Room-Temperature Readout Electronics for ECHo-100k

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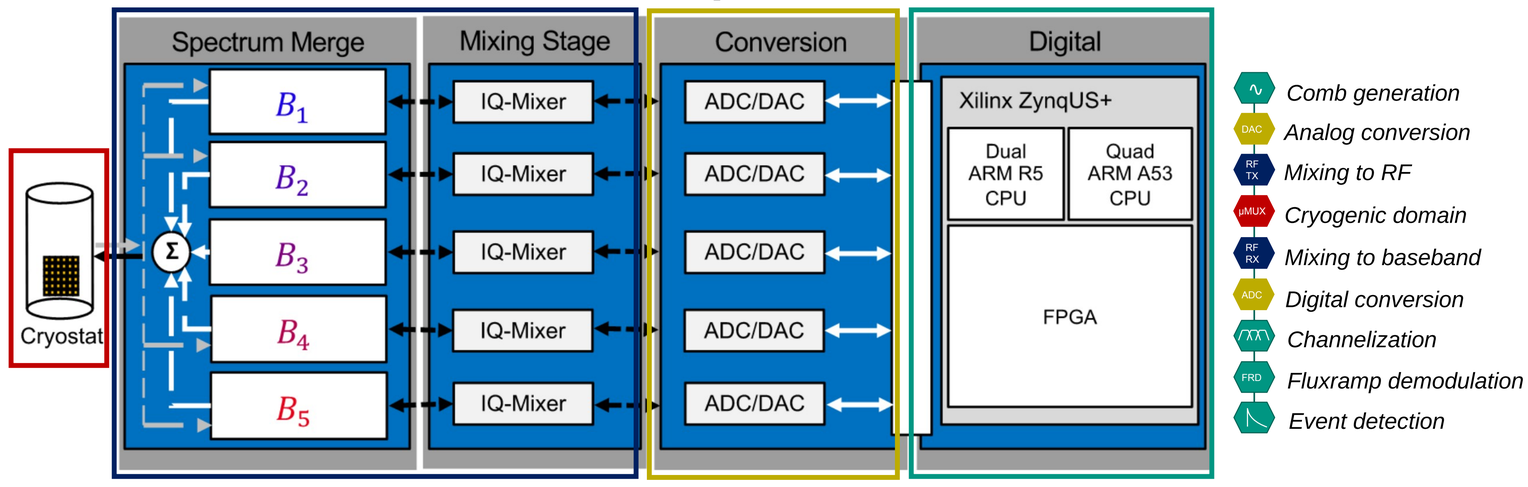
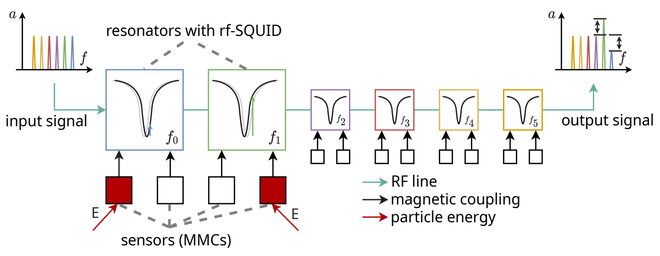
Main features of the ECHo electronics

- 400 Channels per platform
- 15 platforms for > 10 k Sensors
- Input Frequency-Range: 4 to 8 GHz
- Configurable via software
- Full online event processing
- Data rate decimation: 20 Gb/s → 32 MB/s

Readout concept

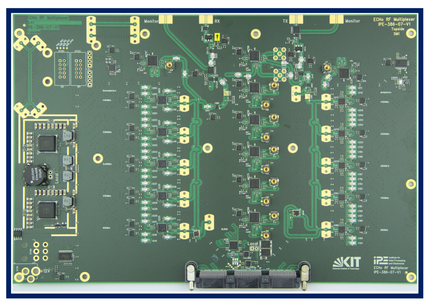


Microwave SQUID multiplexer



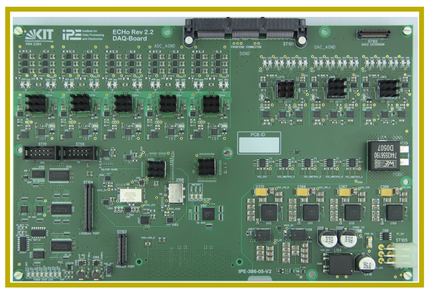
- Stimulated frequency comb with range 4-8 GHz
- Channel bandwidth: 1 MHz Spacing: 10 MHz
- Tones are amplitude modulated by sensor signal

