MicroTCA-based Motion Controller

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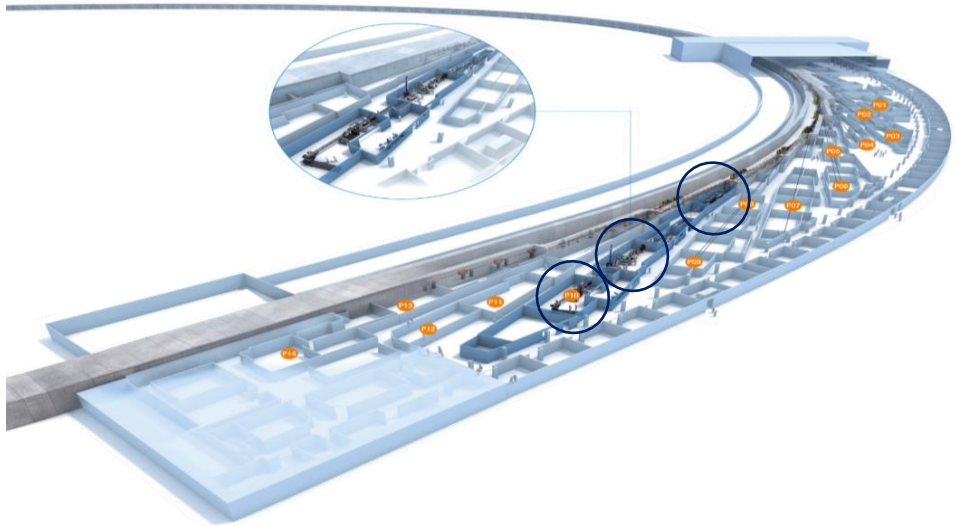
HELMHOLTZ

DESY.

Motivation

DESY Experimental Needs:

- Requirement to control motors in experiments.

