Dual AC voltage source – DualDAC3

Two-channel audio frequency ultra-stable arbitrary waveform generator

Description and specifications 1.1

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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 up to 5 megasamples/second and maximum number of samples per period of 16384 for each channel. Maximum amplitudes of each two output channels 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.

Figure 1 below illustrates the main features of DualDAC3 (DD3).

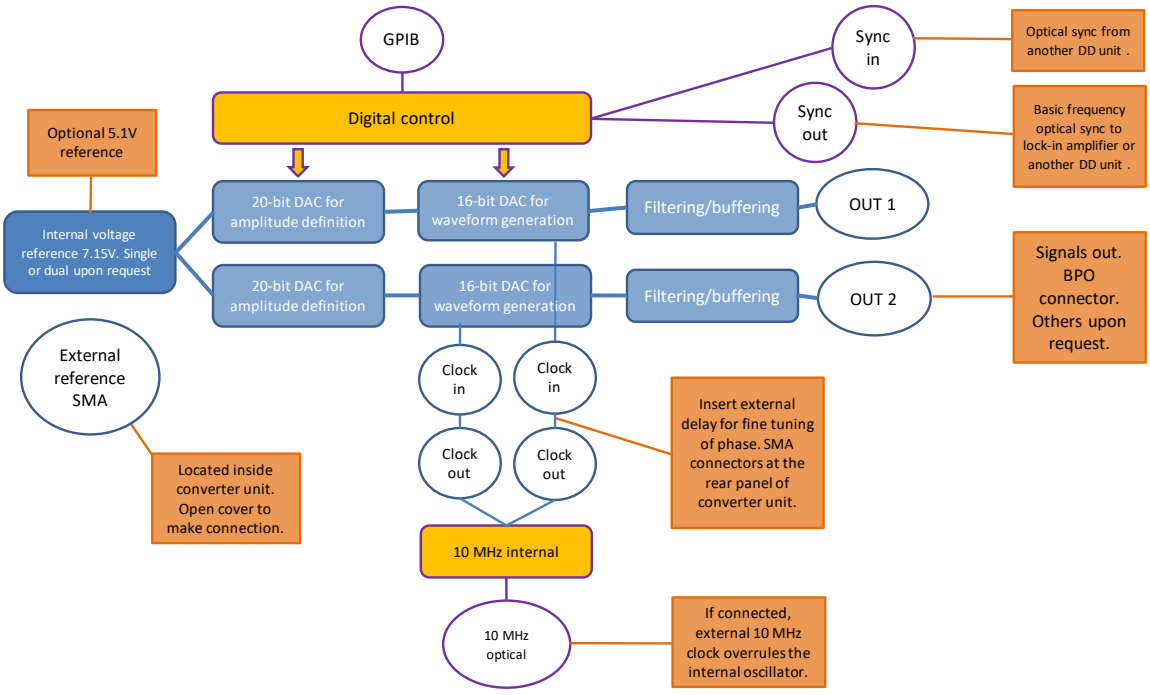


Figure 1: The main features of DualDAC3.

DualDAC 3 system consists of three units attached into 19-inch 3U-high sub-rack. The converter unit consists of DACs, output driving and filtering circuits, and output connectors. The controller unit is composed of digital control circuits for converters and connection to computer. The power supply unit (PSU) in the rear panel contains isolating DC/DC converters for other units as well as a temperature controller for the 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 operate 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, the user needs software that supports IEEE-488 (i.e. GPIB) bus. National Instrument LabView –software is available for controlling DD3.

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 V_{ref} = 7.15 V, <1 ppm/°C. Option: external references between 3 V and 7 V provided by the user. Connectors need to be added to the front panel auxiliary connector panel windows.
- Optical sync in connector for synchronizing several DD3 units (Broadcom HFBR-2416TZ)
- IEEE-488 connector for computer control
- Power supply 18 V – 24 V provided by the user (a linear power supply is recommended)
    - Temperature controller power between +5 V and +12 V, connectors in the rear panel

Figure 2: The controller unit with optical sync input/output, 10 MHz clock input (optical) and GPIB connector.

Figure 3: The converter unit with both outputs (BPO connector) connected. The shield is grounded using a large crocodile clip.

