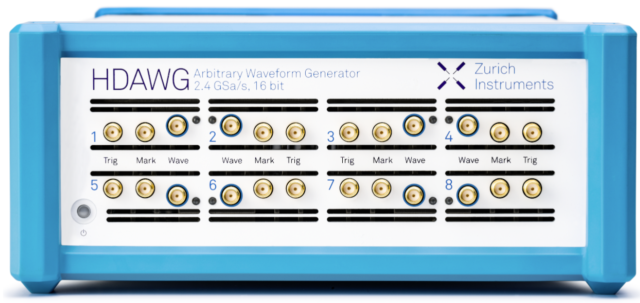
HDAWG
Arbitrary Waveform Generator

Zurich
Instruments

2.4 GSa/s, 16 bit
4, 8 and more channels
Product Leaflet
Release date: July 2023

Key Features

- 2.4 GSa/s, 16 bit, 750 MHz
- 5 V_{pp} maximum amplitude
- Scalable up to 144 output channels
- High channel density
- Less than 50 ns trigger to output delay
- Digital modulation at multiple frequencies
- Controlled via LabOne®, LabOne Q, or API



Summary

The Zurich Instruments HDAWG multi-channel Arbitrary Waveform Generator (AWG) has a high channel density 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 with 16-bit vertical resolution. Output switching is supported between a direct mode with maximized bandwidth and superior noise performance and an amplified mode that boosts the signal amplitude to a maximum of 5 V_{pp}. Temporal synchronization of up to 18 HDAWGs is supported through the Zurich Instruments PQSC.

LabOne provides a state-of-the-art programming concept that combines the performance and flexibility of an AWG with the accessibility of a function generator. The LabOne user interface, the LabOne Q software framework, and a choice of APIs for Python, C, MATLAB®, LabVIEW™and .NET enable 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, 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 NV center experiments.

NMR and Spectroscopy

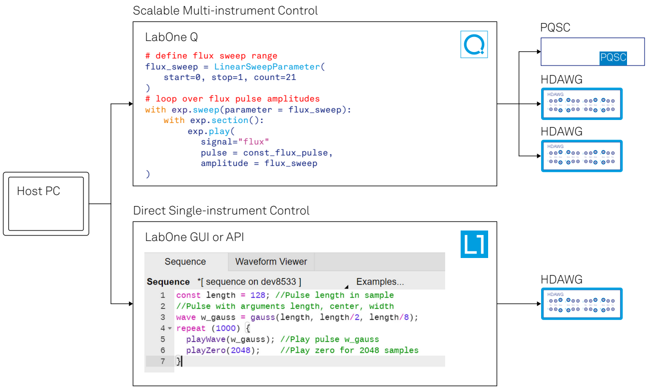
Signals in NMR and other spectroscopy applications occur at timescales from nanoseconds up to seconds. The HDAWG can speed up these measurements by applying a variable sampling rate and/or parametric sweeping. Using digital modulation, an arbitrary envelope can be imposed on one or multiple carrier signals with minimal waveform upload time while phase-coherence is maintained over long times.

Semiconductor 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.

