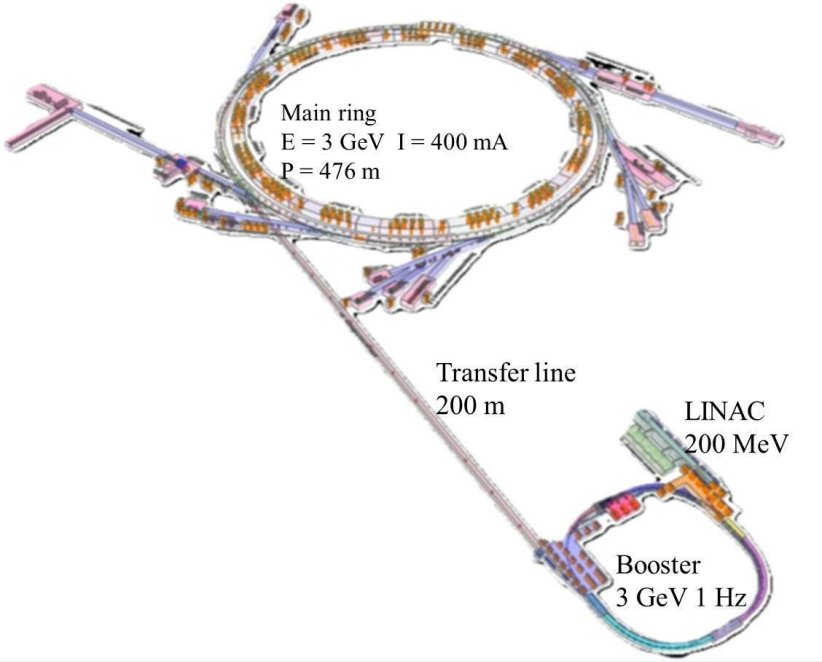
Control system for power supplies of magnetic system elements of the SRF "SKIF" accelerator complex

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The SKIF accelerator complex



3 GeV
beam energy

476 m
ring circumference

400 mA
beam current

16
identical sectors at main ring

1 Hz
injection cycle

5 of 6
insertion devices superconducting

About 2,500 power supplies

DC power supplies

magnets of the linac, transport lines and storage ring

Ramped power supplies

booster magnets: full-range current change within hundreds of ms

Pulsed sources

injection and extraction magnets: short pulse of given amplitude

Accuracy and stability

1000 ppm

orbit-correction magnets in the transport lines

a few ppm

main lattice magnets of the storage ring

Control tasks

1. Synchronous control of booster magnets with high mutual accuracy during acceleration (≈400 ms)
2. Setpoint tracking by DC supplies verified at the moment of beam passage (linac, transport lines)
3. Synchronous current change in all focusing magnets of the ring (>500 supplies) when an insertion device changes
4. Continuous monitoring of all devices, tied to beam motion: to detect deviations in beam in real time

Requirements and solution

Required for each power supply

- monitoring of all parameters
- synchronization of output current execution
- simple integration of new supplies
- flexible adaptation to new tasks



Solution

Universal embedded controller: common hardware and software, only two types, used in all SKIF magnet power supplies

EPICS





Control system software environment of SKIF, with tools for rapid GUI development, data archiving and more

IOC

Input-Output Controller

program that talks to a device, publishes its state and implements control



PV

Process Variable

named variable of a given data type: the basic element of an IOC



Channel Access

network protocol

access to any PV from any point of the control network

Three-level control system

User level	Operator applications with GUI: monitoring of beam parameters, changing operating modes
Server level	IOCs, mostly inside the embedded controllers. Common services: databases, save/restore of operating modes
Equipment level	Specialized or industrial controllers: primary processing and digitization of signals

Universal controller: software

Specialized part

- specific to each power supply type
- control of power circuits, digital I/O
- PVs individual for this type of power supply

Universal part

- data processing
- interaction with the control system
- Identical common PVs for all supply types

