Moku Arbitrary Waveform Generator

User Manual

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Introduction

Arbitrary Waveform Generators are essential for producing precise, custom electrical signals to simulate real-world conditions in applications like radar system testing, communication protocol development, quantum computing, and sensor signal emulation. The Moku Arbitrary Waveform Generator can generate custom waveforms with a significant number of points at high update rates, allowing for the creation of complex and custom-defined waveforms beyond the standard sinusoidal, square, or triangular forms. The Arbitrary Waveform Generator provides users with a high level of flexibility and control for customizing waveform generation.

The Moku Arbitrary Waveform Generator can load waveforms from a file, or input as a piecewise mathematical function with many segments, enabling you to generate truly arbitrary waveforms. The Arbitrary Waveform Generator offers pulsed and burst modulation modes. In pulsed mode, waveforms can be output with long periods of dead time between pulses, allowing you to excite your system with an arbitrary waveform at regular intervals over extended periods of time. In burst mode, waveforms can be output with a defined number of cycles, N cycle mode, or continuously, start mode, based on a trigger signal, allowing you to excite your system with an arbitrary waveform for a set number of waveform cycles per trigger or continually once a trigger event occurs.

This manual is intended to help users understand the user interface and underlying architecture of the instrument. It also includes a general example in the quick start guide and a small number of in-depth examples to provide a foundation for new users.

These user manuals are tailored to the graphical interfaces available on macOS, Windows, iPadOS, and visionOS. If you'd prefer to automate your application, you can use Moku API; available for Python, MATLAB, LabVIEW, and more. Refer to the API Reference to get started.

AI-powered help is available to aid both workflows. AI help is built into the Moku application, and provides fast, intelligent answers to your questions, whether you're configuring instruments or troubleshooting setups. It draws from Moku manuals, the Liquid Instruments Knowledge Base, and more, so you can skip the datasheets and get straight to the solution.

Access AI help from the main menu .

For more information on the specifications for each Moku hardware, please refer to our product documentation, where you can find the specifications and the Arbitrary Waveform Generator datasheets.

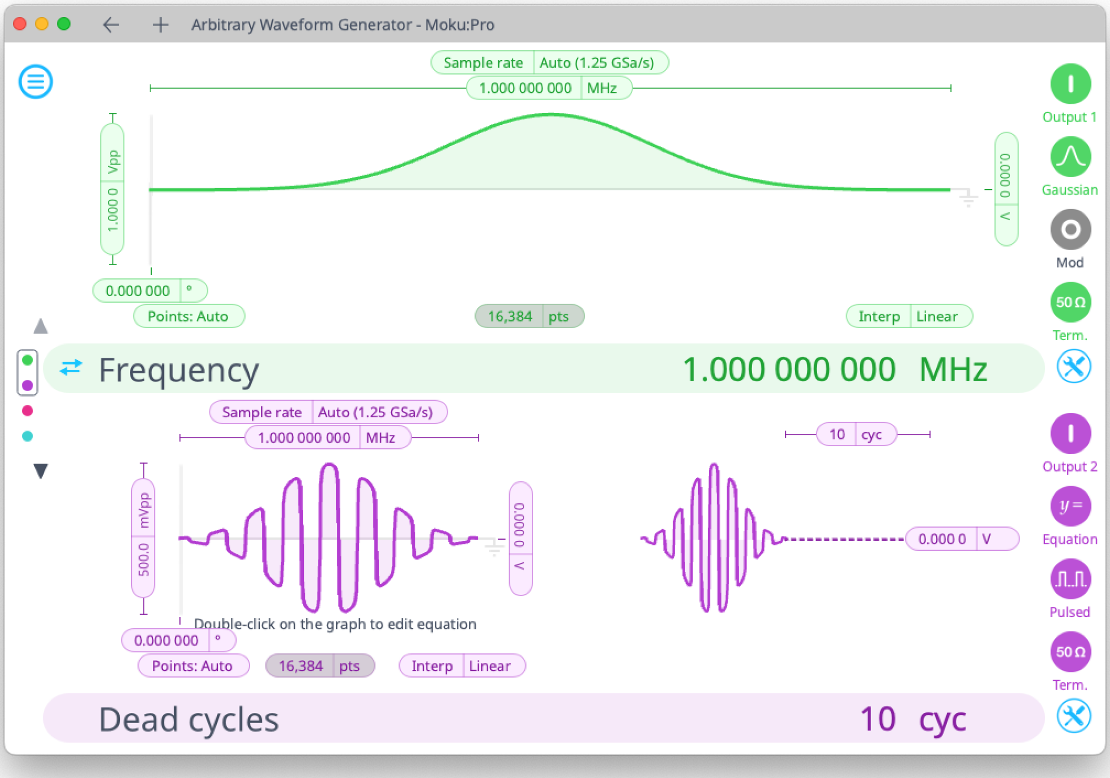

Figure 1. Arbitrary Waveform Generator user interface showing the output signal and modulated output.

Quick start guide

Here we outline how to output a chirped waveform from an equation with burst modulation in order to highlight the typical workflow of the Arbitrary Waveform Generator. More detailed examples may be found in the Examples section.

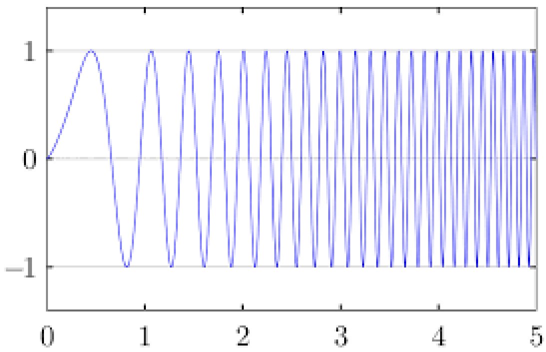

Figure 2. CHIRP Signal

- **Step 1: Set the waveform type**
  - Select the equation waveform $y=$ to output.
  - Double click on the waveform graph to edit the equation. Input the instantaneous CHIRP equation $\cos(2 \cdot \pi \cdot (mt + f) \cdot t)$, to output a CHIRP signal with a chirp rate of 10 Hz/s, starting at 1 Hz input $\cos(2 \cdot \pi \cdot (10 \cdot t + 1) \cdot t)$.

- **Step 2: Set the output termination (if available)**
  - Set the termination of your Moku to match the load impedance of your circuit.
- **Step 3: Set your waveform parameters**
  - Setting the output parameters to output
    - Frequency = 1 Hz
    - Sample Rate = `Auto`, to use the maximum sample rate without skipping any points.
    - Amplitude = 1 Vpp
    - Offset = 0 V
    - Phase = 0 degrees
    - Points = `Auto` , for the smoothest waveform output.
    - Interpolation = `Linear`, for the smoothest waveform output.
- **Step 4: Copy waveform settings from one channel to another**
  - Copy the waveform from Output 1 to Output 2 with the button attached to the Output 2 preview or by right clicking the Output 2 preview graph and selecting *Copy settings from Output 1.*
- **Step 5: Turn a channel ON**
  - Toggle the outputs ON/OFF for Output 1 with the / buttons.
- **Step 6: Synchronize your waveforms**
  - Sync the waveforms after any changes to your waveform parameters with the button. Do this after any change in the Arbitrary Waveform Generator to ensure all waveforms are synchronized.
- **Step 7: Modulate the waveform (optional)**
  - Select Burst modulation for the modulation type on Output 1
  - Set the Burst mode to N cycle then update the parameters
    - Cycles = 3
    - Trigger = Input 1
    - Front end settings may remain as default
    - Trigger level = 0 V

