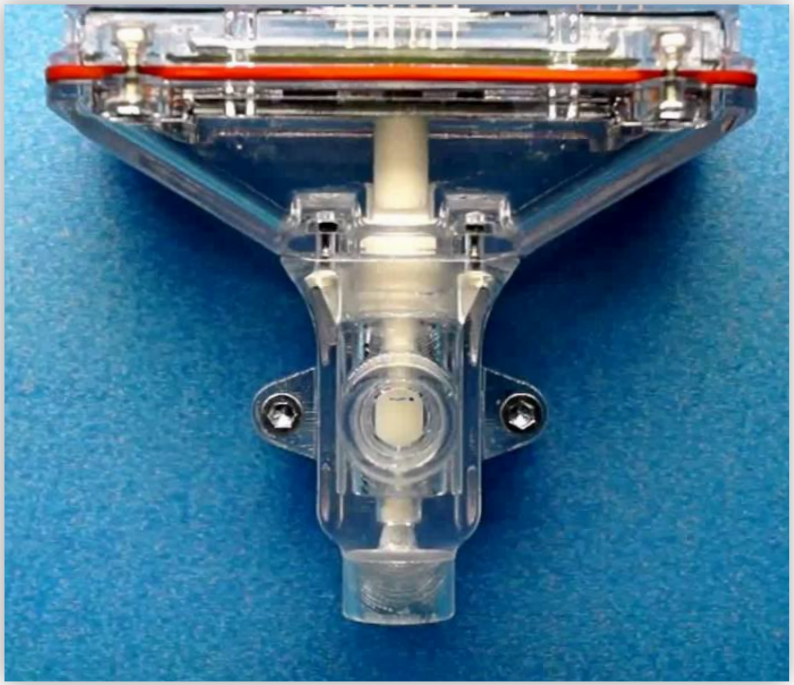
SAARLAND UNIVERSITY

Intelligent Material Systems Laboratory

Modeling and Simulation of a Bundle of SMA Wires Driving a Hydraulic Valve



[source: youtube.com, Actuator Solutions]

