Motivating with industrial applications in the course *Programmering og modellering*

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Dynamic positioning

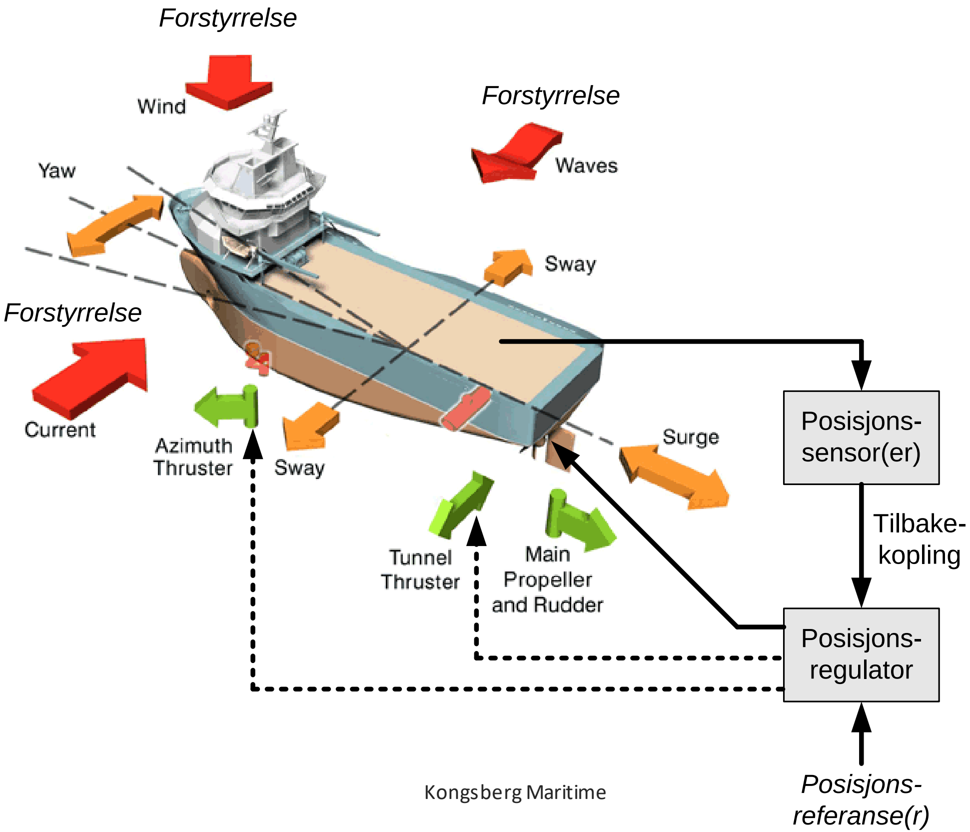
Two examples of applications:

- Liquid tank
- Ship

Dynamic positioning (of ships)

Tangaroa's Dynamic Positioning System - How does it work?

Dynamic positioning = position control system



Kongsberg Maritime

Mathematical model

Model of the ship motion along the surge axis, based on Newton's Law of Motion:

m*ddy = Fp + Fh + Fw

where:

y is position [m]
dy is speed [m/s]
ddy is acceleration [m/s^2]
m is mass [kg]
Fh = Dx*(uc - dy_dt)*abs(uc - dy_dt) is hydraulic damping force [N]
Fw = cWx*Vw*abs(Vw) is wind force [N]

Simulator programming (in e.g. Python) is based on the Euler method (forward; expilcit).

The position controller

In industrial automatic control systems, the PID (proportional-integral-derivative) controller is prevalent.

The PID controller function is mathematically very simple:

u = up + ui + ud

where:

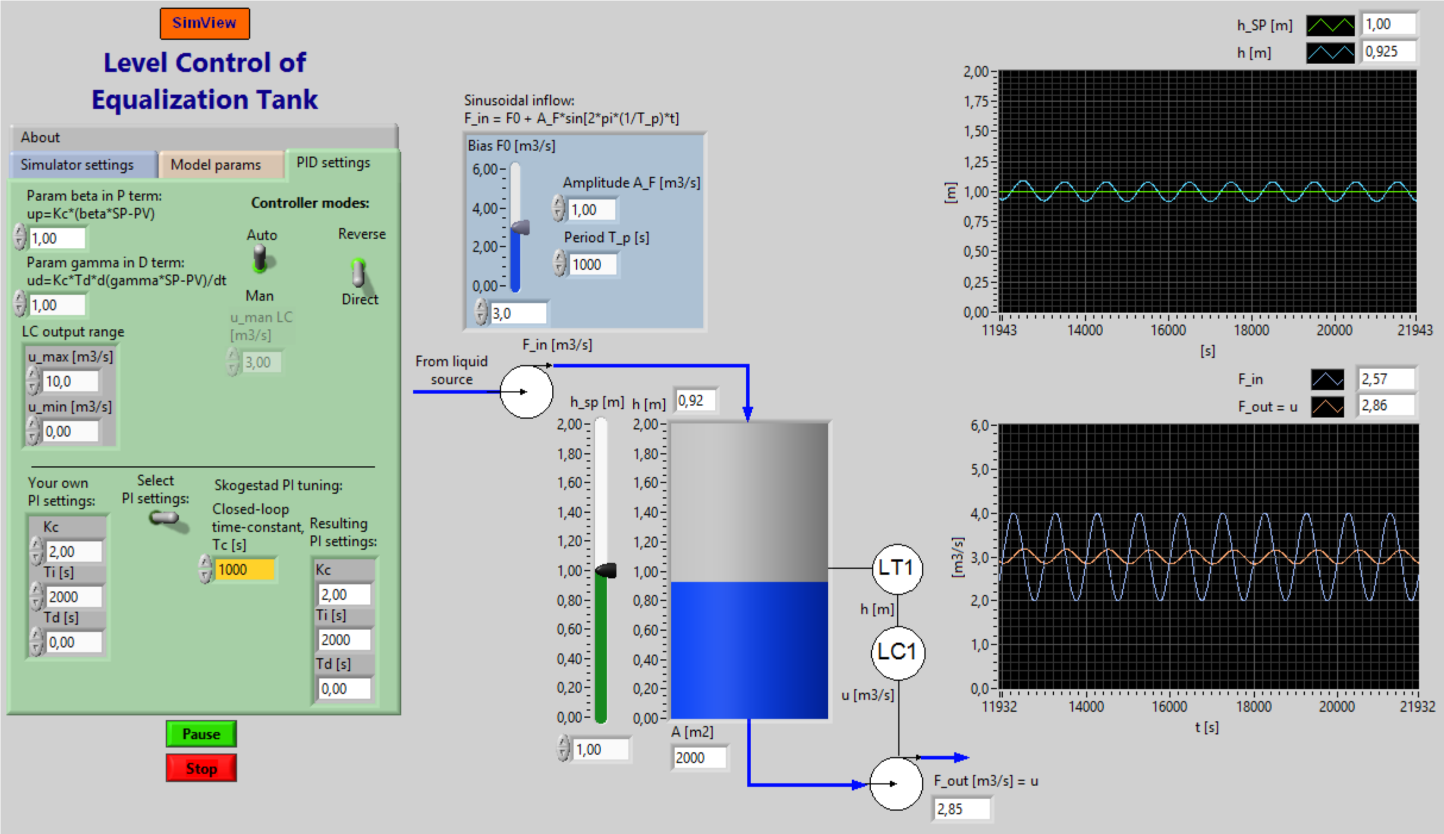
up_k = Kc*e_k (the P-term)
ui_k = ui_km1 + (Kc/Ti)*Ts*e_k (the I-term)
ud_k = Kc*Td*(e_k - e_km1)/Ts (the D-term)

which can be easily programmed (in the simulator).

Demo:
Running an Euler-based simulator programmed in Python
(which includes real-time plotting and animation with Pygame)

