

Zurich
Instruments

HDAWG Arbitrary Waveform Generator

2.4 GSa/s, 16 bit
4, 8 and more channels

Product Leaflet

Release date: November 2017

Key Features

- 2.4 GSa/s, 16 bit, 750 MHz
- 5 V_{pp} maximum amplitude
- Scalable up to 64 output channels
- Highest channel density available
- Less than 50 ns trigger to output delay
- Digital modulation at multiple frequencies
- LabOne[®] AWG Sequencer and Compiler

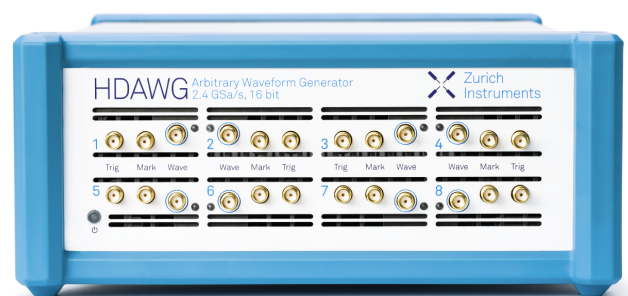
Summary

The Zurich Instruments HDAWG multi-channel Arbitrary Waveform Generator (AWG) has the highest channel density on the market and is designed for advanced signal generation up to 750 MHz bandwidth. The HDAWG comes with either 4 or 8 DC-coupled, single-ended analog output channels. The outputs can be individually switched between a direct mode, with maximized bandwidth and superior noise performance, and an amplified mode, that boosts the signal amplitude to up to 5 V_{pp}. Two markers per channel are available and allow precise setup synchronization while maintaining the full 16 bit output resolution.

LabOne[®] provides a state-of-the-art programming concept that combines the performance and flexibility of an AWG with the ease-of-use of a function generator. The platform-independent LabOne User Interface (UI) and a choice of APIs for LabVIEW[®], .NET, MATLAB[®], C, and Python enable easy measurement automation and fast integration into an existing control environment.

Applications

The HDAWG is a high-end instrument designed to meet the requirements of demanding applications by extending the basic AWG functionality with additional waveform memory, function generator functionality, internal oscillators and a set of pulse counters.



Quantum Computing and Phased-array Radar

Multiple HDAWG instruments can be controlled and automatically synchronized using a single user interface, enabling efficient scaling of radar and quantum computing systems while reducing complexity and lab space required. The short 50 ns reaction time to an external trigger signal enables quantum error correction methods with high fidelity. The internal oscillators minimize waveform upload times, ensure phase coherence and provide a simpler waveform definition. The integrated pulse counter helps simplify setups for trapped ion and N-V center experiments.

NMR and Spectroscopy

Signals in NMR and other spectroscopy applications occur at timescales from nanoseconds up to seconds. The HDAWG can speed up these measurements by applying a variable sampling rate and/or parametric sweeping. Using digital modulation, an arbitrary envelope can be imposed on one or multiple carrier signals with minimal waveform upload time while phase-coherence is maintained without additional effort.

Semiconductor Device Testing

Nested sequencing, waveform iteration, and dynamic sequencing with DIO control are ideal for realizing signals for extensive high-throughput testing. Multiplying or adding the AWG signal with a function generator signal extends the possibilities and helps simplify and speed up daily measurement routines.

Highlights

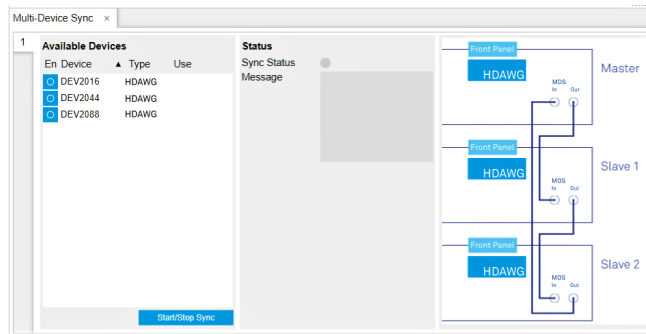
High-level AWG Programming

```
Sequence *pattern_1.seqc [ Examples... ]
1 const fs = 2.4e9; // sampling frequency
2 const n = 8000; // waveform length
3
4 wave w_chirp = chirp(n, 10e6/fs, 30e6/fs);
5 wave w_gauss = gau
6
7 const A = 0x0f; w_gauss local wave gauss(const samples, const amplitude=1.0,
8 const B = 0x1e; // snippet const position, const width)
9 // Gaussian pulse with arbitrary amplitude (a), position
10 // (p), width (w) and number of samples (N).
11
12 repeat (1000) {
13   playWave(w_gauss, w_gauss, w_gauss, w_gauss);
14   if (getAnaTrigger(1)==0) {
15     playWave(w_chirp);
16     setDIO(config_A);
17   } else {
18     setDIO(config_B);
19   }
20   wait(400);
21 }
```

