
- Pulse width 20
- Edge time 20
- Duty cycle 21
- DC level 21

Modulation types and trigger modes 21

- Modulation sources 21
- Trigger sources 21
- Amplitude modulation 22
- Frequency modulation 22
- Phase modulation 22
- Pulse-width modulation 22
- Burst mode 23
- Sweep mode 23

© 2024 Liquid Instruments. All rights reserved.

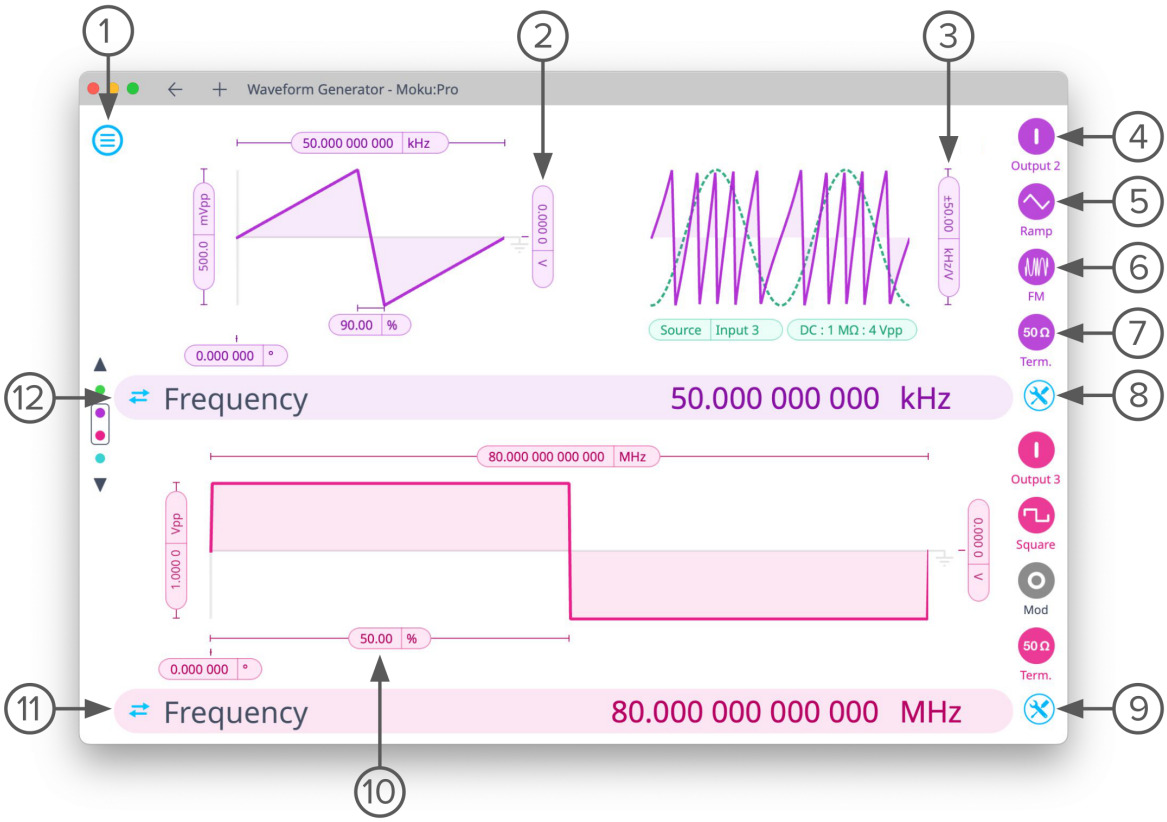
Ensure Moku:Pro is fully updated. For the latest information, visit:

liquidinstruments.com

© 2024 Liquid Instruments. All rights reserved.

User Interface

Moku:Pro is equipped with four output channels. You can tap the ^ or v icons to navigate between channels.

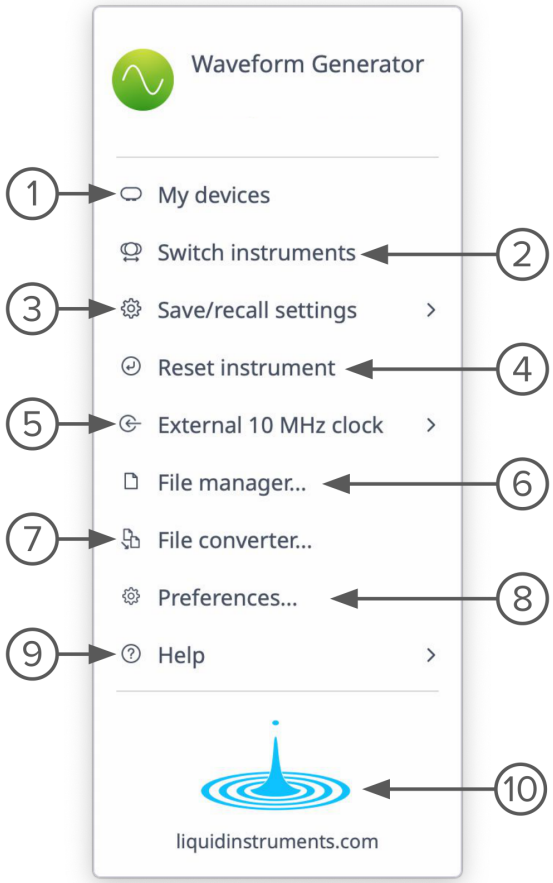


ID	Description	ID	Description
1	Main menu	**7**	Configure output load (50 Ω or 1 MΩ)
2	Configure offset	**8**	Settings (Ch 2)
3	Configure modulation depth	**9**	Settings (Ch 3)
4	Enable / disable output	**10**	Configure square duty cycle
5	Waveform shape	**11**	Switch parameter representations
6	Configure modulation	**12**	Switch parameter representations

© 2024 Liquid Instruments. All rights reserved.