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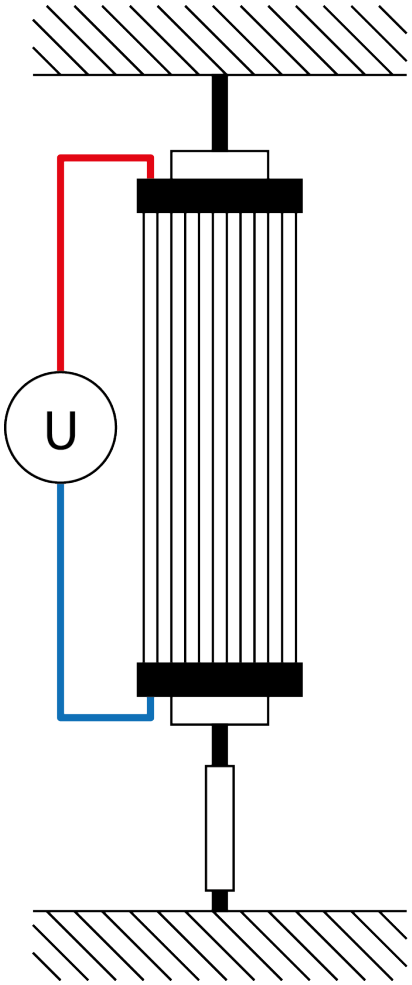
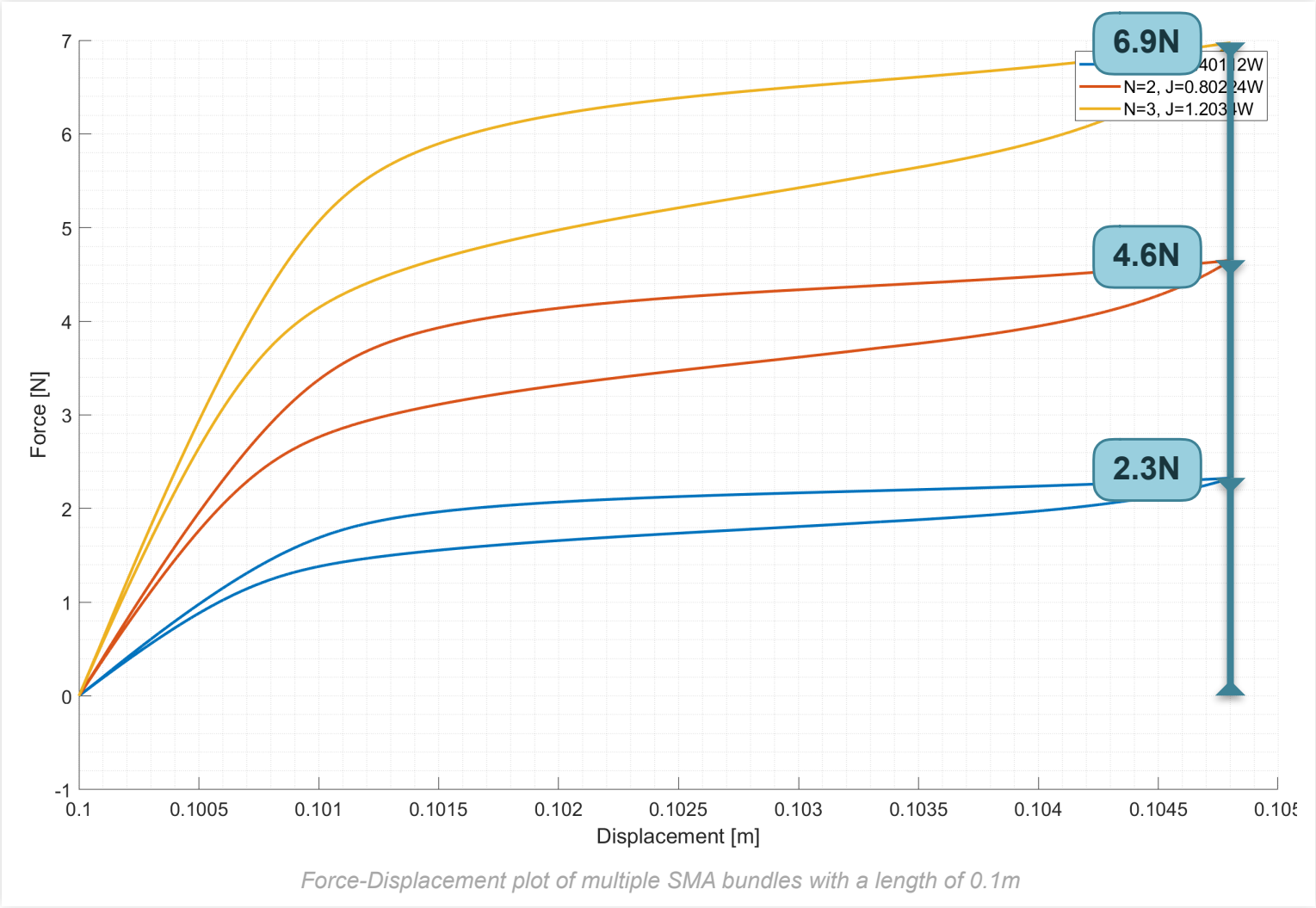
ZeMA

task 1 - the actuator



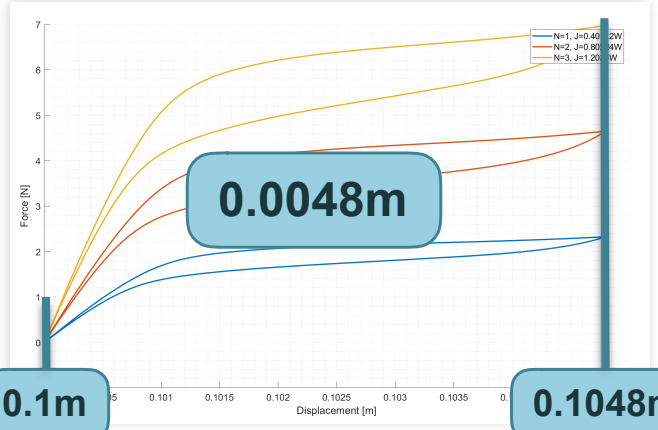
- plot SMA actuator against a force / displacement gauge
- different wire lengths
- different wire quantities