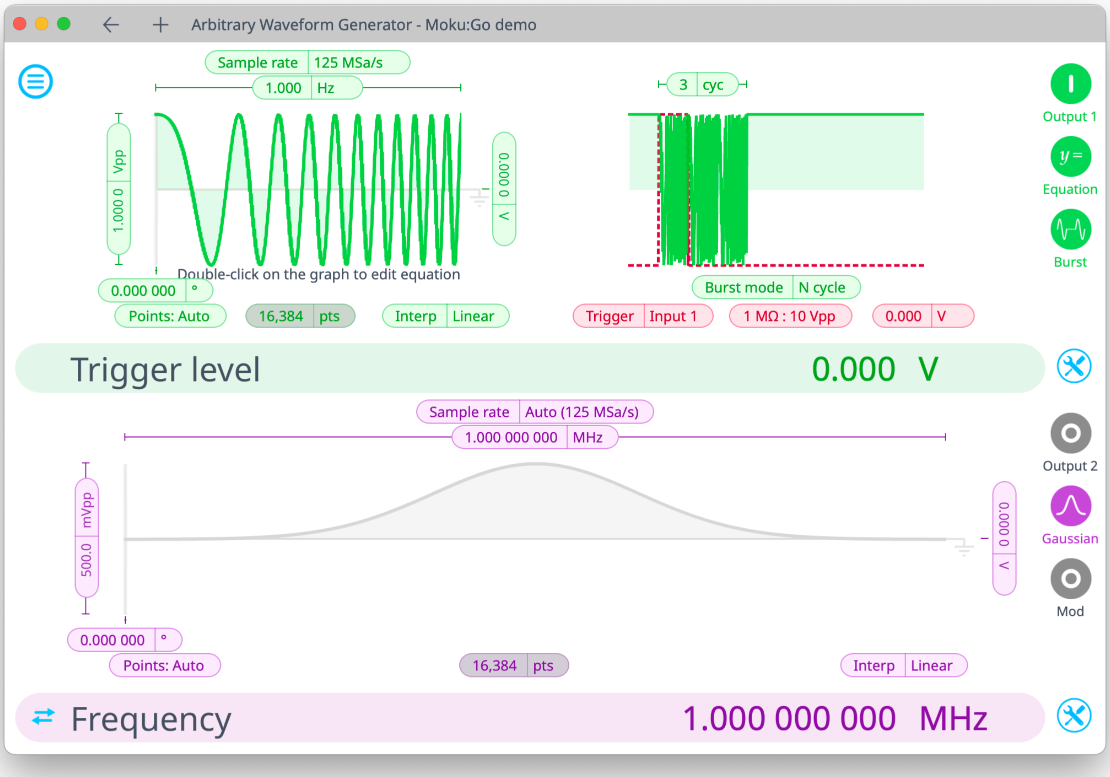

Figure 3. Screenshot of the Moku app configured to output a CHIRP signal.

Principles of operation

Generating waveforms

The Arbitrary Waveform Generator creates output waveforms by sampling a user defined lookup table (LUT). This can be from a LUT that is pre-defined for the pre-set waveforms, or a user defined LUT. The pre-set waveforms available include Sine, Gaussian, Exponential Rise, Exponential Fall, Sinc, and Cardiac. The user defined LUT options are the Equation and Custom waveforms.

1	0.0490676743274180
2	0.098017140329561
3	0.146730474455362
…	
128	-2.449293598294706e-16

Wavetable

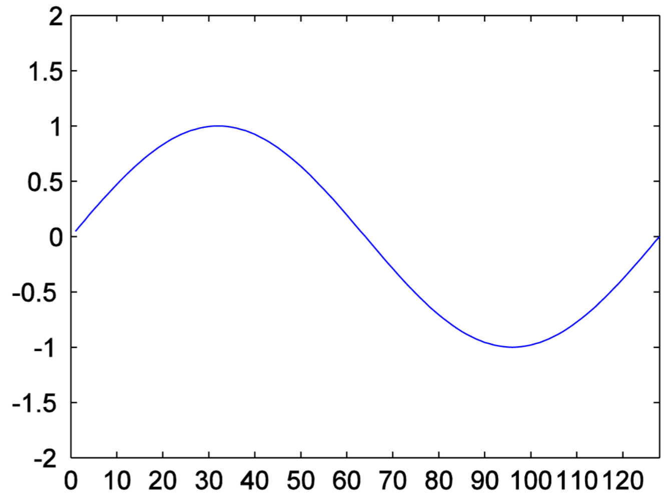

Figure 4. LUT to waveform example

Lookup table

When the waveform is updated in the Moku app, the populated Lookup Table (LUT) values, optional interpolation, and dead-time values are read for each period of the waveform. The Arbitrary Waveform Generator then recreates the waveform from this information, sending it through the device output or routed internally, if in Multi-instrument Mode.

Maximum recommended sample rate. The maximum safe frequency of the generated waveform is equal to the sample rate divided by the number of points in the waveform. Exceeding the maximum recommended waveform frequency will result in some points being skipped at your selected sample rate.

For example, the maximum safe **frequency** of a 1000-point waveform being sampled at 125 MSa/s is 125 MSa/s / 1000 Sa = 125 kHz.

Pre-set sample rate modes are supported, which define the sample rate and therefore the length of the LUT. Automatic or ‘Auto’ sample rate selection can be chosen to minimize the points of your waveform skipped.

Interpolation

Opposed to the maximum recommended sample rate, if the samples loaded to the Arbitrary Waveform Generator are too coarse relative to the sample rate (a few samples spread far apart), linear interpolation will calculate intermediary samples between the loaded samples, creating a continuous and coherent representation.

The option to apply interpolation is available for all waveform types in the Arbitrary Waveform Generator, and is default set to linear interpolation. No interpolation will be applied by selecting Interpolation to be "None". Linear interpolation will create a smoother waveform, especially if your loaded waveform has few points, whereas no interpolation will step between the points loaded, which becomes visibly quantized if the number of waveform points is less than the maximum points available.

Linear interpolation is useful for waveforms with no sharp edges, such as sine- and cosine-based waveforms, and waveforms with few sample points. Interpolating between the samples creates smoother signals and can reduce the quantized effects of 'coarse' signals with few points.

"None" interpolation is typically desirable for waveforms that have sharp edges, such as pulse and square waves, as the sharp-edge quality is beneficial to the shape of the waveform.

Figure 5. Linear interpolation (top) versus "None" interpolation (bottom)

For example, if a 1000-sample waveform is loaded to the custom output of the Arbitrary Waveform Generator, at a sample rate of 1 kSa/s, this 1000 sample waveform is sampled every second. The clock rate of the Moku is much faster than this, outputting many more samples between the uploaded samples. If the first sample is at 0.5 V and the second is at 1 V, the Moku needs to decide if the output remains at 0.5 V for the entire 1 ms between samples and then 1 V for 1 ms, etc. as a step function (this is "None" interpolation), or if the signal is a ramp function that is increasing from 0.5 V to 1 V over the 1 ms time interval (this is "Linear" interpolation) and it will generate intermediate samples to “smooth” out the waveform.

Difference between the Arbitrary Waveform Generator and Waveform Generator

Moku offers two waveform generation instruments: the Arbitrary Waveform Generator and the Waveform Generator. While similar in function, they are optimized for different use cases. The Arbitrary Waveform Generator allows users to define fully custom waveforms by uploading their own coefficients. In contrast, the Waveform Generator produces six standard waveforms and includes built-in modulation options such as AM, FM, and PM. Although the Arbitrary Waveform Generator doesn't offer built-in modulation, users can incorporate modulation directly into the waveform definition. In summary, use the Arbitrary Waveform Generator for custom or complex waveform needs, and the Waveform Generator for standard signals.

Waveform types

The available pre-loaded waveforms in the Arbitrary Waveform Generator are more niche, while those in the Waveform Generator are more standard. The Arbitrary Waveform Generator is able to generate all pre-loaded waveforms in the Waveform Generator (see Equation waveforms), however they may not be generated with the same optimized algorithm.

Arbitrary Waveform Generator	Waveform Generator
• Sine • Gaussian • Exponential Rise • Exponential Fall • Sinc • Cardiac • Equation • Custom	• Sine • Square • Ramp • Pulse • Noise • DC

Modulation types

The Arbitrary Waveform Generator can load in any pre-modulated signal from a text file, however the Waveform Generator has more in-build modulation options available.

Arbitrary Waveform Generator	Waveform Generator
• Pulsed • Burst	• Amplitude • Frequency • Phase • Pulse Width • Burst • Sweep

Using the Arbitrary Waveform Generator

User interface

The Moku Arbitrary Waveform Generator is equipped with multiple output channels which are configured in two parts: The high-level channel configuration, edited in the buttons on the right of the interface, and the waveform and modulation parameter editor, edited in the waveform preview.

If there are more channels available than visible, click the ▲ and ▼ icons to navigate between the channels.