Common PVs

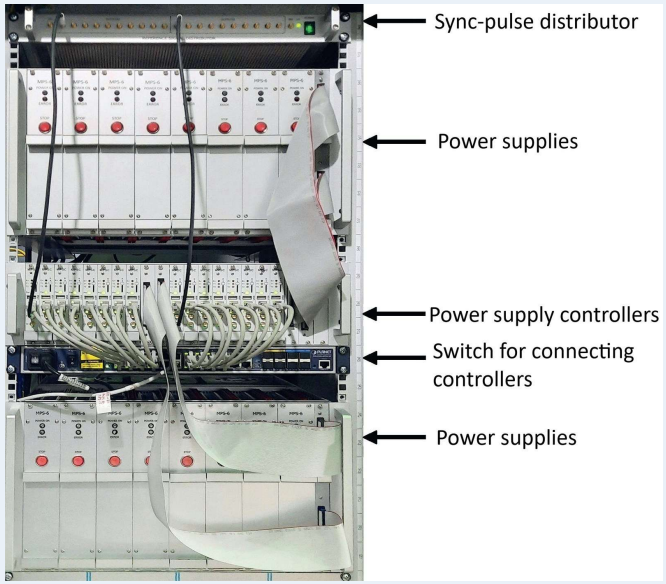
Current/voltage measurements: scalars, waveforms