The LabOne UI is designed to get you going quickly by providing hardware control in an intuitive and easily readable form. After defining the waveforms and sequences in the LabOne AWG Sequencer, the LabOne AWG Compiler translates it into machine language and transfers it to the hardware in a minimum amount of time. LabOne sequencing supports loops with dynamically varying delay and conditional branching points.

In addition to the standard waveforms, e.g. Gaussian, Blackman, sinc, etc., LabOne contains all the essential math and array editing tools required for advanced waveform design. You can easily add, multiply, cut, and concatenate waveforms or organize them in segments. Importing measured signals or waveforms calculated in another tool like MATLAB is a simple drag-and-drop action.

Multi-device Synchronization (MDS)

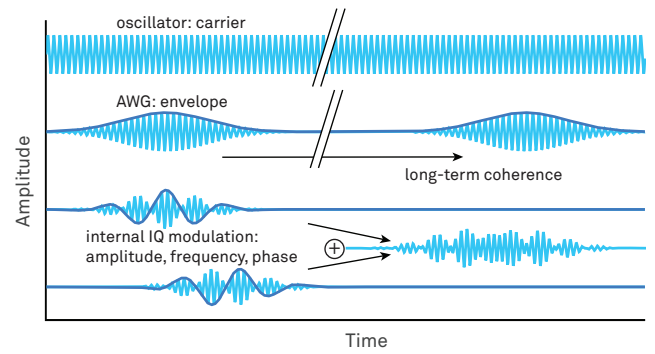


With MDS multiple HDAWGs can be operated much as a single multi-channel AWG:

- Operate all instruments from a single UI/API
- Absolute synchronization of all output channels
- Phase locking of all instrument clocks
- Synchronized time stamps and sampling rates for UHF series instruments

When multiple instruments are used, the LabOne AWG Compiler takes care of distributing your master sequence program across all instruments. An automated trigger exchange protocol ensures synchronized playback timing. Using MDS you can also build up a complete signal generation and acquisition system, including UHF instruments, comprising lock-in amplifier, boxcar, digitizer and AWG functionality up to 600 MHz.

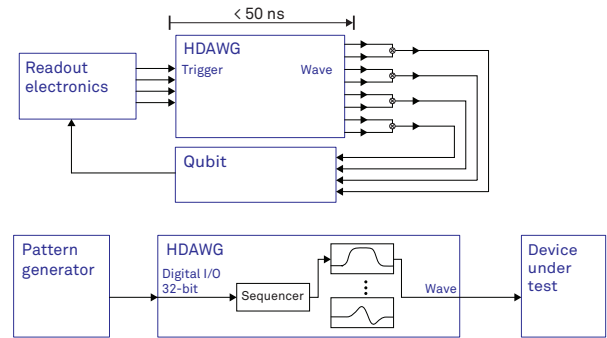
Oscillators, Modulation and Phase Control



The HDAWG is equipped with digital oscillators to generate the sinusoidal carrier of a signal independently of the programmed AWG envelope signal. This means that long signals can be generated with very fast waveform upload and precise phase coherence across many pulses. Carrier frequencies and phases that would otherwise be written to a static waveform can be freely adjusted and swept.

The HDAWG-MF Multi-frequency option increases the number of oscillators and enables full digital I/Q modulation to implement frequency, phase, amplitude modulation techniques as well as frequency-domain multiplexing, or phase cycling. With the HDAWG-FG Function Generator option, the modulation concept extends beyond sinusoid carriers to general carrier waveforms.