Buffer tanks

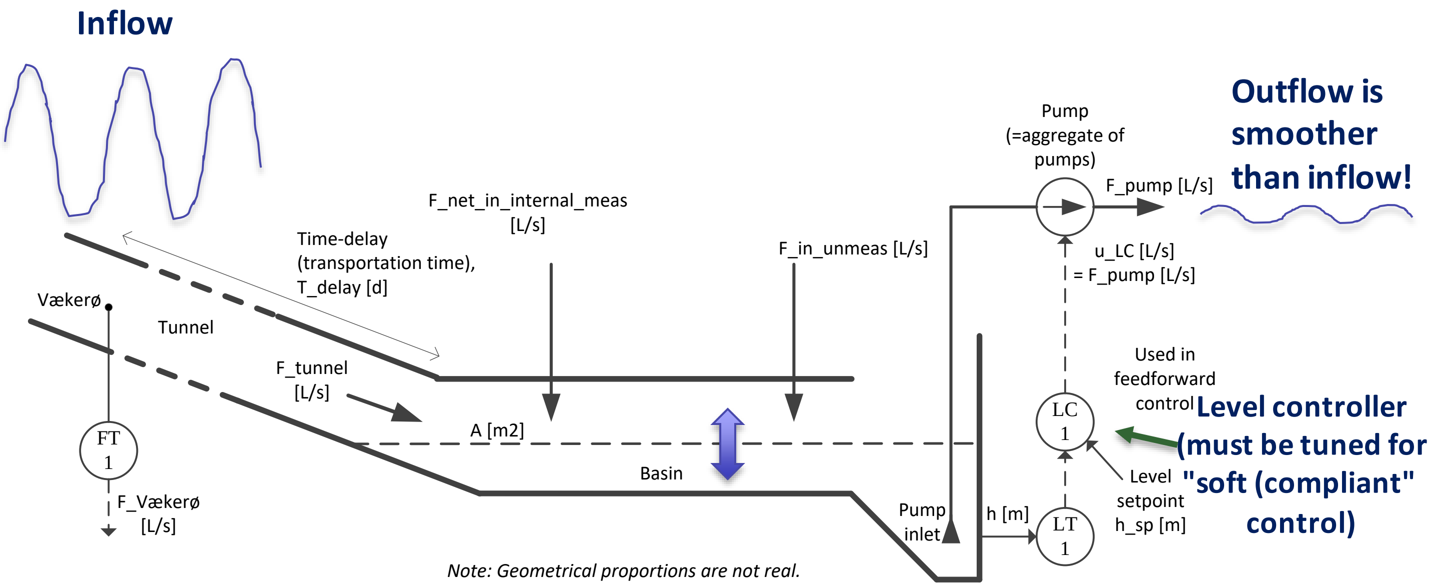
Varying inflow is attenuated with a tank with a sluggish level controller



Applications of buffer tanks:

- Equalization magazines at the inlet (supply) of a water resource recovery facility
- Dams in hydropower plants
- Oil/water/gas separators in the oil/gas production

One of the applications:
Level control of equalization magazine upstreams the VEAS water resource recovery facility (wrrf) or resource recovery facility (wrrf), at Slemmestad, south of Oslo, Norway:



Mathematical model

Material balance of the water in the tank:

A*dh_dt = F_in - F_out

where:

h is water level [m]

A is cross sectional area of tank [m2]

F_in is inflow [m3/s]

F_out is inflow [m3/s]

Discrete-time model Euler (forward; explicit) for simulator programming:

h_kp1 = h_k + (Ts/A)*(Fin_k - Fout_k)