Main Menu

The main menu can be accessed by pressing the icon, allowing you to:



ID	Description
1	Select device or return to selection screen
2	Select instrument or return to instrument selection screen
3	Save and load instrument settings
4	Reset the instrument to its default state (cannot be undone)
5	Enable or disable external 10 MHz reference clock
6	Open File manager to access saved data files
7	Open File converter to convert ".li" data files to other formats
8	Access settings for app theme and channel colors
9	Help • Access the Liquid Instruments website • Show the Moku Shortcuts list • Access the Instrument Manual • Report a bug to Liquid Instruments • About – show app version, check update, or license information
10	Launch the liquidinstruments.com website

© 2024 Liquid Instruments. All rights reserved.

Output Configuration

Enable / disable outputs



shows the output channel is disabled, tap to enable.



shows the output channel is enabled, tap to disable.

Termination

Select between 50 Ω and 1 MΩ termination impedance.

Selecting the correct termination

Moku:Pro's outputs have an impedance of 50 Ω. As such, voltages supplied to a 50 Ω load will be reduced by a factor of two due to the voltage divider formed by the closed circuit. Moku:Pro compensates for this voltage division into 50 Ω loads by doubling the output voltage that is displayed on the interface. A consequence of this is that the voltage measured across a high-impedance load will be *twice* the value displayed on the interface since the voltage division of the high-impedance circuit is comparably small.

Selecting a termination of 1 MΩ does not double the amplitude of the generated signal.

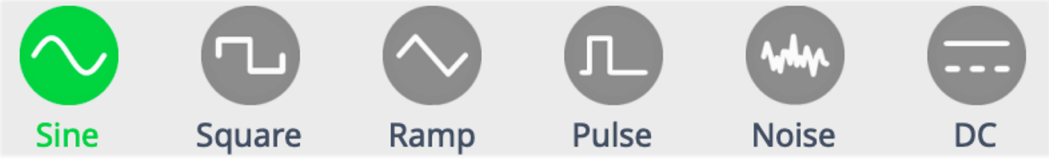
Phase synchronization

The phase of the two outputs can be synchronized by selecting the Configuration options button and then tapping **Sync phase**.

© 2024 Liquid Instruments. All rights reserved.

Waveform types

Each channel can be set to generate one of six predefined waveforms.



Each of Sine, Square, Ramp, and Pulse can be configured for Frequency, Amplitude, Offset and Phase.

The Square wave is low jitter and symmetric (50% duty cycle)

The Ramp type has a variable symmetry setting, while the Pulse provides a highly configurable square wave with variable duty and slew rate.

The DC setting provides an accurate and stable voltage reference.

The noise type provides approximately Gaussian white noise.

Sine wave

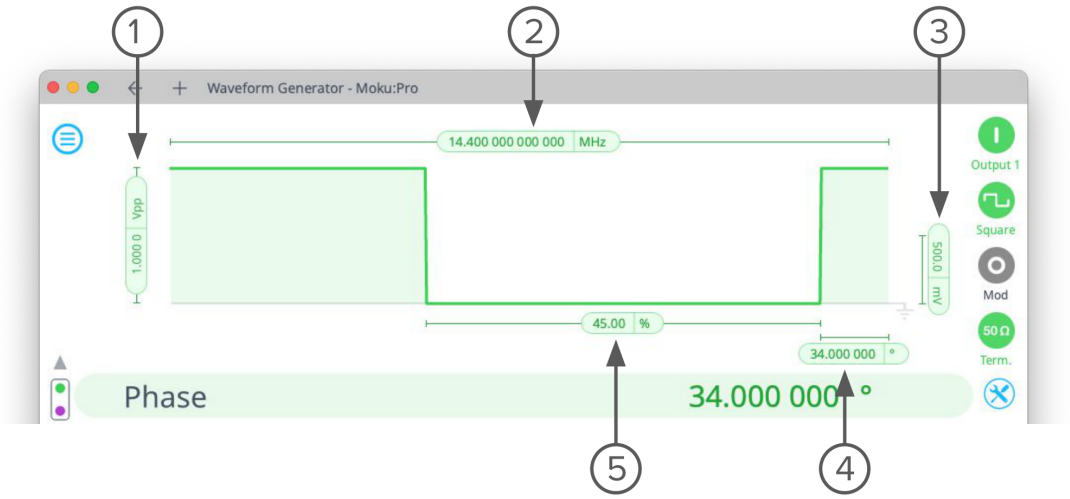


ID	Description	ID	Description
1	Amplitude (High level)	**3**	Offset (Low level)
2	Signal frequency (Period)	**4**	Phase

Tap or click pill **1 - 4** to select and change values. The selected parameter is shown in, and can be edited from, the bar below. Select alternative representations (shown in parentheses) by clicking the ⇄ button.

