Appendix I

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Dual AC voltage source – DualDAC 2

Two-channel audio frequency ultra-stable arbitrary wave generator

Description and specifications v0.4

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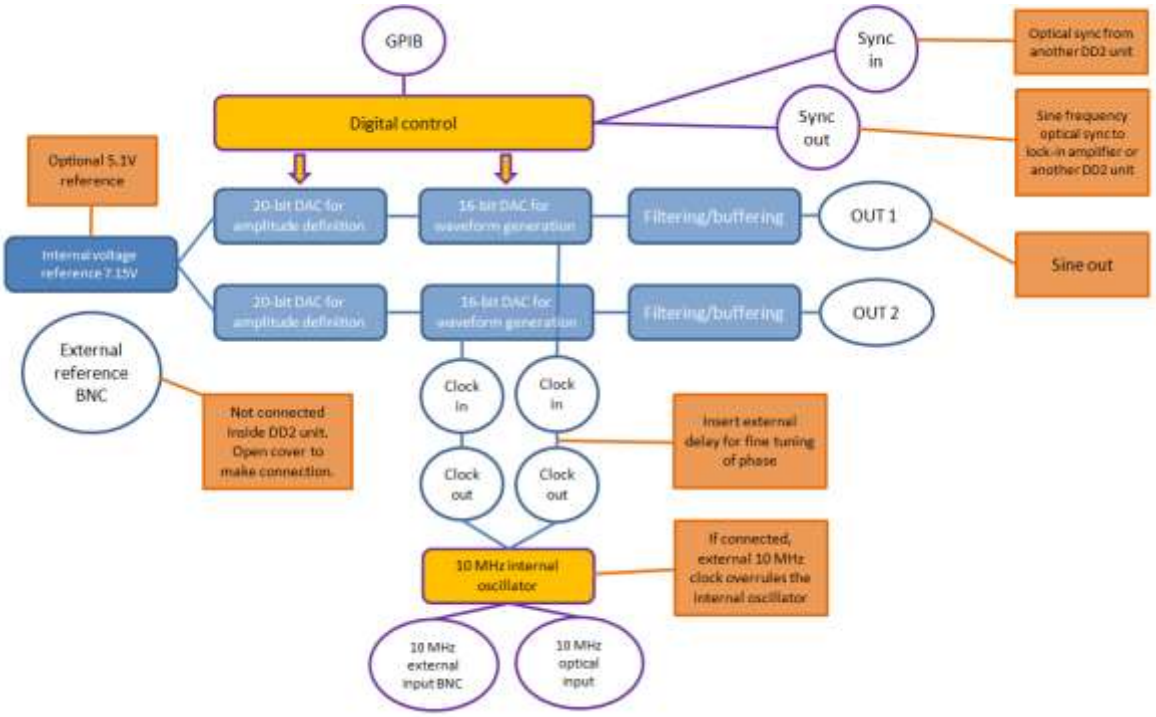
Description:

DualDAC 2 is a dual precision arbitrary wave generator for metrological applications at low frequencies (0.1 Hz - 20 kHz). Waveforms are defined by two individual 16-bit DACs with sampling rate of 2Msps and maximum number of samples per period of 16384 for each channel. Maximum amplitudes are adjustable with separate 20-bit DACs. Full scale amplitude maximum is defined by internal Zener reference of 7.15 V (other values upon request). The following picture illustrates the main features of DualDAC2 (DD2).



DualDAC 2–system consists of three units attached into 19-inch sub-rack. Converter unit consists of digital-to-analog converters, output driving and filtering circuits and output connectors. Controller unit is composed of digital control circuits for converters and connection to computer. Regulator unit contains voltage regulators for other units. Converter unit is temperature-controlled.

A number of DualDAC 2 systems can be synchronized to work together. Each system is given an own IEEE-488 address and the maximum number of units is limited only by the IEEE data bus. In order to operate DD2, user needs software that supports IEEE-488 (i.e. GPIB) bus. National Instrument LabView –software is available for controlling DD2.

The output voltage waveforms at both channels are updated at zero crossing so that waveform continuity is preserved.