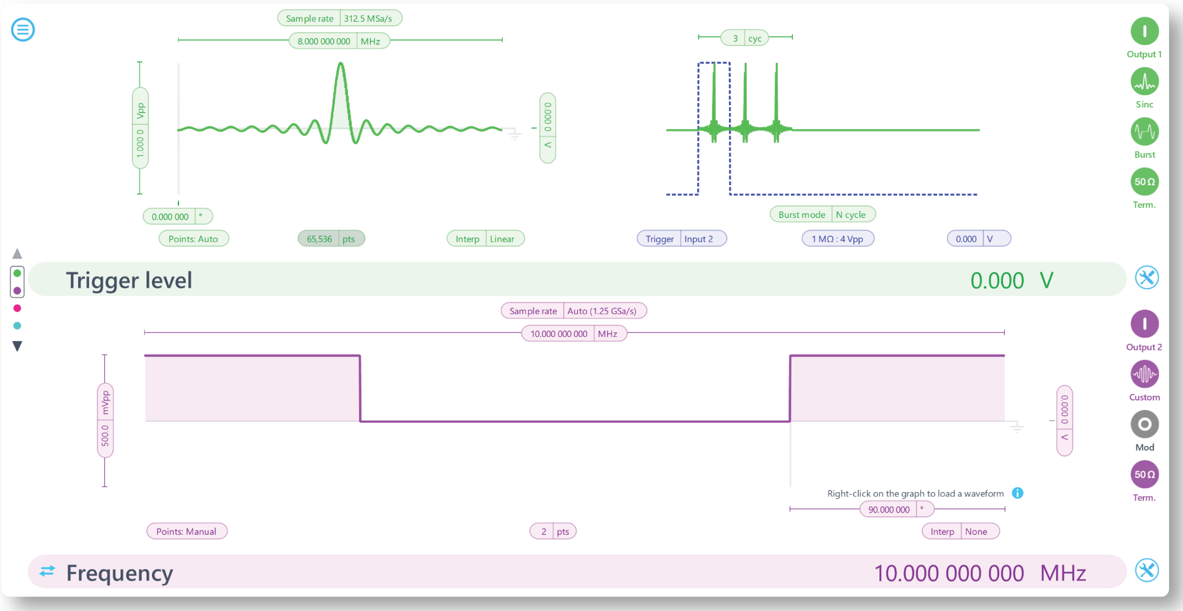

Figure 6. Arbitrary Waveform Generator User Interface

Synchronizing waveforms

To set the phase offset between all waveforms to zero, the "Sync phase" button must be clicked after all waveform and modulation parameters have been changed. Many parameter changes re-starts the waveform from the beginning of its cycle, misaligning the relative phase between waveform outputs. In the Arbitrary Waveform Generator, the "Sync phase" button is found by clicking the configuration button.

To synchronize all instruments across all slots in Multi-instrument Mode, click the Sync button in the ‘Build your system’ interface. This will align clock timing within and between instruments.

Configuring outputs

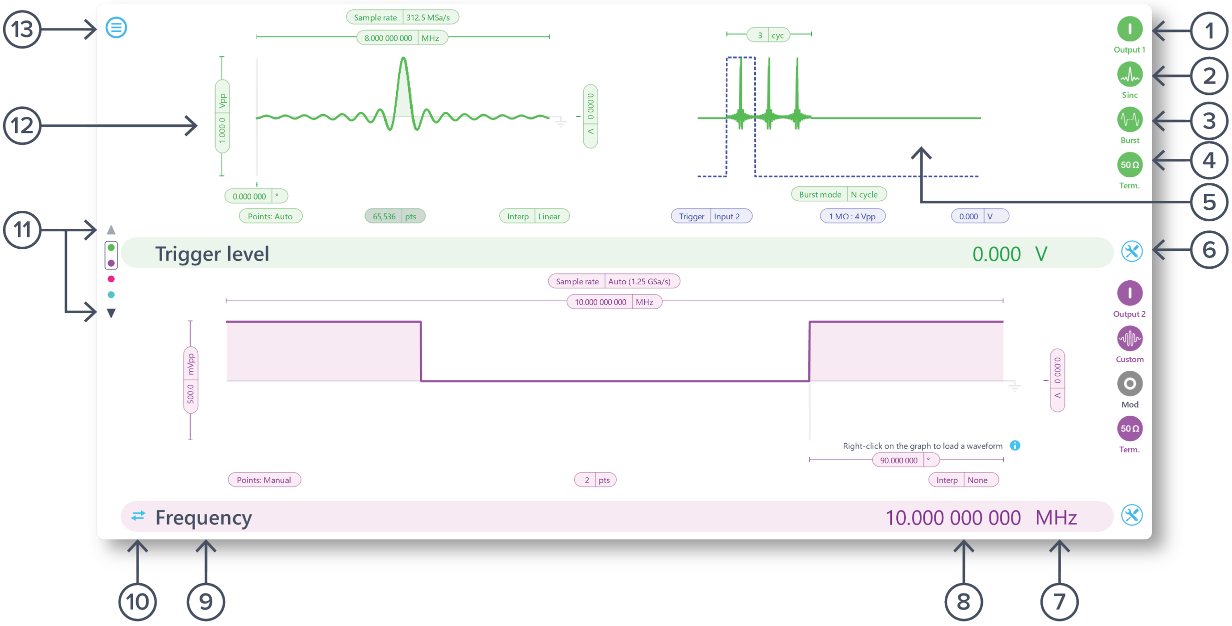

Figure 7. Arbitrary Waveform Generator high-level channel configuration

① Toggle the output channel on and off
② Set the waveform type
③ Set the modulation type
④ Toggle the termination (hardware dependent)
⑤ Waveform preview graph
⑥ Open the output channel context menu; sync waveforms, copy settings from another channel, or load a new waveform
⑦ Select the units of displayed parameter
⑧ Enter the value of the displayed parameter
⑨ Label of the displayed parameter
⑩ Switch parameter representation
⑪ Click through available output channels
⑫ Click to configure parameter
⑬ Main Menu

Waveform types

There are two main classes of waveforms in the Arbitrary Waveform Generator; predefined waveforms and custom waveforms. The predefined waveforms include sine, Gaussian, exponential rise, exponential fall, sinc, and cardiac waveforms. The custom waveforms can be user-defined and loaded from a file, or input as a piece-wise mathematical function. This flexibility allows users to generate waveforms that are customized to the requirements of their specific applications.

Predefined waveforms

Waveforms can be generated with one of the pre-set waveforms in the Arbitrary Waveform Generator:

- **Sine** Represents the a fundamental periodic waveform sin(t), characterized by its smooth oscillations. Best used to simulate household power sources or for frequency response analysis.
- **Gaussian.** The Gaussian waveform follows a Gaussian distribution, characterized by its bell-shaped curve with a symmetric peak. This waveform is used in applications requiring controlled bandwidth, low noise, and minimal distortion, such as communication systems and radar pulse shaping. The Gaussian waveform is characterized by the fundamental equation $f(t) = \exp\left(-x^2\right)$.
- **Exponential rise.** Exponential growth waveform characterized by $\log_2(x)$. Essential for transient and filter response and capacitance charging.
- **Exponential fall.** Exponential decay waveform characterized by 0.5^x. used in time signal decay analysis and capacitance discharging.
- **Sinc.** The Sinc waveform is derived from the mathematical sinc function $\mathrm{sin}c(t) = \frac{1}{t}\sin(t)$, featuring a main lobe with zero crossings and decaying side lobes. The sinc function in the time domain has a rectangular pulse in the frequency domain. This has useful applications in medical imaging, digital signal processing, specifically for anti-aliasing filtering, pulse shaping in digital communication systems, and spectral analysis.
- **Cardiac.** The Cardiac waveform simulates the electrical activity of the heart over time, otherwise known as the cardiac cycle. It is valuable in medical research, simulation studies, and training scenarios related to cardiology, allowing easy replication of heart rhythms for analysis and experimentation.

Custom waveforms

Generate a custom waveform loaded from a file or defined by a piecewise equation in the equation editor:

- **Custom.** These can be loaded from your clipboard or from a local csv file, see Custom waveforms for all requirements and tips.
- **Equation.** A piecewise mathematic function that can be parameterized using a single equation or a series of segmented equations, see Equation waveforms.

Creating unique waveforms

Custom waveforms can be generated with equations or by uploading custom waveforms.

Custom

The Custom waveform populates the LUT with the uploaded data, this is executed and output with the selected interpolation, frequency, phase, amplitude, and modulations. See further examples for an in-depth walk-through of creating custom waveforms.

Amplitude scaling

The Amplitude of the waveform is normalized to the range [-1, +1] and scaled to the desired amplitude and offset, meaning the waveform will be clipped if it exceeds this range. A python or MATLAB script can be used to normalize the values of the Custom waveform to a [-1, +1] range.

Interpolation

'Linear' or 'None' Interpolation can be applied to the Custom waveform. 'Linear' Interpolation will create a smoother waveform, especially if your loaded waveform has few points, whereas 'None' Interpolation will step between the points loaded, which may cause the waveform to step between points if not configured properly, see Interpolation.

