MicroTCA @ European XFEL

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DESY
Outline

1.6 km cold accelerator

3.3 km

European XFEL
MicroTCA Systems
Control System DOOCS
First MicroTCA Crate in the Injector

The Gun

One MicroTCA Crate as seen by the Control System
The Cold Linac

Racks for:
- Vacuum
- Cryo
- Magnets
- RF
- LLRF
- Coupler
- Diagnostics

Pulse Transformer for Klystron

10 MW Klystron with 2 Wave Guides, 1.3 GHz
One RF Station = 4 Modules = 32 Cavities = 5 MicroTCA \approx 50m
XFEL Key Dates

- FLASH First lasing at 109 nm: 2000
- Injector operation started: Dec. 2015
- Main tunnel closed: 13. 1. 2017
- First Beam in dump 2.5 GeV: 25. 2. 2017
- 12 GeV in main dump: 8. 4. 2017
- Beam permission SASE 1: 26. 4. 2017
- Beam in SASE 1 dump (~1 km): 27. 4. 2017
- First Light: 2. 5. 2017
- User runs since: Sept. 2017

6 weeks:
- 2 km beam line,
- 700 cavities
From VME (FLASH) ➔ MicroTCA (XFEL)

VME is 35 years old!!!

- Redundant fans & power supplies
- Internal clock & trigger distribution
- Modular: reusable components
- Complete remote management
- Modern high-speed data transfer
- Highest signal quality
- I/O cables from rear side
We started with MTCA.0 single modules:

- TAMC100 as carrier for IP Timing
- DESY development DMAC01 to understand the standard:
  - AMC with Virtex 5 and PCIe
  - MMC code on Atmega128
  - 2* ADC 100MSPS

➤ Single modules are too small & cables from front are not optimal
Timing Synchronises, MPS Permits

Parallel operation of N beam lines

Bunch pattern

Timing

Laser

Permissions

Stop laser

Stop dump

Kicker

MPS

MPS

MPS

MPS

MPS

MPS

MPS

bunches in experiment A

bunches in experiment B

<= 2700 bunches in main linac

0.6 ms

100 ms
The Timing System

- Distributes:
  - Triggers, gates, clocks (10ns ... 5ps resolution)
  - Bunch information (charge, destination,...), unique ID

- Link drift compensation: Jitter ~10ps RMS
Can be used as a **timing receiver** or **transmitter**

Optional **RTM**: 9 transmitters, Further triggers or clocks

**MicroTCA backplane**: TCLKA and TCLKB, 8 * M-LVDS

**Transmitter** Piggyback with link delay

**IN** OUT OUT OUT

Fiber optics

3 * Trigger out 1 * Clock out
3 * Trigger out 1 * Clock out
3 * Trigger out 1 * Clock out
4 * General I/O
RTM Timing Extension Modules

9 Lemo outputs (50 Ohm):
- Triggers, Clocks, Data
- 3 channels with 5ps resolution

9 SFP outputs:
- length compensated fiber links

9 Fiber outputs (ST):
- Triggers, Clocks, Data
- used for modulators
Beam-Loss and Coupler Interlock

~350 Multipliers

Beam Loss Monitors:
- PhotoMultiplier readout RTM
- DAMC2 with interlock logic

784 Power Couplers

Coupler Interlocks:
- Analog readout RTM
- DAMC2 with interlock logic
Diagnostics: Based on Modular MicroTCA

Photon Gas Monitor Detector:
• ADC @ \leq 7 GSPS

128 channel Spectrometer:
• Shaper/Amplifier RTM
• 32 ch. ADC @ 54 MSPS

Toroid Protection:
• Analog readout RTM
• SIS8300 ADC @ 108 MSPS

Kicker, FC, etc. readout:
• Amplifier RTM
• SIS8300 ADC @ 108 MSPS
Magnets, Vacuum, Cameras, slow IO, ...

**ESD:** Digi/analog IO

**ESD:** 4* CAN IO

**Kontron:** 4* Ethernet IO

**Tews:** 16 * RS-232 IO

**Concurrent**

**CPU:** i7 Quad-Core
**PCIe Gen3**
**Redundant SSD**
**Remote console**
XFEL Injector: Controls Rack for 1.3 and 3.9 GHz

σ(dA/A) = 0.0057 %
Integration of Controls, Management and Development

- **DOOCS IPMI-Server**
- **IPMI / HPM.1**
- **MCH**
- **MMC Firmware**
- **FPGA Firmware**
- **Slot Management**

**Controls**

- **jddd Panels**

**Development**

- **>ipmitool**
- **FPGA + Controller Cart**
- **MAP file**

**MicroTCA Crate**

- **DOOCS x2timer-Server**
- **LINUX Driver**
- **PCIe**
- **FPGA**
DOOCS Architecture

XFEL: > 600 000 Channels Archived
Front-end Servers in MicroTCA

Physical Device Server

Toroid Server

Toroid 1 . . . Toroid N

ADC DMA Server

Location 1 . . . Location N

IO Device Server

dev Node

Linux Driver

DAQ

Ethernet

Central Timing

MicroTCA backplane

Triggers, Clocks, Interlocks, Data

CPU

Driver

s4

Timing Server

Location 1

Driver

s2

Central Timing
LLRF System: Complex Systems Require Lots of Diagnostics
Summary

- **XFEL** is in operation and delivers beam to experiments
  - Very fast startup since HW & SW was debugged in FLASH & XFEL Injector
- ~250 **MicroTCA** crates are installed and operational
- Parallel operation of $\geq 3$ beam lines:
  - Full HW/SW integration in MPS, Timing, Subsystems
- XFEL is controlled by **DOOCS**, has $>8$ M properties (addressable items)
  - All fast data is controlled by MicroTCA, including photon experiments
- MicroTCA provides:
  - High speed data transfer
  - excellent analog performance
  - Complete local & remote management
  - Redundancy $\rightarrow$ high availability