© 2024 Liquid Instruments. All rights reserved.

Square wave

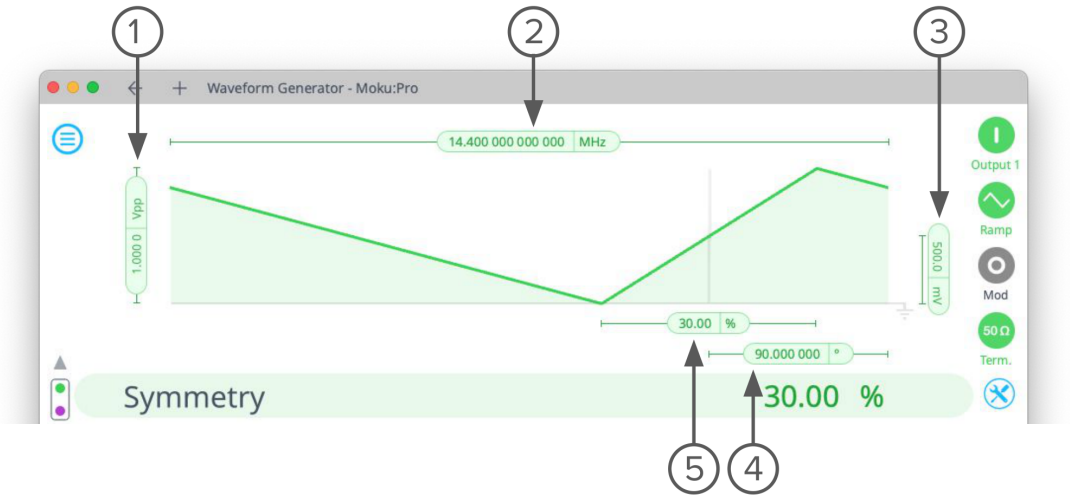


ID	Description	ID	Description
1	Amplitude (High level)	**4**	Phase
2	Signal frequency (period)	**5**	Duty cycle
3	Offset (Low level)		

Tap or click pill **1 - 5** to select and change values. The selected parameter is shown in, and can be edited from, the bar below. Alternative representations (shown in parentheses) can be selected by clicking the ⇄ button.

© 2024 Liquid Instruments. All rights reserved.

Ramp wave

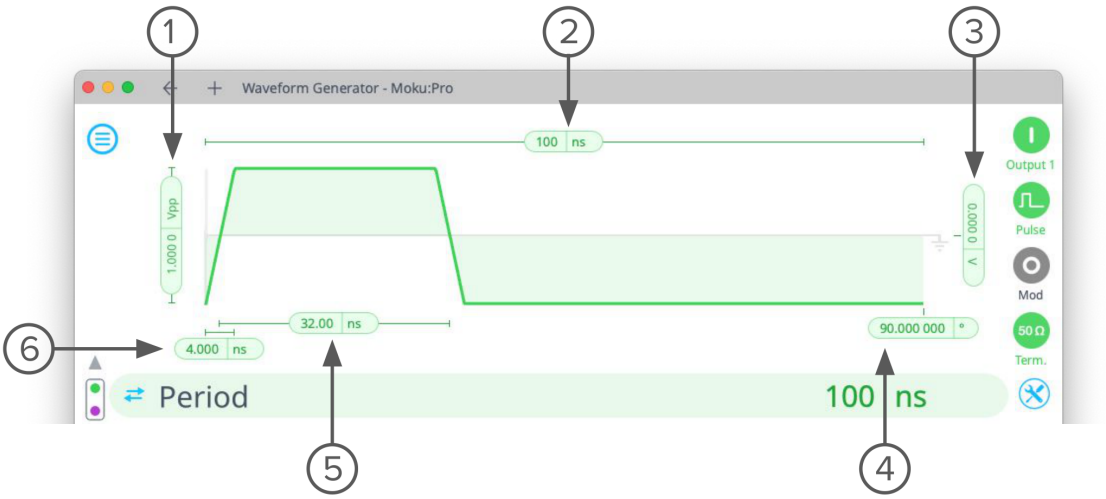


ID	Description	ID	Description
1	Amplitude (High level)	**4**	Phase
2	Signal frequency (period)	**5**	Symmetry
3	Offset (Low level)		

Tap or click pill **1 - 5** to select and change values. The selected parameter is shown in, and can be edited from, the bar below. Alternative representations (shown in parentheses) can be selected by clicking the ⇄ button.

© 2024 Liquid Instruments. All rights reserved.