Inputs:

- 10 MHz clock (BNC connector 2V sine recommended or optical receiver Avago's HFBR-2526ETZ, internal if unplugged)
- Internal dc reference voltage Vref = 7.15 V, <1 ppm/C. Option: external reference between 3 – 7 V provided by user. BNC connector

- Optical sync in connector for synchronizing several DD2 units
- IEEE-488 connector for computer control
- power supply +15V, -15V, +8V, +5V provided by user
    - Converter power +/- 15V in regulator unit: Binder 680-series 3-pin socket
    - Controller power +8V in regulator unit: Binder 680-series 2-pin socket
    - Temperature controller power +5V (or different if marked in rear panel): banana connectors in rear panel
    - Versions with fan have separate 2.5mm dc power connector in rear panel. AC/DC power adapter is typically included

Figure 1: Controller unit with optical sync input/output, 10 MHz clock input (optical/electrical) and GPIB connector.

Figure 2: Regulator unit with two Binder-680 connectors as inputs. Power cables from Binder-680 to 4 mm bananas are provided.

Figure 3: Converter unit with output 1 (BPO connector) connected. Clock in/out connectors shorted with short BNC cables.

Outputs:

- Two arbitrary wave outputs locked to same user-specified frequency with individually controlled amplitude between 0 – Vmax and phase. Vmax is adjusted using 20-bit DAC with maximum value Vref. Maximum output current 4 mA, (separate option: 70 mA with buffers). The analog output ground is floating relative to the digital ground. BPO connector (other connectors upon request)

- Two outputs/inputs for sample clocks for external fine tuning of phases
- optical trigger (sync out) for sine frequency (separate option for optical-to-TTL pulse converter for e.g. multimeter or lock-in amplifier), ST connector

Figure 4: Optical-to-TTL converter a.k.a. fibre receiver

How to get started:

See separate operation manual.

Specifications:

1) The sine wave amplitude resolution of each channel at full amplitude is about 1 ppm at 1 kHz.
2) The sine wave phase resolution of each channel is better than 1 mdegree at 1 kHz.
3) The amplitude stability of each channel is determined by the dc reference voltage stability. With a Fluke 5700 calibrator as a reference voltage source (with an internal Zener), sine wave amplitude stability is about 1 ppm for days.
4) The stability of amplitude ratio 1:1 is better than 1 ppm at 1 kHz for days.
5) The stability of amplitude ratio 1:10 is better than 2 ppm at 1 kHz for days.
6) Sine wave offset less than 1 mV at full amplitude 7.15 V
7) 20-bit DAC amplitude linearity better than +/- 5 uV in range 0 – 5 V
8) 16-bit DAC amplitude linearity better than +/- 25 uV in range +/-5 V

Test procedures and data:

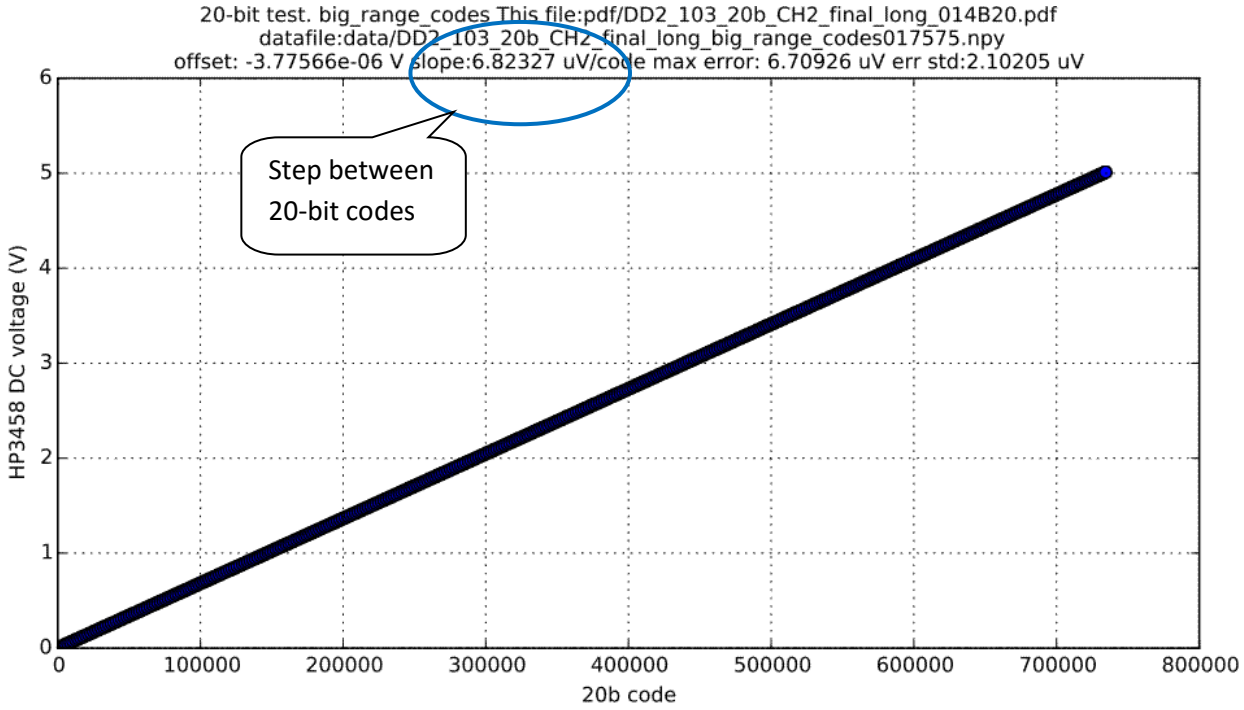
Each DualDAC2 unit undergoes a test procedure where the following data is measured and the data and relevant computer scripts are made available to customer. Tests are performed in standard office environment with internal temperature control on and the unit has been on at least 30 minutes before starting the test procedure.

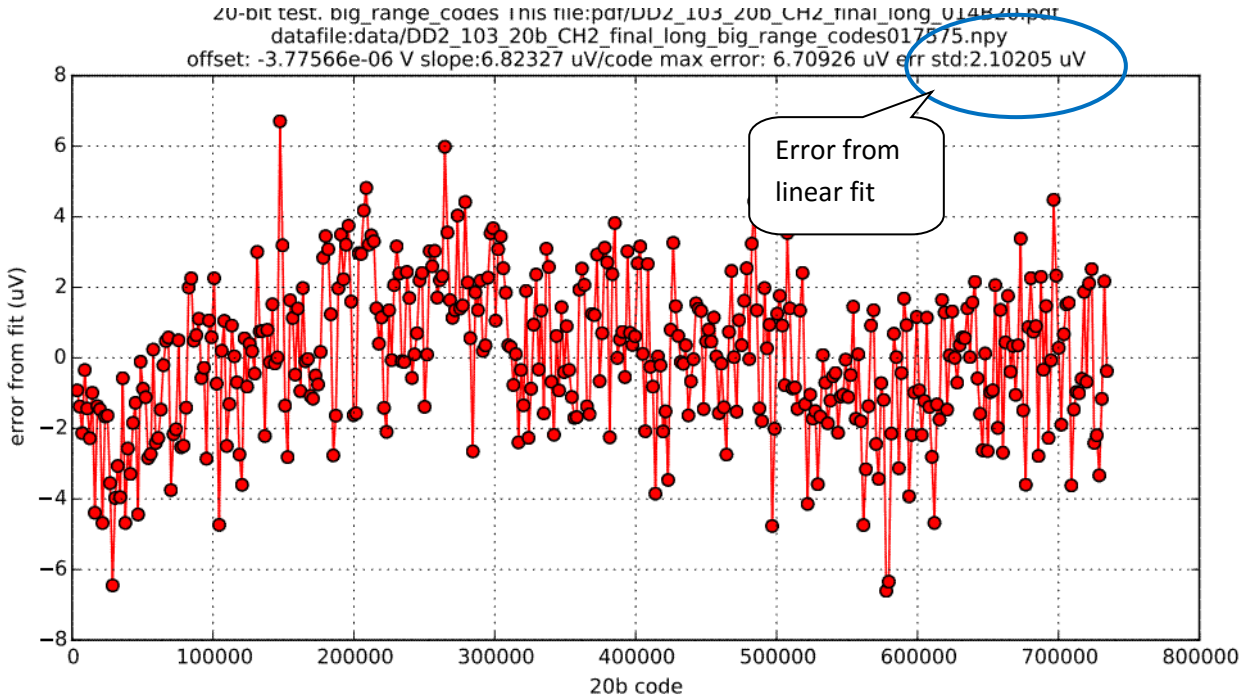
1) Internal reference voltage Vref = 7.15 V +/- 0.1V

2) DC values at output. Measured using HP3458A. Some measured values shown with specifications.