Outputs:

- Two arbitrary waveform outputs locked to same user-specified frequency with individually controlled phase and amplitude between 0 V and V_{max}.
    - BPO connector (other connectors upon request)
    - V_{max} is adjusted using a 20-bit DAC with maximum value V_{ref}
    - Maximum output current 50 mA with filter/buffers
    - The analog output grounds are floating relative to the digital ground
- Two 4 mm 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 optical-to-TTL pulse converter (Fig. 4) for e.g. multimeter or lock-in amplifier, Broadcom HFBR-1414TZ, ST connector

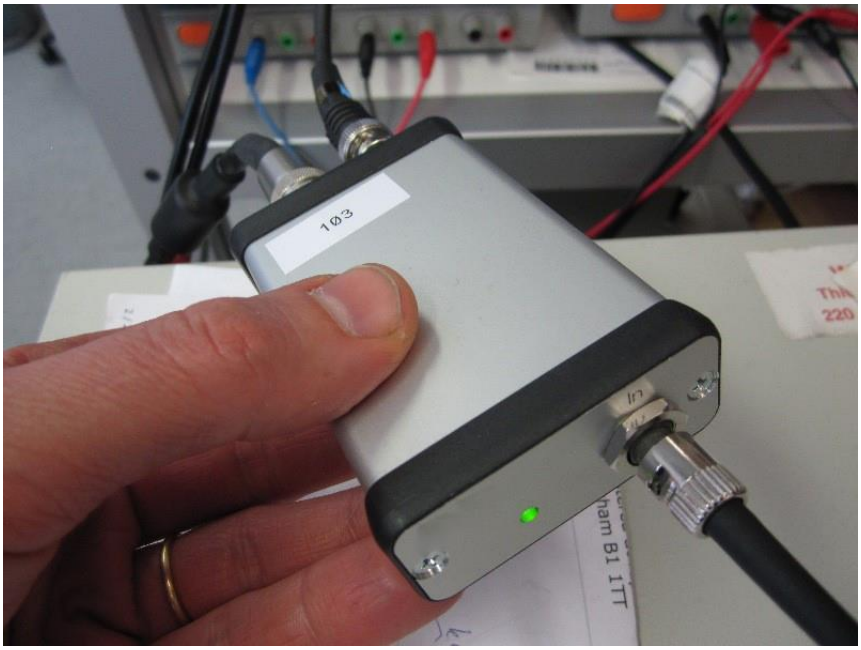


Figure 4: Optical-to-TTL converter a.k.a. fibre receiver.

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 millidegree 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. For short term stability, see Fig. 5 illustrating Allan deviation of the output voltage measured with a quantum voltmeter based on a programmable Josephson junction array.
4) The stability of amplitude ratio 1:1 is better than 1 ppm at 1 kHz for days. See Fig. 6 with the result measured using an inductive voltage divider and a lock-in amplifier as a null indicator.
5) The stability of amplitude ratio 1:10 is better than 2 ppm at 1 kHz for days.
6) Offset voltage less than 1 mV at full amplitude 7.15 V
7) 20-bit DAC amplitude linearity better than ±5 µV in the range from 0 V to 5 V
8) 16-bit DAC amplitude linearity better than ±25 uV in the range from –5 V to +5 V