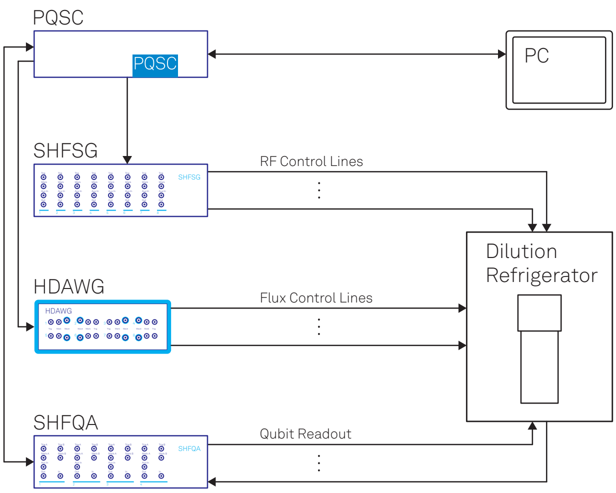
Highlights

Efficient AWG Programming



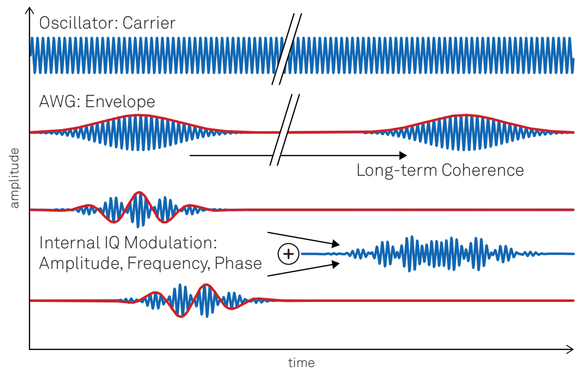
The LabOne UI is designed to get you going quickly by providing hardware control in an intuitive and easily readable form. The LabOne AWG Sequencer combines waveform generation, sequencing, and real-time control instructions in one programming language. This approach simplifies signal generation even when complex timing and control flows are needed. The LabOne AWG Sequencer is embedded in the LabOne graphical user interface and is also accessible through APIs in Python, MATLAB®, LabVIEW, and .NET.
LabOne Q provides a full measurement framework for quantum computing that includes pulse sequencing in Python. It automates the synchronization, the programming of multiple instruments of different kinds, and the instrument setting optimization. LabOne Q thereby provides a scalable approach to experiment control.

Scalable System Approach



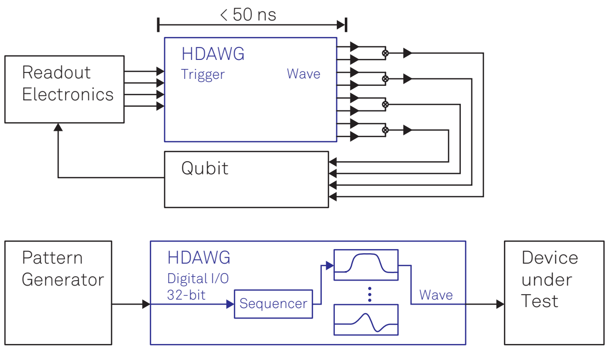
Each pair of channels of the HDAWG has its own AWG core for creating phase- and timing-programmable waveforms, so that a single HDAWG8 instrument can generate up to 4 IQ signal pairs or 8 real-valued signals.
The PQSC allows up to 18 HDAWGs to be combined in a single setup, corresponding to a system with up to 144 fully synchronized AWG channels. When using a PQSC, the HDAWG can also be combined with any combination of the Zurich Instruments SHFSG, SHFQC, and SHFQA. Such a system could be used for experiments with spin qubits, fluxonium qubits, or flux-tunable transmons coupled to superconducting readout resonators.

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.

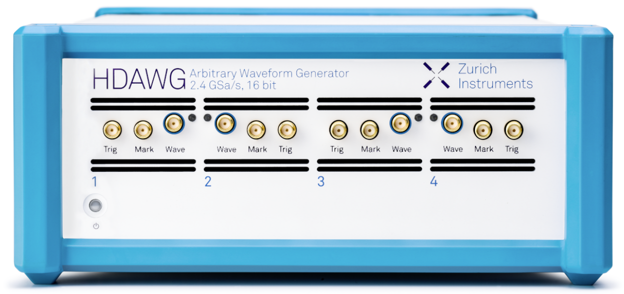
Low-latency Triggering and Sequence Branching



Thanks to the low-latency design, the HDAWG is able to generate its first sample on the signal output less than 50 ns after detecting an external trigger on one of the trigger inputs on the front panel. This is essential for feedback experiments in quantum computing where device properties are short-lived, and each nanosecond that is saved improves the experimental outcome tremendously.
In order to generate signals with a high complexity and real-time control, the HDAWG is able to store up to 1024 pre-stored waveforms in a programmable memory. The HDAWG can then decide which waveforms to play based on the information received over ZSync from a PQSC, on the results of the HDAWG-CNT Pulse Counter option, or on the bit-pattern applied to its 32-bit digital input. The information received in this way could represent a digital modulation pattern, a device-specific test waveform, or a multi-qubit state readout result.

Models and Upgrade Options

The HDAWG series comprises the 4 channel model HDAWG4 shown on the right and the 8 channel model HDAWG8. The two models 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 at any later time without sending the instrument back to Zurich Instruments.