Uploading a custom waveform

To upload a Custom waveform, right click (Desktop app) or tap (iPad) the waveform preview area and select how to load the waveform, from local files or from clipboard.

The Custom waveform may be a comma-separated values (CSV) or delimited text file, but it may only contain numbers and formatting characters: comma, newline, space, and letter characters indicating scientific notation e.g. 10e3 for 10000.

Sample rate

The maximum safe frequency of the generated waveform is equal to the sample rate divided by the number of points in the Custom waveform. Exceeding the maximum recommended frequency, or sample rate will result in some points being skipped.

For example, the maximum safe frequency of a 1000-point waveform at 1 GSa/s is 1 GS/s / 1000 samples = 1 MHz.

Equation

The Equation waveform type enables you to design arbitrary waveforms using multiple piecewise mathematical functions. The waveform can be configured in one or multiple segments, each with their own function and definable fractional time period.

Equation editor

The Equation editor allows you to define arbitrary mathematical functions for each segment in the waveform. A large range of common mathematical expressions including trigonometric, quadratic, exponential, and logarithmic functions are available to generate a waveform.

The variable 't' represents time in the range from 0 to 1 periods of the total waveform, meaning that the input equation needs to be within the horizontal bounds of [0, 1] to remain undistorted. The waveform equation should also be scaled to be within the vertical bounds of [-1, +1] to avoid distortion and for accurate amplitude scaling.

The Arbitrary Waveform Generator will then scale, offset, shift, repeat, and modulate the entered equation as entered in the amplitude, offset, phase, and frequency of the waveform, as set in these cells.

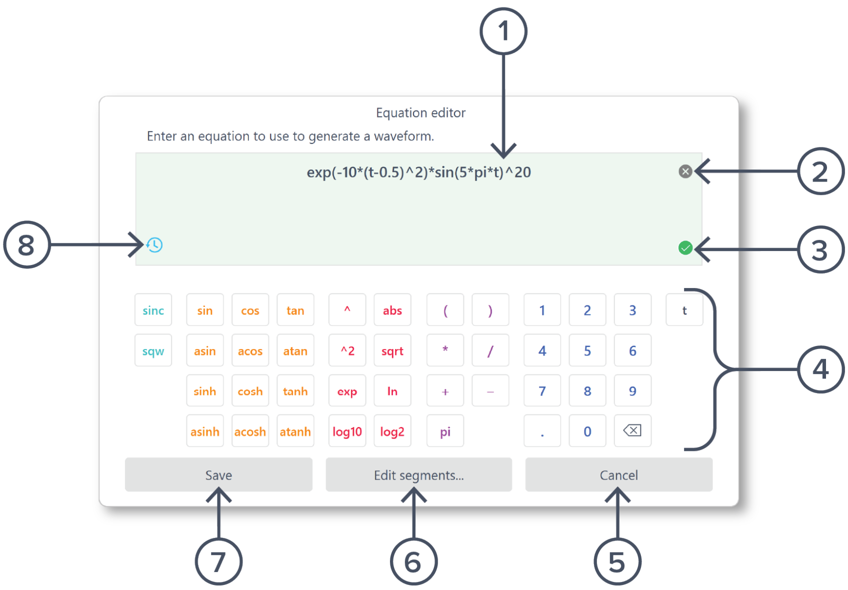

Figure 8. Equation editor pop-up in the Arbitrary Waveform Generator

① Current arbitrary mathematical equation entered
② Delete current equation
③ Equation validation success
④ Interactive keyboard of variables, operands, functions, parameters, and backspace
⑤ Cancel equation editing, exit out of the pop-up without applying any changes
⑥ Open the waveform segment editor
⑦ Save the current equation, apply the waveform, and exit the pop up
⑧ Open a history of recently used equations

Waveform segments

Multiple waveform segments can be added and their time-fractional time periods defined within a single period of the total waveform. This is edited in the waveform segments portions of the editor.

Figure 9. Waveform segment editor in the Arbitrary Waveform Generator

① Segment label that corresponds to the list below
② Preview of waveform
③ Add another segment
④ Remove this segment
⑤ Open the equation editor pop-up for this section
⑥ Cancel equation editing, exit out of the pop-up without applying any changes
⑦ Save the current equation, apply the waveform, and exit the pop up
⑧ Edit the time bounds for the segment

Previewing output waveforms

Using Multi-instrument Mode, your waveforms can be quickly performance tested to ensure the waveforms are output as expected. This is a good idea if your system is very sensitive or if it is your first time using the Equation and Custom waveform types.

Connect the output of the Arbitrary Waveform Generator to the input of the Oscilloscope. Load your waveform into the Arbitrary Waveform Generator, turn the output on, and view its signal in the Oscilloscope. Its signal characteristics can be measured in the Measurement panel, accessed by the measurements button.

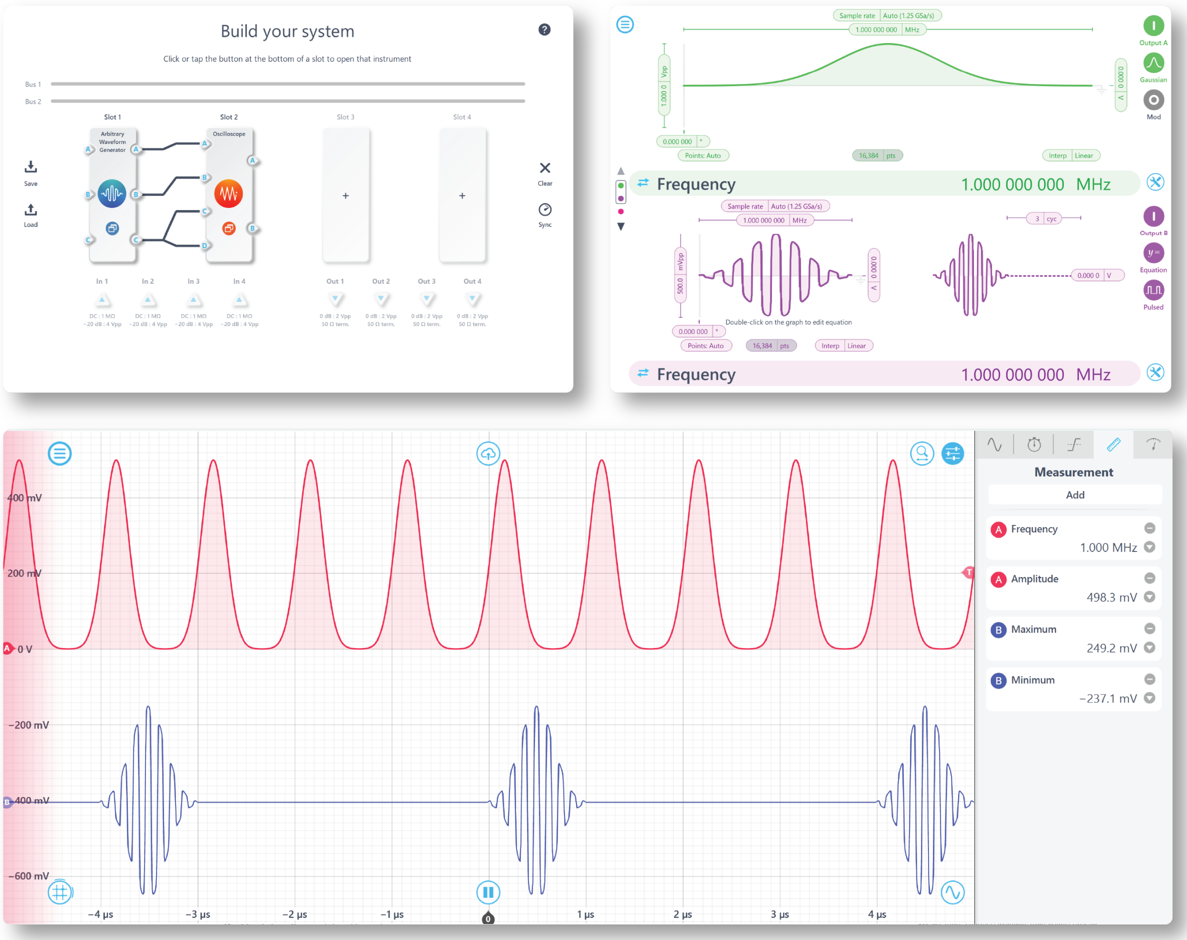

Figure 10. Previewing Arbitrary waveforms in Multi-instrument Mode

Waveform parameters and controls

There are parameters that can be controlled across all waveform types. These are frequency, amplitude, offset, and phase.