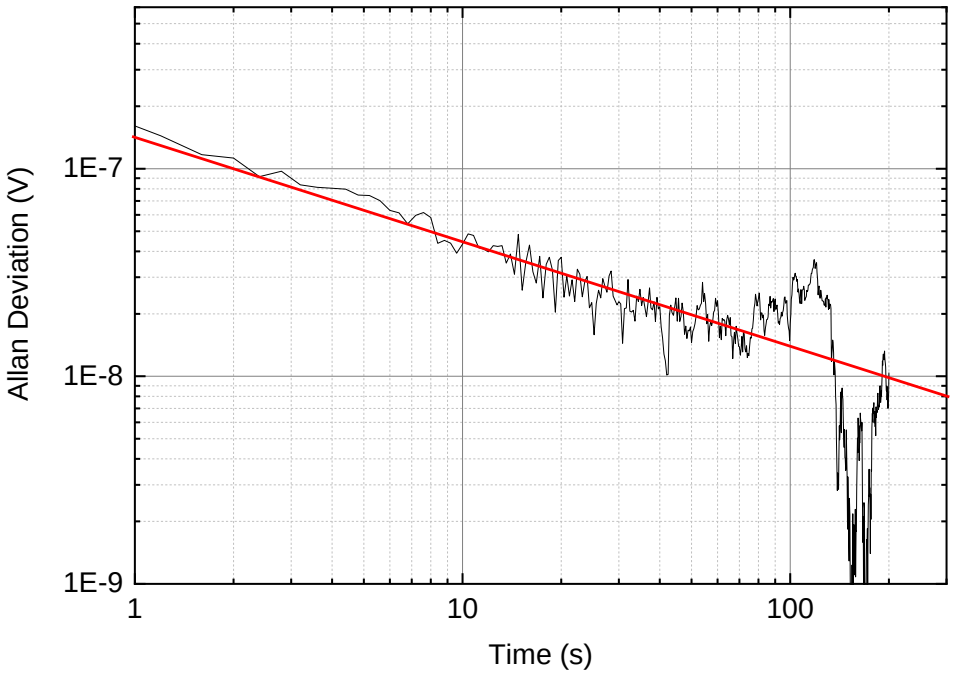


Figure 5: Allan deviation of a single channel output voltage at level of 1 V over a short period of 1000 s. Drifts of the internal Zener dominate with averaging times over 100 s.

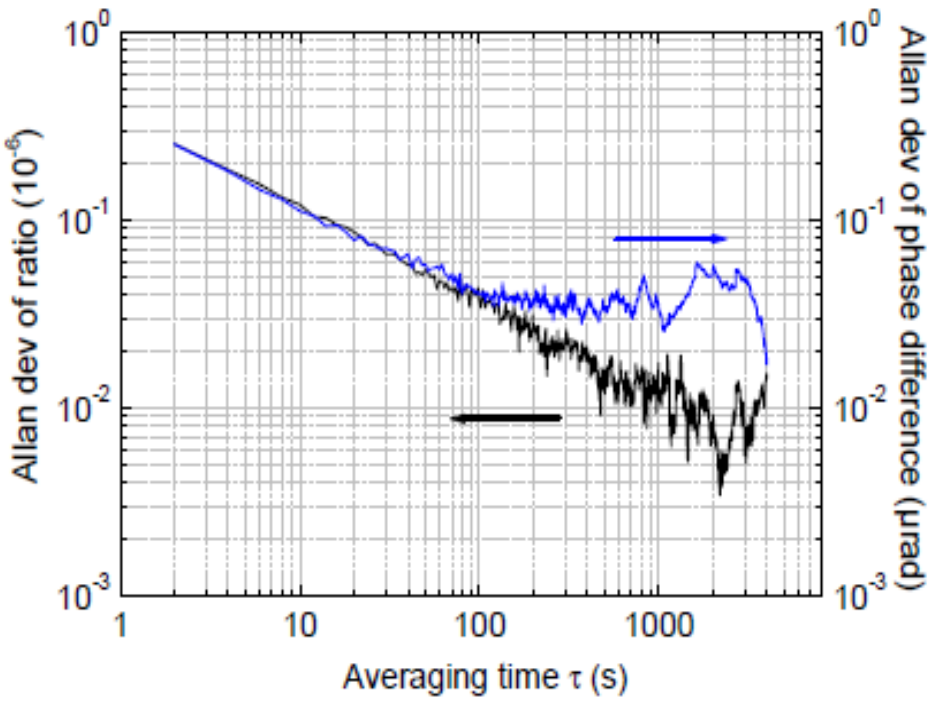


Figure 6: Allan deviation of the ratio of output voltages from two channels (black) and phase difference between the output signals (blue). In this example, a single Zener voltage reference which the two output channels are tracking allows averaging the voltage ratio down to 10 parts per billion precision.

Test procedures and data:

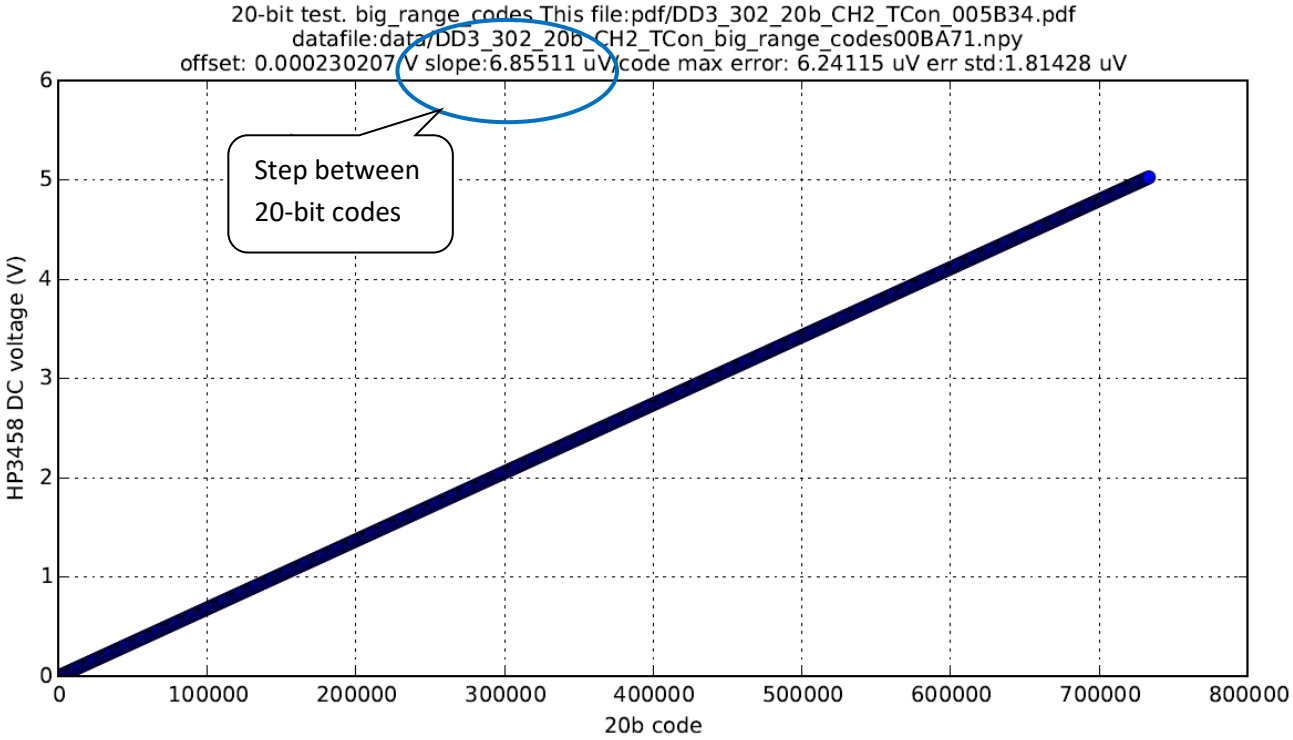
Each DualDAC3 unit undergoes a test procedure where the following data are measured (the data and relevant computer scripts are available to the customer). Tests are performed with internal temperature control switched on in a standard office environment, and the unit has been on for at least 30 minutes before starting the test procedure.

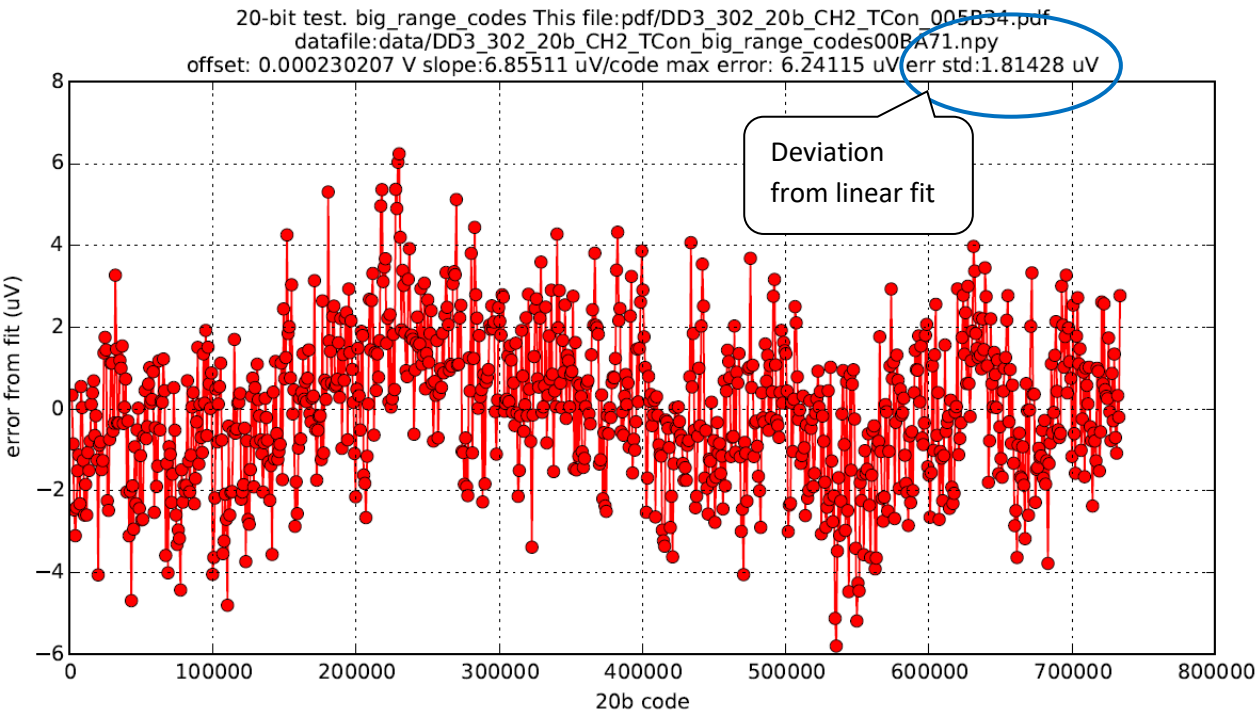
1) Internal reference voltage V_{ref} = 7.15 V ± 0.1V