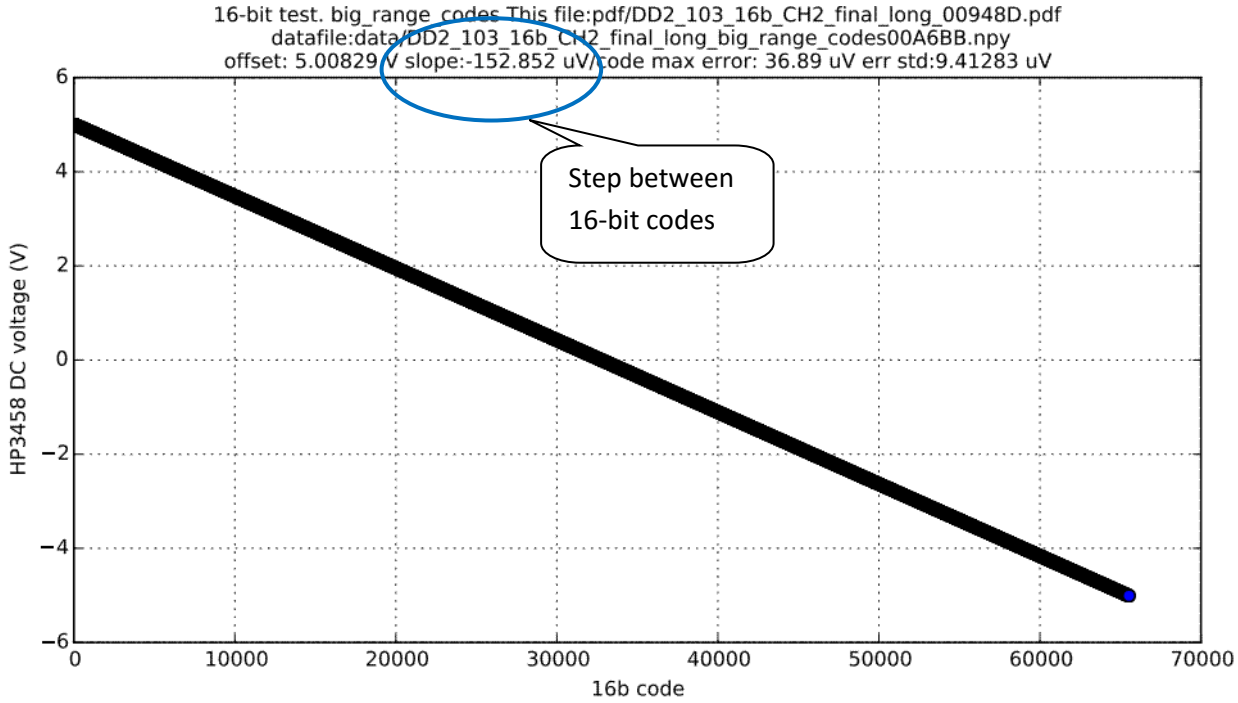
20-bit DAC value 16-bit DAC value	0 “ZERO”	734 000 “ABOUT 5V”	(2^20)-1 = 1 048 575 “FULL VREF”
0 “POS FULL SCALE”	CH1: -157 uV CH2: -1 uV Spec: +/- 200 uV	CH1: 5.00815 V CH2: 5.00828 V Spec: 0.7Vref +/- 2 mV	CH1: 7.15456 V CH2: 7.15468 V Spec: Vref +/- 3 mV
32768 “CENTER”	CH1: -97 uV CH2: +67 uV Spec: +/- 200 uV	CH1: -493 uV CH2: -369 uV Spec: +/- 700 uV	CH1: -658 uV CH2: -561 uV Spec: +/- 1000 uV
(2^16)-1 = 65535 “NEG FULL SCALE”	CH1: -43 uV CH2: +141 uV Spec: +/- 200 uV	CH1: -5.00897 V CH2: -5.00889 V Spec: -0.7Vref +/- 2 mV	CH1: -7.15568 V CH2: -7.15565 V Spec: -Vref +/- 3 mV

