QDAC

Ultra-stable high-resolution D/A converters for gate control in quantum electronics, 24 or 48 channels, with built-in waveform generators and current measurement on each channel

QDevil

The Devil is in the detail

The QDAC

The QDAC series from QDevil are high-precision low-noise computer-controlled voltage generators designed for DC and low-frequency control of high impedance devices, such as gates in quantum electronics. In addition to precise and stable voltage output, the QDAC can measure output currents, for example to detect leaking gates or shorted bonding wires. The QDAC originates from the laboratories of the Center for Quantum Devices at the University of Copenhagen, where it is used for quantum computing research. The QDAC is available with either 24 or 48 channels and offers a cost effective way of getting many high quality D/A converter channels..

Highlights

- 24 or 48 channels 20-bit low-noise, high-stability voltage sources.

- Voltage ranges ±10 V or ±1.1 V with nominal step sizes of 19 µV and 2.1 µV, respectively.

- Less than ±2 µV drift in 10 hours.

- Temperature coefficient less than 3 µV/°C in 10V range.

- Current measurement up to 100 µA (10 V range) and 1 µA (1.1 V range), 24 bit resolution.

- All channels are updated synchronously every millisecond.

- 8 independent low-frequency function generators (sine/triangle/ramp/square) and one pulse generator.

- Arbitrary waveform generator (AWG) with up to 8-second-long waveforms.

- Waveforms can be routed to any number of outputs.

- Galvanically isolated digital outputs for external synchronization to the waveform generators.

- Galvanically isolated optocoupled USB/serial communication port.

- Friendly command set makes programming easy from any high-level language or from a terminal.

- Python library included, support for QuCoDeS.

SYNC

In order to synchronize external equipment to any of the waveform generators, several configurable SYNC outputs are provided. These will output a TTL-compatible 5V pulse at a configurable delay after the (re)start of the selected waveform generator. To avoid ground loops, the SYNC outputs are galvanically isolated from the other BNC outputs. There are two SYNC outputs on the 24-channel QDAC and five on the 48-channel version.

For synchronization with data acquisition software, the QDAC can also send a sync message to the connected computer via the USB connection.

CAL

Any DAC channel can additionally be routed to the CAL output. This is useful for automatic calibration of each channel (if desired), or the diagnostic monitoring of the selected channel. On request the CAL output can be modified to an external SYNC channel instead.
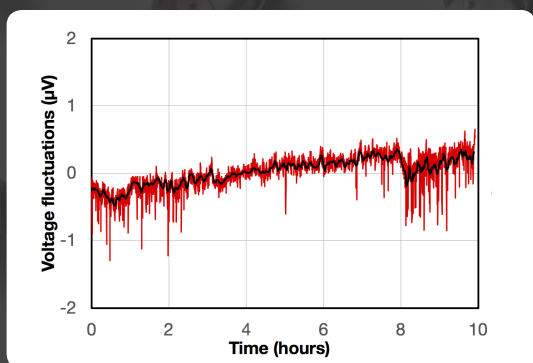
Stability is extremely important for quantum experiments, which typically last days. Voltage fluctuations (DC - 1.5 Hz) over time in the ±10 V range at 25°C .
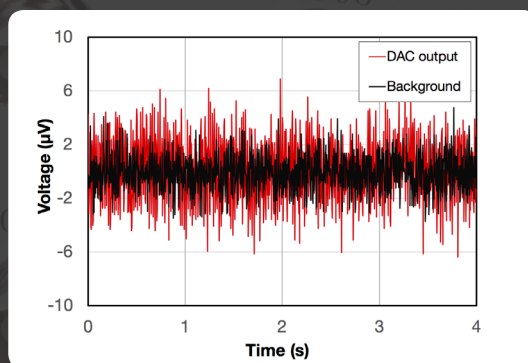
Short timescale fluctuations: DAC output (red), background (black). Average rms noise in 30Hz-1MHz is about 10 nV/√Hz, and 0.10 µV/√Hz in 30-1000 Hz at 0V output in the ±10V range.

Summary

Number of channels	24 / 48
Voltage ranges	±10 V, ±1.1 V configurable by software on each channel individually
Voltage resolution	20 bits 1 LSB = 2.1 µV (1.1 V range) 1 LSB = 19 µV (10 V range)
Temperature coefficient	< 3 µV/°C @ 25°C, 0.1 V output (10V range)
Stability	< ±2 µV fluctuations in 10 hours (10V range) (temperature stable within ±0.3°C)
Maximum integral non-linearity	1.7 LSB (typical)
Maximum differential non-linearity	0.7 LSB (typical)
Current output	±1 mA (10 V range) ±10 µA (1.1 V range)
Update rate	1 kHz
Predefined waveform generators	8 (sine/triangle/ramp/square)
Arbitrary waveform generator	Up to 8000 samples / 8 sec
Pulse train generator	1
Sync outputs	2 (24-channel units) 5 (48-channel units)
Current sensing (each channel)	100 µA (10 V and 1.1 V range) 1 µA (1.1 V range)
Current resolution	24 bits, 200 ms settling time
Power	±15 V (24-chan: 0.8 A, 48-chan: 1.5 A) 5 V (24-chan: 1.5 A, 48-chan: 3 A)
Dimensions (incl. feet)	24-chan. unit, cm: 45 x 32 x 18.5 48-chan. unit, cm: 45 x 32 x 27.5
Weight	24-chan. unit: 5.5 kg 48-chan. unit: 7.7 kg

The 48 channel version of the QDAC, without the optional rack mounts.