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

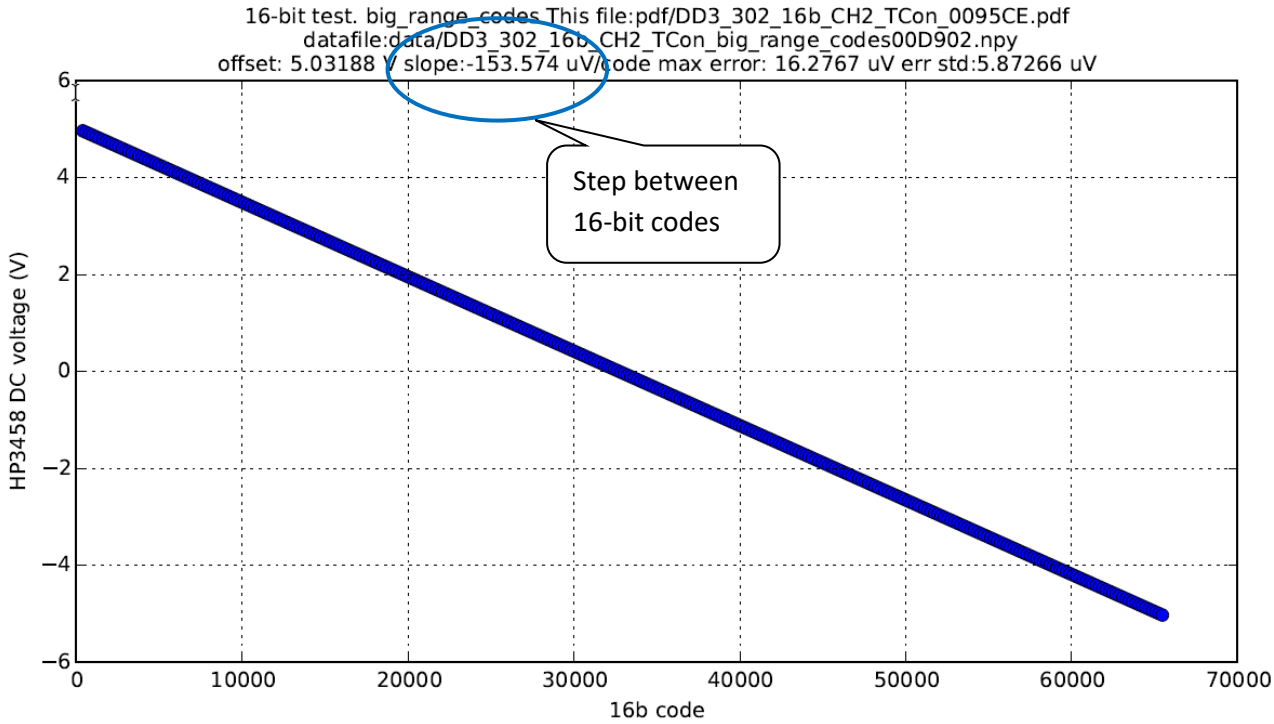
20-bit DAC value / 16-bit DAC value	0 “ZERO”	734 000 “ABOUT 5V”	2^{20} - 1 = 1 048 575 “FULL VREF”
0 “POS FULL SCALE”	CH1: +184 µV CH2: +174 µV Spec: ± 200 µV	CH1: 5.03198 V CH2: 5.03181 V Spec: 0.7 Vref ± 2 mV	CH1: 7.18846 V CH2: 7.18825 V Spec: Vref ± 3 mV
32 768 “CENTER”	CH1: +63 µV CH2: +38 µV Spec: ± 200 µV	CH1: -360 µV CH2: - 470 µV Spec: ± 700 µV	CH1: -548 µV CH2: -695 µV Spec: ± 1000 µV
2^{16} - 1 = 65 535 “NEG FULL SCALE”	CH1: -58 µV CH2: -87 µV Spec: ± 200 µV	CH1: -5.03249 V CH2: -5.03260 V Spec: -0.7 Vref ± 2 mV	CH1: -7.18927 V CH2: -7.18941 V Spec: -Vref ± 3 mV

