Appendix I

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Dual AC voltage source – DualDAC 3

Two-channel audio frequency ultra-stable arbitrary waveform generator

Description and specifications v0.1

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Description:

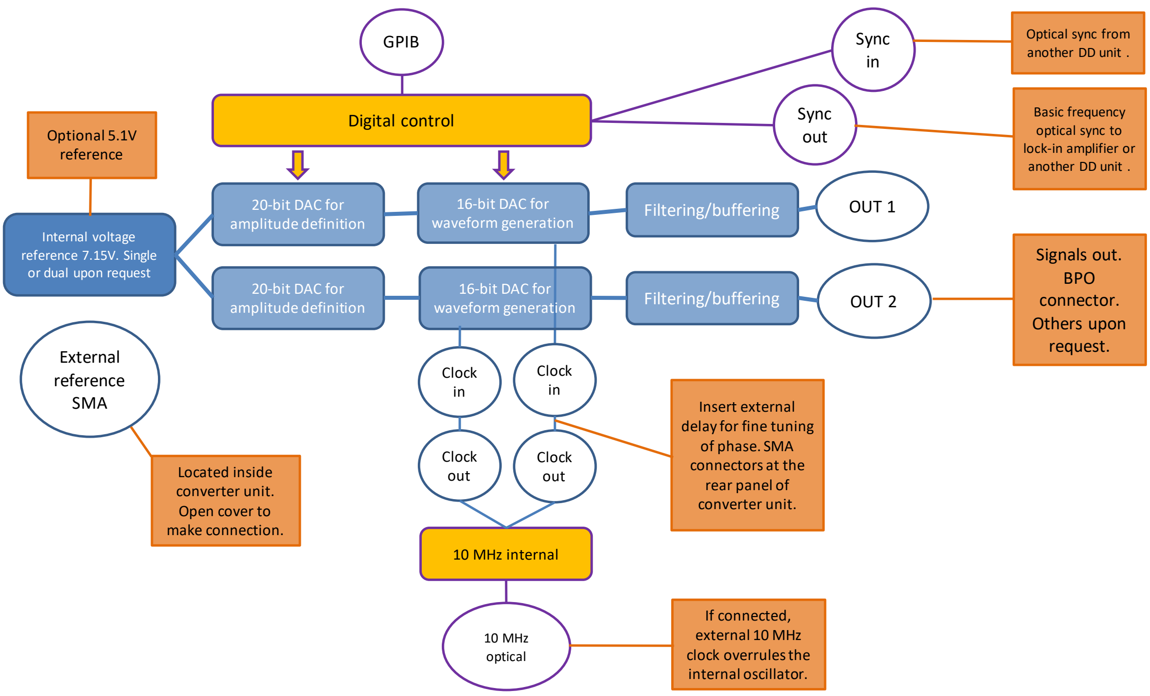
DualDAC3 is a dual precision arbitrary waveform generator for metrological applications at low frequencies (0.1 Hz - 20 kHz).

Some applications are:

- digital impedance bridges
- reference source for electrical power meter and power quality analyzer calibrations
- calibration of thermal converters and analog-to-digital converters

Periodic waveforms are defined by two individual 16-bit digital-to-analog converters (DACs) with sampling rate of 2Msps and maximum number of samples per period of 16384 for each channel. Maximum amplitudes of each two output channel are adjustable with separate 20-bit DACs. Full scale amplitude maximum is defined by single internal Zener reference of 7.15 V (other values upon request). Optionally, the customer can request separate Zener references for both output channels or use own external references.

The following picture illustrates the main features of DualDAC3 (DD3).



DualDAC 3 (DD3) system consists of three units attached into 19-inch 3U-high sub-rack. Converter unit consists of DACs, output driving and filtering circuits and output connectors. Controller unit is composed of digital control circuits for converters and connection to computer. Power supply unit (PSU) in rear panel contains isolating DC/DC converters for other units as well as temperature controller for converter. If two separate Zener references are used, the grounds of the two channels can be isolated from each other.

A number of DD3 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 DD3, user needs software that supports IEEE-488 (i.e. GPIB) bus. National Instrument LabView –software is available for controlling DD3.

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

Inputs:

- 10 MHz clock (optical receiver Broadcom HFBR-2416TZ, internal if unplugged, tolerates +/-1 kHz offset in frequency)
- One (or two by request) internal dc reference voltage Vref = 7.15 V, <1 ppm/C. Option: external references between 3 – 7 V provided by user. BNC connectors needs to be added to front panel.
- Optical sync in connector for synchronizing several DD3 units (Broadcom HFBR-2416TZ)
- IEEE-488 connector for computer control
- power supply +18V - 24V provided by user
    - Temperature controller power +5V - +12V: connectors in rear panel

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

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Figure 2: Converter unit with both outputs (BPO connector) connected. Shield is grounded using large crocodile clip.