Figure 11. Arbitrary Waveform Generator parameters

① Edit frequency parameter
② Edit offset parameter
③ Edit phase parameter
④ Edit amplitude parameter

Frequency

The frequency of the waveform can be entered as different parameter representations, which each have their own units. The options are Frequency (Hz), Period (s), or Update rate (pts/s). Switching between the parameter representations can provide more information about the waveform being generated.

For example, consider an arbitrary waveform with a frequency of 125 kHz, 10,000 points. The period of this waveform will be the inverse of the frequency, 8 µs.

$$frequency^{-1} = period = \left(125 \cdot 10^3\right)^{-1} = 8 \cdot 10^{-6} = 8\mu s$$

The update rate of this waveform is the frequency times by the number of points, 1.25 Gpts/s.

$$frequency \cdot points = 125 \cdot 10^3 \cdot 10,000 = 1.25 \cdot 10^9 = 1.25 \cdot 10^9$$

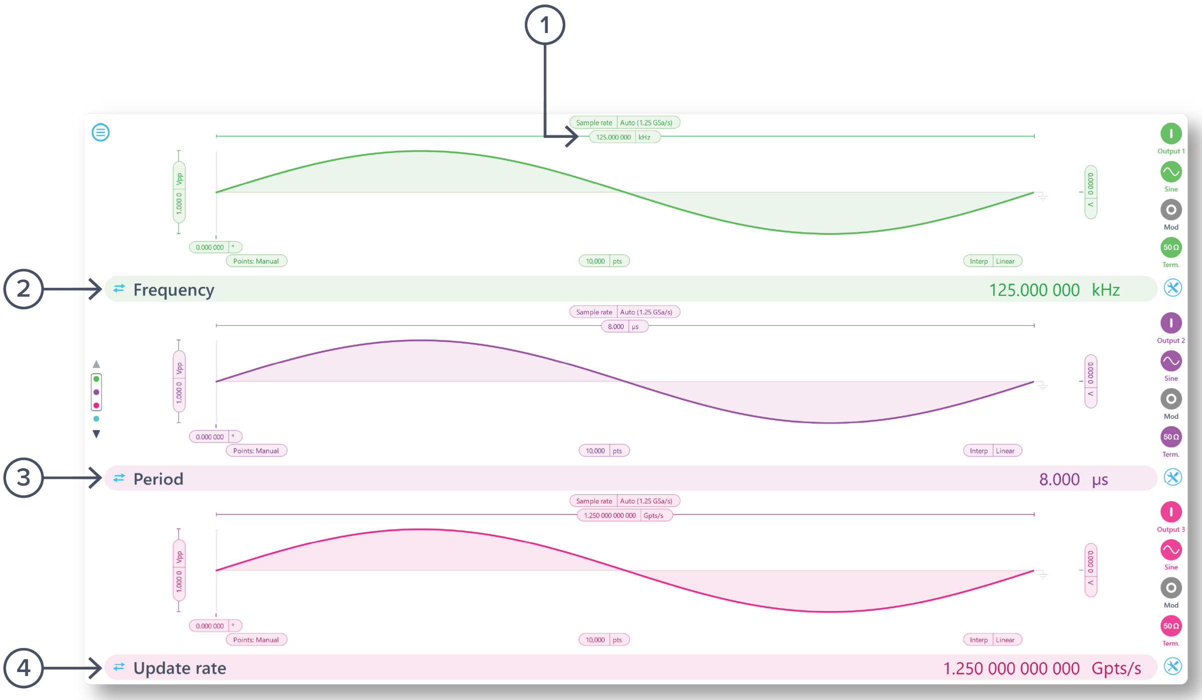

Figure 12. Arbitrary Waveform Generator frequency parameter options

① Frequency parameter displayed location
② Frequency example
③ Period example
④ Update rate example

Amplitude

The amplitude (Vpp) and offset (V) parameters of the waveform are a parameter pair that can also be defined as high level (V) and low level (V).

For example, consider a waveform with an amplitude of 1 Vpp and an offset of -500 mV. The high level will be 0 V and the low level will be -1 V.

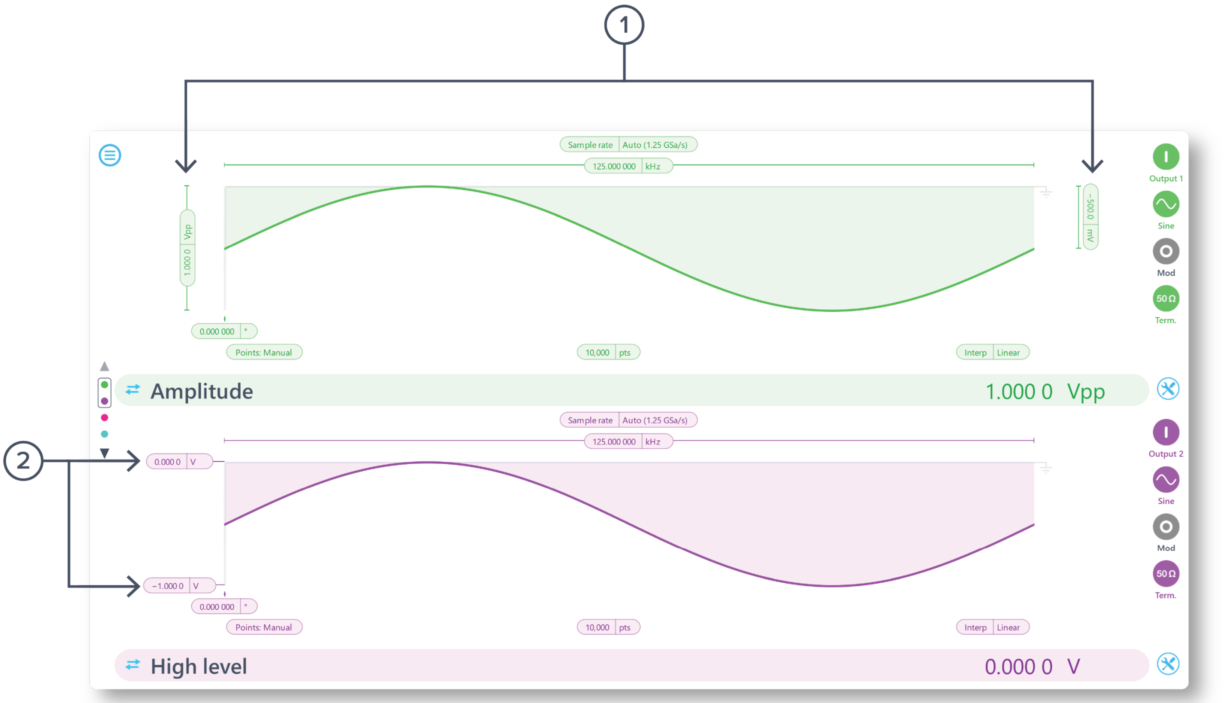

Figure 13. Arbitrary Waveform Generator amplitude and offset parameter options

① Amplitude and offset parameter pair locations

② High level and low level parameter pair locations

Modulation parameters and controls

Modulation is off by default. Turn on pulsed or burst modulation to add dead time between your waveform or trigger the output.

Output modulation modes

The Arbitrary Waveform Generator supports three output modes: normal, pulsed, and burst.

Normal: In normal mode, the output waveform is repeated continuously with no dead time between cycles.

Pulsed: In pulsed mode, the output waveform can be configured to have up to 2^18 = 262144 cycles of dead time between each repetition of the arbitrary waveform.

Burst: In burst mode, the output waveform can be triggered from another signal source. The output, once triggered, varies according to the trigger mode.

Pulsed modulation

Your output waveform can be configured to have a maximum of 262,144 cycles of dead time between each repetition of the arbitrary waveform.