Optimized for low noise

In order to keep noise at low levels and to prevent ground loops, the QDAC is designed to use a galvanically isolated external power supply. Furthermore, the USB connection is isolated from the chassis and is opto-coupled. Ventilation is entirely passive without a rotating fan.

The large spacing of the BNC connectors on the front panel allows the use of, e.g. additional external low pass filters, voltage dividers, monitoring tees, etc. as needed.

Each unit has been calibrated at the factory, but the command set also allows programming the DAC outputs directly with their native 20-bit binary values.

Easy computer control

The QDAC is controlled through a USB/serial interface using simple commands easily used from any programming language or even from a terminal program. QDevil supplies a Python library and examples for straightforward integration with Python programs.

In addition, because the QDAC is based on prototypes developed at the University of Copenhagen, a driver for QCoDeS already exists. QCoDeS is a Python based modular acquisition framework for experimental work with quantum computing devices. It is developed and maintained by the Copenhagen-Delft-Sydney-Microsoft quantum computing program and is open source.

Waveform generators

The QDAC contains 10 independent function generators. One is an arbitrary waveform generator (AWG) which can hold up to 8000 points, corresponding to 8 seconds. One is a pulse train generator for which the pulse width and spacing can be set to any integral of milliseconds. The remaining eight function generators have predefined waveforms, sine/triangle/ramp/square, which have configurable period and duty cycle.

In addition, all function generators have the option for setting the number of repetitions, including endless, and they can be output on a single or on multiple channels with a voltage amplitude and offset selected individually for each channel.

Various waveforms can be generated. The SYNC outputs can mark the beginning of selected waveforms.
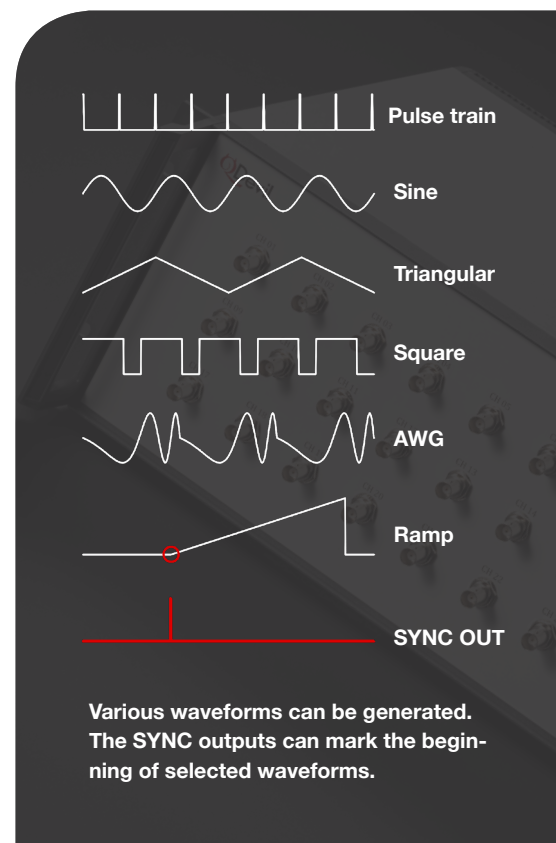
Item no.	Description
Q301	QDAC - 48 channel 20 bit quantum gate voltage source and measurement unit
Q302	QDAC - 24 channel 20 bit quantum gate voltage source and measurement unit
	- The QDAC requires a power supply capable of supplying ±15V and +5V with common 0V reference, galvanically isolated from mains ground for best noise performance (for example QL355TP from Thurlby Thandar Instruments).

About QDevil

QDevil was founded in 2016 with the mission of developing and producing auxiliary electronic components specialized for quantum electronics research. Product development is done in close collaboration with universities, in particular with the University of Copenhagen.

QDevil's first product is the 24 channel QFilter for reducing electron temperature below 100 mK. It is built on a design developed and patented by Ferdinand Kuemmeth and Charles Marcus while working at Harvard University. The QFilter has been improved since the initial introduction, with high-quality metal connectors and better shielding.

The product portfolio has quickly increased with a 24-channel breakout box, the QBox, two sample holder boards, several specialty cables, and the QDAC, a 24- or 48-channel gate controller DA converter.