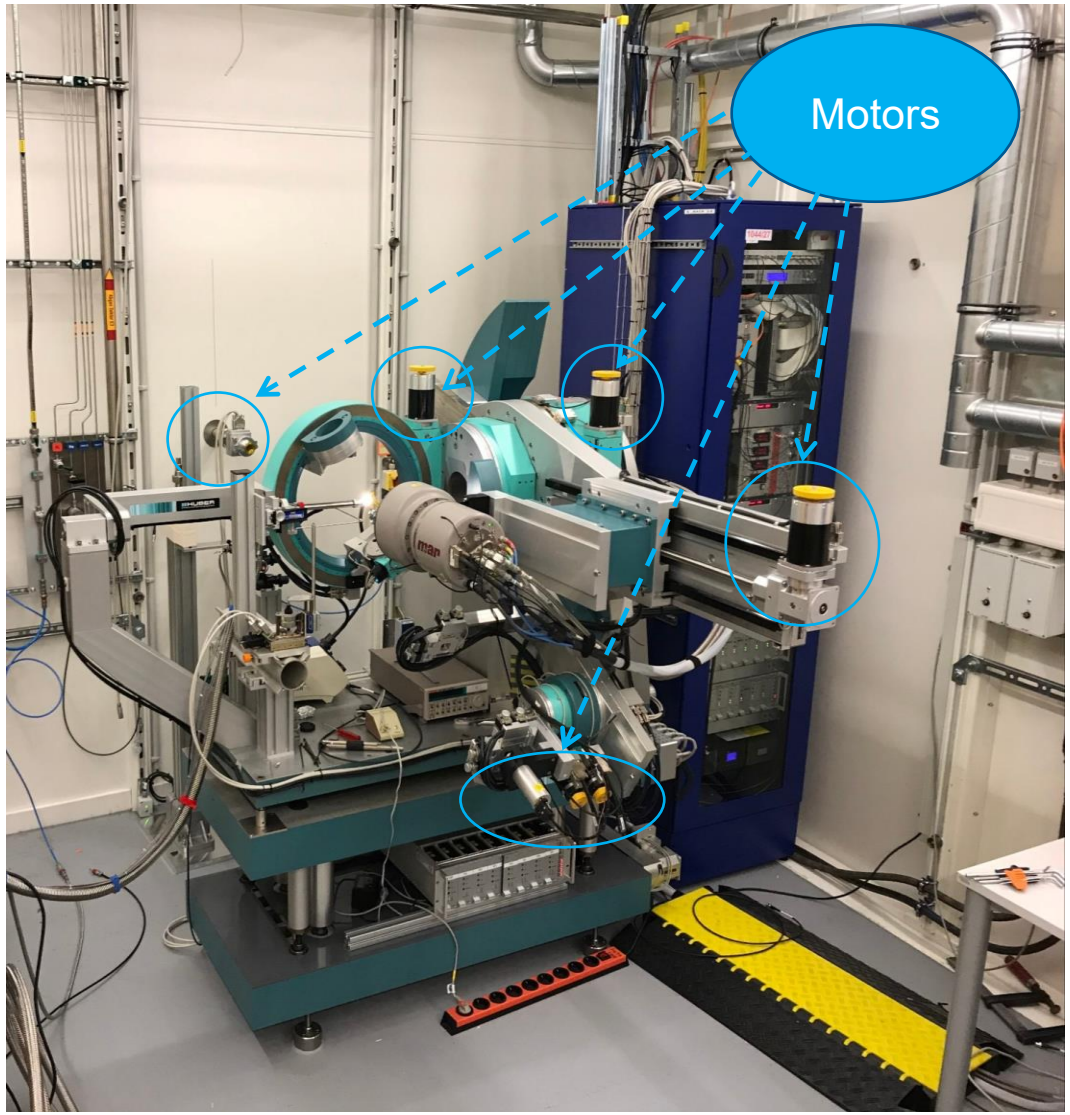


PETRA IV MicroTCA Infrastructure:

- Planned replacement for VME systems.
- Lack of a suitable multi-axis motion controller.

Enhancements Needed:

- Increase the number of motors for synchronous motion.
- Address experiment-specific requirements, such as position-triggered data acquisition.



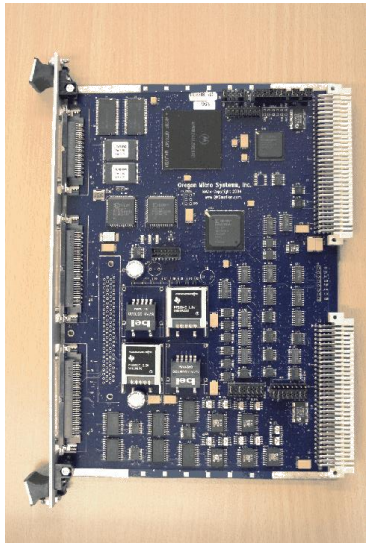
Diffractometer at Beamline
(Martin Tolkiehn)

Large Investments on DESY Campus

- Beamlines equipped with hundreds of existing motor drivers.
- Commercial drivers integrated into proprietary ZMX+ frame.

- Legacy hardware, but good enough to keep.
- Incompatible interface:
  - Users complain about long, stiff cables.
  - Sensitive connectors (SCSI II).
  - 4 cables per motor driver frame.
  - Wide connector unsuitable for MicroTCA.
- Limited number of encoders.
- Need for a drop-in replacement due to the outlined issues.

