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Quantum Computer in the Solid State

Scalable Room Temperature Control Electronics for Advanced High-Fidelity Qubit Control

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Motivation

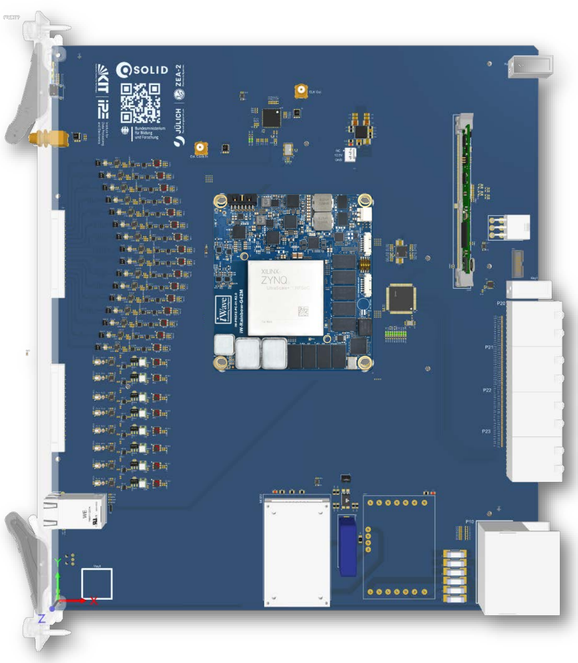
Overcoming commercial quantum control systems drawbacks:

- Individual optimizable rotation and flux control pulse generation
- Full access to the entire electronics stack and affordable platforms
- Low-level processing performed in real-time on FPGAs
- Fully customizable form factor
- Future performance improvements

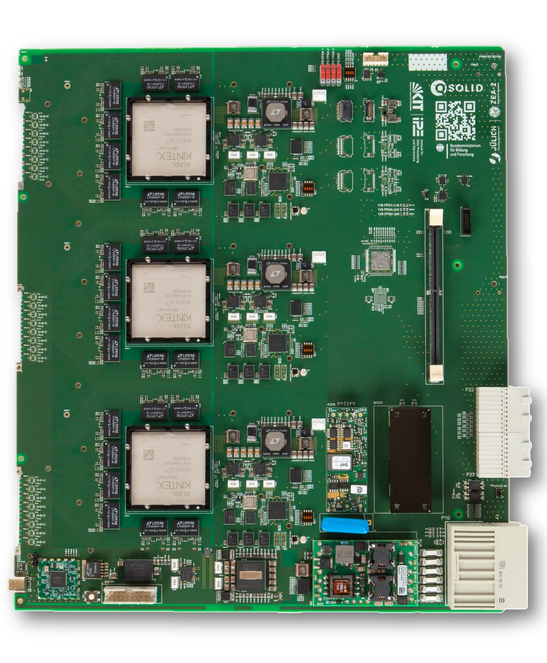
System Specifications

Integration of the hardware system heading for:

- Differential Flux Control outputs: DC…1 GHz
- Output voltage noise < 2 nV/sqrt(Hz) (100 kHz – 10 MHz range)



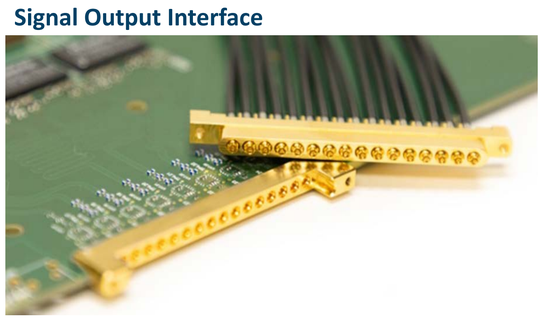
The **Hub** card (illustration) consists of the **iW Rainbow G42M** SoM with an AMD ZU49DR RFSoC allow software defined qubit readout and control to the required center frequency between 4-7 GHz and a channel spacing of 50 MHz. Controls up to 10 interconnected FPGAs through the backplane of the **ATCA** crate [1,2].



The **Node** combines three **AMD Kintex Ultrascale XCKU115** with eight **LTC2000** DACs each [1]. Low latency approach uses up all 598 HP I/O pins of the driving XCKU115 FPGA since one LTC2000 requires 35 LVDS pairs for parallel waveform data reception.