Setpoints: scalar and waveform

Status: interlocks, power on/off state

Control: power on/off, interlock reset

Controllers in operation



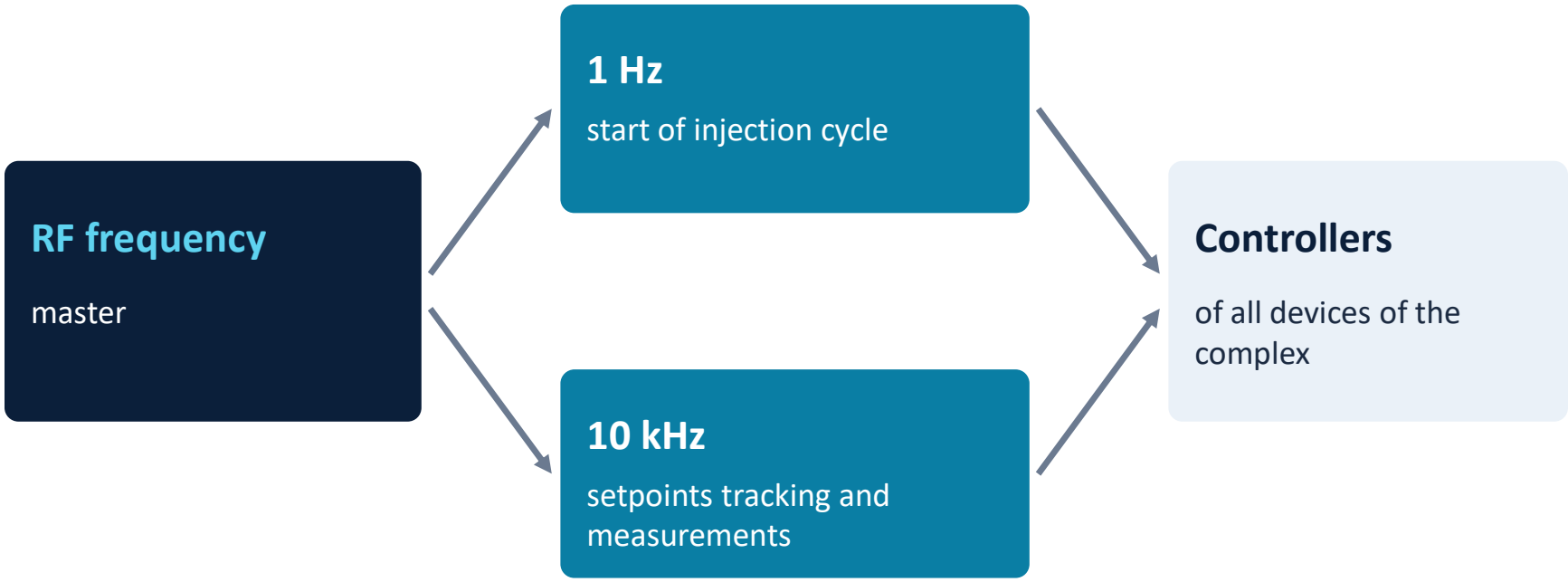
Rack with low-power power supplies



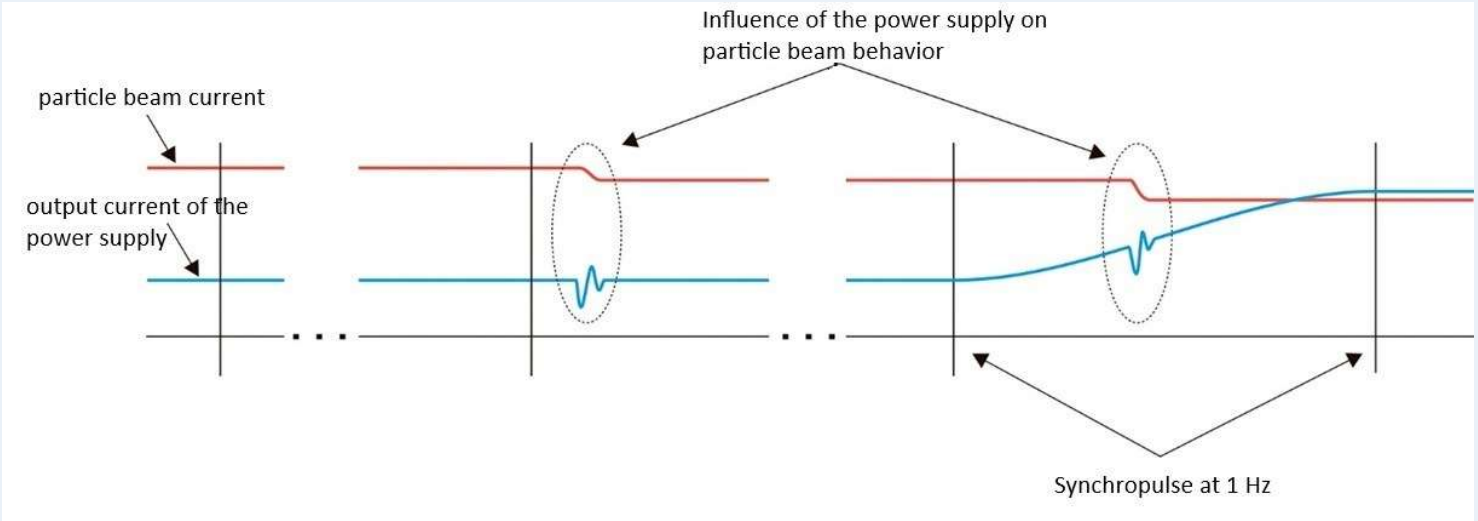
MPS-20-50 power supply with the embedded controller

- one controller per power supply
- controllers connected via Ethernet switch
- sync pulses from a common distributor

Device synchronization



Linking devices to the beam



Device and beam parameters measured at 10 kHz → faulty devices found automatically