Pulse wave

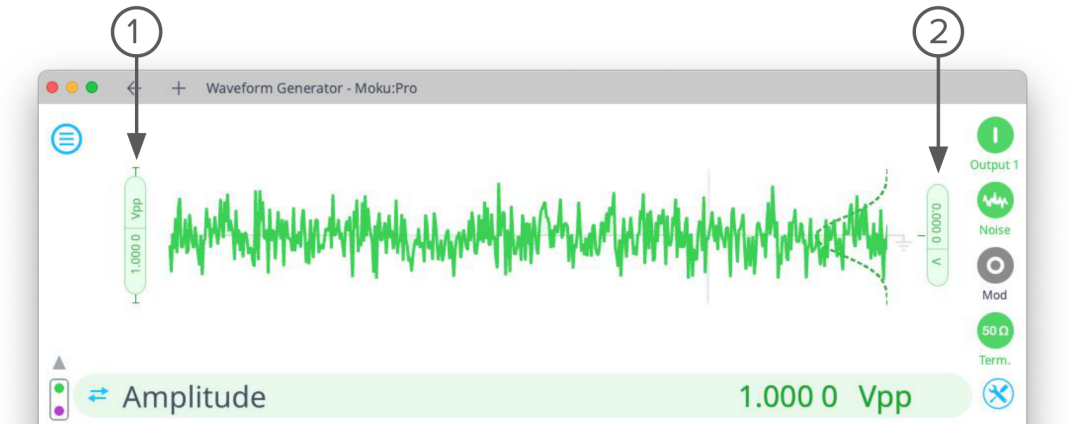


ID	Description	ID	Description
1	Amplitude (High level)	**4**	Phase
2	Signal frequency (Period)	**5**	Pulse width
3	Offset (Low level)	**6**	Edge time

Tap or click pill **1 - 6** to select and change values. The selected parameter is shown in, and can be edited from, the bar below. Alternative representations (shown in parentheses) can be selected by clicking the ⇄ button.

© 2024 Liquid Instruments. All rights reserved.

Noise

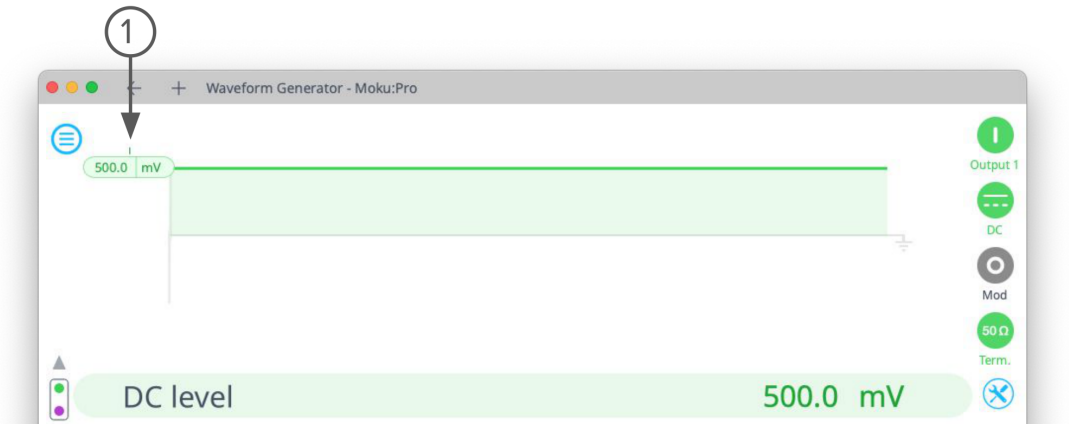


ID	Description	ID	Description
1	Amplitude (High level)	**2**	Offset (Low level)

Click pill **1, 2** to select and change values. The selected parameter is shown in, and can be edited from, the bar below. Alternative representations (shown in parentheses) can be selected by clicking the ⇄ button.

© 2024 Liquid Instruments. All rights reserved.

DC wave



ID	Description
1	DC level

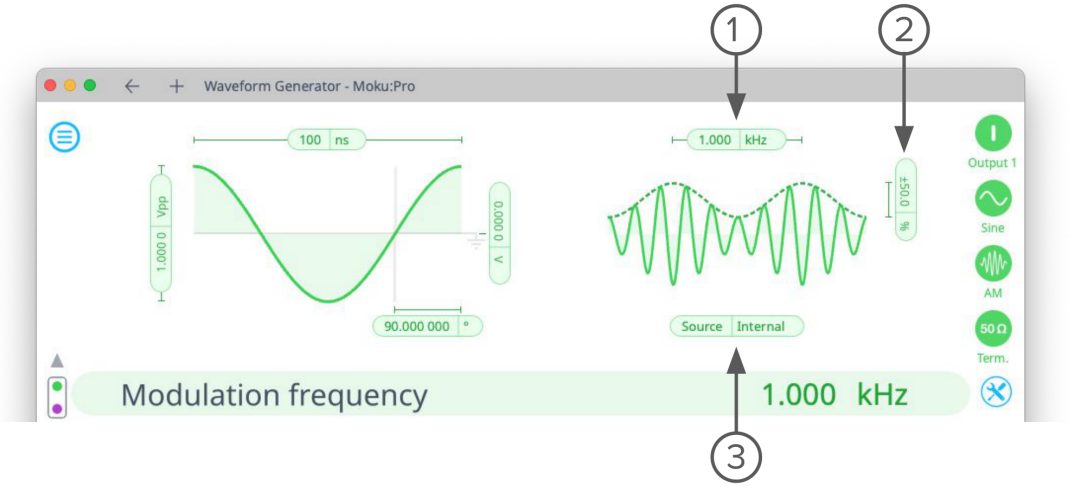
Tap or click pill **1** to select or change the DC value.

© 2024 Liquid Instruments. All rights reserved.

