Remote Control of Experiments (RCE)(202100225)

Information session

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Motivation

- Modern techniques for an engineer: Control of distributed systems by computer.
- Already an old idea.
- Re-inspired by the Covid-19-virus measures: Remote work.
- Implemented in own experiments in the SLT-laboratories.
- Experimental counterpart of Computational Physics.

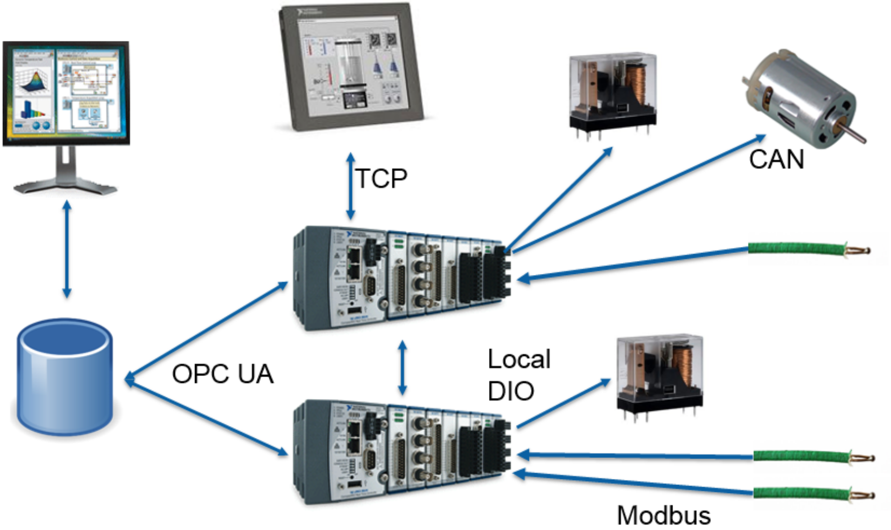
Elements in the course I

- Structures and approaches
  - Architectures for measurement and control.
  - Different demands $\leftrightarrow$ Different approaches.
  - Research versus industry.
- NI: Measurement & Control
  - Distributed system – Ethernet, local embedded systems, dedicated modules.
  - LabVIEW programming – transparent over distributed system.
  - G-web server: access via Internet browser.
- Beckhoff: Control & Monitoring – *optional*
  - Industry standard – PLC structure.
  - Distributed system – bus/ethernet, local stations, dedicated modules.
  - TwinCAT3: programming and control software.