SCSI connector on back panel of DESY ZMX+ frame

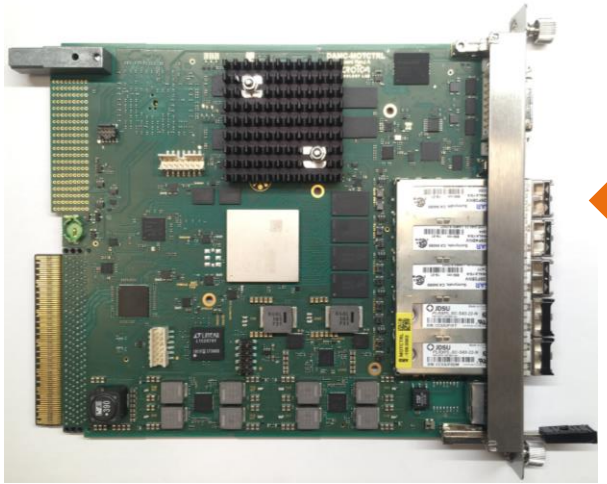


VME based Motion Controller - OMS MAXv

PETRA IV Motion Control

Hardware

DAMC-MOTCTRL:
- Funded by DESY Generator Program.
- MicroTCA.4 based Motion Controller.
- Controls up to **48 motors/axis** per card.
- Replaces six VME cards, i.e. three ZMX frames can be operated with one card.
- Four SCSI cables have been replaced with a single fiber link.

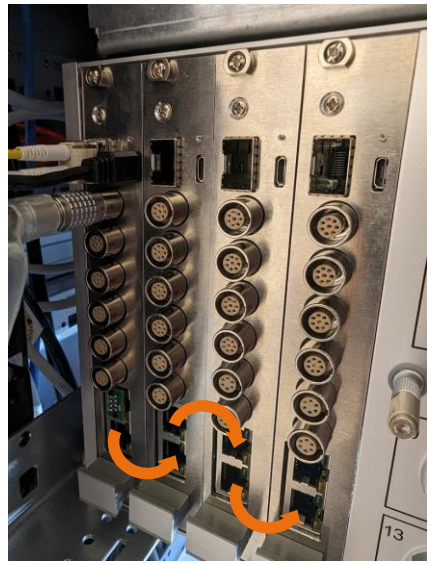


Heterogeneous Processing:
- Zynq UltraScale+ (XCZU2EG) with 2GB DDR4 32-bit.
- Kintex (XC7K160) with 4GB DDR3 64-bit.

SFP+ Ports (5 in Total):
- 3x Motor interfaces.
- 2x Ring topology (EtherCAT, SERCOS).

GPIOs:
- 26-pin connector supporting 3.3V/5V GPIOs.

ZMX+ Connection Board:
- Drop-in replacement for the deprecated interface card of the ZMX+ frame.
- Artix (XC7A50T).
- 6 LEMO 8-pin:
  - 4x Encoder Inputs.
  - 2x Direct Motor Step & Direction.
- 2 RJ45:
  - Interconnection between boards within the ZMX+ frame (daisy chain).



