Fast Versatile and Programmable Multichannel Arbitrary Signal Generator

HAP-Workshop

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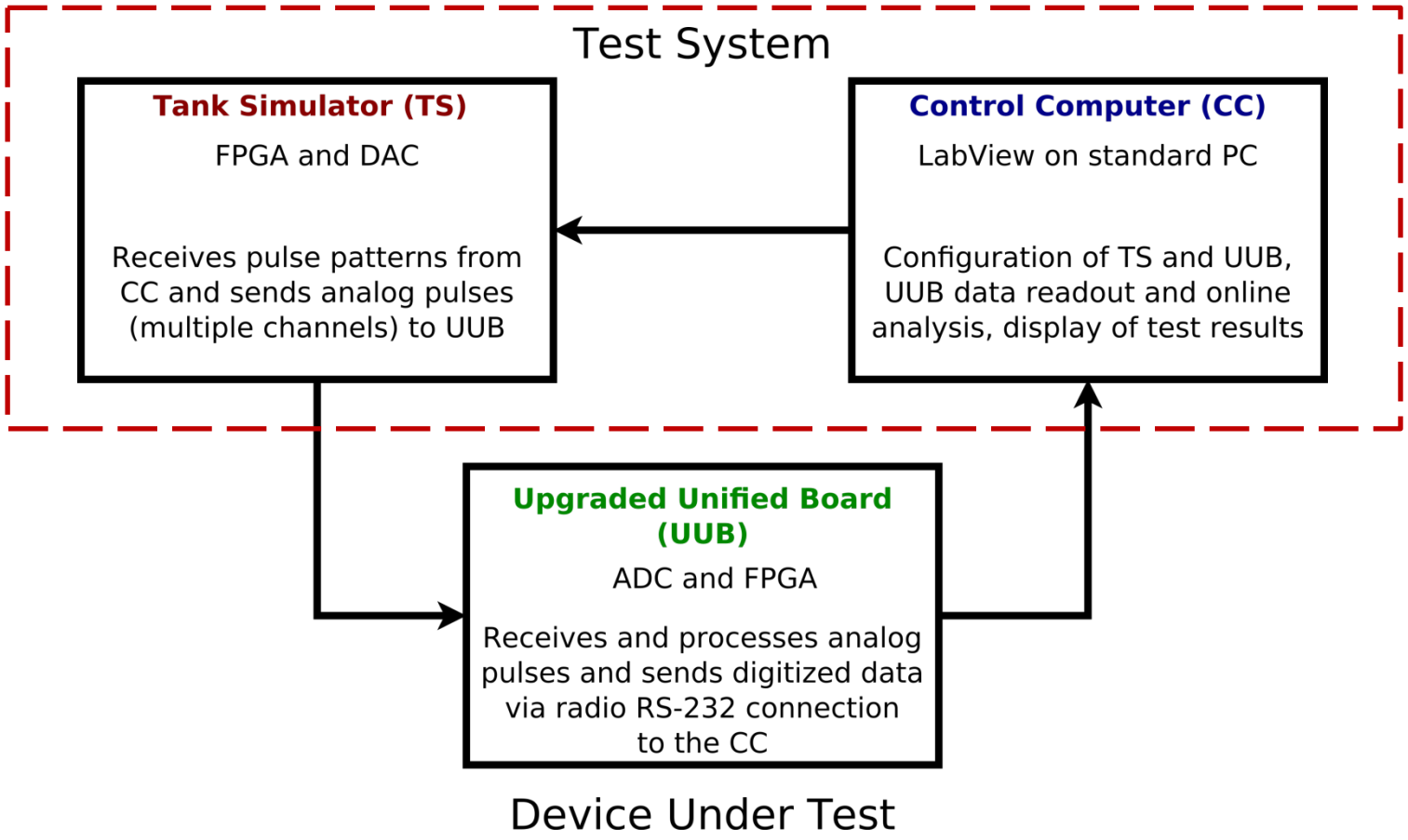
Application: Auger Tank Simulator

- Upgrade of the Pierre Auger Observatory Surface Detector Electronics (SDE).
- New electronics boards for the ~1600 water Cherenkov detectors.
- Part of the test-system for these boards, emulating a real detector‘s behavior including:
  - PMTs
  - Environmental sensors
  - Radio
  - Battery with solar panels

Application: Auger Tank Simulator

- Arbitrary PMT signal wave form for single events and extensive air showers.