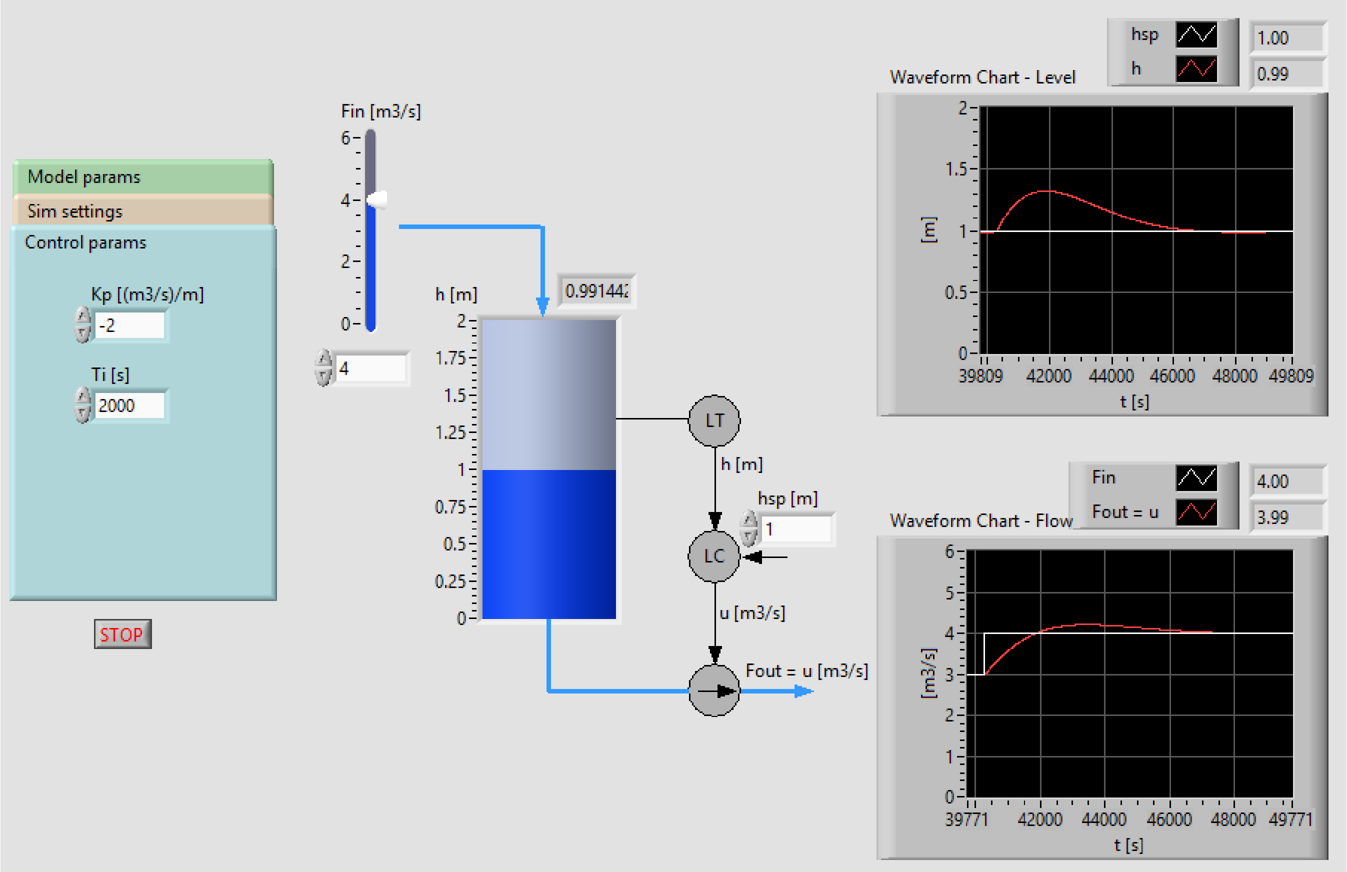
Ts is time-step [s]

At the "fagdag" 16 Dec 2017, pupils from Bamble, Porsgrunn and Skien high schools programmed a simulator of a tank with level control system using LabVIEW (National Instruments).