Controller hardware and SoM

What the controller needs

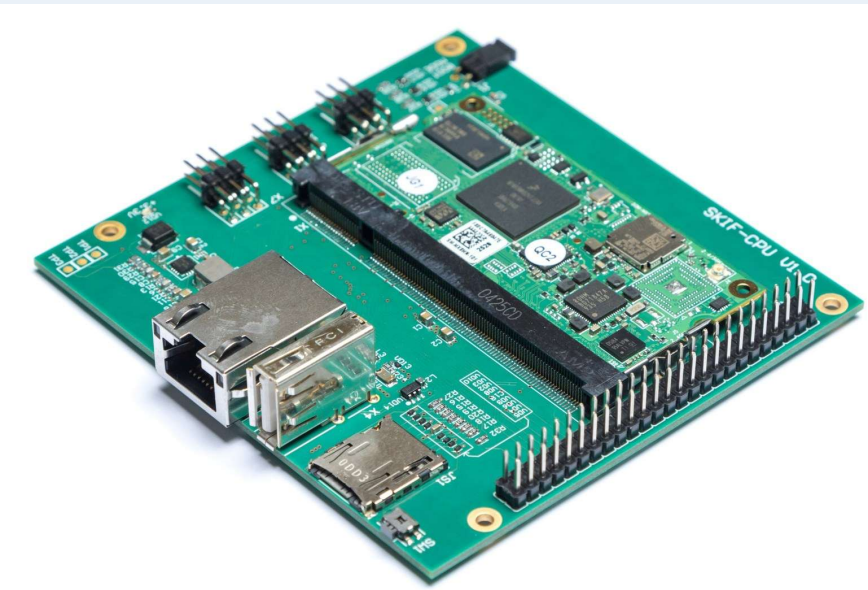
- Ethernet to the control system
- hardware interfaces to the device
- Linux
- performance for data, OS and IOC
- real-time capability: fixed response time



VAR-SOM-MX8M-NANO SoM

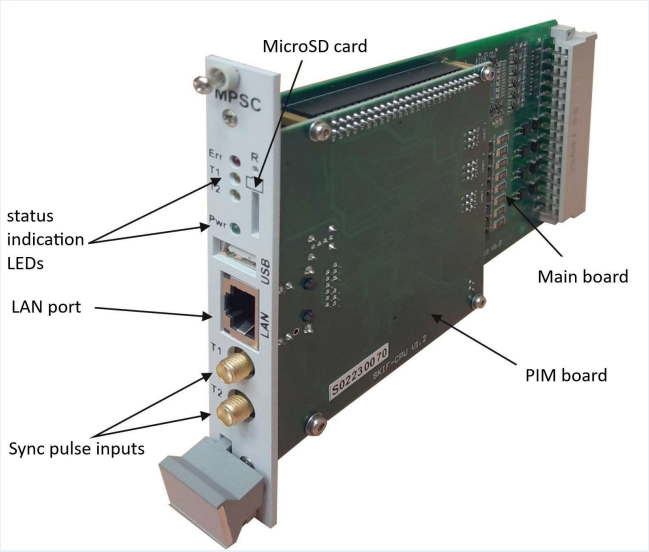
- Quad-core Cortex-A53: Linux
- Cortex-M7: real-time tasks

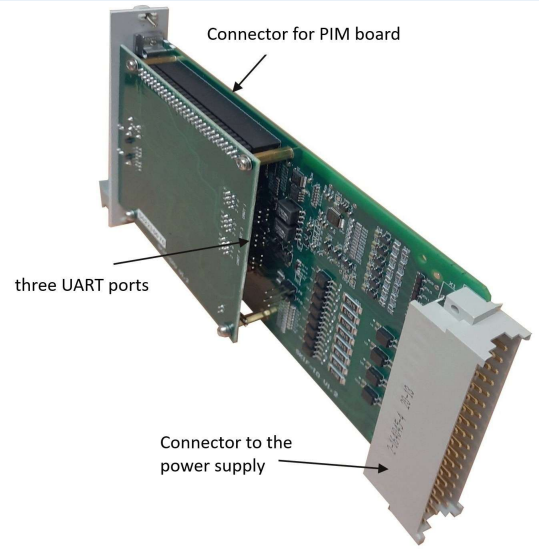
Processor interface module (PIM)



- Ethernet, USB, microSD, UART x3,
- board-to-board connector for mounting on the main board
- adapter: SoM can be replaced, compatibility kept
- universal interface: SPI link to the ADC/DAC