Specifications	Keystone	Moonshot
RF Qubit Readout & Control		
Channels	10	30
Carrier Frequency	5-7 GHz	
Spacing	> 50 MHz	
Sampling Rate	> 1 GS/s @14 bit	
Jitter Stability	<100 fs rms, <5 ppm	
Flux Control		
Channels	24	120
Bandwidth	> 500 MHz	
Sampling Rate	> 2 GS/s @16 bit	
Waveform Memory	100 µs per Channel	
Signal Output	DC…1 GHz @10 dBm	

Signal Output Interface

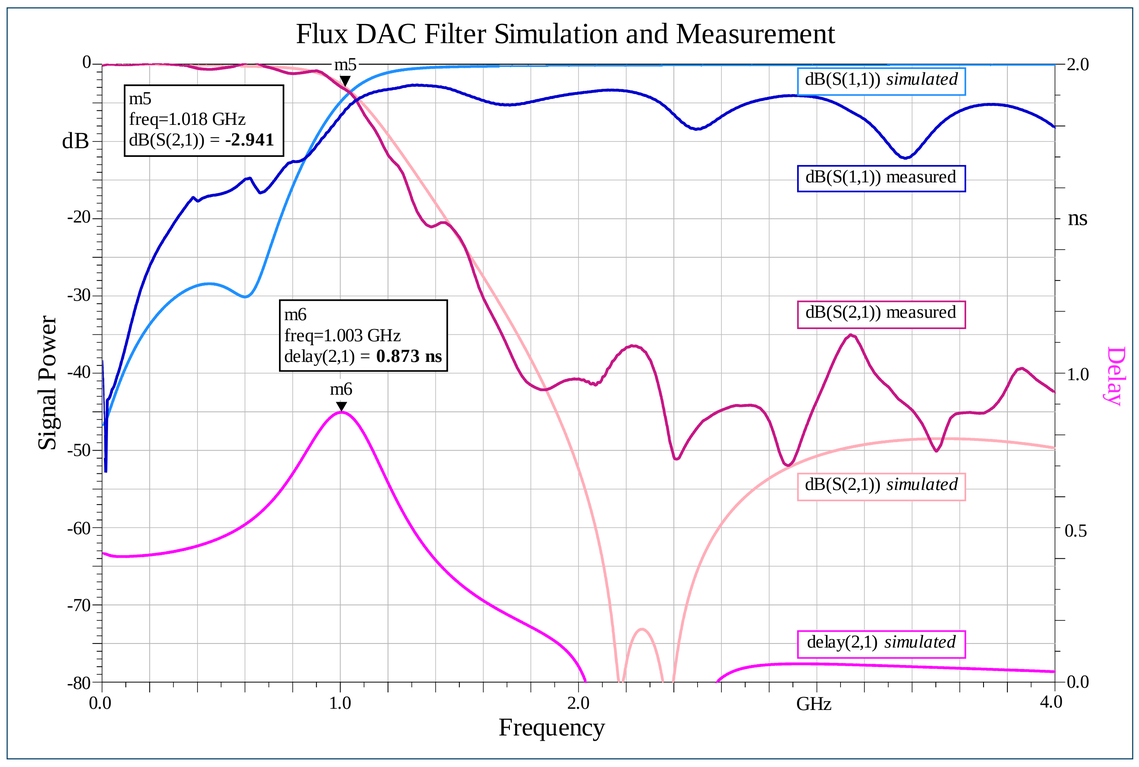


- *Rosenberger block plug connector*
- *Edge Mount WSMP®*
- *16/32 channel each with 2.54 mm pitch return loss of ≤25 dB (DC to 12 GHz) [6]*
- *480 quasi-differential coaxial lines*

Flux DAC Performance

Analog front-end configuration:

- Low latency current steering DAC: LTC2000 running @2.5 GS/s [4]
- 5th order Inverse Chebyshev @1 GHz
- Signal pre-distortion for improving non-linearities in cryostat



*Flux signal output from **DC to 1 GHz @ 10 dBm,** tunable to a cutoff frequency from 0.5 to 1 GHz with a **group delay** of **0.8 ns**. Filter specific notches in stopband suppress the digital DAC frequencies*

Conclusion

The development of a qubit control demonstrator for a 30-qubit device offers valuable insights into transitioning from room-temperature to cryogenic electronics, highlighting a critical pathway for future advancements in scalable quantum computing hardware.

a) Illustration of a full assembled ATCA crate insert. Holding 4 Hub cards capable of reading and controlling 40 qubits, mastering up to ten additional Node cards capable of driving 24 direct flux lines each. b) Interconnectivity, thermal management and power through Dual-Dual-Star crate from nVent Schroff, based on PICMG standard AdvancedTCA [1,3]. c) Shock protection transportation box from ProCase.

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