Arbitrary signal generator: Generic requirements

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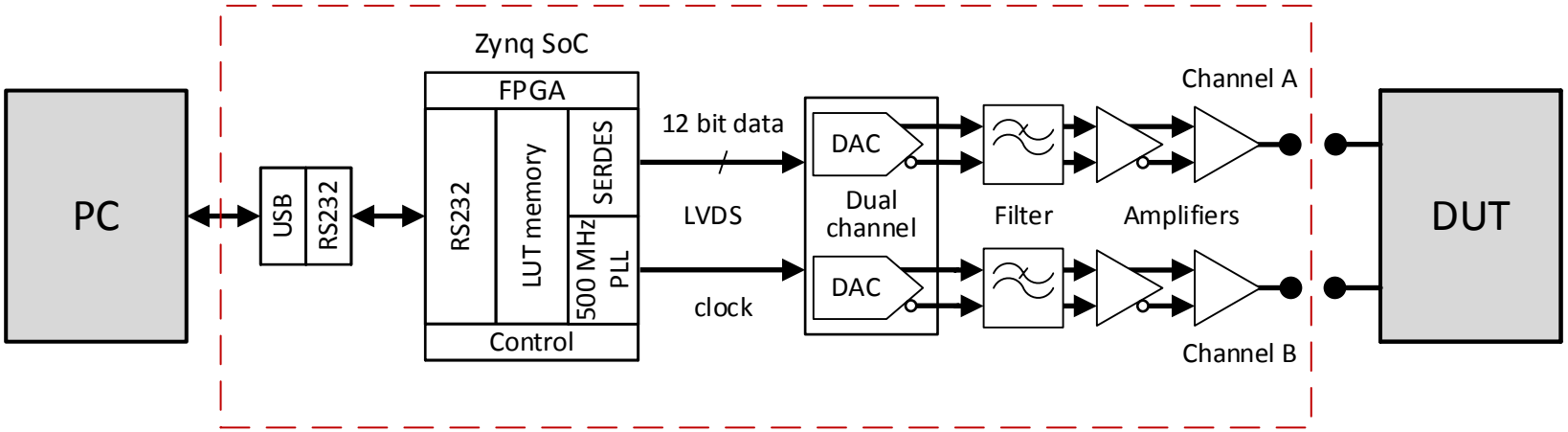
- Generation of quickly adjustable electrical potentials → arbitrary signal shapes.
- Low voltage amplitudes ~ a few V.
- Update rate of several hundred MHz.
- Several independent channels per device.
- Internal storage for wave forms.
- High stability over temperature and time.
- On-board control capabilities with FPGA and/or microprocessor.
- Computer interface for fast control-data transmission.