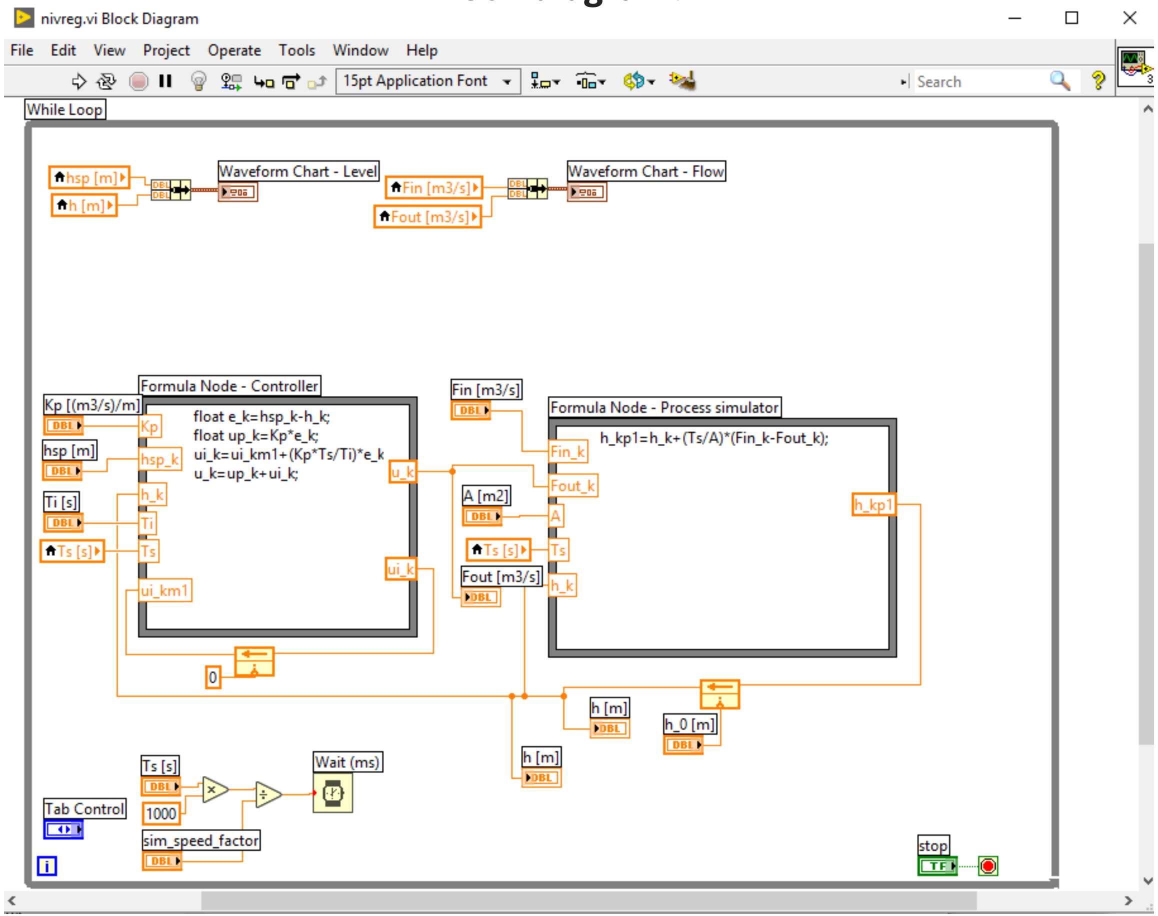
Demo (the resulting LabVIEW program)....

The front panel and the block diagram of the program are shown on the following pages.

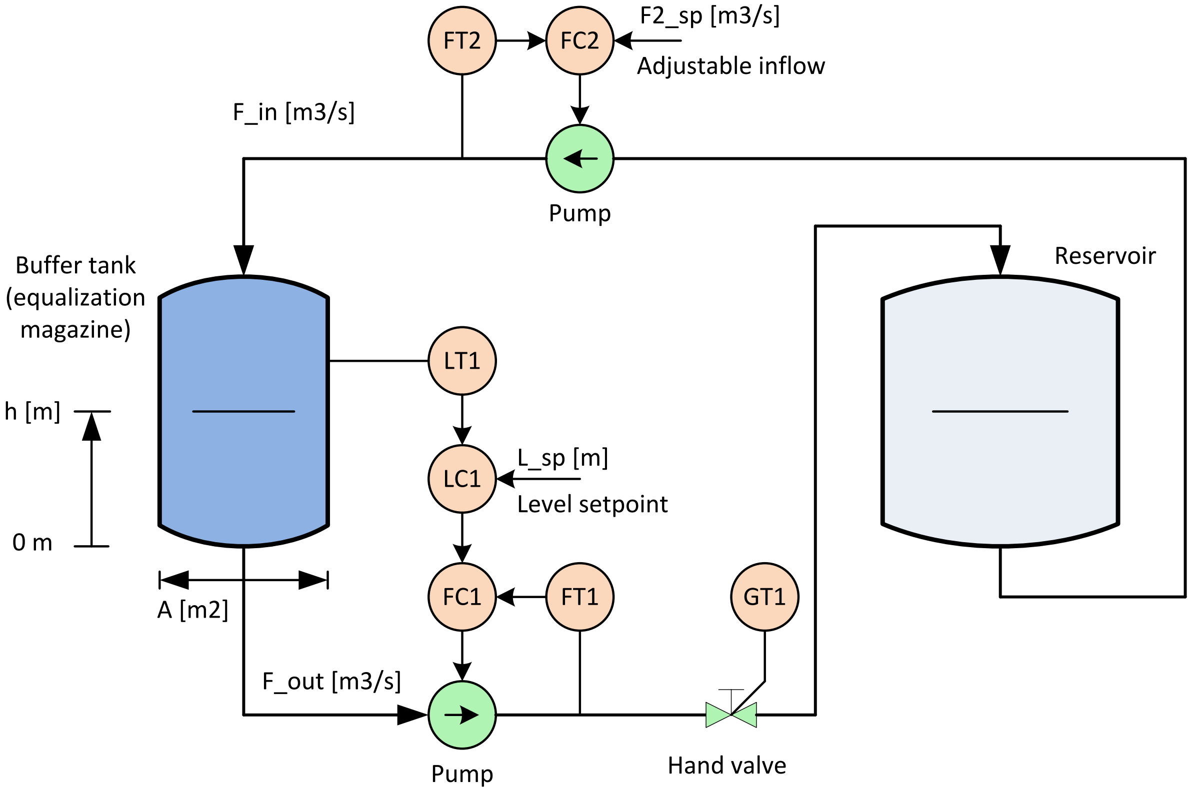
Front panel:


Model params
Sim settings
Control params
Kp [(m3/s)/m]
-2
Ti [s]
2000
STOP
Fin [m3/s]
6
4
2
0
4
h [m]
0.991442
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
LT
h [m]
hsp [m]
1
LC
u [m3/s]
Fout = u [m3/s]
Waveform Chart - Level
hsp
h
1.00
0.99
[m]
2
1.5
1
0.5
0
39809
42000
44000
46000
48000
49809
t [s]
Waveform Chart - Flow
Fin
Fout = u
4.00
3.99
[m3/s]
6
5
4
3
2
1
0
39771
42000
44000
46000
48000
49771
t [s]

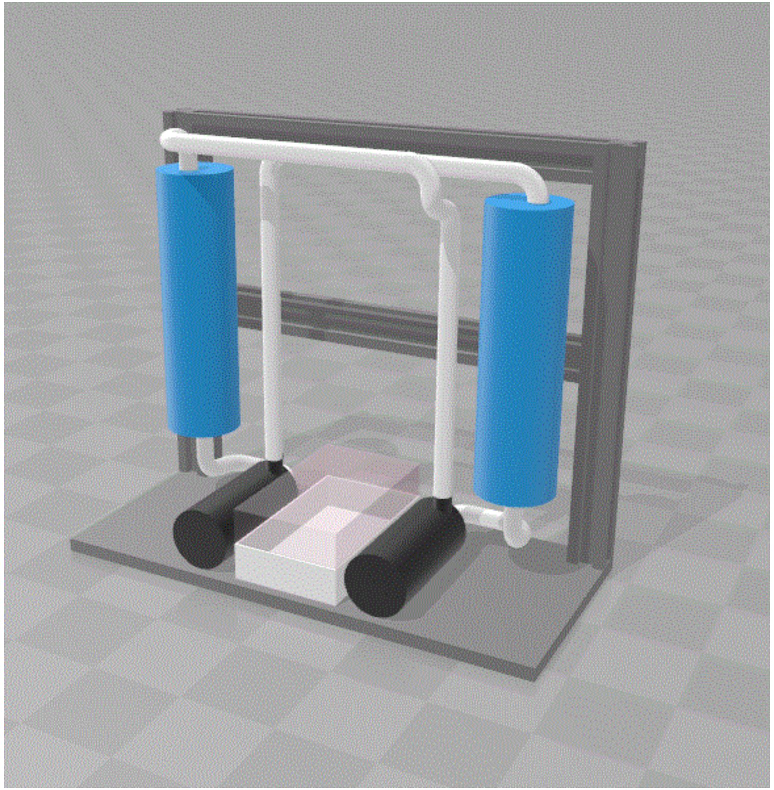
Block diagram:



At USN (Porsgrunn) we now build 12 tank rigs for educational and research purposes. They will be used in Programmering og modellering.