Modulation types

The Moku:Pro Waveform Generator supports several modulation modes. The modulation types available vary between waveforms: pulse-width modulation (PWM) only applies to the Pulse waveform type, while Noise only supports Amplitude Modulation (AM) and reduced triggering functionality. All other waveform types support amplitude, frequency, or phase modulation as well as all available trigger options.

Amplitude modulation

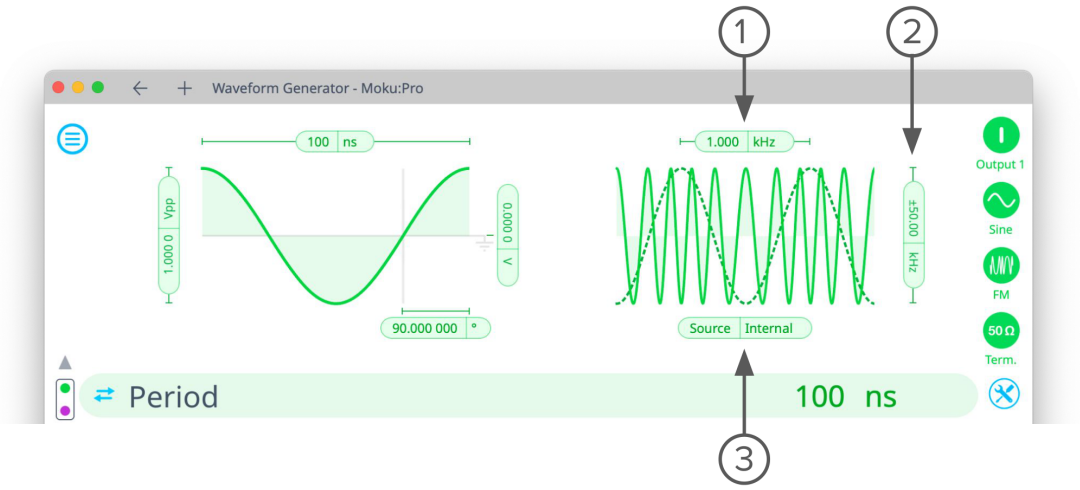


ID	Parameter	Description
1	Frequency	Only for "Internal" modulation; the frequency of the sine wave being used for modulation.
2	AM depth	Fractional depth of modulation. 100% depth will reduce the signal amplitude to zero for a full-range negative modulation signal
3	Modulation source	The modulation source can be an internally-generated sinewave, Moku:Pro analog input[1], or another Waveform Generator channel.

[1] By default, this analog input is DC-coupled with a 1 MΩ impedance. If an AC-coupled input signal or a 50 Ω impedance is required, please configure the front end in Multi-instrument Mode.

© 2024 Liquid Instruments. All rights reserved.

Frequency modulation

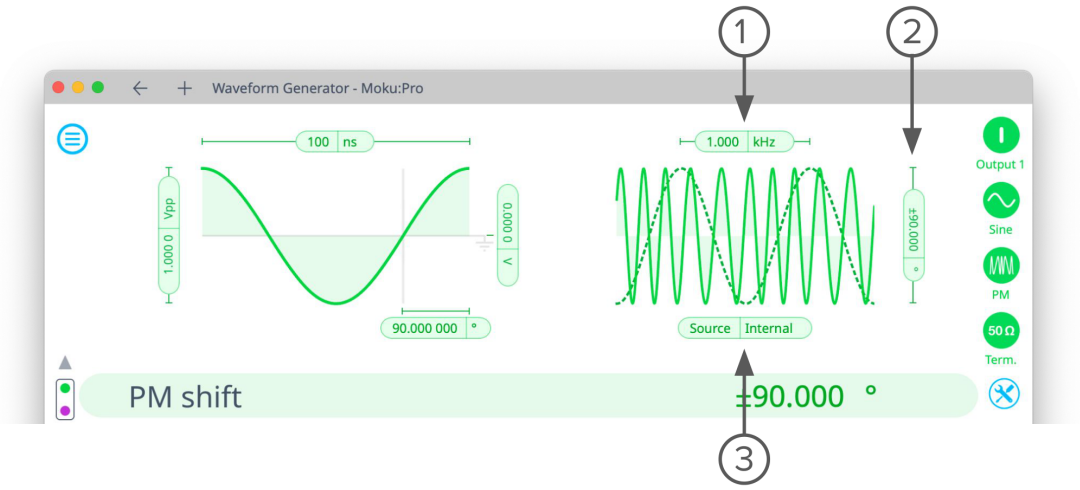


ID	Parameter	Description
1	Frequency	Only for "Internal" modulation; the frequency of the sine wave being used for modulation.
2	FM deviation	Full-range frequency deviation. A full-range input signal will vary the output frequency by this amount.
3	Modulation source	The modulation source can be an internally-generated sinewave, Moku:Pro analog input[2], or another Waveform Generator channel.

[2] By default, this analog input is DC-coupled with a 1 MΩ impedance. If an AC-coupled input signal or a 50 Ω impedance is required, please configure the front end in Multi-instrument Mode.

© 2024 Liquid Instruments. All rights reserved.