Low-latency Triggering and Sequence Branching

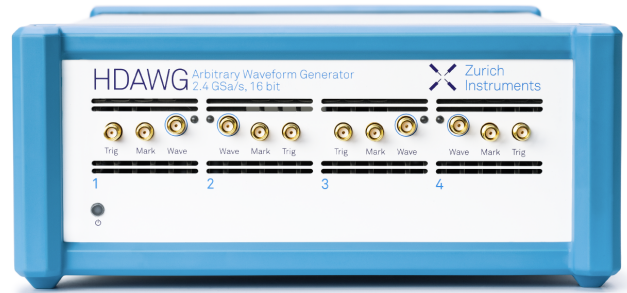


Thanks to the low-latency design, the HDAWG is able to generate its first sample on the output less than 50 ns after detecting an external trigger on one of the TTL inputs on the front panel. This is essential for feedback experiments in quantum computing where device properties are short-lived, and each nanosecond saved improves the experimental outcome tremendously. The 4 or 8 output channels of the instrument can be grouped in units of 2 or 4. Each of these groups can then be individually triggered which increases flexibility when distributing signals to separate parts of a device or setup.

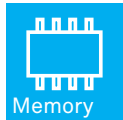
In order to generate signals with a high complexity and real-time control, the HDAWG is able to select from up to 1024 pre-stored waveforms in a programmable memory based on the bit-pattern applied to its 32-bit digital input. These could represent a digital modulation pattern, a device-specific test waveform, or a multi-qubit state readout result.

Models and Upgrade Options

The HDAWG4, shown on the right, is the 4 channel model and the HDAWG8, see first page, comprises 8 channels. They are technically identical except for the channel number and features associated with individual channels, e.g. number of oscillators. Please note that 4 channel instruments cannot be upgraded to 8 channels. The following options can be added to enhance the basic functionality when purchasing the instrument or any later time without sending the instrument back.



HDAWG-ME Memory Extension



- 500 MSa waveform memory per channel instead of 64 MSa

The HDAWG-ME option enables playback of longer signal patterns with sample-by-sample definition of the signal. This is particularly valuable when playing back waveforms with non-standard and non-repetitive noise or replaying the signals recorded with a UHF instrument.

HDAWG-FG Function Generator



- 4 or 8 channel function generator
- Square, sawtooth, triangle, etc.
- Modulation by AWG signal
- Summing with AWG signal

The HDAWG-FG option simplifies the generation of standard signals and extends the range of signals that can be generated by adding or multiplying its signal with that of the AWG. Control of the signal frequency, amplitude, and duty cycle is enabled by direct digital synthesis (DDS) technology, while a specialized graphical user interface facilitates the adjustment of waveforms with a few clicks.

HDAWG-MF Multi-frequency



- 4 oscillators per channel pair
- Independent envelopes for multiple carriers
- Output adder for 4 modulated signals

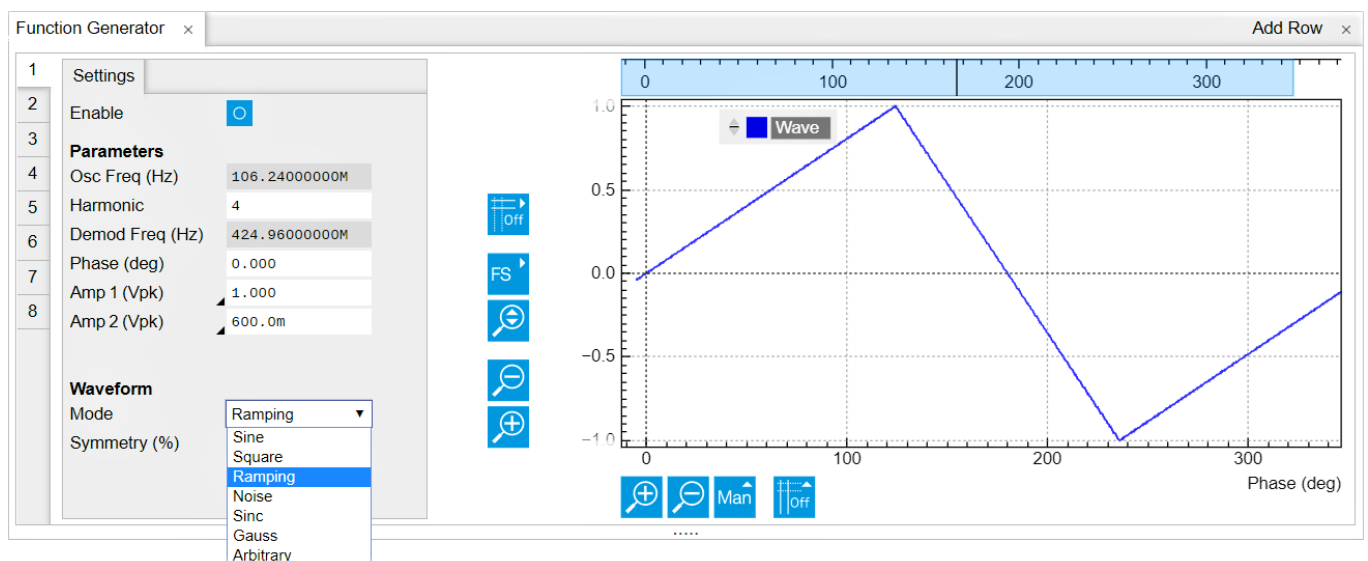
The HDAWG-MF option extends the number of oscillators and enhances the modulation capabilities of the HDAWG. This means faster waveform upload and more flexibility in applications where multiple superimposed carrier frequencies need to be tuned.