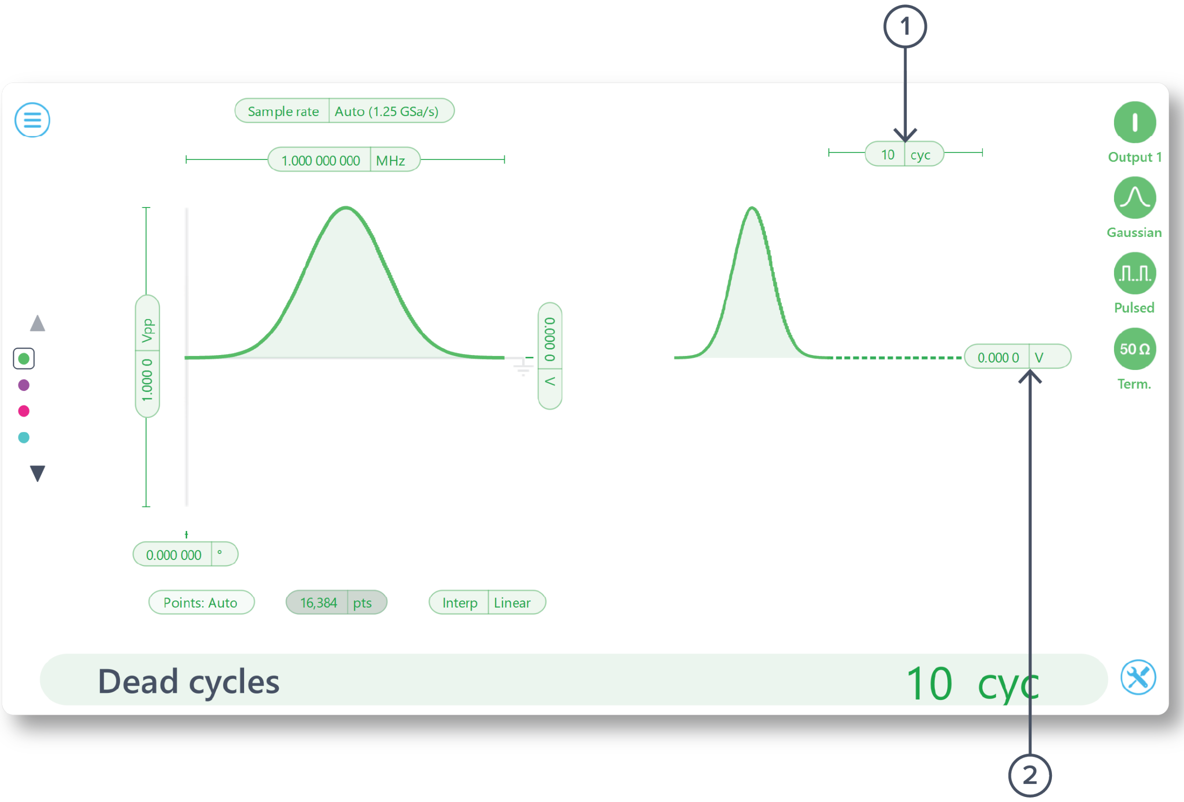

Figure 14. Pulsed modulation in the Arbitrary Waveform Generator

① Set the **Dead Cycles** between each repetition of your arbitrary waveform. The period of each cycle of dead time is equal to the selected period of the waveform. E.g. if the period of your waveform is 10 ns, then 1 cycle of dead time will be 10 ns.

② The **Dead Voltage** is the voltage that is output while in its “dead time”. This can be configured to equal any DC value between the waveform’s minimum and maximum voltages.

Burst modulation

In burst mode, the output waveform can be triggered from an input signal, the external trigger (if available) or manually. Once triggered, the output signal will repeat the waveform continuously if Start mode is selected. If N-Cycle mode is selected, the waveform will be repeated N times each time the trigger condition is met. If Manual trigger is used as source, click the ↻ button to trigger the waveform.

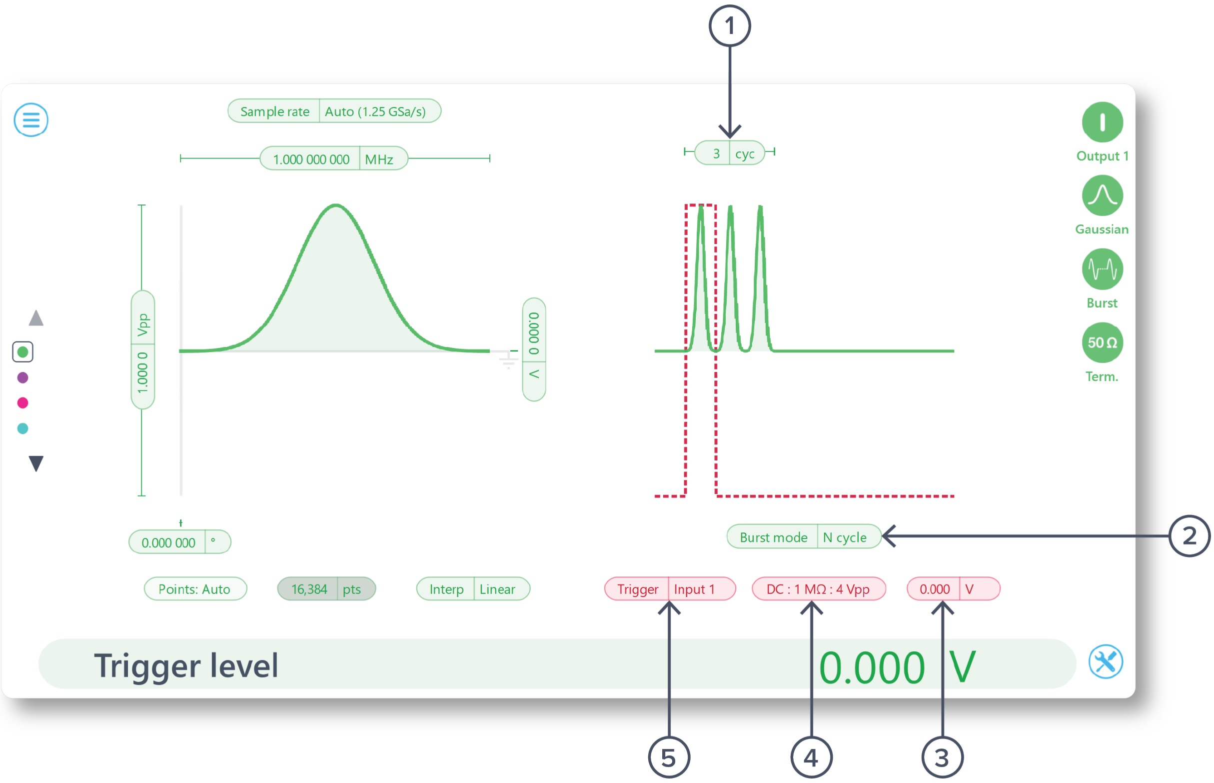

Figure 15. Burst modulation in the Arbitrary Waveform Generator

① **Burst cycles** is available in N-Cycle mode only, it is the number of waveform cycles to generate before returning to the offset, or dead voltage, and re-arming the trigger.

② **Burst mode** is available in N-Cycle or Start modes, the Start mode generates infinite loops of the waveform after the trigger event. N-Cycle generates a user defined number of cycles after the trigger event, before returning to the dead voltage and re-arming the trigger.

③ **Trigger level** sets the voltage level to trigger at.

④ **Frontend settings** sets the input range, impedance, and coupling. This sets the input channel settings to match the input signal. E.g. for a 1 Vpp signal, the input range option within the closest order of magnitude will be most accurate.

⑤ Select a **Trigger source** option; internal Input channels, External trigger (if available) or Manual trigger.

Termination and impedance matching

Moku:Lab, Moku:Pro, and Moku:Delta outputs, or Digital to Analog Converters (DACs), have a fixed 50 Ω load. When you connect the output to a 50 Ω device, the output voltage distributes to the internal load and external load equally. When you connect the output to a high impedance (Hi-Z) device, most of the voltage distributes to the external load.

Figure 16. Relationship between termination and displayed amplitude

Changing the "Load"/"Term" on the user interface does not affect the actual driving voltage. Instead, it only changes the scale for the display to reflect the voltage drop across the external load. The displayed voltage under the high load is twice the displayed number under the 50 Ω load. In the plot below, it can be seen that the "Term" is set to 50 Ω, resulting in a voltage output of 1 Vpp. When the "Term" is changed to "Hi-Z", the voltage reading changes to 2 Vpp. Although the voltage output source remains unchanged, the voltage reading in the interface is doubled because the voltage distribution on the load doubles when the load changes from 50 Ω to high impedance.

Moku:Go has a fixed 200 Ω output load and therefore the termination is fixed as Hi-Z in the interface.

Examples

Custom waveform example

Here we outline how to generate a custom waveform to highlight how to generate pre-modulated signals in the Arbitrary Waveform Generator. In this example we will define an amplitude modulated signal, upload it to the Arbitrary Waveform Generator, and apply pulsed modulation.