Interconnected ZMX+ Connection boards

PETRA IV Motion Control

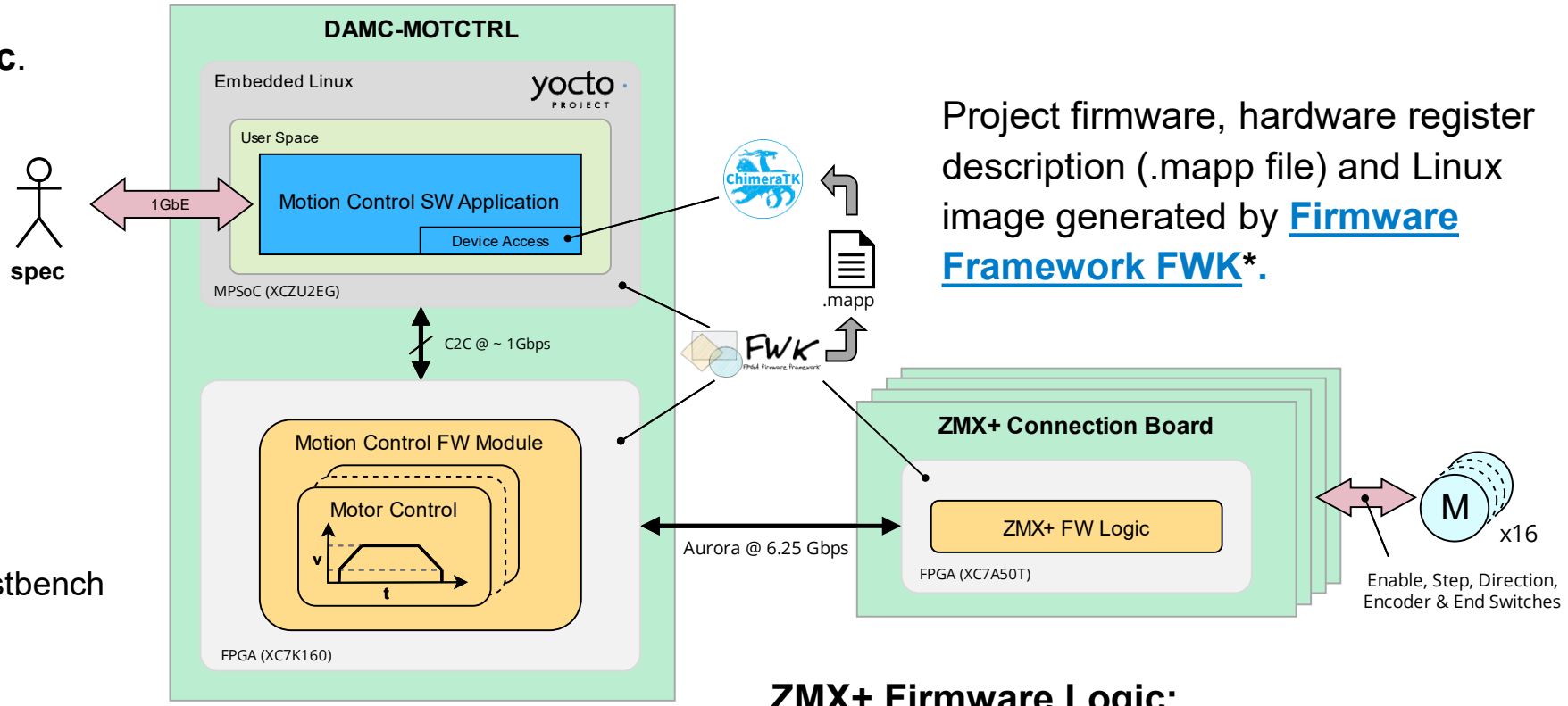
Firmware Overview – FW Version 1.2.1

Motion Control SW Application:

- Interface to external high-level instrument control software **spec**.
- Parses motion commands and orchestrates axis logic.
- Uses UIO backend of **ChimeraTK-DeviceAccess**.

Motion Control FW Module:

- Generic multi-axis controller.
- Verified using:
  - Universal VHDL Verification Methodology (**UVVM**),
  - Coroutine-based cosimulation testbench environment (**cocotb**).
- Wraps per-axis submodules.
  - Linear acceleration profile.
- **Clock-edge synchronous motion**.
- Per-axis encoder and limit switches.



Single-board operation

Project firmware, hardware register description (.mapp file) and Linux image generated by **Firmware Framework FWK***.

ZMX+ Firmware Logic:

- Multiplex / demutiplex motor signals.
- Apply user front panel interface.