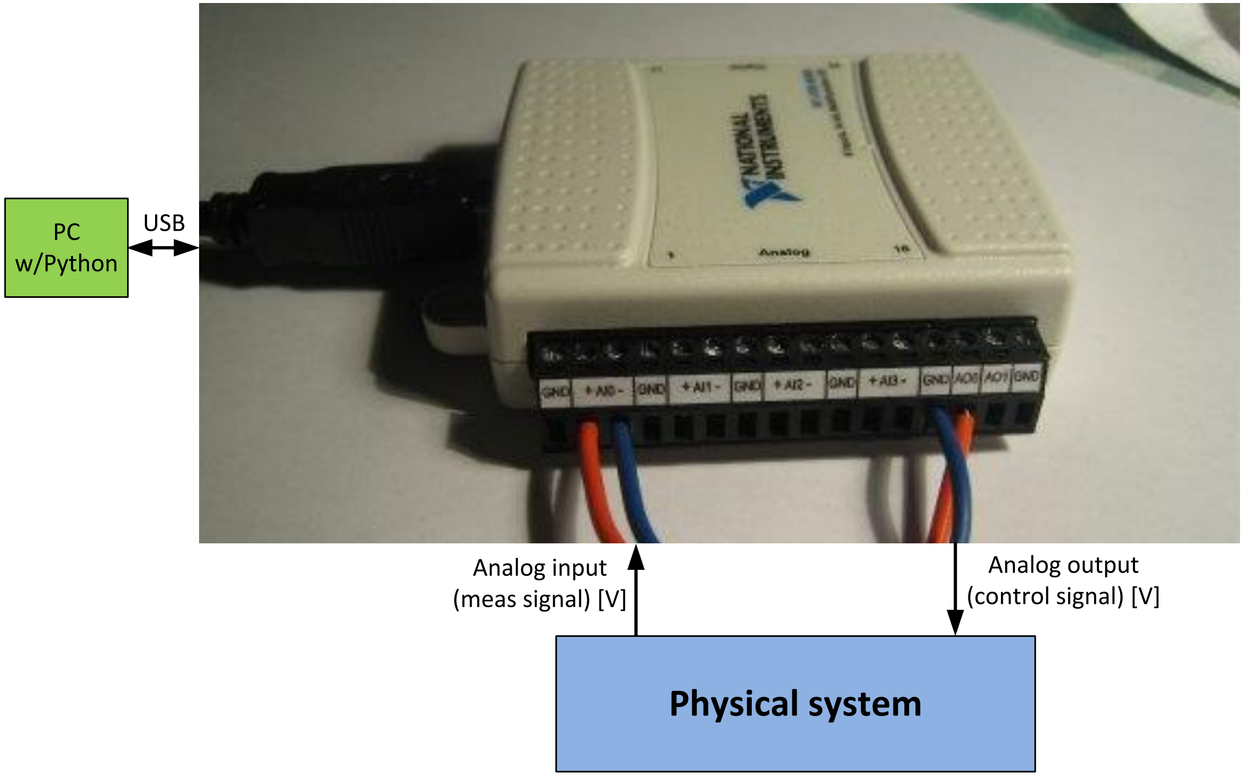


3D drawing of the tank rigs:



Drawing by Cecilie Gløsmyr and Olav Vangen,
USN students

Analog IO (input output) with Python using NI USB-6008 IO device



Drawing by Cecilie Gløsmyr and Olav Vangen,
USN students

Python commands for analog IO (input output)

```
import nidaqmx

#---------------------------------------
# Analog output (control signal):

ao_task = nidaqmx.Task()
ao_task.ao_channels.add_ao_voltage_chan('Dev15/ao0','heater_control',min_val=0.0,max_val=5.0)
ao_value = 3.1
ao_task.write(ao_value)

#---------------------------------------
# Analog input (measurement signal):

ai_task = nidaqmx.Task()
ai_task.ai_channels.add_ai_voltage_chan("Dev15/ai0",terminal_config=nidaqmx.constants.TerminalConfiguration.RSE)
ai_value = ai_task.read(number_of_samples_per_channel=1)
```

Drawing by Cecilie Gløsmyr and Olav Vangen,
USN students

Conclusion

- **Realistic, industrial examples will probably motivate pupils for mathematical modelling and programming, and for university studies.**

- **Automatic control (feedback control) is prevalent in technical systems, and I suggest that the basic principles are introduced in high school (at least in *Programmering og modellering*).**

Drawing by Cecilie Gløsmyr and Olav Vangen, USN students