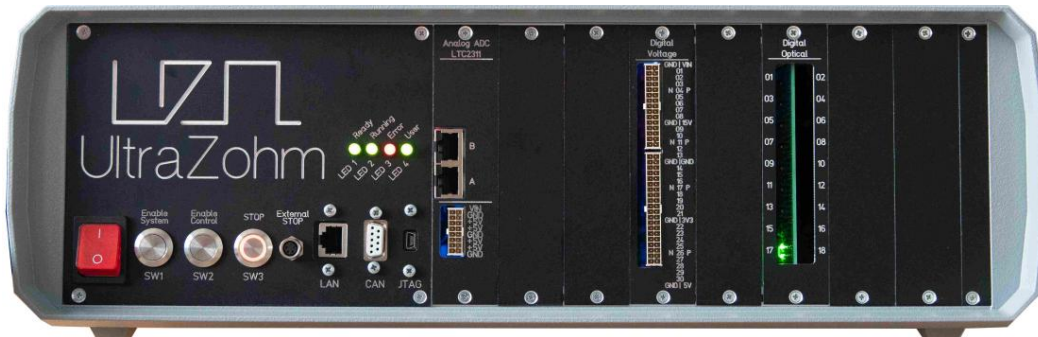


UltraZohm - Open-Source Rapid Control Prototyping Platform for Power Electronics



Research Foci

- Open-source rapid control prototyping (RCP) platform enabling reproducible, hard real-time experiments in power electronics and electrical drive research.
- Heterogeneous MPSoC/FPGA compute architecture to accelerate computationally intensive control and estimation (e.g., finite control set (FCS) model predictive control (MPC), machine-learning-based control).
- Modular hardware concept with a carrier board and standardized analog and digital adapter cards for measurement, sensing, and gate/IO interfacing.
- Ecosystem of available adapter cards, peripherals, and inverter interfaces, complemented by corresponding FPGA IP cores and C-code drivers (full-stack reference implementations).
- Model-based development workflows, including automatic code generation and FPGA acceleration (e.g., Vivado/Vitis integration, HLS-based design flows).
- Community-driven development to share infrastructure, reduce duplicated engineering effort, and accelerate academic output.

Contact

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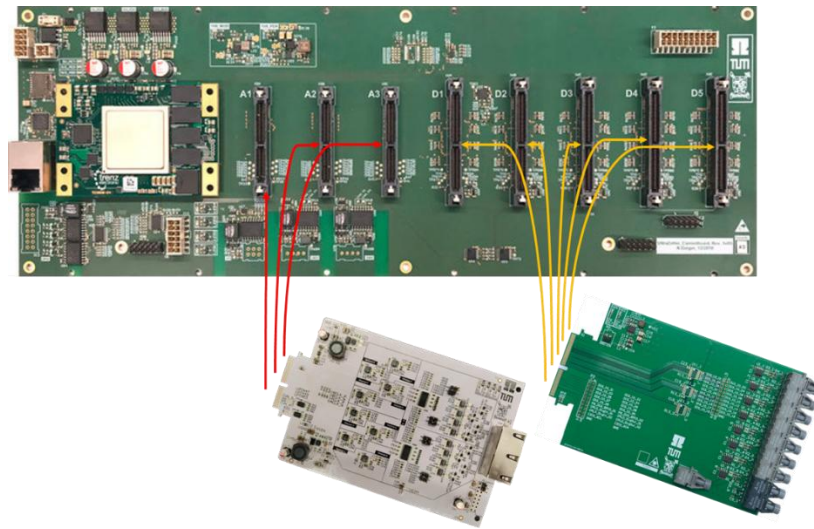
Links

- Documentation: docs.ultrazohm.com
- Software repository: bitbucket.org/ultrazohm/ultrazohm_sw
- Funding context (KI-Power): <https://www.elektronikforschung.de/foerderprojekte/ki-power>
- Distribution www.zohm-control.org