Phase modulation

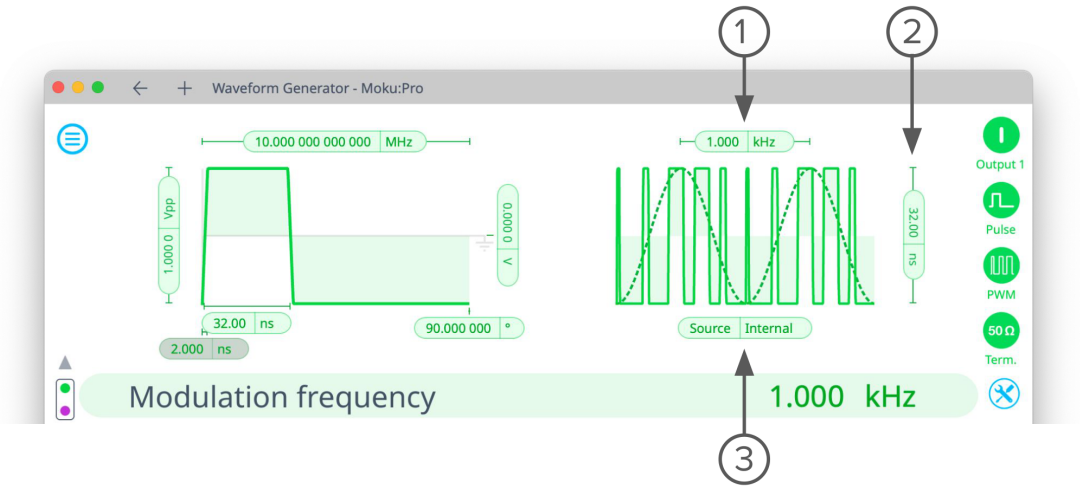


ID	Parameter	Description
1	Frequency	Only for "Internal" modulation; the frequency of the sine wave being used for modulation.
2	Depth	Full-range phase deviation. A full-range input signal will vary the output phase by this amount.
3	Modulation source	The modulation source can be an internally-generated sinewave, Moku:Pro analog input[3], or another Waveform Generator channel.

[3] By default, this analog input is DC-coupled with a 1 MΩ impedance. If an AC-coupled input signal or a 50 Ω impedance is required, please configure the front end in Multi-instrument Mode.

© 2024 Liquid Instruments. All rights reserved.

Pulse-width modulation



ID	Parameter	Description
1	Frequency	Only for "Internal" modulation source. The frequency of the sine wave being used for modulation.
2	Depth	Full-range pulse-width deviation. A full-range input signal will vary the output width by this amount.
3	Modulation source	The modulation source can be an internally-generated sinewave, Moku:Pro analog input[4], or the other Waveform Generator channel.

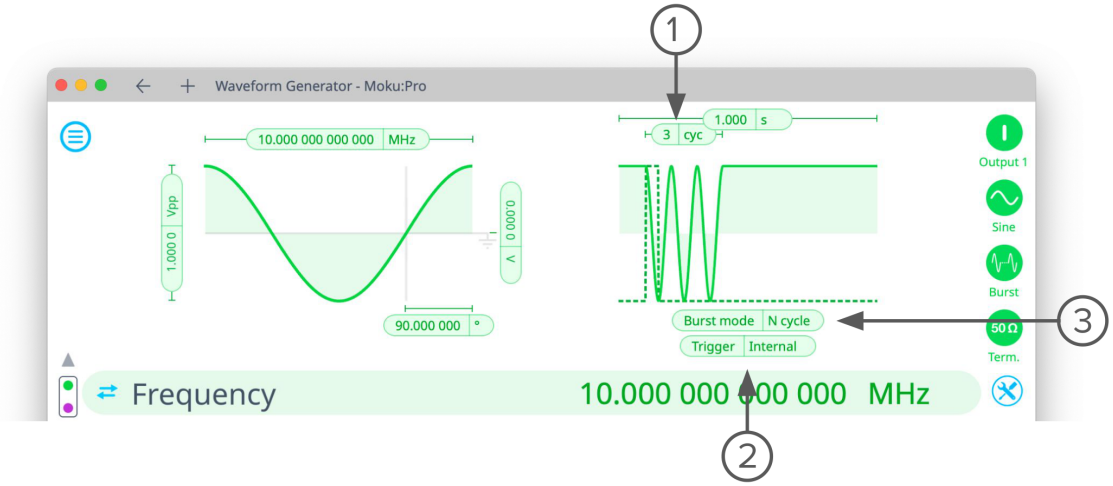
[4] By default, this analog input is DC-coupled with a 1 MΩ impedance. If an AC-coupled input signal or a 50 Ω impedance is required, please configure the front end in Multi-instrument Mode.

© 2024 Liquid Instruments. All rights reserved.

Triggered modulation modes

Sine, Square, Ramp, Pulse, and Noise waves can be triggered from an internal or external source. The behaviour upon receipt of the trigger signal varies according to mode.

