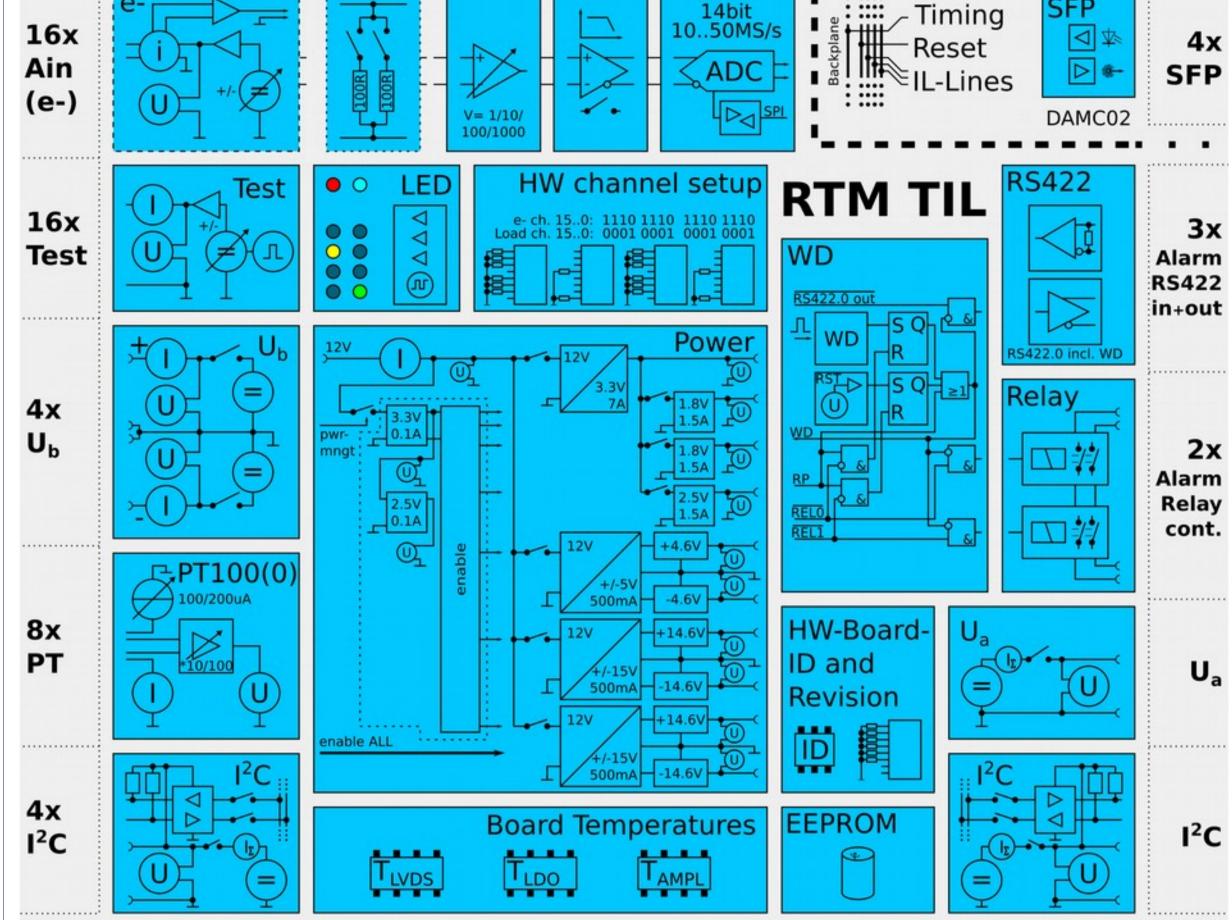# Next Generation Cavity and Coupler Interlock for the European XFEL