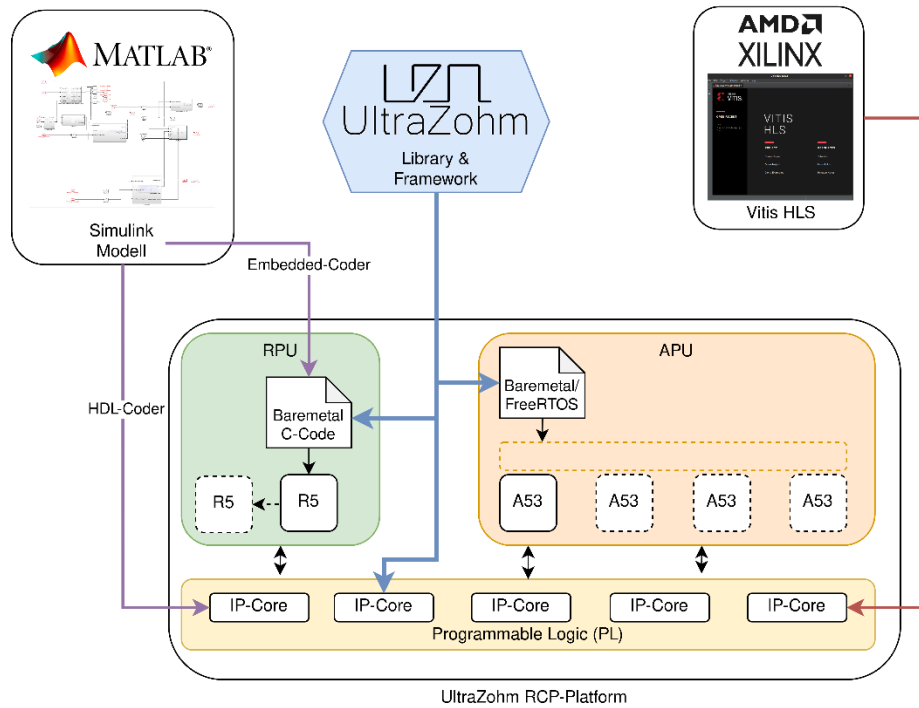
Short Description

UltraZohm is a community-based, open-source RCP platform for research on power electronics and electrical drives. It integrates a Xilinx Zynq UltraScale+ MPSoC (ARM application cores, real-time cores, and FPGA fabric) into a modular carrier-board system, providing a reusable reference platform for deterministic real-time control and rapid experimentation.

Standardized adapter slots enable scalable interfacing: up to five digital adapter cards provide up to 150 fast digital I/Os (e.g., gate signals), while up to three analog adapter cards can be populated with 8- or 24-channel ADC inputs per card (configuration dependent).



In addition, the project maintains a growing library of documented adapter cards, peripherals, and interfaces to compatible inverters (including digital inverter modules and inverter adapter concepts). Crucially for research reproducibility, these hardware building blocks are complemented by corresponding FPGA IP cores and C-code drivers and framework modules, forming a coherent full-stack reference implementation from IO and protection up to real-time control software.