Outputs:

- Two arbitrary waveform outputs locked to same user-specified frequency with individually controlled amplitude between 0 – Vmax and phase. BPO connector (other connectors upon request). Vmax is adjusted using 20-bit DAC with maximum value Vref. Maximum output current 50 mA with filter/buffers). The analog output grounds are floating relative to the digital ground.
- Two 4mm banana connectors for analog output grounds
- Two SMA outputs and inputs for sample clocks for external fine tuning of phases
- optical trigger (sync out) for basic frequency (separate option for optical-to-TTL pulse converter for e.g. multimeter or lock-in amplifier), Broadcom HFBR-1414TZ, ST connector

Figure 2: 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 24 hours.
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 DualDAC 3 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 real 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: +184 uV CH2: +174 uV Spec: +/- 200 uV	CH1: 5.03198 V CH2: 5.03181 V Spec: 0.7Vref +/- 2 mV	CH1: 7.18846 V CH2: 7.18825 V Spec: Vref +/- 3 mV
32768 “CENTER”	CH1: +63 uV CH2: +38 uV Spec: +/- 200 uV	CH1: -360 uV CH2: - 470 uV Spec: +/- 700 uV	CH1: -548 uV CH2: -695 uV Spec: +/- 1000 uV
(2^16)-1 = 65535 “NEG FULL SCALE”	CH1: -58 uV CH2: -87 uV Spec: +/- 200 uV	CH1: -5.03249 V CH2: -5.03260 V Spec: -0.7Vref +/- 2 mV	CH1: -7.18927 V CH2: -7.18941 V Spec: -Vref +/- 3 mV