HDAWG-CNT Pulse Counter



- 4 or 8 counter modules
- 300 MHz maximum count rate
- Adjustable discriminator level
- Background subtraction

The HDAWG-CNT Pulse Counter option adds a photon detection capability for experiments using photo-multiplier tubes or APDs. Multiple pulse trains on the trigger inputs or the DIOs can be analyzed with five distinct modes of operation including time-tagging for statistical analysis. Sequence branching conditions can be defined based on counter values, enabling ultra-fast feed-forward loops for quantum error correction.



The Function Generator tab in the LabOne UI gives direct access to standard waveform definitions and displays a preview according to the set parameters. These standard signal shapes with tunable frequencies can be multiplied with or added to the AWG waveforms.

Specification

General

| | |
|-----------------------------|--|
| Dimensions including bumper | 23.2 × 10.2 × 43.0 cm 9.2 × 4.0 × 16.9 inch |
| Weight | 4.6 kg; 10.2 lbs |
| Power supply | AC: 100 – 240 V; 50/60 Hz |

Arbitrary Waveform Generator

| | |
|-----------------------------|-------------------------------------|
| Channels | 4 or 8, depending on model |
| Markers | 2 per channel (1 on SMA, 1 on DIO) |
| Resolution | 16 bit |
| Waveform memory per channel | 64 MSa 500 MSa (HDAWG-ME option) |
| Sequence length | 16384 instructions |
| Waveform granularity | 8 samples |
| Minimum waveform length | 32 samples |

Wave Output

| | |
|---------------------------------------|--|
| Output modes | amplified, direct |
| Frequency range, max. ampl. into 50 Ω | 0 – 750 MHz, 0.8 V _{pp} 0 – 300 MHz, 5.0 V _{pp} |

Wave Output (continued)

| | |
|----------------------------|--|
| Output impedance | 50 Ω, DC coupled |
| Output ranges (into 50 Ω) | 0.2 to 5.0 V _{pp} (amplified) 0.8 V _{pp} (direct) |
| Offset voltage (into 50 Ω) | ±1.25 V (amplified) 0 V (direct) |
| Output noise above 200 kHz | <30 nV/√Hz (amplified 5 V _{pp}) <12 nV/√Hz (direct) see figure below |

Time Domain Characteristics

| | |
|---|---|
| Sampling rate, internal and external source | 1.5 kSa/s to 2.4 GSa/s (int.) 50 MSa/s to 2.4 GSa/s (ext.) |
| Sampling rate resolution | 7 digits |
| Rise/fall time | <550 ps (amplified, 1 V step) <300 ps (direct, 0.8 V step) |
| Trigger delay to output | <50 ns |
| Skew between channels | <200 ps (any two channels) <20 ps (chan. 1&2, 3&4,...) |
| Skew adjustment | 10 ns (range) 10 ps (resolution) |