- **Step 1: Generate a custom waveform as a CSV or list**
  - Using the code shown below, create a list of numbers that create an amplitude modulated square wave, normalized to ±1
  - The code below follows this method:
    - Generate a time axis list with 1024 points from -π to π
    - From this span, generate a cosine wave
    - Generate another time axis list increasing the frequency by a factor of 10 to generate the square wave carrier
    - Generate the square wave carrier and plot the signals to validate your work
    - Normalise the cosine signal from 0 to +1 and apply the modulation to the square wave
    - Plot the modulated signal to validate and visualise the signal
    - Print the resulting signal and copy the values to clipboard

```
import matplotlib.pyplot as plt
import numpy as np

# Time from -pi to pi
t = list(np.linspace(-np.pi, np.pi, 1024))
# Generate a cos wave for amplitude modulation
cos = np.cos(t)
# Increase the frequency by a factor of 10 to generate the square wave carrier
x = list(np.linspace(0, 10*2*np.pi, 1024))
# Generate a square wave as the carrier
square = [-1 if i < 0 else 1 for i in np.cos(x)]
# Plot your carrier and square waves
plt.plot(t, cos)
plt.plot(t, square)
plt.show()

# Ensure the modulation signal is normalized from 0 to +1
pos_cos = (cos + 1)/2
# Apply the modulation to the square wave
mod = square * pos_cos
# Plot the resulting signal
plt.plot(t, mod)
plt.show()

# Print the resulting values to copy into the Arbitrary Waveform Generator
print(*list(mod), sep=", ")
```

    - Copy the values to clipboard
- **Step 2: Upload the signal to the Arbitrary Waveform Generator**
  - Open the Arbitrary Waveform Generator and select the custom waveform type
  - Right-click on the waveform, hover over load waveform, and select "Load from clipboard"
- **Step 3: Configure the waveform parameters**
  - Set the amplitude to 1 Vpp and the frequency to 125 kHz

- With these settings, the modulation frequency of the sine wave is 125 kHz and the frequency of the square carrier wave is ten times faster at 1.25 MHz
- Set the interpolation to linear and the sample rate to "Auto", these are the default settings
- **Step 4: Apply pulsed modulation**
  - Select pulsed modulation from the modulation types
  - Set the dead cycles to 10 and set the dead voltage to 0 V
- **Step 5: Enable the output**
  - Toggle the output ON

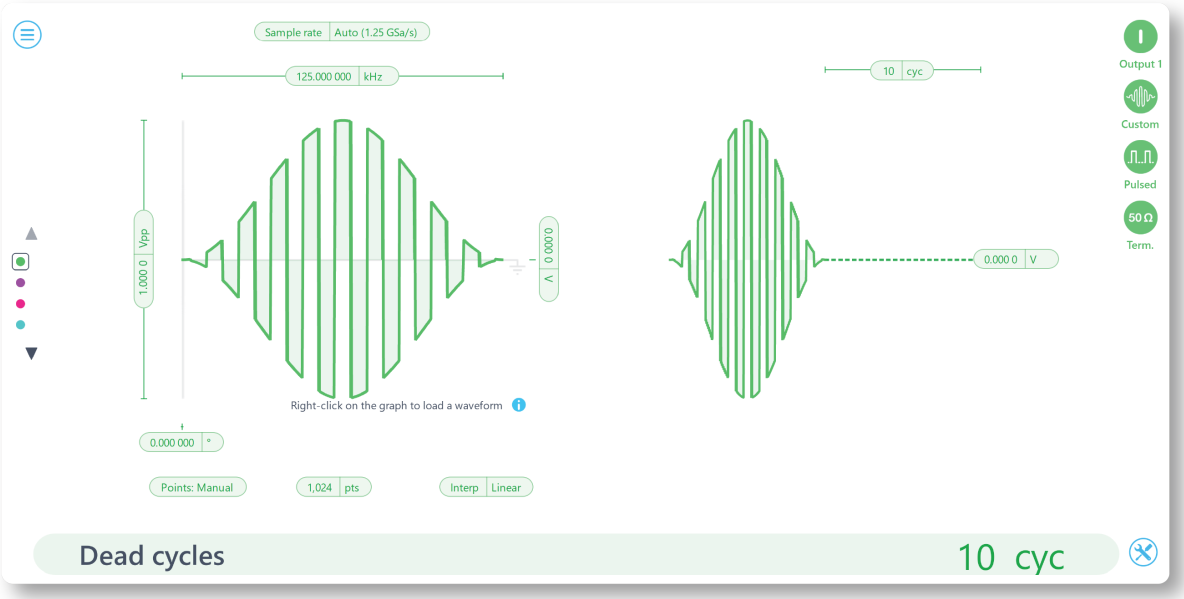

Figure 17. Custom pre-modulated waveform example

Additional Controls

Main menu

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

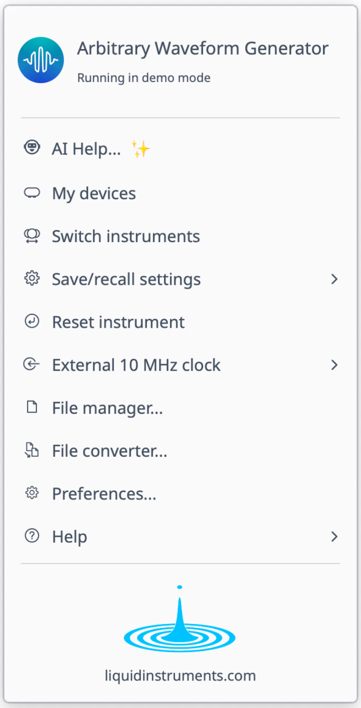

Figure 18. Main menu options for the Arbitrary Waveform Generator.

AI Help... Opens a window to chat to an AI trained to provide Moku-specific help (Ctrl/Cmd+F1)
My Devices returns to device selection screen
Switch instrument to another instrument
Save/recall settings

- Save current instrument state (Ctrl/Cmd+S)
- Load last saved instrument state (Ctrl/Cmd+O)
- Show the current instrument settings, with the option to export the settings

Reset instrument to its default state (Ctrl/Cmd+R)
Sync Instrument slots in Multi-Instrument Mode*
External 10 MHz clock selection determines whether the internal 10 MHz clock is used.
Clock blending configuration opens the clock blending configuration pop-up *
Power Supply access panel*
File Manager access tool
File Converter access tool
Preferences access tool
* If available using the current settings or device.

Help

- **Liquid Instruments website** opens in default browser
- **Shortcuts list** (Crtl/Cmd+H)
- **Manual** Open the user manual in your default browser (F1)
- **Report an issue** to the Liquid Instruments team
- **Privacy Policy** opens in default browser
- **Export diagnostics** exports a diagnostics file you can send to the Liquid Instruments team for support
- **About** Show app version, check for updates or licence information

File converter

The File converter can be accessed from the main menu ☰.

The File converter converts a Moku binary (.li) format on the local computer to either .csv, .mat, .hdf5 or .npy format. The converted file is saved in the same folder as the original file.

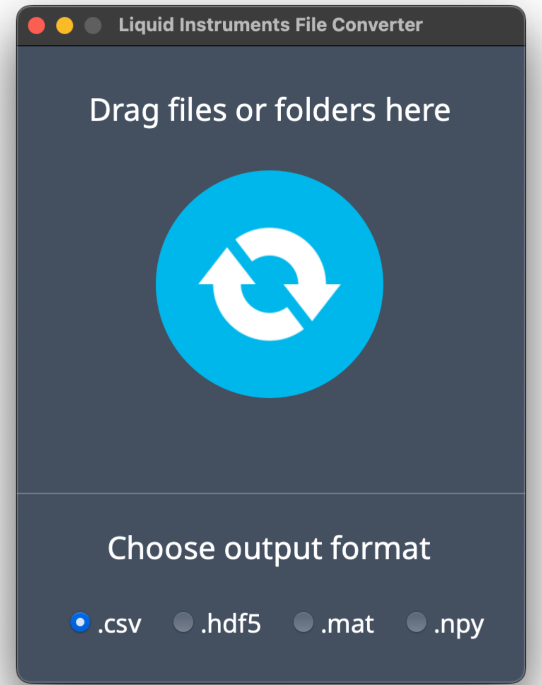

Figure 19. File Converter user interface.

To convert a file:

1. Select a file type.
2. Open a file (Ctrl/Cmd+O) or folder (Ctrl/Cmd+Shift+O) or drag and drop into the File converter to convert the file.

File manager

The File manager allows you to download the saved data from your Moku device to the local computer, with optional file format conversion. Once a file is transferred to the local computer, an icon appears next to the file.