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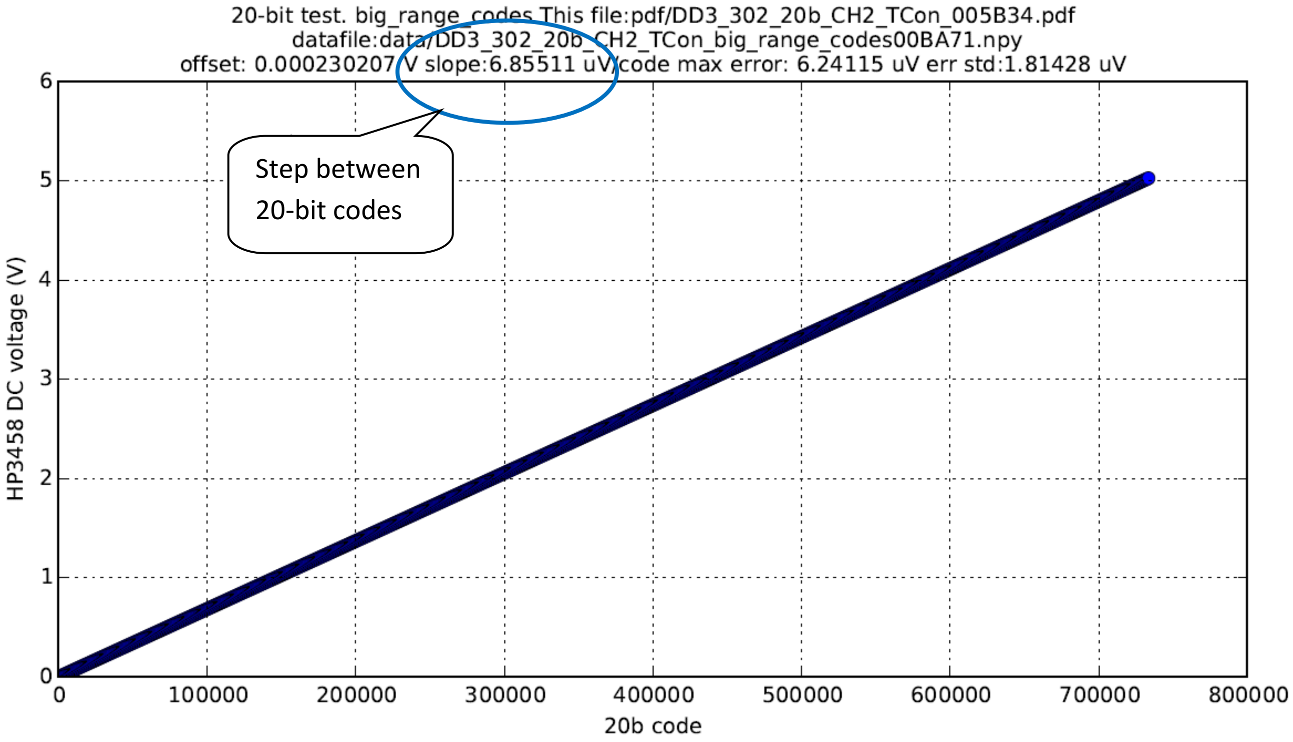
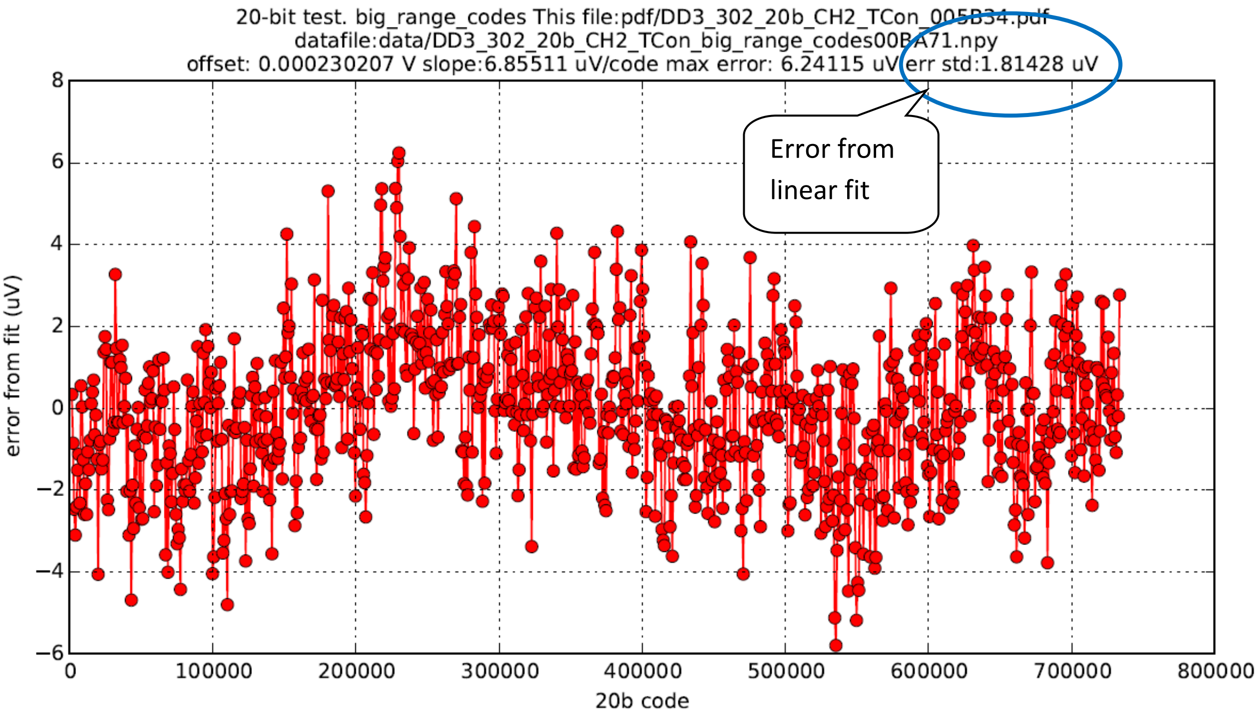
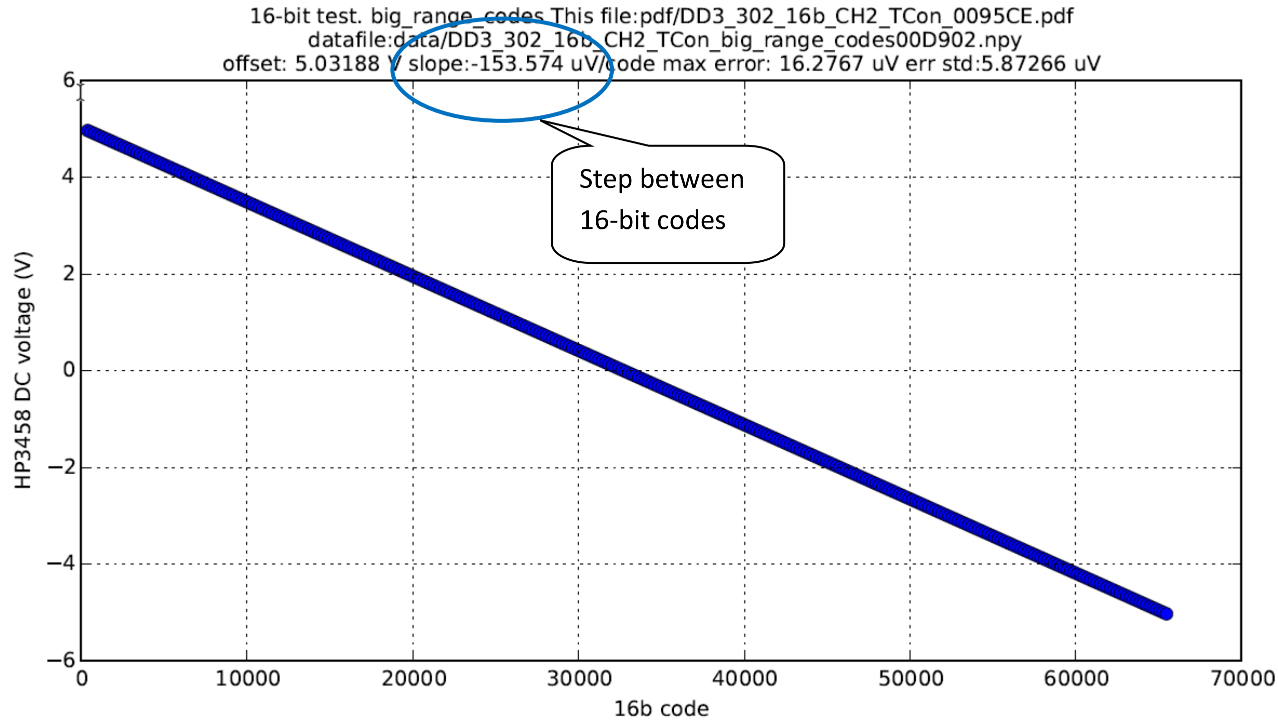
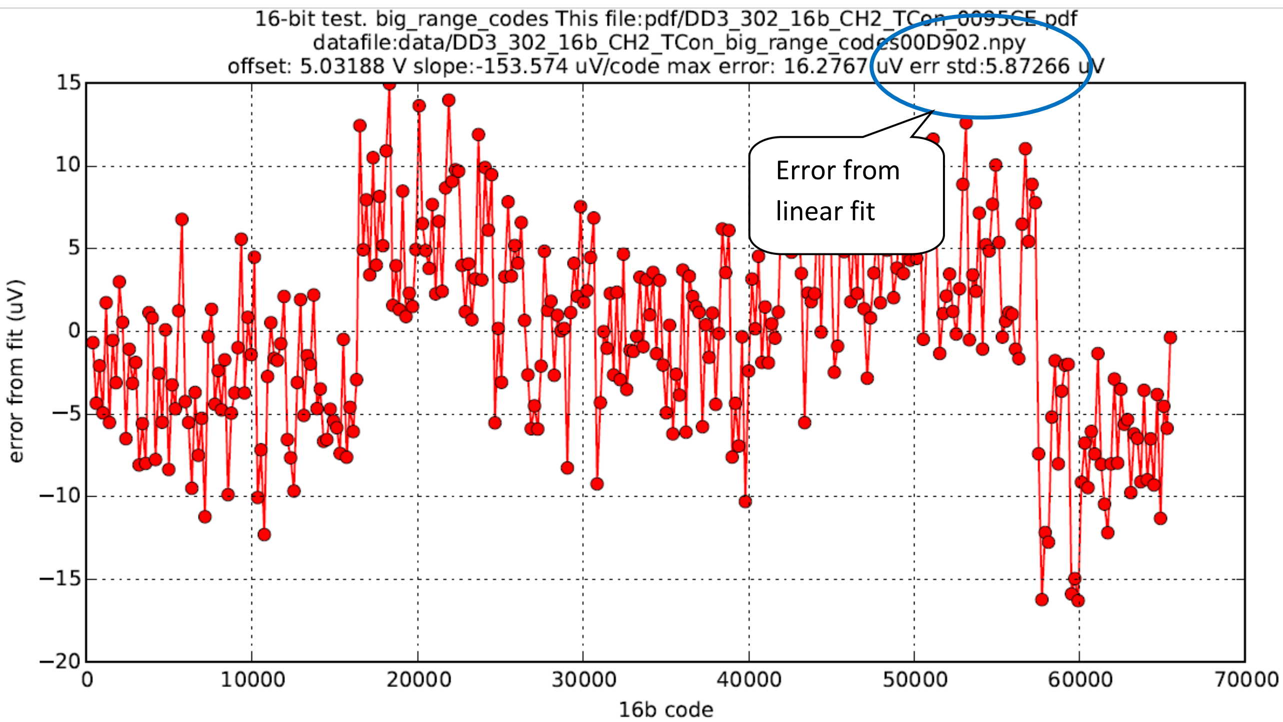
3) DC sweep of 20-bit DAC from 0 – 734 000 when 16-bit DAC is set to positive full scale. Linear fit to data and deviation of data from fit is plotted. Std error allowed +/- 5 uV.





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.





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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 12 hours. Small adjustments to amplitude and phase of one channel are made to obtain zero in the middle.