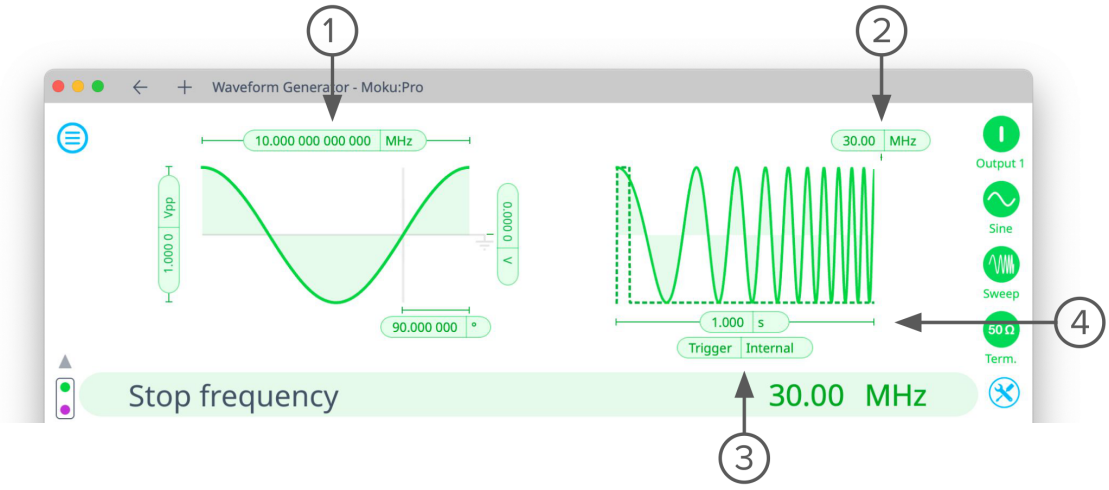
Burst



ID	Parameter	Description
1	Cycle count	N Cycle mode only. The number of cycles or time to output the waveform before re-arming.
2	Trigger source	One of: **Internal:** Trigger automatically at the defined rate. **External**: Trigger event on from rear-panel external trigger input. **Input**: Trigger from associated input channel, at given voltage. **Output**: Trigger from another output channel, at given voltage.
3	Mode	One of: **Gated**: Continue to generate the output signal while ever the trigger event is asserted (level-triggered). **Start**: Begin generation of the waveform on trigger, continue indefinitely. **N Cycle**: Upon receipt of trigger signal, generate N cycles of the waveform then re-arm. Not supported for noise waveform.

© 2024 Liquid Instruments. All rights reserved.

Sweep



Sweep modulation acts like frequency modulation with a sawtooth, where the sawtooth starts on the trigger event.

Sweep modulation is not supported for the Noise waveform as it has no defined frequency.

ID	Parameter	Description
1	Start frequency	Waveform frequency at the trigger event (sweep start).
2	End frequency	Waveform frequency at the sweep end.
3	Trigger source	One of: **Internal:** Trigger automatically at the defined rate. **External:** Trigger event on from rear-panel external trigger input. **Input:** Trigger from associated input channel, at given voltage. **Output:** Trigger from another output channel, at given voltage.
4	Sweep time	Time between sweep start and end (period).

© 2024 Liquid Instruments. All rights reserved.

Instrument Reference

Waveform types

The Moku:Pro Waveform Generator is capable of generating six different signals, each with optional modulation.

Sine wave

The Sine wave is the simplest dynamic signal in the Moku:Pro. It features extremely low harmonic distortion; it's very close to a pure single frequency.

The Sine wave can be modulated by all available modulation types except PWM. Moreover, it forms the basis of the "Internal" selectable modulation source, providing a modulating waveform regardless of whether any channel of the Moku:Pro is currently outputting a Sine wave.

Square wave

The Square wave is a low-jitter waveform with a variable duty cycle and high slew rates. The high analog bandwidth of the Moku:Pro gives very sharp rise and fall times, highly desirable in many applications. If you require slew-rate limits or variable duty cycle in your application, see Pulse wave below.

Ramp wave

The Ramp wave consists of linear ramps from low level to high and back again. The ratio between the time spent rising and the overall period is referred to as the symmetry. If you require configurable dwell times at the high or low levels but common rise and fall times, you may use the Pulse wave with large edge times.

Pulse wave

The Pulse wave is like the Square wave but has configurable duty cycle and edge times (rise and fall time). The trade-off is that at high frequency, Pulse has slightly worse edge jitter behaviour compared to the Square wave.

The Pulse wave also uniquely supports pulse-width modulation (PWM). When PWM is enabled, edge times are fixed to their minimum values.

Noise

Approximately Gaussian, white noise.

DC

Provides a high precision, fixed reference voltage at the output.

© 2024 Liquid Instruments. All rights reserved.

Waveform parameters

Amplitude

Applicable to: Sine, Square, Ramp, Pulse, Noise

Amplitude is specified as a peak-to-peak value; that is, the high level minus the low level. If you wish to specify the high and low levels explicitly, tap the Amplitude pill then the toggle arrows in the parameter bar.

Frequency

Applicable to: Sine, Square, Ramp, Pulse

Specified in Hz. Can also be represented as period in seconds by tapping the toggle arrows in the Frequency parameter bar.

Offset

Applicable to: Sine, Square, Ramp, Pulse, Noise

Center voltage level of waveforms. The alternative representation of this parameter is Low level, which combined with High level also specifies Amplitude.

Phase

Applicable to: Sine, Square, Ramp, Pulse

Defines the phase of the waveform with respect to the internal reference clock of Moku:Pro. By tapping the "Sync phase" button in the Settings drawer, the phase of all outputs will be synchronized.