RF-Frontend



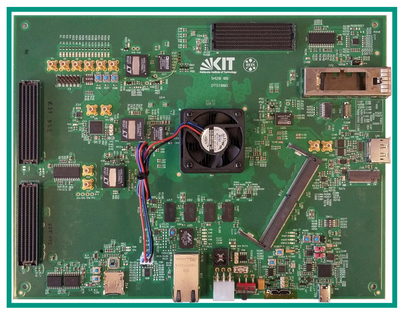
- Two stage mixing for 5 subbands each 800 MHz [2]
- Complex baseband with calibration circuitry
- Integrated Oscillators

Conversion board



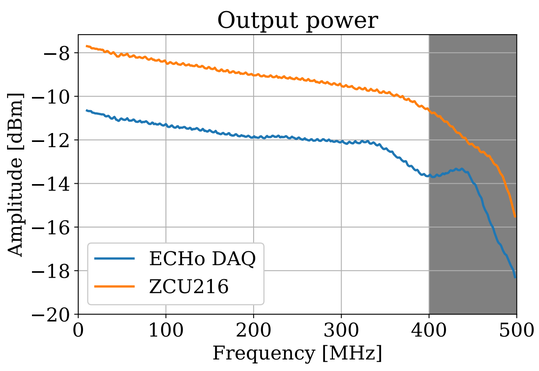
- 10x 1 GS/s 14-bit ADC
- 10x 1 GS/s 16-bit DAC
- Source of clock tree
- Extensible functionality via Add on cards

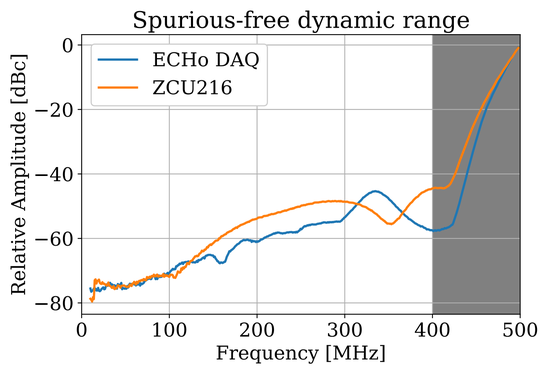
MPSoC



- Xilinx Zynq US+ board designed @ KIT & DESY [3]
- ZU19EG MPSoC
- 8 GTY (28 Gb/s) and 24 GTH (16 Gb/s) links

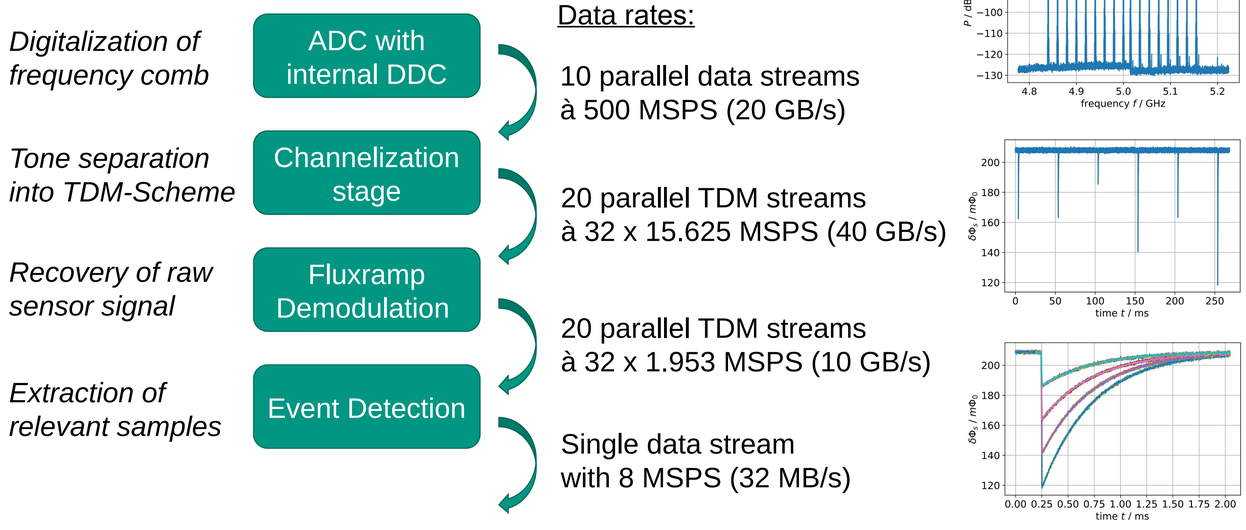
Digital to analog conversion [4]