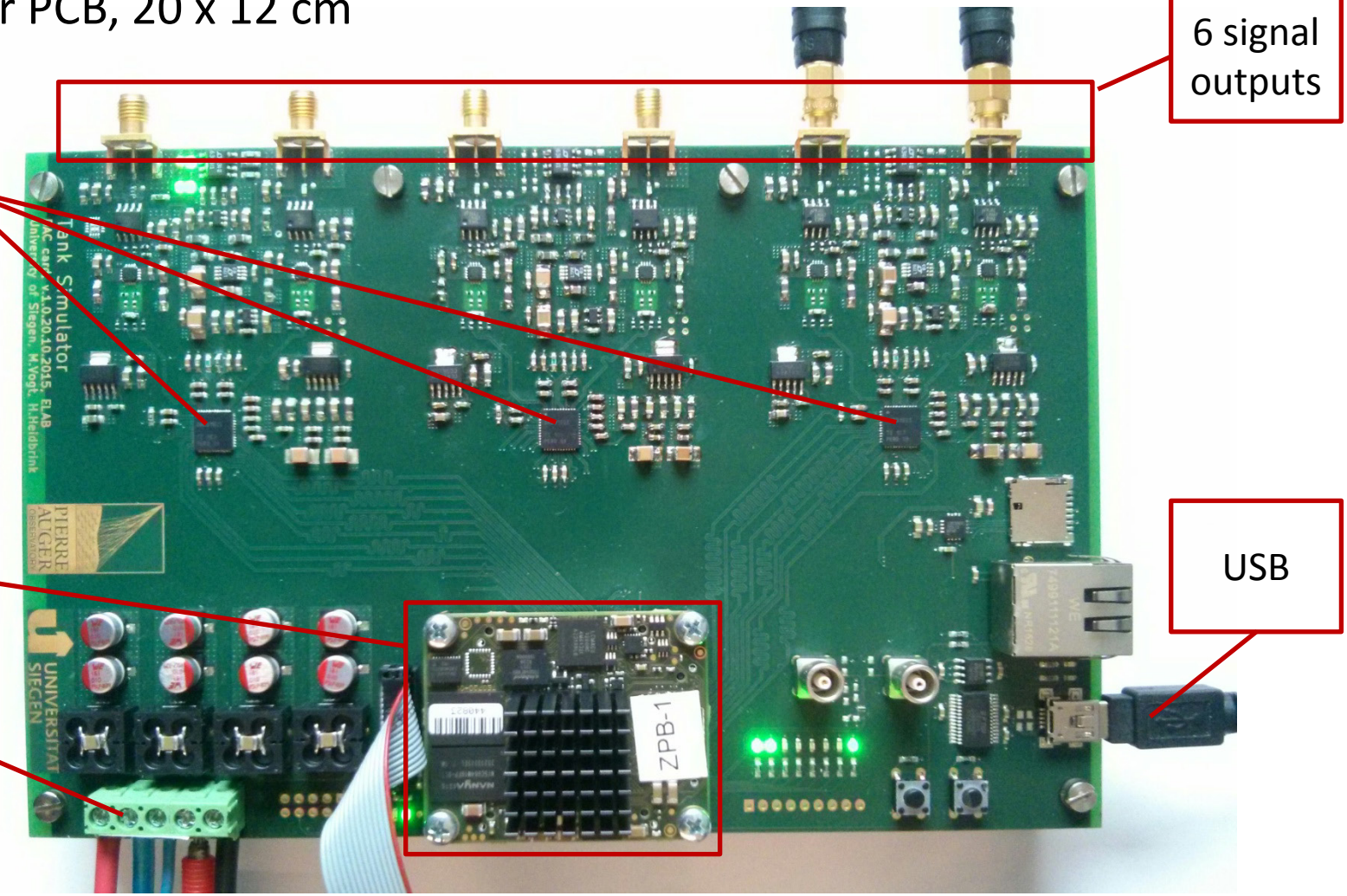
Block diagram (2-ch prototype)



Component	Type	Features
FPGA	Xilinx Zynq 7020	High speed differential i/o
DAC	Texas Instruments DAC3164	Dual channel, 500 Msps, 12 bit
Amplifiers	Analog Devices ADA4927	>1 GHz bw, low noise, gain=2
	Texas Instruments LMH6703	Differential to single-ended conversion, buffer (drives 50 Ohm)
Filter	Passive low pass filter	Cut-off frequency ~ 600 MHz