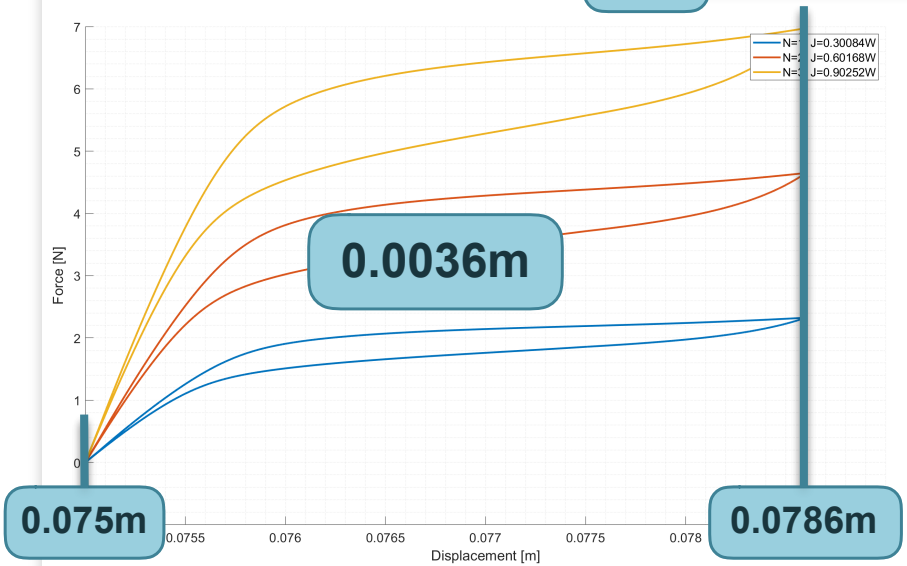
task 1 - SMA hysteresis, Jmax

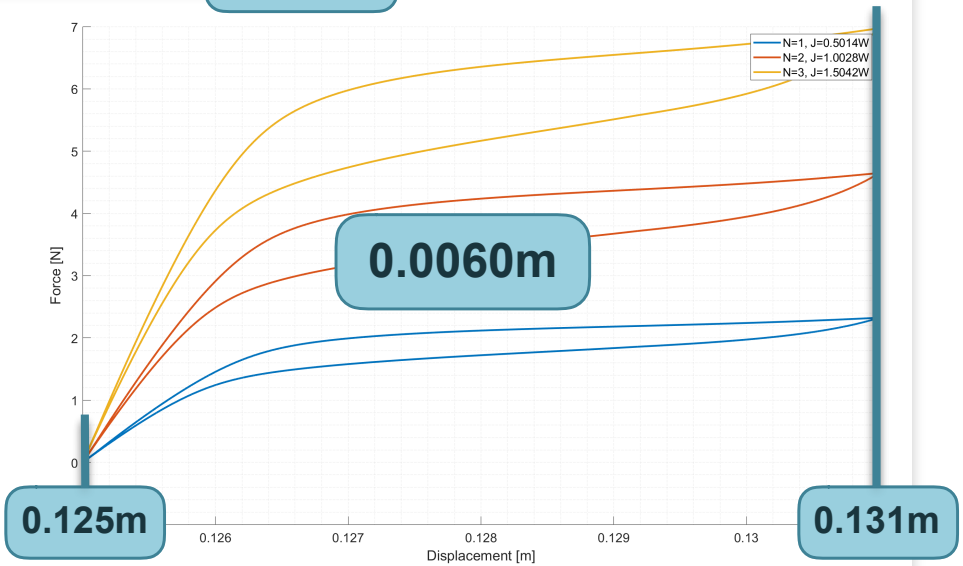


Force-Displacement plot of multiple SMA bundles with a length of 0.1m