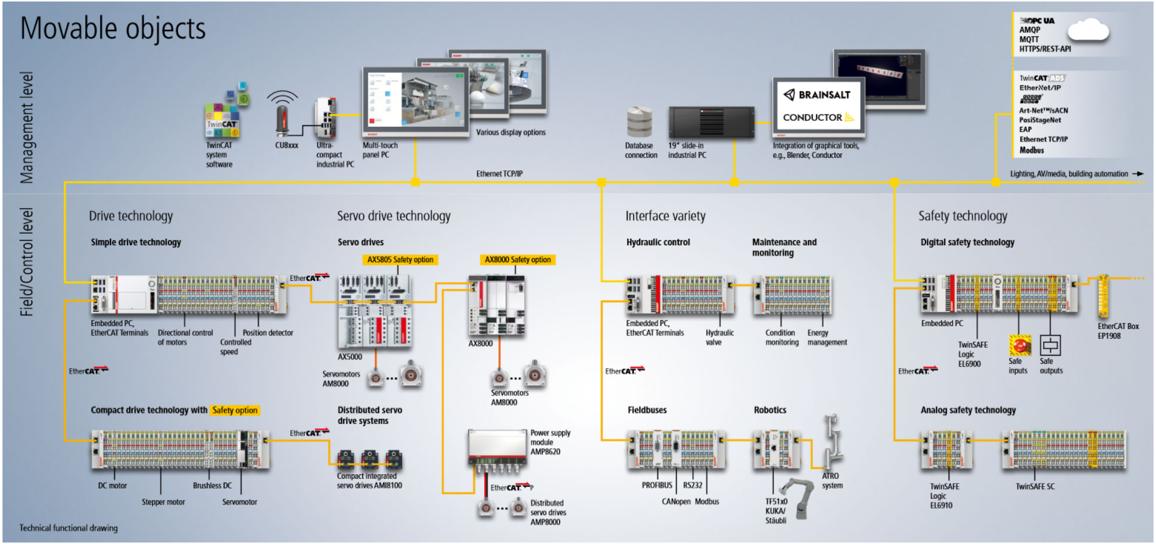
Elements in the course II

- Direct device control and custom-device design
  - Direct control of devices: VISA (Virtual Instrument Software Architecture) an IVI (Interchangeable Virtual Instrument) standard.
  - Communication with commercial instruments: USB, GPIB-bus, RS232.
  - PC-interfacing *e.g.* DAQmx.
  - Micro-controllers: custom devices.
  - Smart sensors: PMod modules.
  - Bus-structures and protocols for sensors: i^{2}C, SPI, UART
- Integrated design & realisation showcase:
  - Design your own Measurement & Control or Control & Monitoring system.
  - Realize your system in hardware and software.
  - Demonstrate your system.
  - Reflect on the performance verses the design specifications.

NI topology



Beckhoff topology



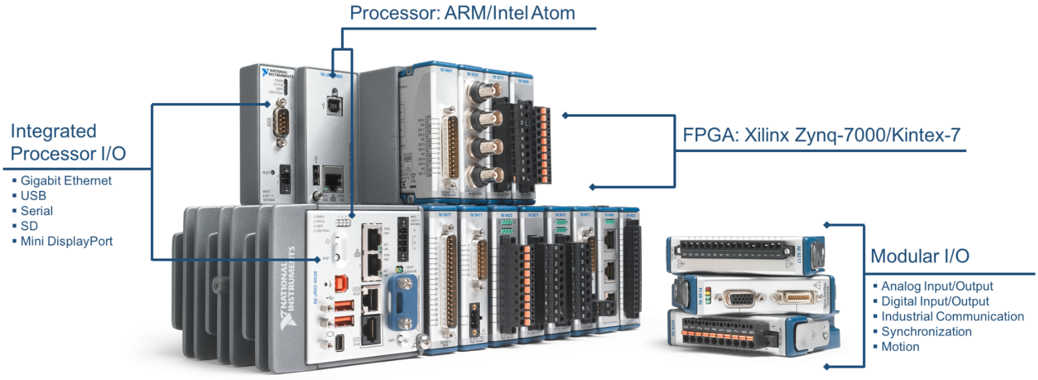
What will you learn?

- Topology of Control & Monitoring and Measurement & Control systems
- LabVIEW programming including G-web programming
- Design of C&M and M&C systems
- Device control via PC
- Device design with micro-controllers and smart sensors
- Design, realize and commission a distributed C&M or M&C system
- TwinCAT programming – *optional*

Course time-line with subjects

week	subject	programming	elements
1	NI structure	LabVIEW – basics	programming language
2		LabVIEW – interfacing	addressing IO
3		LabVIEW – distributed	cRIO + modules
4		LabVIEW – G-Web	
5	Device control	LabVIEW, VISA, pyVISA	GUI and interface
6	Device design	Python & pyVISA	bus: i^{2}C, SPPI; sensors; Pmod
7	Beckhoff structure	TwinCAT 3	embedded PC; fieldbus systems
7	Own design	–	*minimal requirements*
8-9	Realize & test		Build
10	Presentation		Commissioning

The cRIO system



Figuur: The cRIO system.