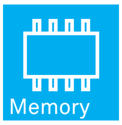


HDAWG-PC Real-time Precompensation

- 4 filter methods
- In-situ tunability
- Precompensation Simulator

The HDAWG-PC Real-time Precompensation option ensures that the signal applied to the device under test equals the signal designed on the HDAWG. Widely configurable digital filters for each output allow the user to invert the effects of spurious capacitances and inductances, AC coupling, signal reflections, amplifier ringing, and others.

HDAWG-ME Memory Extension



- 500 MSa waveform memory per channel instead of 64 MSa

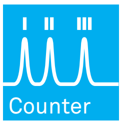
The HDAWG-ME option enables playback of long signal patterns with sample-by-sample definition of the signal. This is particularly valuable when playing back waveforms with non-repetitive elements.

HDAWG-MF Multi-frequency

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

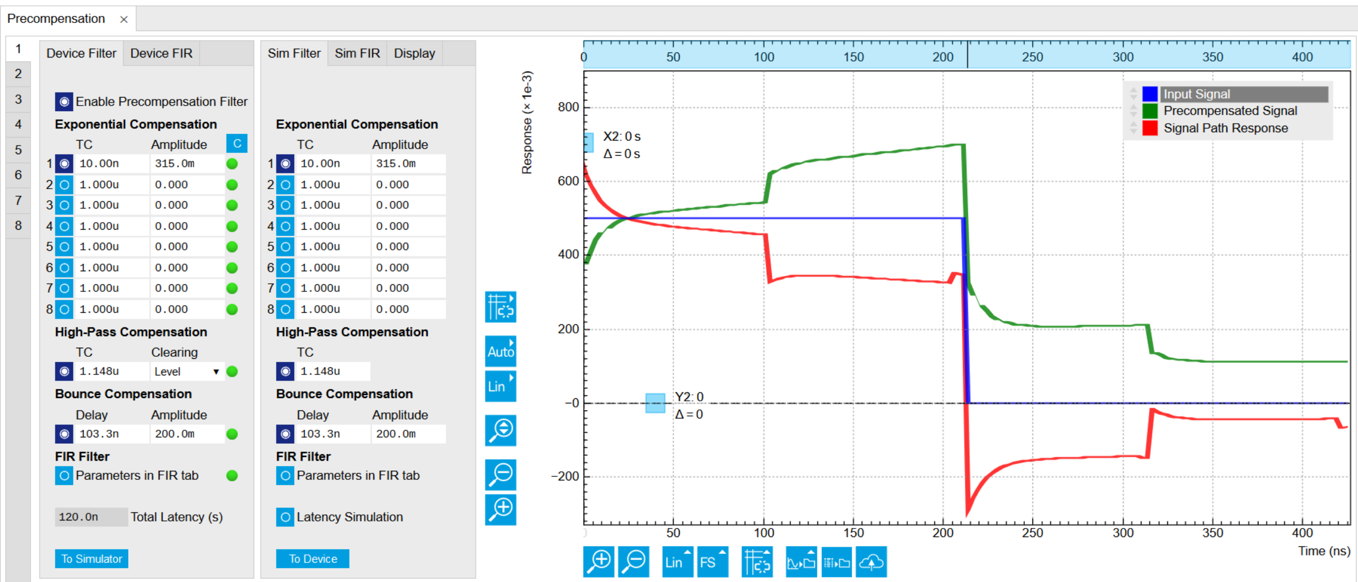
The HDAWG-MF option extends the number of oscillators and enhances the modulation capabilities of the HDAWG. This means faster waveform upload and more flexibility in applications where multiple superimposed carrier frequencies need to be tuned.

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 modes of operation including time-tagging for statistical analysis. AWG sequences can be branched based on counter data, enabling ultra-fast feed-forward loops for quantum error correction.



The Precompensation tab in the LabOne UI provides a simulator to display the effect of imperfections of the transmission lines and how to compensate them. Then the correction parameters can be easily transferred to the device.