*Visit talk Introduction to DESY's firmware framework FWK more

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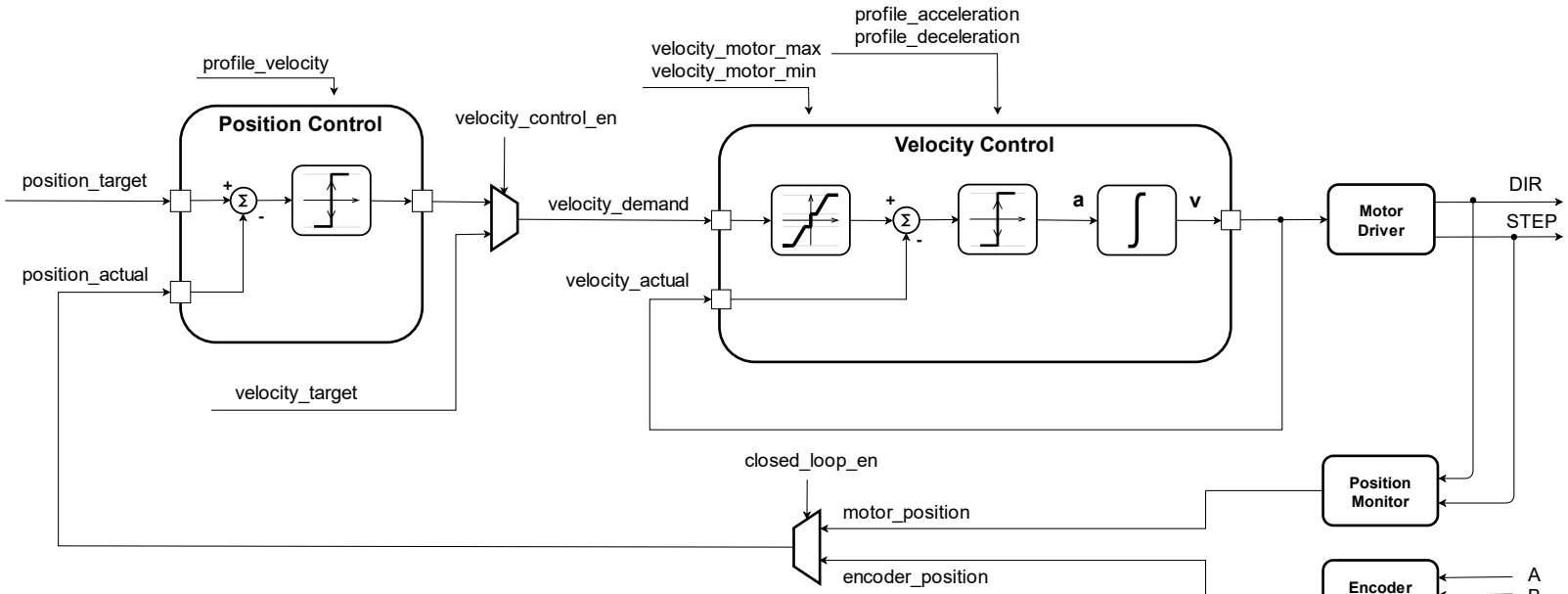
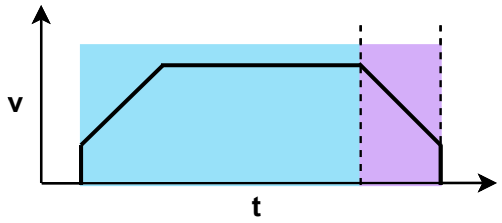
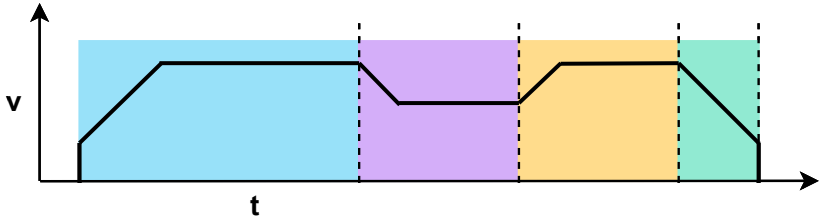
Motor Control Core – Upgrade