The Beckhoff CX700 + fieldbus modules

Device interfacing

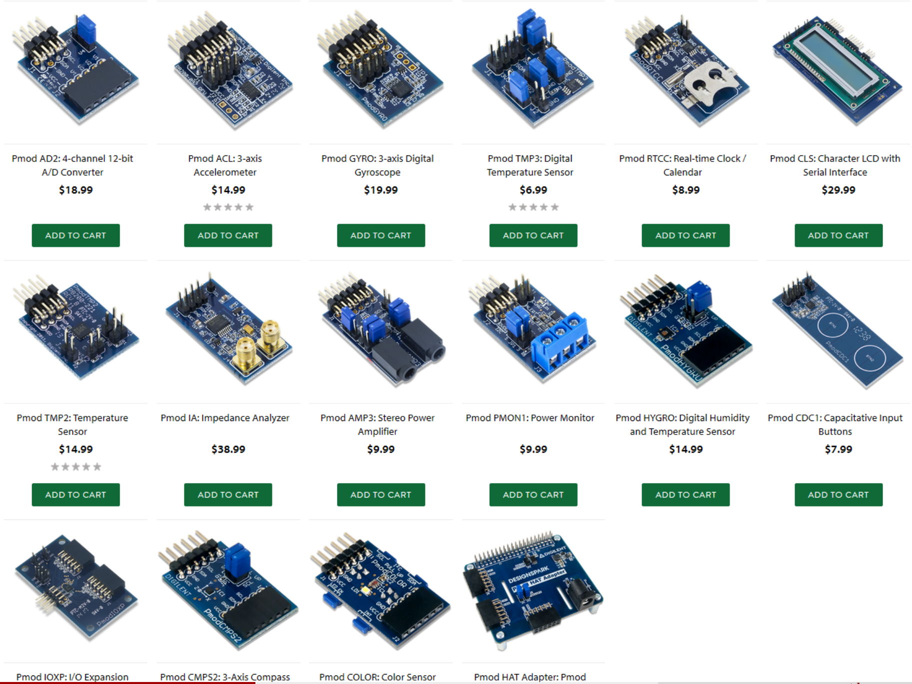
- Introduction DAC, ADC and DIO.
- Introduction device control via: USB, GPIB, RS232.
- Automation of a measurement protocol.
- Explore and test the limits of the interface hardware – software
  - timing
  - resolution
  - control
  - data handling