European XFEL

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Abstract

The safe operation of cavities and couplers in the European XFEL accelerator environment is secured by a new technical interlock (TIL) design, which is based on the XFEL crate standard (MTCA™.4). The new interlock is located inside the accelerator tunnel. Several remote test capabilities ensure the correct operation of sensors for light, temperature and free electrons. Due to the space costs and the very high number of channels, the electronic concept was moved from a conservative, mostly analog electronic approach, with real comparators and thresholds, to a concept, where the digitizing of the signals is done at a very early stage. Filters, thresholds and comparators are moved into the digital part. The usage of an FPGA and an additional watchdog increase the flexibility dramatically, with respect to be as reliable as possible. An overview of the system is shown.
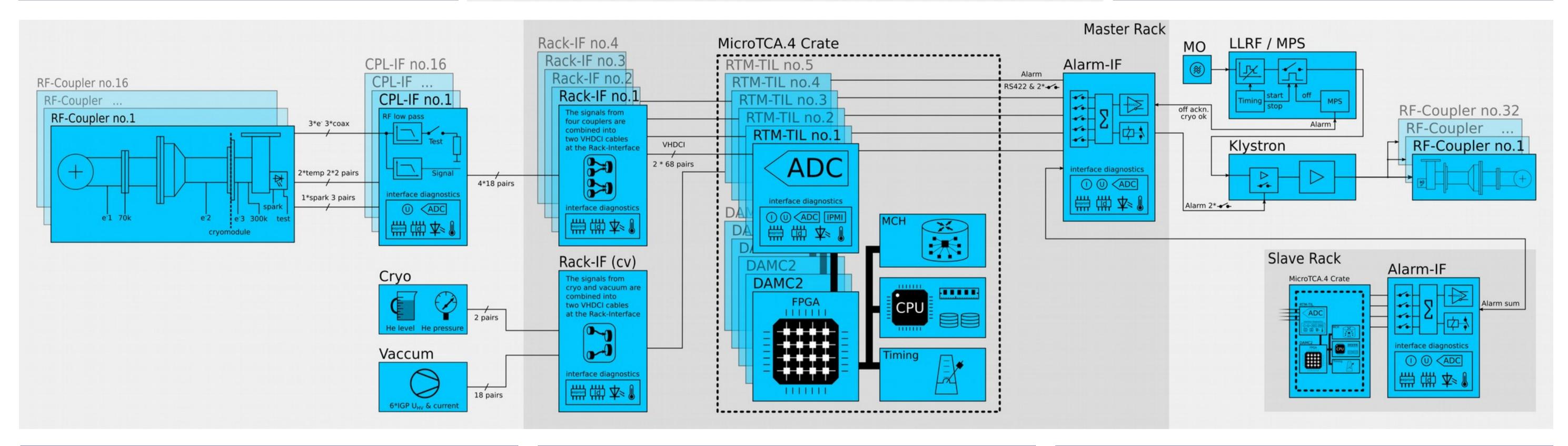
MTCA (Micro Telecommunications Computing Architecture) is a standard defined by the PCI Industrial Computer Manufacturers Group (PICMG®, www.picmg.org).

RTM TIL

Features

- fully remote controlled
- remote test capable including sensor functionallity
- extensive on board diagnostic
- high channel density
  (4 coupler (16 fast analog input, 8 PT100(0)) / board)
- readable RTM hardware configuration and board ID, actual two board variants: coupler and analog input (cryo, vacuum)
- full support of the new PICMG MTCA.4 standard
- hardware ID per coupler (on the CPL-IF)
- input channel overdrive protection (no influence on neighbouring channels)
- analog inputs with switchable loads (10M/100/50 Ohm)
- differential measurement with bias voltage for free electrons (max. 12 channels / board)
- programmable gain amplifiers (PGA: *1/10/100/1000)
- sample decoding logic with automatic resync (single event upset (SEU) save)
- sample frame error and missing sample detection
- low pass and decimating CIC filter (downsampler)
- out of boundary detection (min/max threshold) for all channels
- machine trigger independent interlock
- machine or signal triggered trace output
- alarm inputs via RS422 (external source) and BP (backplane)
- each RTM TIL board is watchdog (WD) protected
- 256 virtual alarm channels per board (212 actual used)
- fast and secure alarm outputs (RS422 + relay contacts)

Rack-Interface (Rack-IF)

- signal distribution (16* fast channel, 8* PT1000, 16* Utest, 4* I²C,...)
- unique block number (VHDCI port, blk. type, blk. no.)
- type Coupler for 4 CPL-IF
- type Cryo, Vacuum (He level, press; IGP press., U_{HV})
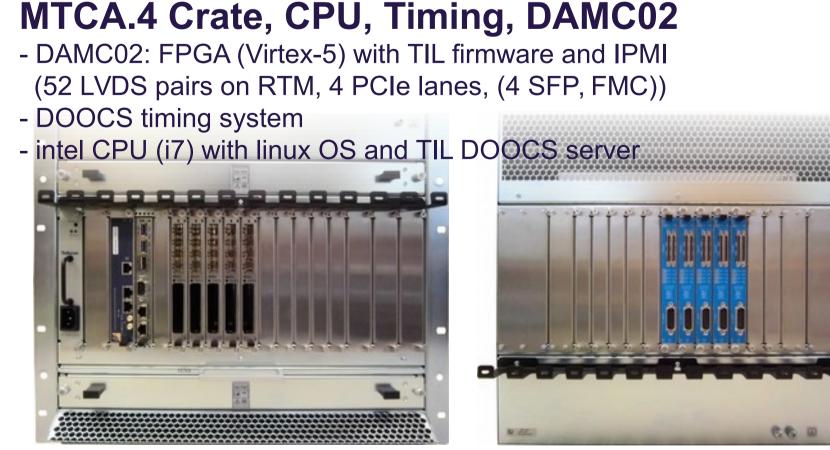- type Other (Injector Gun, HOM temperature, ...)