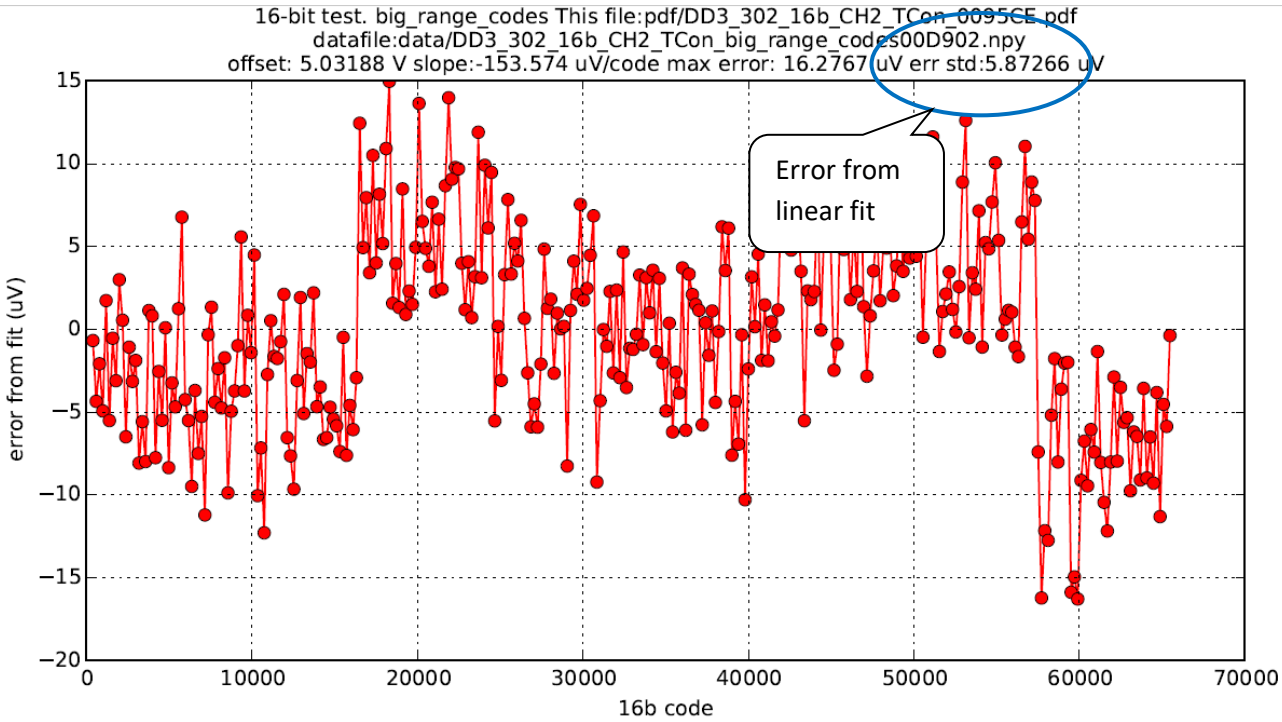
3) DC sweep of 20-bit DAC from 0 to 734 000 when 16-bit DAC is set to positive full scale. Linear fit to data and deviation of data from fit is plotted. Standard error allowed ±5 µV.





4) DC sweep of 16-bit DAC when 20-bit DAC is set to 734 000. A linear fit to the data and the deviation of the data from the fit are plotted. Standard error allowed ±25 µV.





5) The stability of the amplitude ratio of the generated sine waves at 1 kHz with amplitude ratio of 1:1 at 20-bit DAC value 70% (i.e. 734 000), which sets the full scale sine wave amplitude to 5 V. 16-bit DAC amplitude is set to 0.99. An inductive voltage divider is set to 1:1 and the middle point is measured using a 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.