task 1 - SMA hysteresis, Jmax

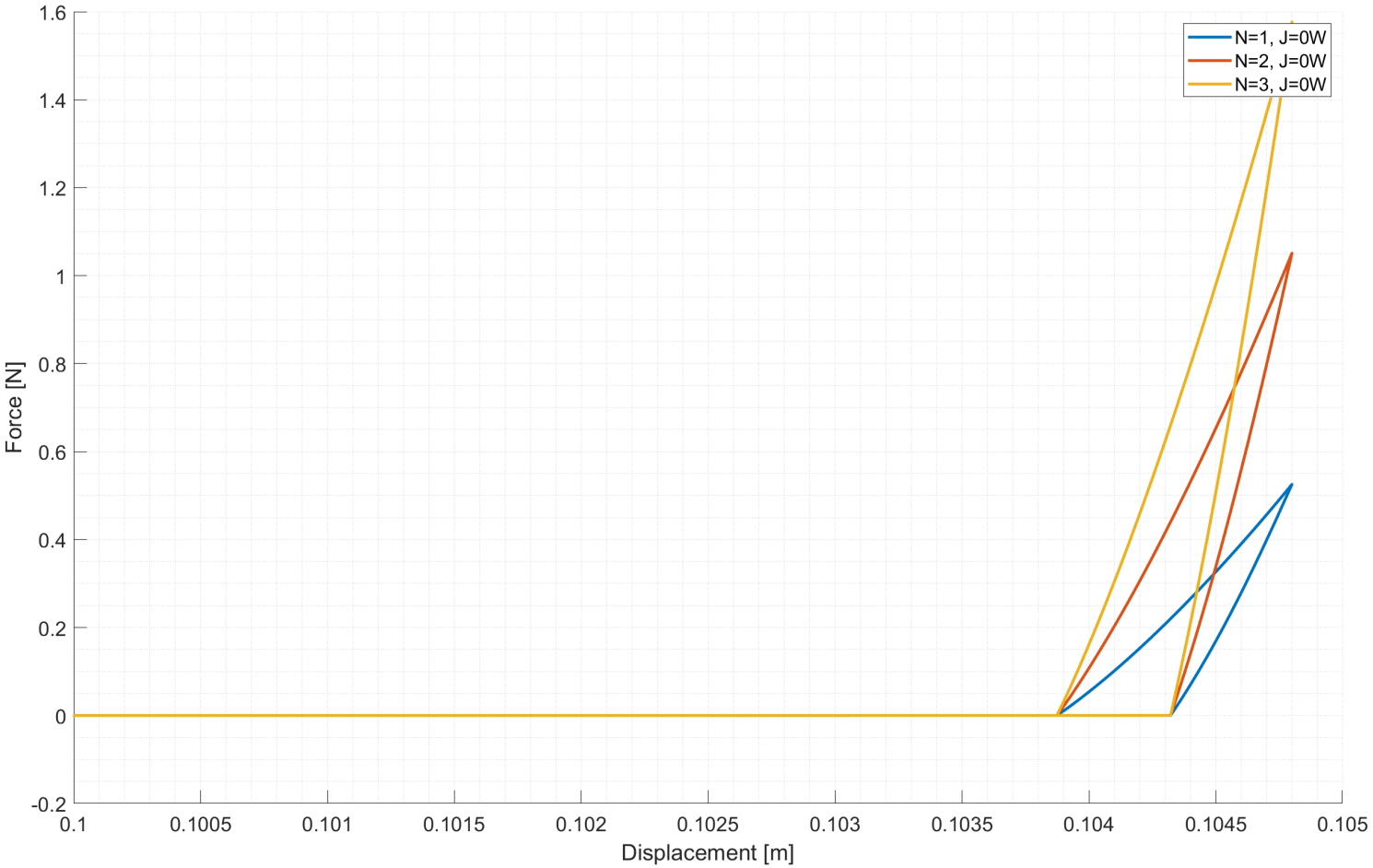






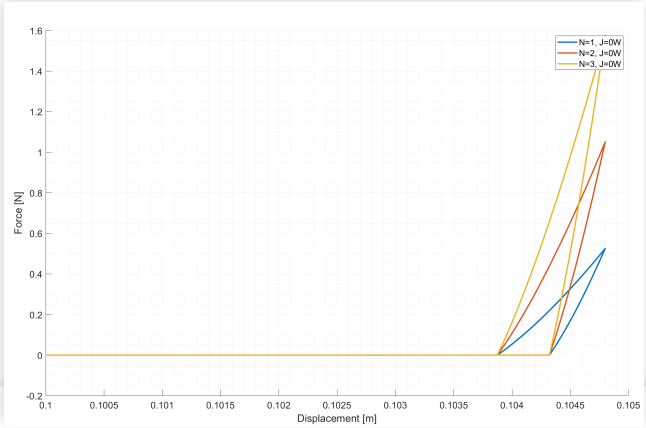
Force-Displacement plot of multiple SMA bundles with a length of 0.075m and 0.125m