6-ch prototype

- 6-layer PCB, 20 x 12 cm

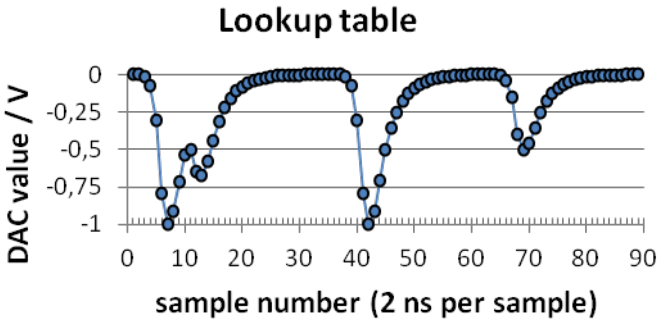


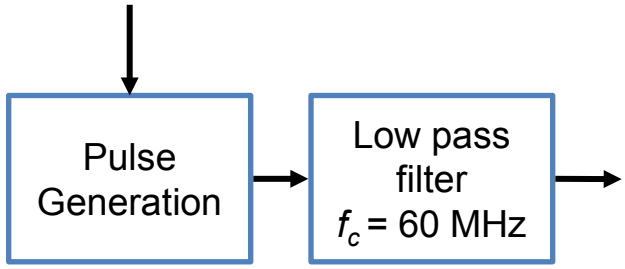
6-ch prototype

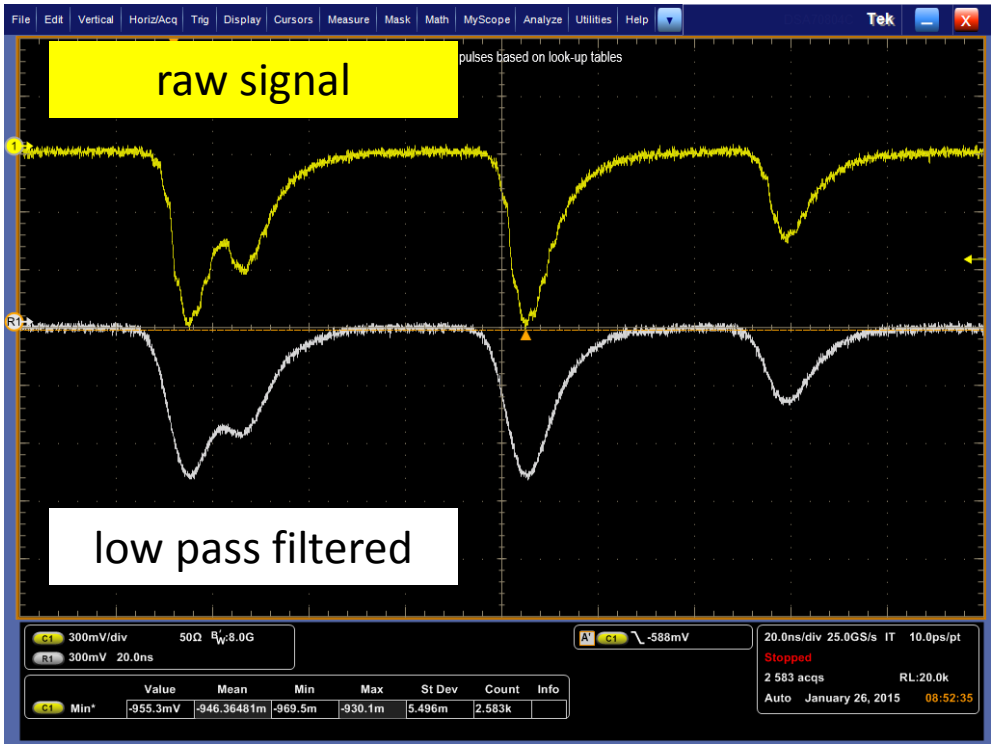
- Board specifications
  - 6 individual output channels
  - Amplitude range: 2 V
  - Amplitude resolution: 12 bit (0.5 mV for a 2 V range)
  - Adjustable offset, set via resistor divider
  - Integrated power supplies and reference voltages
- FPGA-board specifications (Trenz TE0720)
  - Xilinx Zynq 7020 “System on Chip” (SoC)
  - Dual-core ARM Cortex-A9 processor @667 MHz
  - 256 Mbyte DDR3 Memory
  - USB, Ethernet and SD-card interfaces
  - Artix-7 FPGA core, 85k logic cells (comparable to ~1.3 M ASIC gates)
  - ~50 LVDS I/O-pairs accessible

PMT signal shapes

- The output signal is defined by a lookup table.
- Picture below shows raw signal of 10 ns-wide pulses and signal after passing an external low pass filter.