Symmetry

Applicable to: Ramp

Ratio, in percent, between the time spent on the rising edge and the overall period. As symmetry approaches 0% or 100%, the ramp wave becomes a sawtooth (minimum rise and fall times, respectively).

Pulse width

Applicable to: Pulse

Positive width of the pulse. Any specified edge time is split equally between the pulse width and the rest of the cycle; that is, duty cycle is preserved when altering edge time.

Edge time

Applicable to: Pulse

Time taken to transition from low level to high and vice-versa. This limits the slew rate of the signal which can be advantageous in some applications. Edge time is split between high and low time equally, preserving duty cycle. Edge time cannot be adjusted when the Pulse wave is pulse-width modulated (PWM).

© 2024 Liquid Instruments. All rights reserved.

Duty cycle

Applicable to: Square

The percentage of one period that the signal is active, or non-zero. This is similar to pulse width except that the edge time is not factored into the duty cycle due to the fast rise and fall times.

DC level

Applicable to: DC

Fixed voltage to output.

Modulation types and trigger modes

Modulation sources

Each modulation type can be driven by one of three sources.

Internal

Modulation is driven by an internally generated sine wave of configurable frequency. The amplitude of this wave is "full range." It will modulate to the depth specified when configuring the modulation type.

Input

Modulation for a given channel is driven by an analog input. The depth is specified per volt on the input. When this source is selected, the range of the corresponding input can also be selected.

Output

Modulation for a given channel is driven by another output channel (i.e. Output 1 may be modulated by the waveform on Output 3). This allows the user to doubly-modulate a signal by modulating a signal on one channel, then using that signal to modulate the another in turn. This can be useful, for example, when you wish to generate an "ideal" modulated signal on one channel, but then perturb the phase, frequency, or amplitude to test a system's response.

Trigger sources

Burst and Sweep modes change waveform parameters or behaviour upon the detection of a trigger event. There are three possible sources for this event.

Internal

The trigger event is generated automatically at a given rate (specified period).

© 2024 Liquid Instruments. All rights reserved.

External

A rising edge on the back-panel External Trigger Input is used as the trigger source. For trigger level and precision characteristics, refer to the Moku:Pro Technical Specifications available at liquidinstruments.com.

Input

The specified analog input is monitored for a rising edge past the specified voltage.

Output

Another analog output channel is monitored for a rising edge past the specified voltage. Combined with the fact that other outputs can in turn be modulated from a variety of sources, this provides extremely flexible control of the trigger period (included for example changing period based on an external voltage).

Amplitude modulation

Applicable to: Sine, Square, Ramp, Pulse, Noise

Amplitude modulation will change the amplitude of the generated signal proportionally to the modulation input. The actual proportion changed is called the modulation depth, the units of which depend on the modulation source (see discussion of sources above).

Frequency modulation

Applicable to: Sine, Square, Ramp, Pulse

Frequency modulation will change the frequency of the generated signal proportionally to the modulation input. The change in frequency caused by a given input is called the modulation depth and has units of Hz or Hz per volt depending on the modulation source used.

Phase modulation

Applicable to: Sine, Square, Ramp, Pulse

Phase modulation will change the phase of the generated signal proportionally to the modulation input. The change in phase caused by a given input is called the modulation depth and has units of degrees or degrees per volt depending on the modulation source used.

Pulse-width modulation

Applicable to: Pulse

Pulse-width modulation (PWM) changes the width of the positive pulse in the Pulse wave. If the modulation depth is set appropriately, then this can produce traditional 0-100% duty cycle PWM, but it can also produce pulse trains suitable for driving servo motors, electronic speed controllers (ESCs), etc.

© 2024 Liquid Instruments. All rights reserved.

Burst mode

Applicable to: Sine, Square, Ramp, Pulse, Noise

In burst mode, a trigger event causes the given output to begin generating its configured waveform. Burst requires you to specify a sub-mode that defines if or when the generation ends.

N-Cycle: The waveform will stop being generated after the specified number of cycles, at which time it will re-arm and become ready to receive a new trigger. Not available for Noise, which is a continuous waveform and does not have a concept of a "cycle".

Gated: The waveform will continue to be generated while the trigger signal is high (level-triggered).

Start: The waveform generation begins on a trigger signal but will continue indefinitely.

Sweep mode

Applicable to: Sine, Square, Ramp, Pulse

Sweep mode provides a frequency modulation of the input waveform, where the modulation waveform is a ramp wave that begins generation on the detection of a trigger signal. That is, when a trigger is detected, waveform generation will begin at the start frequency and sweep (or "chirp") to the end frequency over a given duration.

Sweep mode has three configurable parameters:

Start frequency: Initial frequency of the output waveform, immediately on detection of a trigger. The start frequency is the frequency of the unmodulated wave.

End frequency: Final frequency of the output waveform, being reached at the end of sweeping duration.

Sweep time: The time taken to sweep from start to end frequency. Upon completion of the sweep, the sweep circuit will re-arm and be ready to receive a new trigger input.

© 2024 Liquid Instruments. All rights reserved.

Ensure Moku:Pro is fully updated. For the latest information, visit:

liquidinstruments.com

© 2024 Liquid Instruments. All rights reserved.