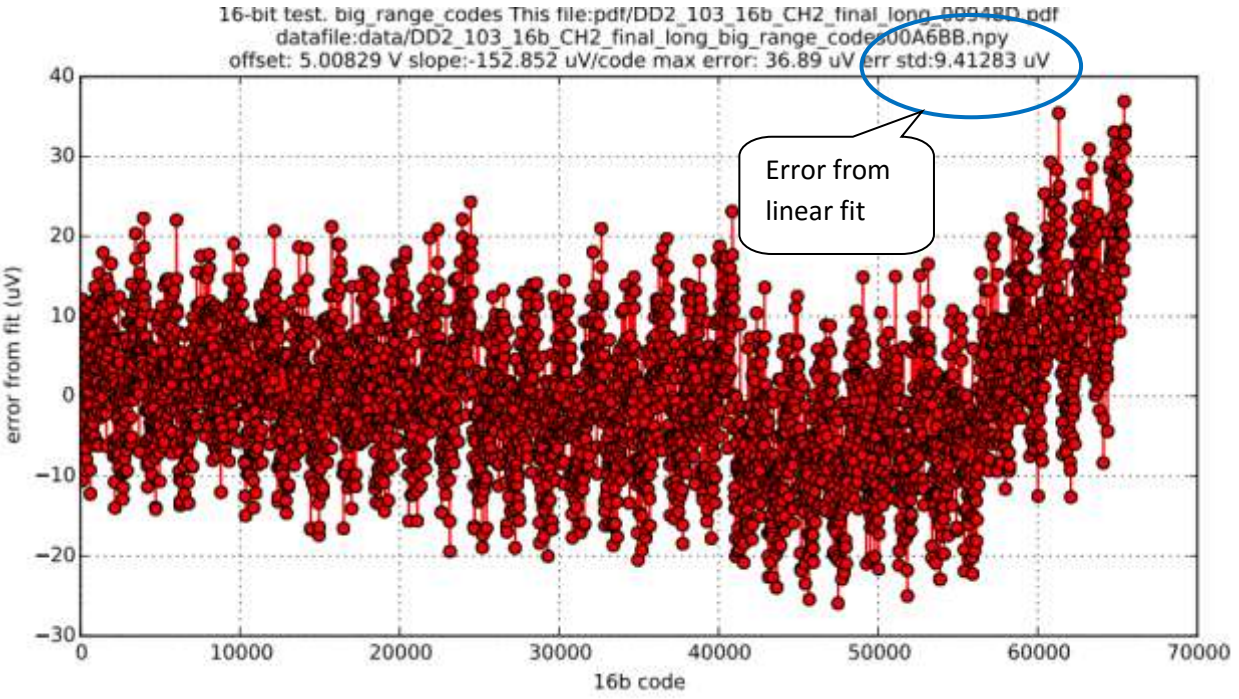
3) DC sweep of 20-bit DAC from 0 – 734 000 when 16-bit DAC is set to positive full scale. Linear fit to data and deviation of data from fit is plotted. Std error allowed +/- 5 uV.





4) DC sweep of 16-bit DAC when 20-bit DAC is set to 734 000. Linear fit to data and deviation of data from fit is plotted. Std error allowed +/- 25 uV.





5) Stability of sine waves at 1 kHz with amplitude ratio of 1:1 at 20-bit DAC value 70% (i.e. 734 000) (sets full scale sine wave amplitude to 5V). 16-bit DAC amplitude is set to 0.99. An inductive divider is set to 1:1 and middle point is measured using lock-in amplifier for more than 24 hours. Small adjustments to amplitude and phase of one channel are made to obtain zero in the middle.