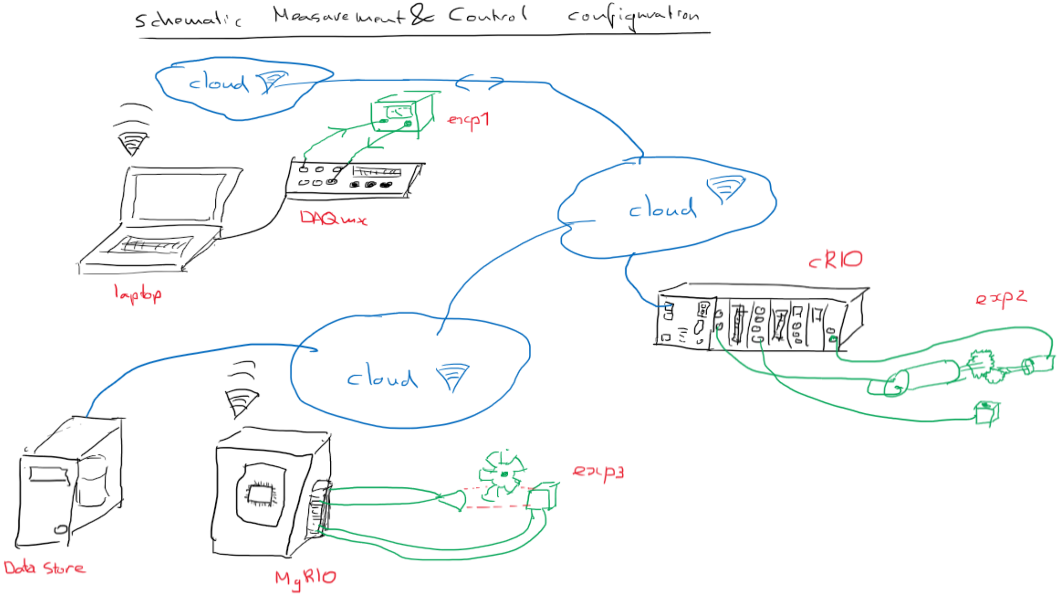
Device design – μ-controller based

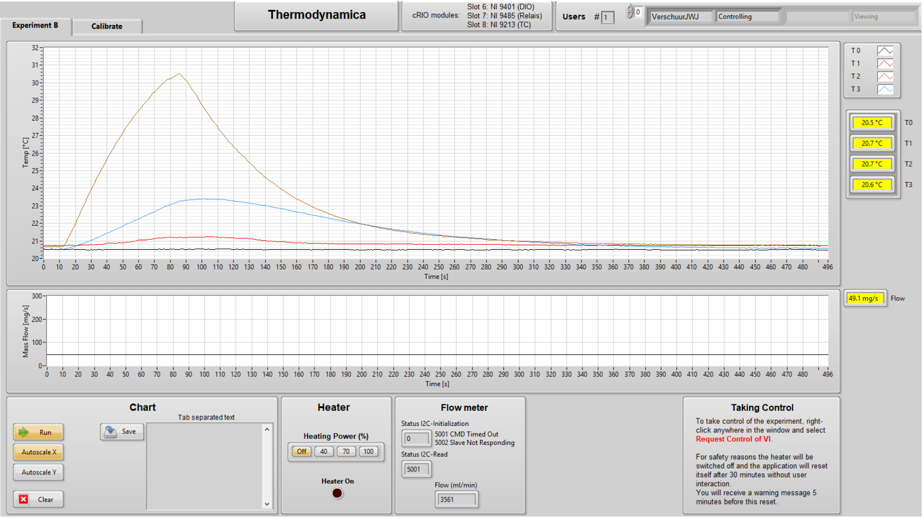
- Use of micro-controller as a measurement device
- Use of bus-structures and protocols: i^{2}C and SPI
- Realise a simple data-logger with remote readout.
- Explore the limits of the system:
  - Timing and speed issues
  - Resolution
  - Controllability

Device design with smart sensors

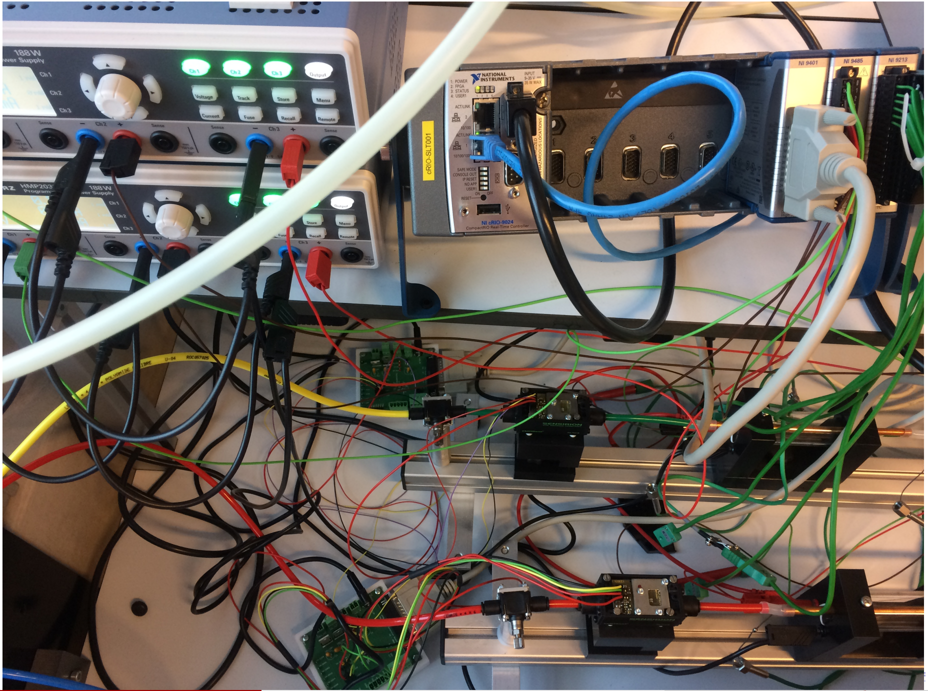
- Explore smart-sensor modules: Pmod
- Explore communication protocols between micro-controller and Pmod's
- Realize a simple Pmod project
- Make a custom device with a micro-controller
- Explore the limits of the system
  - Timing and speed issues
  - Resolution
  - Controllability