Overview of improved motor control logic



Simple positioning command



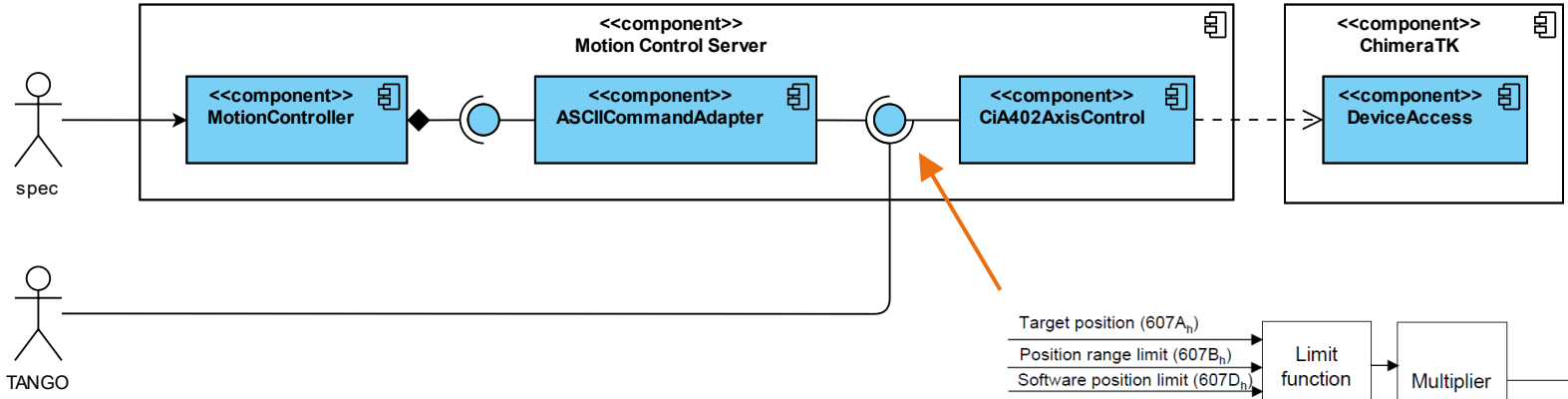
Continuous movement

Generic Control Architecture

- In line with **CANopen Profile CiA402**
- **Closed-loop operation**
- Mode of Operation:
  - Profile Position Mode (single-axis)
  - Interpolated Position Mode (multi-axis)
  - **Homing Mode**
- **Drift detection**
  - Position Window
  - Following Error Window
- **Drift compensation** in software
- Open for extensions
  - Complex trajectory planning
  - S-Curve acceleration