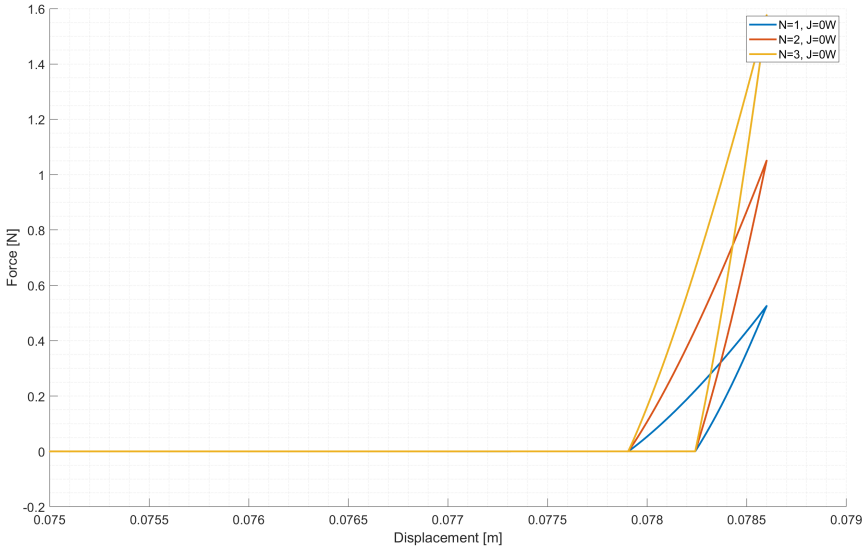
task 1 - SMA hysteresis, J0

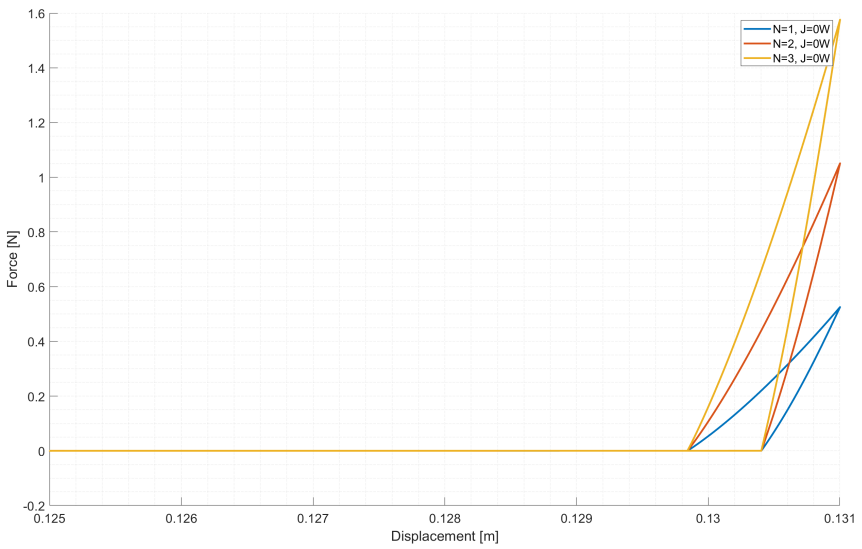


*Force-Displacement plot of multiple SMA bundles with a length of **0.1m***