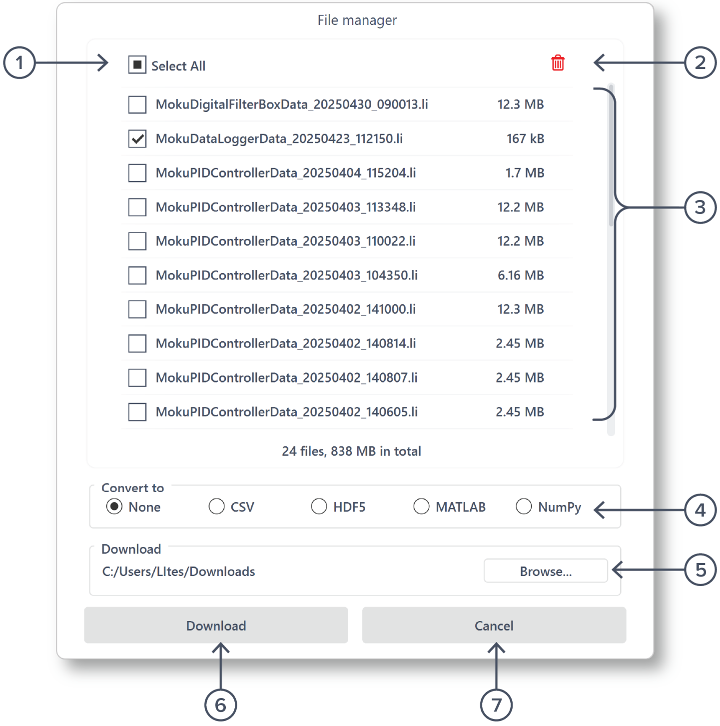

Figure 20. File exporting User Interface and settings.

To save logged data:

① **Select all** files logged to the device's memory, to download or convert.
② **Delete** all the selected file/s.
③ Browse and **select file/s** to download or convert.
④ Select an optional **file conversion format**.
⑤ Select a **location** to export your selected files to.
⑥ **Export** the data.
⑦ **Close** the export data window, without exporting.

Preferences and settings

The preferences panel can be accessed via the Main Menu. In here, you can reassign the color representations for each channel, switch between light and dark mode, etc. Throughout the manual, the default colors are used to present instrument features.

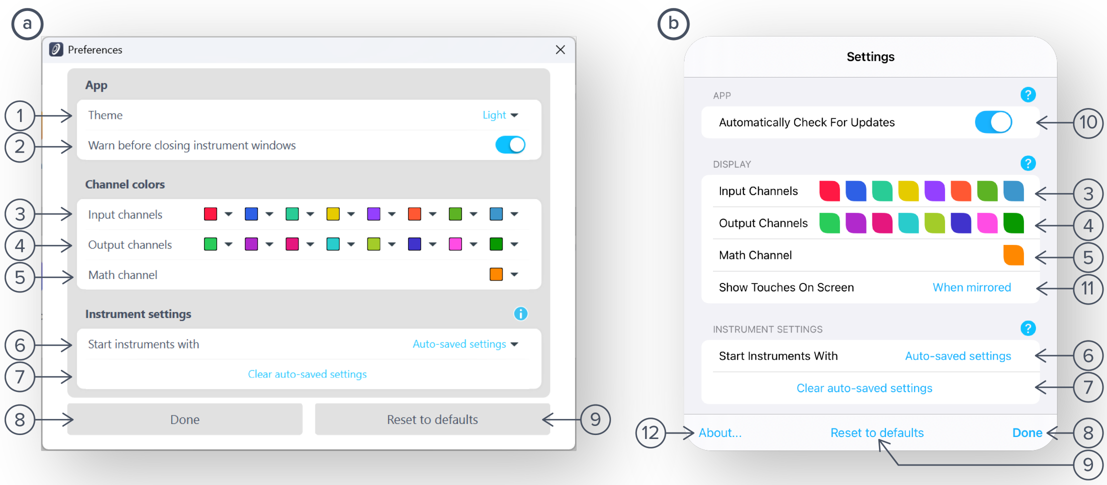

Figure 21. Preferences and settings for the Desktop (a) and for the iPad (b) App.

① Change the App theme, between dark and light mode.
② Choose if a warning opens before closing any instrument windows.
③ Tap to change the color associated with the input channels.
④ Tap to change the color associated with the output channels.
⑤ Tap to change the color associated with the math channel.
⑥ Select if instruments open with the last used settings, or default values each time.
⑦ Clear all auto-saved settings and reset them to their defaults.
⑧ Save and apply settings.
⑨ Reset all application preferences to their default state.
⑩ Notify when a new version of the app is available. Your device must be connected to the internet to check for updates.
⑪ Indicate touch points on the screen with circles. This can be useful for demonstrations.
⑫ Open information about the installed Moku application and license.

External reference clock

Your Moku may support the use of an external reference clock, which allows Moku to synchronize with multiple Moku devices, other lab equipment, lock to a more stable timing reference, or integrate with laboratory standards. The reference clock input and output are on the rear panel of the device. Each external reference option is hardware dependent, review the available external reference options for your Moku.

Reference Input: Accepts a clock signal from an external source, such as another Moku, a laboratory frequency standard, or an atomic reference (for example, a rubidium clock or a GPS-disciplined oscillator).

Reference Output: Supplies the Moku internal reference clock to other equipment that require synchronization.

If your signal is lost, or is out of frequency, your Moku will revert to using its own internal clock until the reference signal returns. If this occurs, check the source is enabled, and that the correct impedance, amplitude, tolerance, frequency, and modulation are attached to the reference. Check the required specifications in the device specsheets.

When the reference returns within range, status changes to "validating" and then "valid" once lock is re-established.

10 MHz external reference

To use the 10 MHz external reference function, ensure "always use internal" is disabled in the Moku application, found in the main menu under "External 10 MHz clock". Then, when an external signal is applied to your Moku reference input and your Moku has locked to it, a pop up will show in the app. On some devices, the external reference information will be shown in the LED status as well, more information can be found in your Moku Quick Start Guide.

Figure 22. Moku main menu with "Always use internal" reference disabled and using an external reference.

Clock blending configuration

If available, Moku blends up to four clock sources simultaneously for more accurate phase, frequency, and interval measurements across all time scales. A low phase-noise Voltage-Controlled Crystal Oscillator (VCXO) is blended with a 1 ppb Oven-Controlled Crystal Oscillator (OCXO) for optimal wide-band phase noise and stability, which can be blended further with an external frequency reference and GPS disciplining to synchronize Moku with your lab and UTC.

The VCXO and OCXO will always be used for the clock generation signal. The external and 1 pps references are optional and can be enabled or disabled in the "Clock blending configuration..." settings from the main menu ☰. The loop bands are adjusted based on the different possible clock source configurations, shown in Figure 23, where the frequencies of the bands represent where each oscillator's phase noise dominates.

Read how the clock blending works on Moku:Delta for more details.

Figure 23. Moku clock blending configuration dialog with an external 10 MHz frequency reference enabled.

① **VCXO jitter reference** is always used for clock generation, handling high frequency jitter with the lowest noise.

② **OCXO jitter reference** is always used for clock generation, ensuring moderate term stability.

③ **External 10/100 MHz frequency reference** uses a "10 MHz" or "100 MHz" external reference to correct drift in the local oscillator, noting your Moku will have to be restarted after each change between a 10 MHz and 100 MHz source.

④ **1 pps synchronization reference** uses an "External" or "GNSS" reference to sync with UTC and correct drift in the local oscillator. The estimated clock stability is a measure of how much the reference performance deviates relative to the local OCXO/VCXO timebase (as currently blended and, if enabled, steered by the external 10 / 100 MHz External reference).

Troubleshooting

Feature missing in waveform: Check the Sample rate requirements for your waveform, if the sample rate is set too high for the number of points in your waveform points will be skipped.

Gritty-looking waveform: Check the Interpolation that best fits your waveform type. Waveforms with square or sharp or square edges are typically best suited to no interpolation, but other waveform types are smoothest with interpolation applied.

Custom waveform is not valid: Review the requirements for loading your own waveforms; the file can only contain numbers, commas, spaces, newline characters, and 'e' for magnitude, e.g. 1e3 for 1000. Letters or special characters outside of this, including headers, will not be accepted.

Waveform is not shown or is clipped: The equation editor will clip the waveform outside of [-1, +1] bounds. Review the requirements for using the equation editor, such that the waveform is appropriately scaled to be shown.

Error message shown: Check the number of points in your waveform; an error is shown when points will be skipped, which occurs when the frequency * points > sample rate.

If your issue is still unable to be resolved, check out our support forum to see how others solved this problem or post your own topic for help.