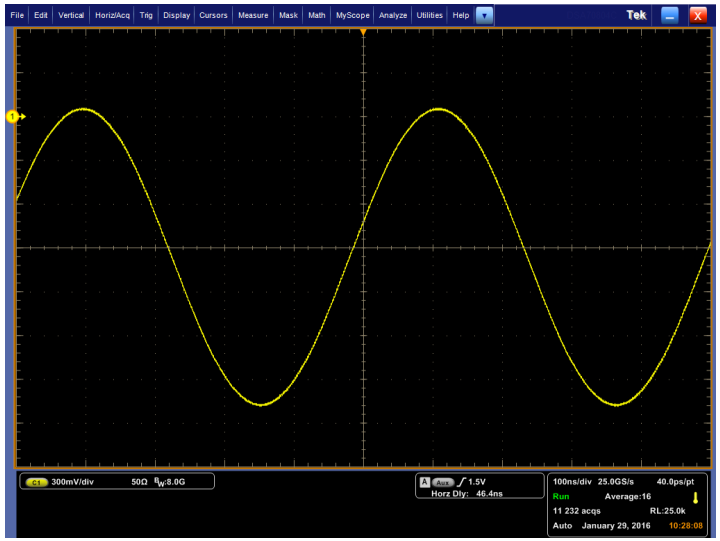


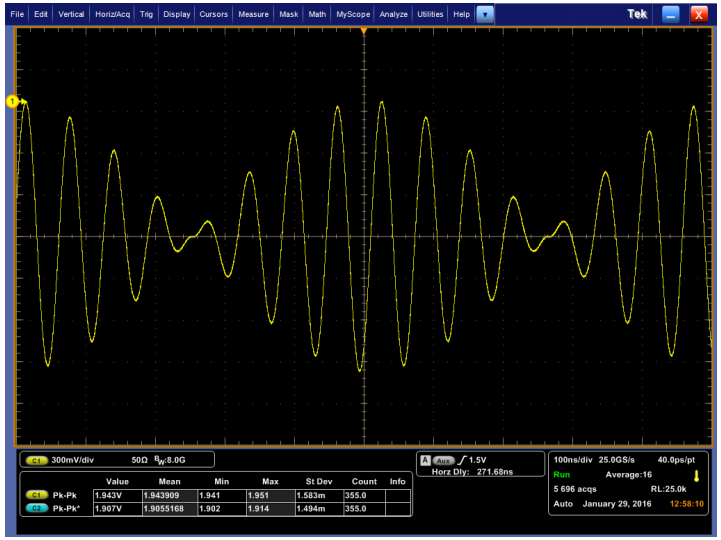


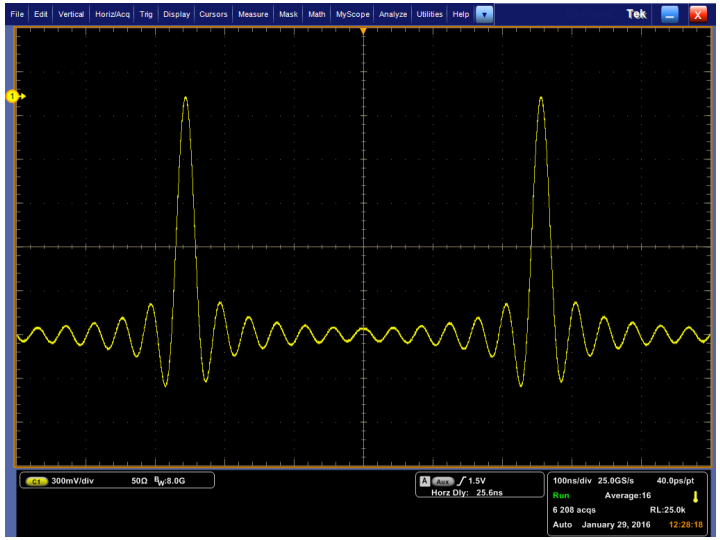
More examples of signal shapes

- Sine, f=2 MHz
- Modulated sine
  f_1=2 MHz, f_2=250 kHz
- $\left.\frac{sin(\pi x)}{\pi x}\right|_{-4\pi \le x \le 4\pi}$