Coupler-Interface (CPL-IF)

- signal distribution (3* e-, 1* Spark, 2* PT1000)
- e- low pass filter and test electronic
- unique ID and coupler, module position

XFEL Cavities and Coupler

- 25 RF stations (XTL) + Injector
- 3 RF stations in one cryo / vacuum section
- 32 coupler (4 accelerator modules) in one RF station

MTCA.4 RTM TIL

- 16ch. analog input (+/-10V, 14Bit, 50MS/s),
  Load (10M/100/50 Ohm), PGA (*1/10/100/1000)
- 0...12ch. e- converter (+/-20mA, Ubias= -14.5...0...+14.5V)
- 16ch. test signal output (8Bit, +/-14.5V, 40mA)
- 8ch. PT100(0) (1kS/s, 12Bit; 200uA, Test: 100uA)
- 4ch. sensor power (+/- 14.5V, 100mA)
- 4ch. sensor I²C bus and power (50kBit, 12V, 100mA)
- alarm outputs (2 relay contacts, 3 RS422 in and out, WD)
- alarm power (12V, 100mA (max. 400mA))
- alarm I²C bus and power (50kBit, 12V, 100mA)
- overcurrent protection

MTCA.4 Crate, CPU, Timing, DAMC02

- DAMC02: FPGA (Virtex-5) with TIL firmware and IPMI
  (52 LVDS pairs on RTM, 4 PCIe lanes, (4 SFP, FMC))
- DOOCS timing system
- intel CPU (i7) with linux OS and TIL DOOCS server

TIL FW and DOOCS Server

- sample decoding unit with auto sync and error detect
- bus and hardware device driver with fail detection
- boundary checks for any analog signal
- trace triggering by signal or machine timing
- interlock works independent from timing and CPU
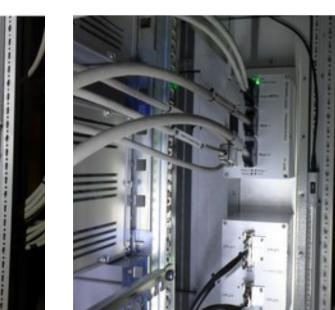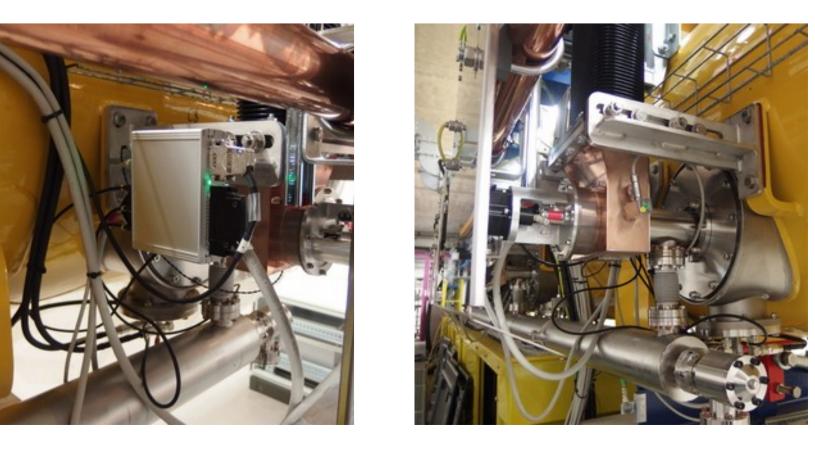

Alarm-Interface (Alarm-IF)

- combine RTM TIL alarms (redundant outputs)
- combine two slave Alarm-IF (cascadable)
- build and distribute the sum alarm
- three alarm ways (two contact loops and fast RS422)
- bidirectional interconnection between the alarm ways
- supporting hard and soft configuration
- test alarm (not ok !) for individual alarm output
- diagnostic for false alarm, ok, relay health

XFEL Rack (master/slave)

- one crate for 16 coupler, incl. cryo, vacuum (master)
- block number and indicators for fast maintenance
- modular system permitts simple block exchange

Summary

- highest possible reliability with great flexibility
- state of the art technologies permit very low space needs
- a robust EMC design is achived
- modular block setup for fast and simple maintenance
- excellent performance at startup and operation of the first RF station
- continous ongoing production of boards, testing parts, building devices, setting up crates, ... the installation at the accelerator is under work
- further features for the TIL system are in preparation

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