Pmod AD2: 4-channel 12-bit A/D Converter
$18.99
ADD TO CART
Pmod ACL: 3-axis Accelerometer
$14.99
ADD TO CART
Pmod GYRO: 3-axis Digital Gyroscope
$19.99
ADD TO CART
Pmod TMP3: Digital Temperature Sensor
$6.99
ADD TO CART
Pmod RTCC: Real-time Clock / Calendar
$8.99
ADD TO CART
Pmod CLS: Character LCD with Serial Interface
$29.99
ADD TO CART
Pmod TMP2: Temperature Sensor
$14.99
ADD TO CART
Pmod IA: Impedance Analyzer
$38.99
ADD TO CART
Pmod AMP3: Stereo Power Amplifier
$9.99
ADD TO CART
Pmod PMON1: Power Monitor
$9.99
ADD TO CART
Pmod HYGRO: Digital Humidity and Temperature Sensor
$14.99
ADD TO CART
Pmod CDC1: Capacitative Input Buttons
$7.99
ADD TO CART
Pmod IOXP: I/O Expansion
Pmod CMPS2: 3-Axis Compass
Pmod COLOR: Color Sensor
Pmod HAT Adapter: Pmod


Schematic Measurement & Control configuration
cloud
exp1
DAQmx
laptop
cloud
cRIO
exp2
cloud
exp3
Data Store
MyRIO



Experiment B
Calibrate
Thermodynamica
cRIO modules: Slot 6: NI 9401 (DIO) Slot 7: NI 9485 (Relais) Slot 8: NI 9213 (TC)
Users # 1
VerschuurJWJ Controlling
Viewing
Temp [°C]
Time [s]
T 0
T 1
T 2
T 3
20.5 °C T0
20.7 °C T1
20.7 °C T2
20.6 °C T3
Mass Flow [mg/s]
49.1 mg/s Flow
Chart
Run
Autoscale X
Autoscale Y
Clear
Save
Tab separated text
Heater
Heating Power (%)
Off 40 70 100
Heater On
Flow meter
Status I2C-Initialization
5001 CMD Timed Out
5002 Slave Not Responding
Status I2C-Read
5001
Flow (ml/min)
3561
Taking Control
To take control of the experiment, right-click anywhere in the window and select Request Control of VI.
For safety reasons the heater will be switched off and the application will reset itself after 30 minutes without user interaction.
You will receive a warning message 5 minutes before this reset.


NATIONAL INSTRUMENTS
NI cRIO-9024
CompactRIO Real-Time Controller
cRIO-SLT001
NI 9401
NI 9485
NI 9213

Final Assignment

The final assignment:

- Project based structure: Engineering project.
- You can co-design your own final assignment.
- Combination with work for your Bachelor assignment is possible.
- It is an engineering project:
  - Loop through: explore – design – build – test
  - The outcome is a product:
    - it works
    - it meets criteria
    - it fulfils a purpose
    - it is more than a proof of principle

Learning outcomes

Computer as tool:

- Control of laboratory equipment: local and remote.
- Computer interfacing with experiments for measurements (automation).
- Analysis and presentation of measurement data.
- Set up measurement-control-steer loops.

Programming environment LabVIEW, Python, TwinCAT:

- Graphical programming – diffusing the hardware–software interface.
- Design and realise a functional user interface to control an experiment; also remote.
- Topology, communication & synchronisation of processes.
- Set-up distributed control & measurement structures.
- PLC-programming – sequential tasks and actions.

Engineering:

- Design a remote/distributed measurement-control or control-monitor system.
- Realise the system using the appropriate hardware and software.
- Test the system, make a performance report and compare with the design criteria.

Scheduling & Grading

Scheduling:

- Scheduling: see course time-line (above).

Grading:

- Compact journal of the guided-tour problems.
- A design report.
- A working system.
- A performance report.
- A manual (optional).
- Presentation and discussion of the work and results.

Disclaimer

This course is as good as YOU make it!

Note that:

- This is the second time this course is part of the Applied Physics program.
- During and after initial run major adjustments made.
- It is still under development.
- So ...
  - If you expect a well balanced course: *this is* **NOT** *for you!*
  - If you like to explore new fields: *this is your chance!*
  - If you like hands-on work: *this is for you to put your hands on!*
  - If you like designing technical solutions: *this is where you can take control!*

end