Full time range 1 µs

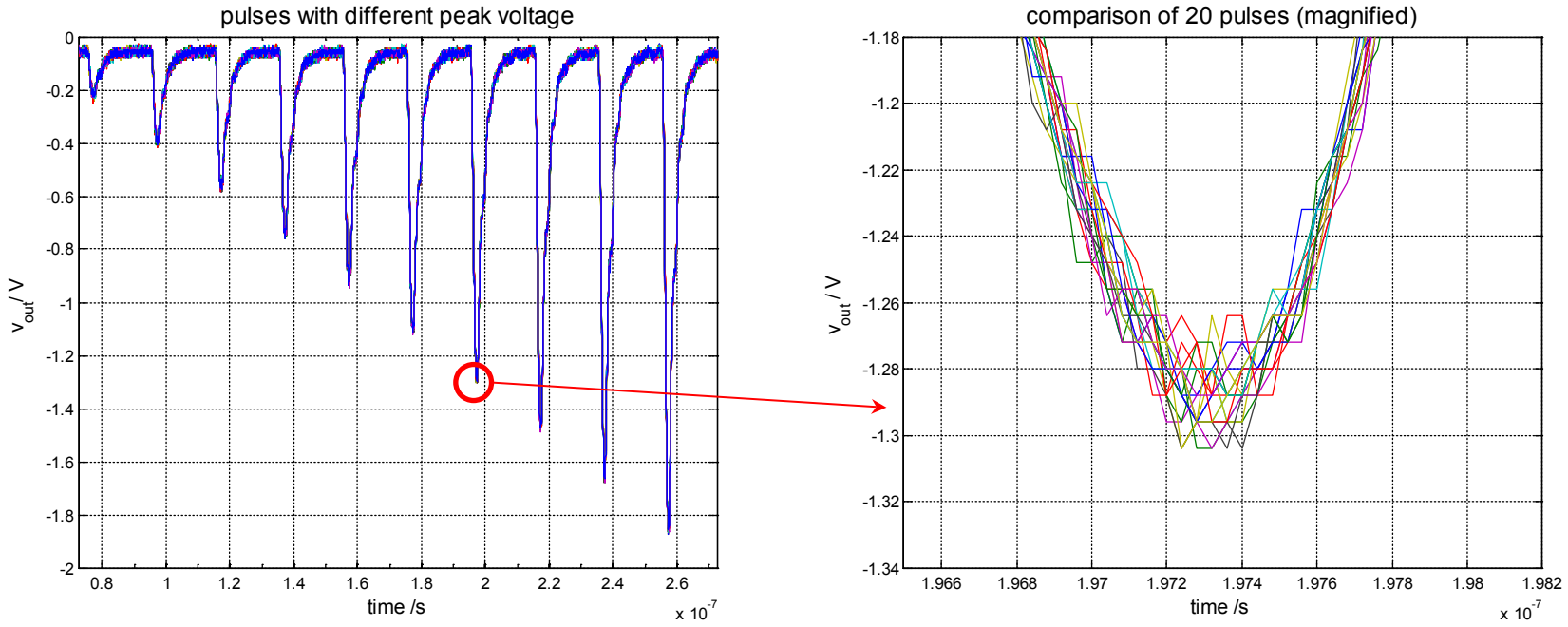






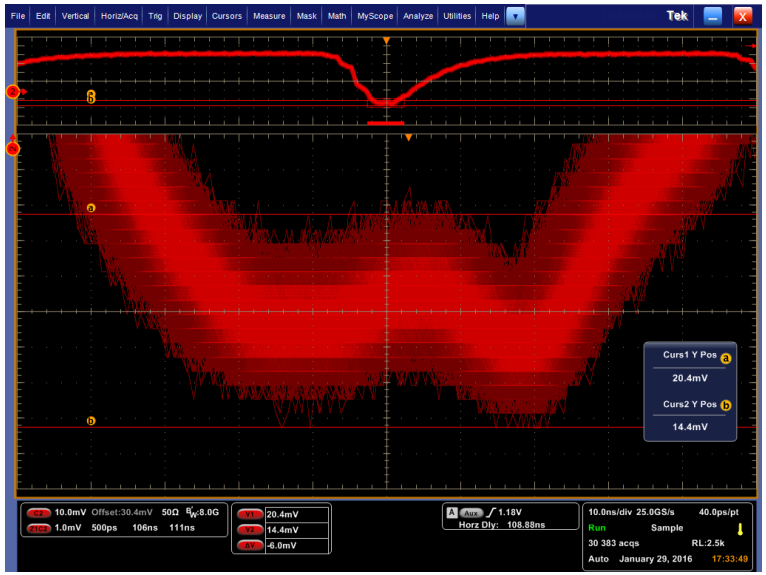
Stability and noise

- Multiple 5 ns wide pulses throughout the full dynamic range with different peak voltages have been analyzed.
- Pulse amplitudes are repeatable at a precision of ~ $\pm 15\ mV$.



Stability and noise

- Several thousand 10 ns wide pulses with two different peak voltages have been analyzed.