Main board





6 ADC channels

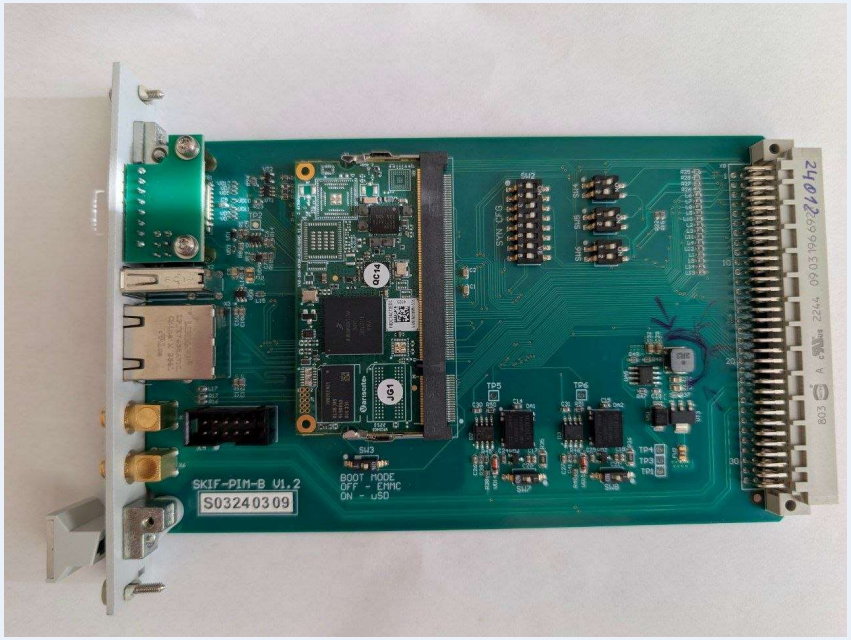
1 DAC channel

8 digital inputs

4 digital outputs

DIN 41612 to the supply · microcontroller for DAC/ADC via SPI

Second version of the device



- Only two boards: the SoM and a modified PIM
- Fully digital interaction with the power supply via SPI
- Purpose-developed data exchange protocols

Software architecture

U-Boot

loads the Linux kernel and the real-time program

Linux (Debian) on Cortex-A53

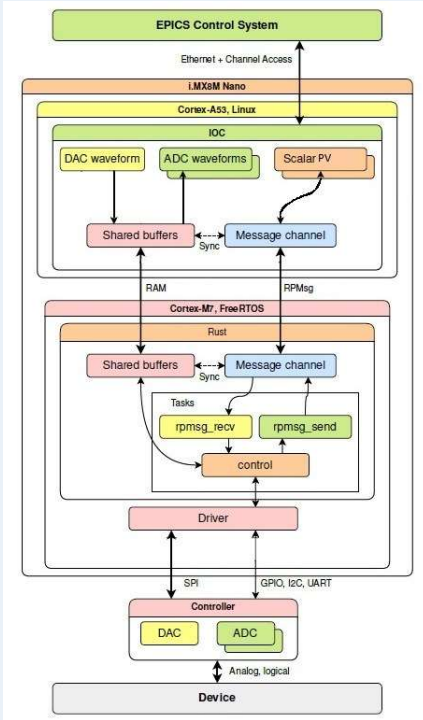
networking and IOC; not real-time: delays of up to several ms

FreeRTOS on Cortex-M7

time-critical programs, low-level device interaction

Inter-processor link

shared RAM buffers for waveforms; RPMsg channel for commands



Adapting to a new power supply

Universal software: unchanged

- DAC/ADC and digital I/O exchange
- with synchronization signals
- data transfer between Linux and real-time core
- basic IOC with the common PVs

Lower level

handling of data channels specific to the supply type

Upper level

ADC data → physical quantities (current, voltage, temperature); setpoints → DAC data

Infrastructure

Root file system over NFS: OverlayFS

Layer of each individual controller

Layer of the power supply type

Base layer: files common to all

TFTP: network boot files (Linux image, device tree, real-time program)

NFS: root file systems of the controllers

Firmware configurations for each type of supply

Monitoring of controllers, notification of malfunctions

Conclusions

- Universal embedded controller (two types) now used in all SKIF magnet power supplies
- Common PV set simplifies client software; IOCs run inside the controllers
- 1 Hz and 10 kHz synchronization ties all devices to the beam: faulty devices found automatically

Thank you for your attention!