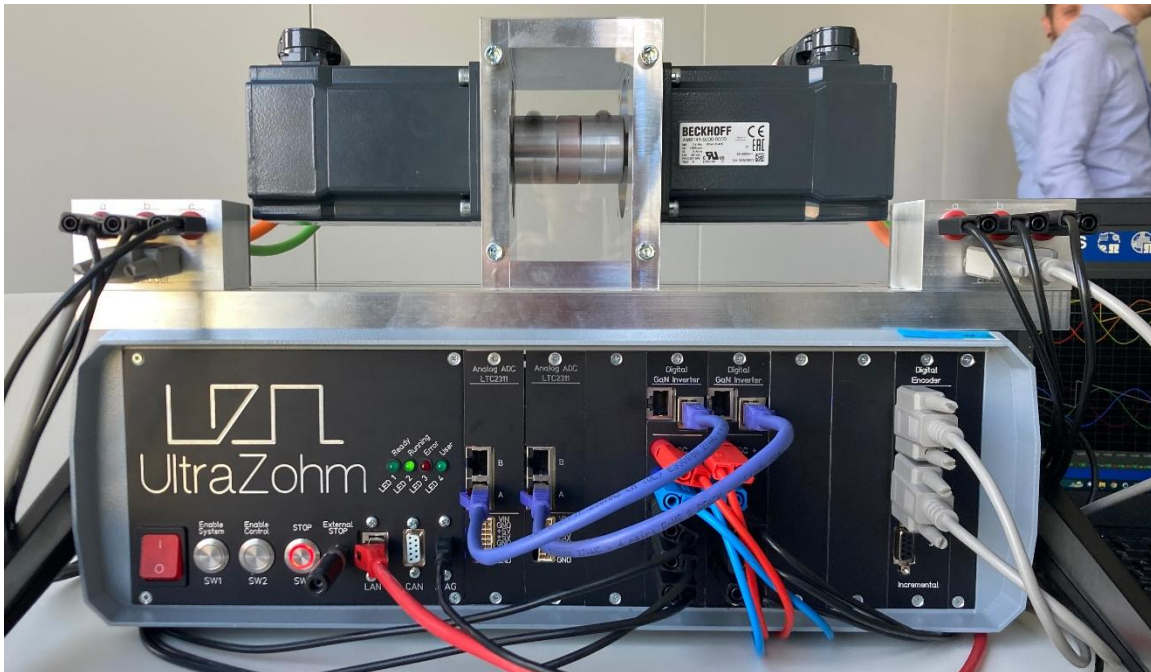
UltraZohm is designed for hard real-time control with control frequencies typically in the range of 10 to 400 kHz, while compute-intensive tasks can be offloaded to the FPGA. This enables advanced research workflows such as controller-in-the-loop plant emulation on the FPGA, fast data acquisition and preprocessing, and hardware acceleration of optimization and inference pipelines.

The platform is fully open source (software and documentation under Apache-2.0, hardware under CERN-OHL-P), allowing researchers to inspect and adapt the complete signal chain and processing stack without black boxes.

Community and Demonstrated Use Cases

UltraZohm has been used as an experimental platform in academic publications and demonstrators across power electronics and drive-control topics, including but not limited to:

- Real-time implementation of long-horizon direct model predictive control for multilevel inverters and drives.
- Nonlinear current control for synchronous reluctance machines using analytical flux linkage representations.
- Controller-in-the-loop and FPGA-based plant emulation for very high sampling-rate experiments.
- Research on multilevel converter control (including MMC concepts) and multi-phase drive control.



Publications (selected)

S. Wendel, A. Geiger, E. Aufderheide (Liegmann), D. Arancibia, E. Duren, T. Kreppel, F. Rojas, F. Popp-Nowak, M. Diaz, A. Dietz, R. Kennel, B. Wagner, "UltraZohm – A powerful real-time computation platform for MPC and multi-level inverters," *Proc. IEEE PRECEDE*, 2019, doi: 10.1109/PRECEDE.2019.8753306, <https://ieeexplore.ieee.org/document/8753306> .

E. Aufderheide (Liegmann), T. Schindler, A. Dietz, R. Kennel, "UltraZohm—An Open-Source Rapid Control Prototyping Platform for Power Electronic Systems," *Proc. IEEE ACEMP/OPTIM*, 2021, doi: 10.1109/OPTIM-ACEMP50812.2021.9590016, <https://ieeexplore.ieee.org/document/9590016> .

E. Aufderheide (Liegmann), P. Karamanakos, R. Kennel, "Real-Time Implementation of Long-Horizon Direct Model Predictive Control on an Embedded System," *IEEE Open Journal of Industry Applications*, 2022, doi: 10.1109/OJIA.2021.3133477, <https://ieeexplore.ieee.org/document/9640575> .

S.-W. Su, H. Börngen, C. M. Hackl, R. Kennel, "Nonlinear Current Control of Reluctance Synchronous Machines With Analytical Flux Linkage Prototype Functions," *IEEE Open Journal of the Industrial Electronics Society*, 2022, doi: 10.1109/OJIES.2022.3208329, <https://ieeexplore.ieee.org/document/9896947> .

S. Klass, H. Börngen, D. Manoharan, R. Kennel and M. L. Heldwein, "High-Frequency Switching of State-of-the-Art Wide Band Gap Inverters and its Impact

on Encoderless Control Schemes," *IEEE Proc. SPEC/COBEP*, 2023, doi:
10.1109/SPEC56436.2023.10407581,
<https://ieeexplore.ieee.org/document/10407581> .