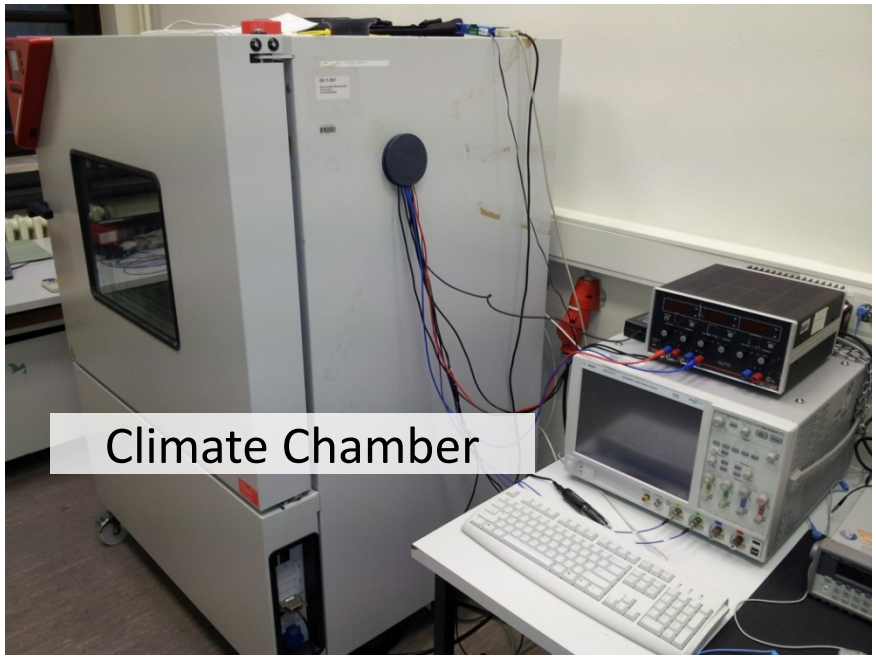
Peak voltage: 60 mV

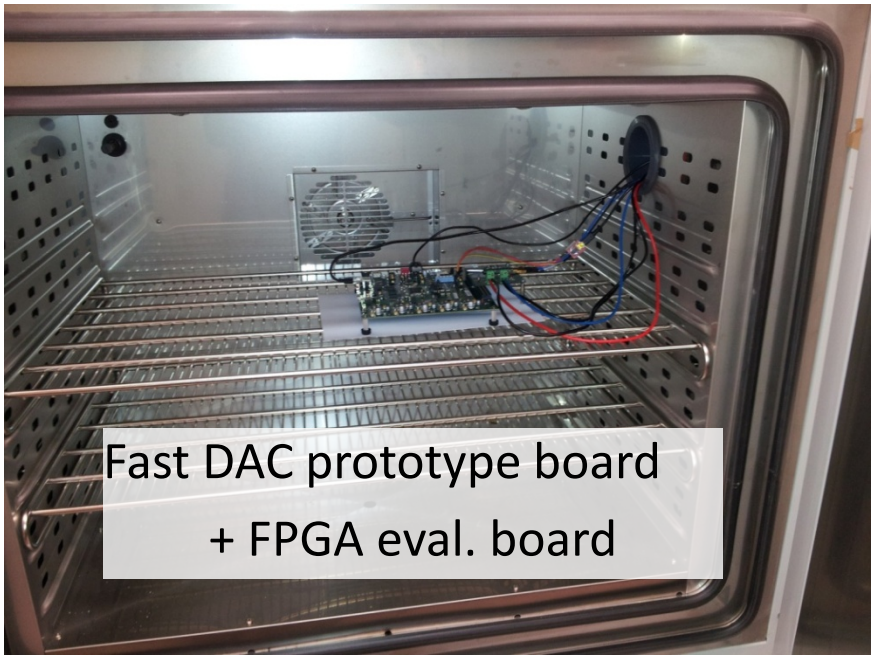
Peak voltage: 1800 mV

Amplitude/mV	Noise (peak-peak)/mV	Noise RMS(δ)/mV
60	4.8	0,8
1800	28	4,7

Temperature stability

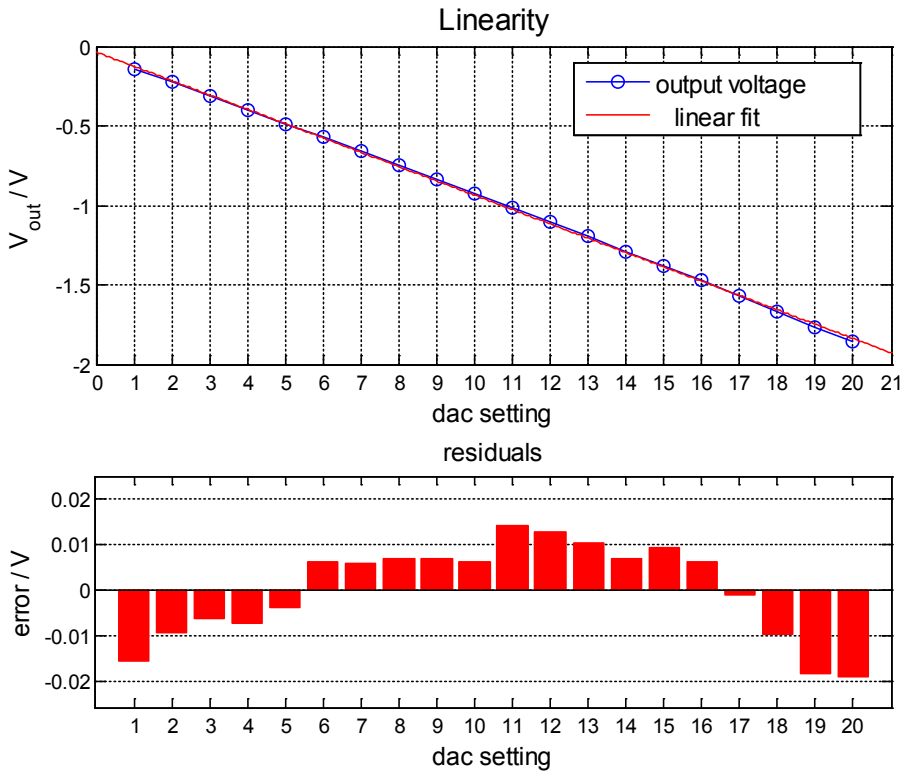
- Verification of pulse shape stability at various temperatures (17°C , 27°C, 37°C).
- Less than 0.5% per 10°C deviation in amplitude and width for both channels of 2-ch prototype.





Linearity

- Pulse amplitude linearity was measured to be within ~ 15 mV over the full dynamic range of -0.1 ... -1.8 V.
- Further improvements are expected by using a calibrated LUT.



Summary

- Development of Arbitrary Signal Generator in progress
  - 6-ch prototype
  - 2 V amplitude
  - 500 µV amplitude resolution
  - Minimum pulse width at half maximum ~5 ns
  - ≤0.5% deviation per 10°C
  - ≤5 mV RMS-noise at full amplitude
- Cost estimate for the generator board: 1000 €
- Possible application in instrumentation for experimental physics