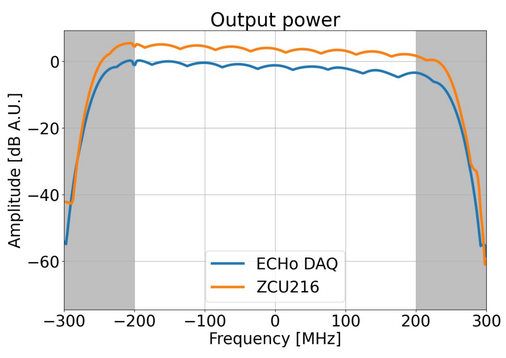


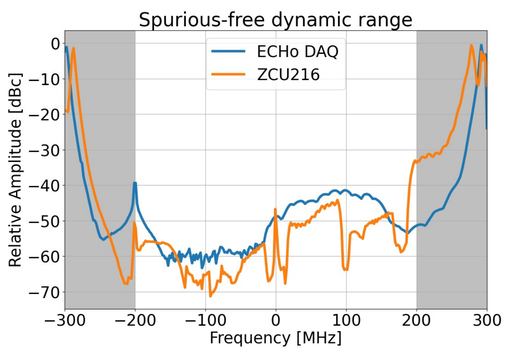
- Single tone between +/- 500 MHz with -1 dBFS
- Anti alias low-pass filter
- Output power measured with spectrum analyzer
- SFDR from DC to 1 GHz

Digital Signal Processing [1]

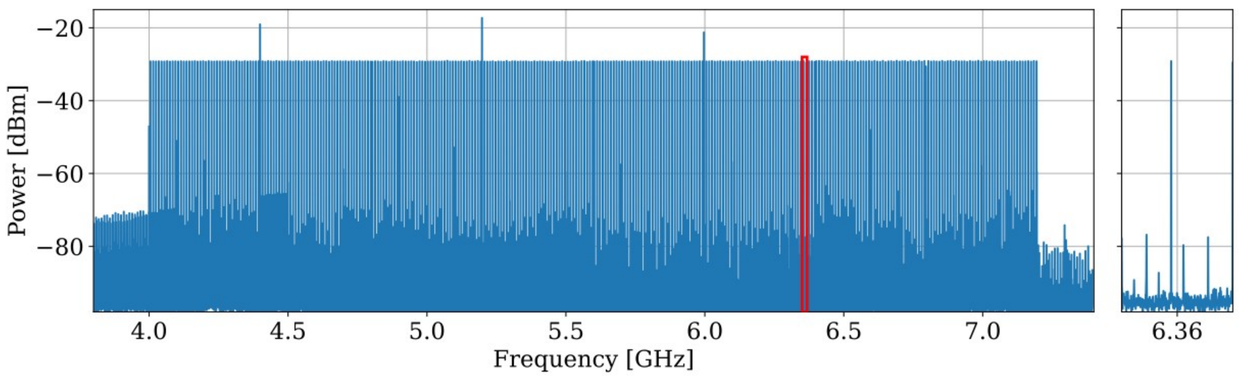


Analog to digital conversion [4]





- ADC @ 1 GSPS with internal DDC (+/- 200 MHz)
- Tones generated from DAC in loopback
- Data acquisition with DMA on FPGA
- FFT with 2^{15} samples



- Frequency comb containing 320 tones corresponding to 4 bands [5]

Conclusions

- Full-scale DAQ electronics ready and in production for 15x units
- Online data processing validated with detector emulator
- ECHo DAQ analog performance is similar to commercial RFSoC
- Cryogenic measurements of full system are still pending

References

[1] Karcher et al, 2022. DOI: 10.1007/s10909-022-02858-x
[2] Gartmann et al, 2022. DOI: 10.1007/s10909-022-02854-1
[3] Muscheid et al, 2023. DOI: 10.1088/1748-0221/18/02/C02067
[4] Gartmann et al, 2024. DOI: 10.1088/1748-0221/19/02/C02078
[5] Muscheid et al, 2024. DOI: 10.48550/arXiv.2404.03096