PETRA IV Motion Control

Towards Generic Control System Interface



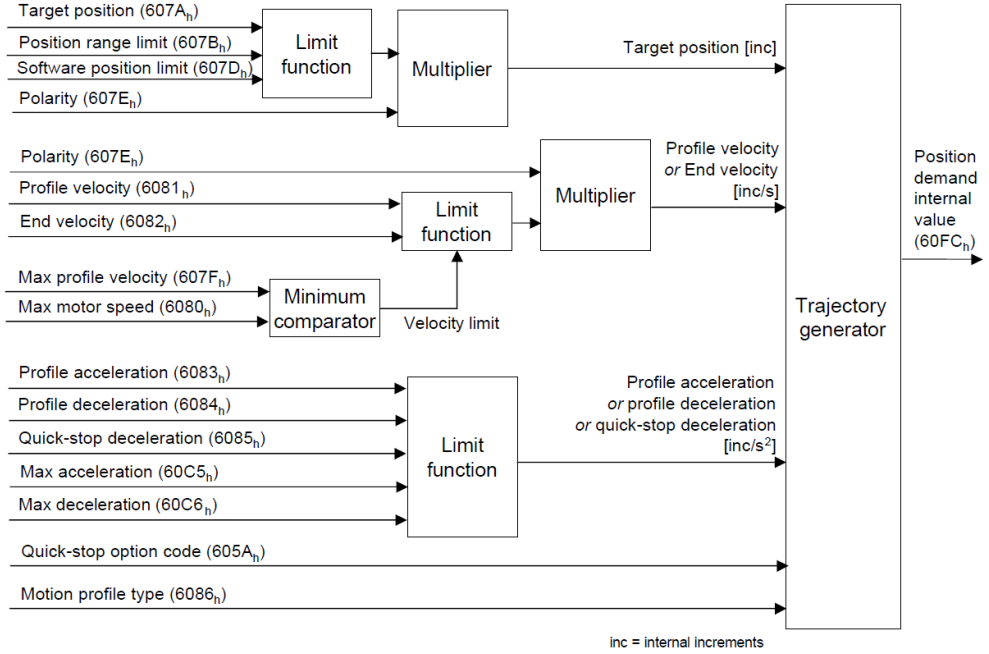
Previous state

- Interface for **spec software** through ASCII commands
- Control system interface was missing

Direct TANGO interface nearly completed

- Based on EtherCAT Object Dictionary (CiA402 profile)

Interface for DOOCS, EPICS and OPC UA planned

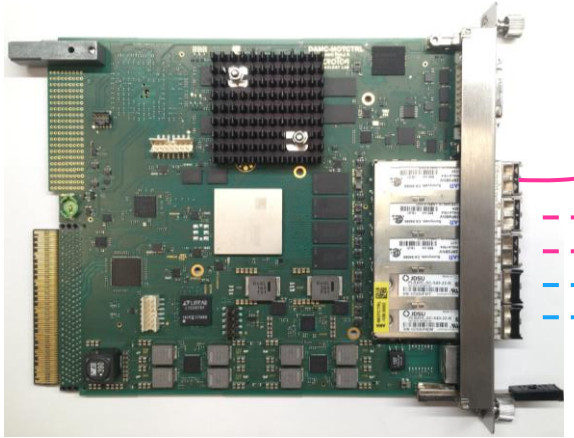


Object dictionary for profile position mode (CANopen CiA402)

PETRA IV Motion Control

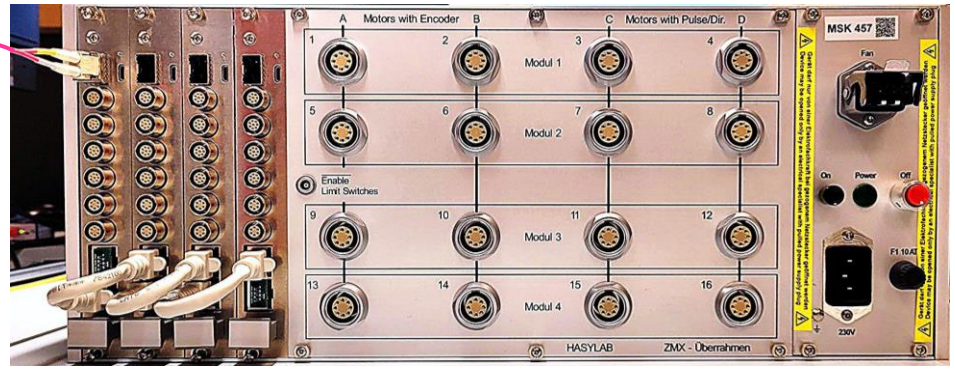
Next Steps

- **Extension to 48 motors:** 3 x ZMX+ Crates, hosting 16 motor, per axis encoder and limit switches each.



+32 motors (soon)

Synchronization



ZMX+ Frame (backside)

- **Native EtherCAT Interface:**
  - Short cycle times (<< 1 ms) and precise synchronization (<< 1µs)
  - Seamless synchronization with other commercial off-the-shelf components
  - Solution for inter-board synchronization

Thank you

Also visit “MicroTCA for photon beamlines - on-the-fly scans with spec”

Check out the source code and documentation:

- **Open-Source PETRA IV Motion Control Project**
- **Open-Source Motion Control Firmware Module**

Contact

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