The Modular Control Concept of the Neutron Scattering Experiments at the European Spallation Source ESS

Thomas Gahl
Group Leader Motion Control & Automation

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Outline

• The European Spallation Source
• Neutron Beam Characteristics
• Neutron Beam Line + End Station = Instrument
• Challenges and Requirements for a Control System
• Modular Instrument Control Concept
• Time Stamping and Synchronisation
• Use Cases: Motion Control + Robotics
• Acknowledgments
ESS – a collaborative project

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Paul Scherrer Institute - PSI
ESS – 17 European partner countries
ESS – worlds most powerful source of neutrons
(for science applications)

- 5MW proton accelerator, 800m long
- 16 instruments, up to 160m long
- 1.843 B€

~ 1.2 km
Neutron Beam Characteristics

- 14 Hz rep rate
- 71.4 ms cycle time
- 2.86 ms pulse time
- 4% duty cycle
- Energy range meV to eV, speed \(2000 – 200\) m/s

![Diagram showing neutron beam characteristics with timing annotations: 2.9 ms, 30.7 ms, 30.7 ms, 71.4 ms, 68.2 ms.](image)
Time Distance Diagram and Instrument Length

White beam instrument with mechanical chopper, instrument length up to 160m
Challenges and Requirements

• Organisational (in-kind)
  – Standardized controls infrastructure provided by ESS
  – Need for modularity and clear interface definitions

• Technical (pulsed neutron source, large area)
  – Distribution of centralised timing signal
  – Synchronisation experiments to proton pulse
  – Time stamping of data
  – Electrically separate parts of instruments into zones (grounding concept)

• Operational (large area, high availability, limited access)
  – Advanced diagnostics tools, remote diagnostics
  – Standardised modules, easy to replace
  – Preemptive maintenance
Modular Instrument Control Concept

1. Beam Extraction & Bunker Area
2. Beam Transport & Conditioning Area
3. Sample & Detector Area
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Modular Instrument Control Concept

- What can (or has to) be done locally will be done locally
- Clear functionalities and interfaces for a single box
- Linked together by an already existing facility wide network infrastructure
Timing system (synchronisation)

- Coupling of all timing to one single source – high precision (1ns jitter)
- Everywhere in the facility available, (time-) compensated cable lengths
- Custom clocks could be used in synchronized motion control as virtual axis

Master CLOCK
88 Mhz

Custom CLOCK
i.e. 10 khz

Master Pulse,
14 Hz

Custom Pulse,
\(n \times 14\) Hz

Master Pulse
with delay \(\Delta t_n\)

\(\Delta t_n\)
Timing synchronisation (Motion Control)

Transfer absolute timing information from Control Box to the local HW control unit:

- Synchronise a timer on the control unit (pulse + absolute time information over Command interface)
- Timestamp in the control unit direct readings of the sensor with minimal latencies
- Transfer the sensor readings through the Control Box into EPICS
- Local distribution of control unit functionalities with real time field busses
Timing synchronisation (Robotics)

Coordinated movement of robot and standard motion control

- Use motion control unit as master for both types of control
- Synchronise motion control unit with facility timing as described
- Distribute time and connect standard axes and robotics controller over RT field bus
- Ethercat interfaces to robot controller
  - mxAutomation (KUKA)
  - UNIVAL (Stäubli)
Transfer absolute timing information from Control Box to the local HW control unit (read out electronics):

- Synchronise a timer on the electronics
- Timestamp Neutron data and meta data in the read out electronics with minimal latencies
- Transfer Neutron data (large volumes) through the Bulk Data Interface (BDI) to the DMSC data aggregator
- Transfer the meta data (small volumes) through the Control Box into EPICS
- Synchronously vs. asynchronously
Timing synchronisation (Chopper)

Transfer absolute timing information from Control Box to the local HW control unit:

- Synchronise a timer on the control unit
- Timestamp in the control unit; direct readings of the sensor with minimal latencies
- Transfer the TDC readings through the Control Box into EPICS
- Alternative: Time stamp in Control Box (needs digital input in CB)
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Neutrons see the light elements

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