task 1 - SMA hysteresis, J0

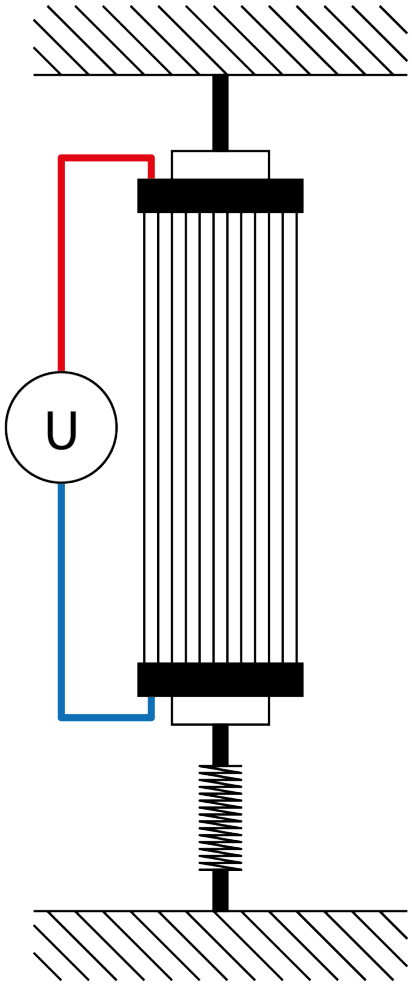






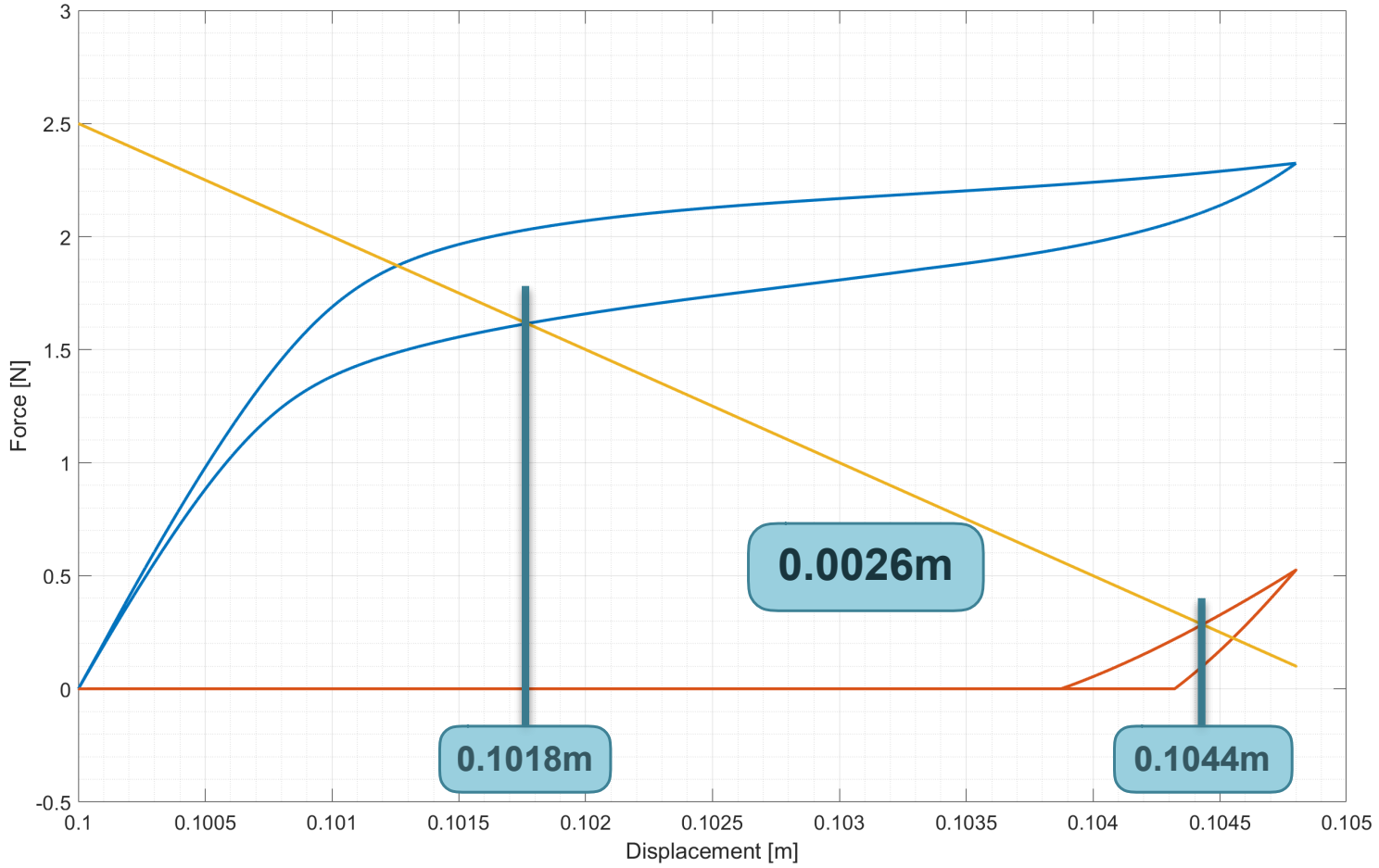
*Force-Displacement plot of multiple SMA bundles with a length of **0.075m** and **0.125m***