Specifications

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

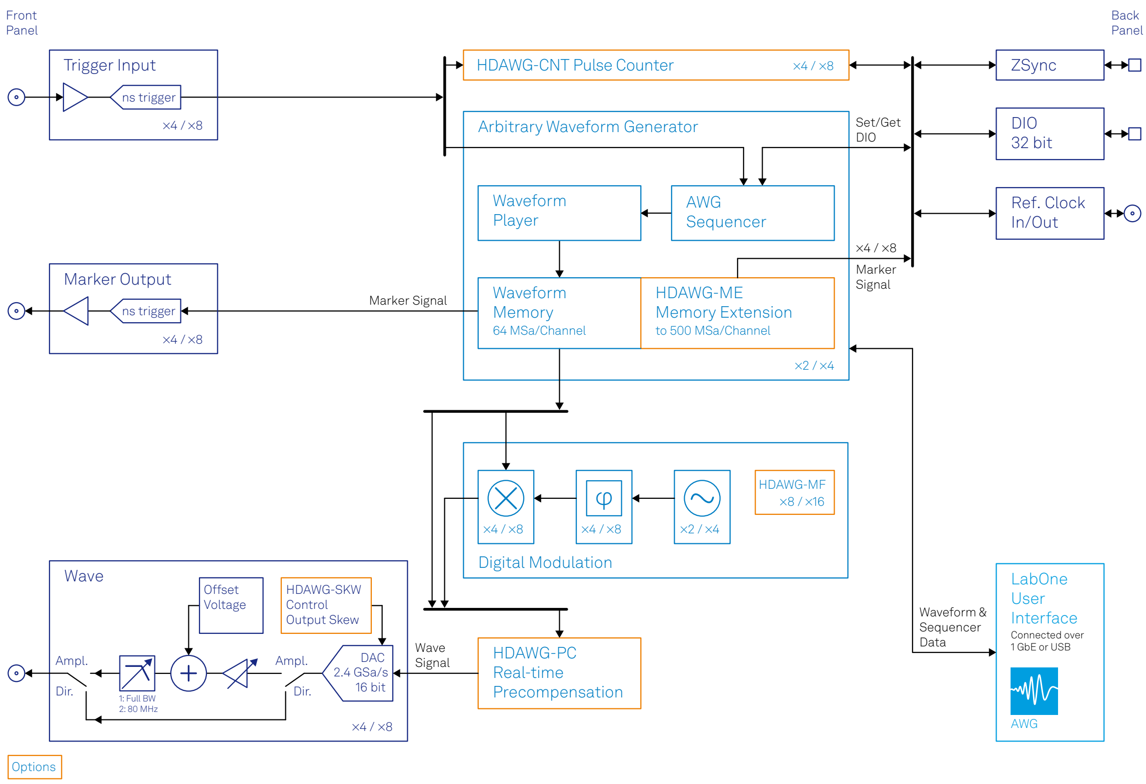
Channels	4 or 8, depending on model
Markers	2 per waveform, 1 SMA output per channel, 32 bit real-time DIO output
DAC vertical resolution	16 bit
Waveform memory per channel	64 MSa 500 MSa (HDAWG-ME)
Sequence length	16,384 instructions
Waveform granularity	16 samples
Minimum waveform	32 samples
Number of oscillators	1 per channel pair 4 per channel pair (HDAWG-MF)

Wave Output

Output ranges (into 50 Ω)	±0.1 V to ±2.5 V (amplified) ±0.4 V (direct)
Output impedance	50 Ω, DC coupled
Offset voltage (into 50 Ω)	±1.25 V (amplified) 0 V (direct)

Time & Frequency Domain Characteristics

Base Sampling rate	100 MSa/s to 2.4 GSa/s
Sampling rate division	2^{0} to 2^{13}
Sampling rate res.	7 digits
Bandwidth (–3dB, corrected for sin(x)/x roll-off)	0 – 600 MHz (ampl. ±0.5 V) 0 – 300 MHz (ampl. ±2.5 V) 0 – 750 MHz (direct)
Rise time (20% to 80%)	400 ps (ampl., 1 V step) 1000 ps (ampl., 5 V step) 300 ps (direct, 0.8 V step)
Output noise > 200 kHz	<35 nV/√Hz (ampl., high Z) <12 nV/√Hz (direct, high Z)
Output noise at 1 Hz	4 μV/√Hz (amplified, high Z)
Phase noise (100 MHz)	<–135 dBc/Hz (Δf 10 kHz) <–148 dBc/Hz (Δf 1 MHz)
SFDR (100 MHz)	80 dBc (excl. harmonics)
Worst harmonic component	–65 dBc (HD2) (ampl. ±0.5 V) –47 dBc (HD3) (ampl. ±2.5 V) –53 dBc (HD2) (direct)
Output period jitter	3 ps RMS (synchr. trigger)
Trigger uncertainty	3.3 ns (asynchr. trigger)
Trigger delay to output	<50 ns
Skew between channels	<200 ps



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