task 2 - SMA against spring



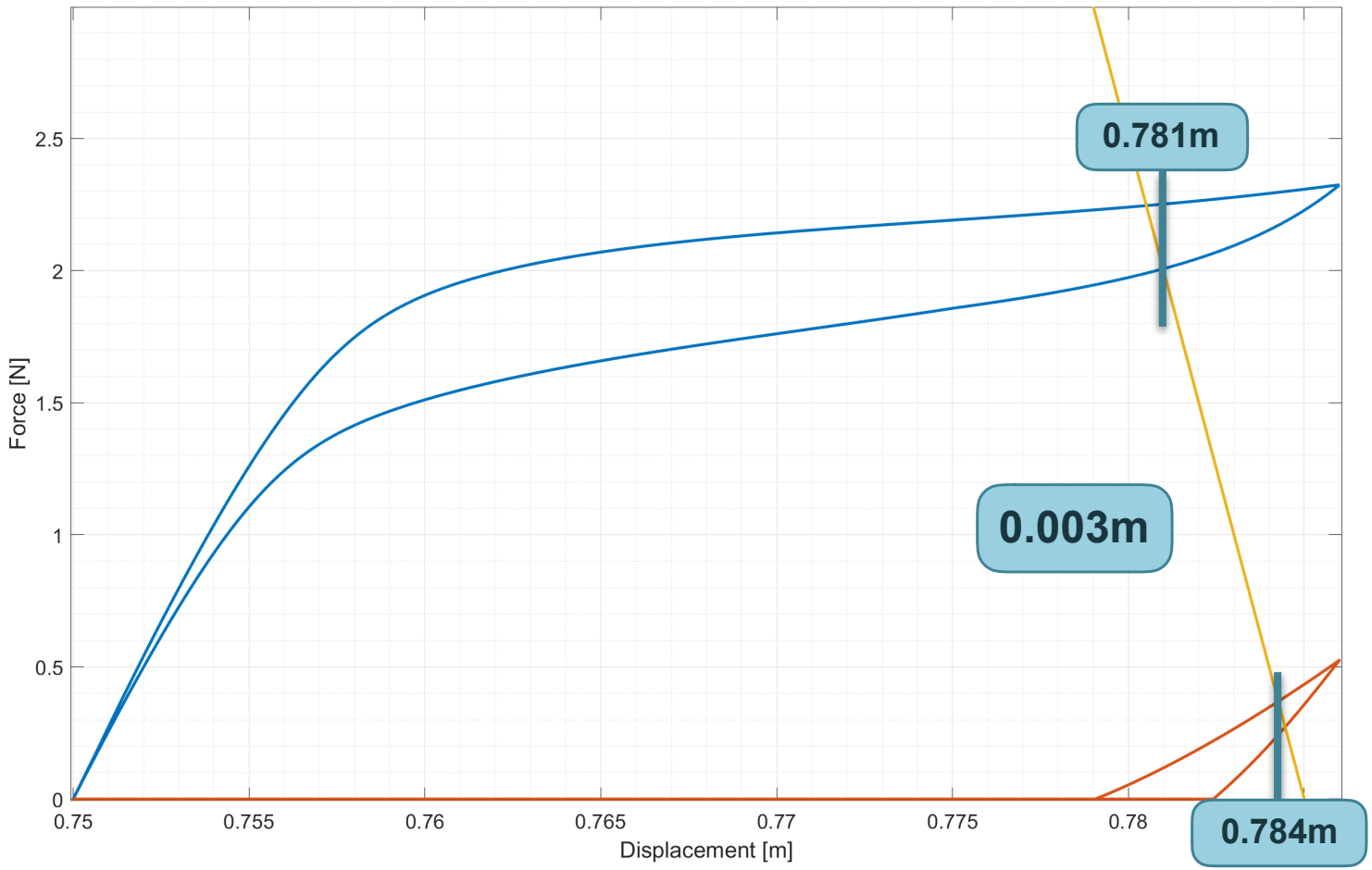
- plot SMA actuator against a spring load
- choose L0 and N so that the stroke is greater than 0.022m

task 2 - SMA against spring



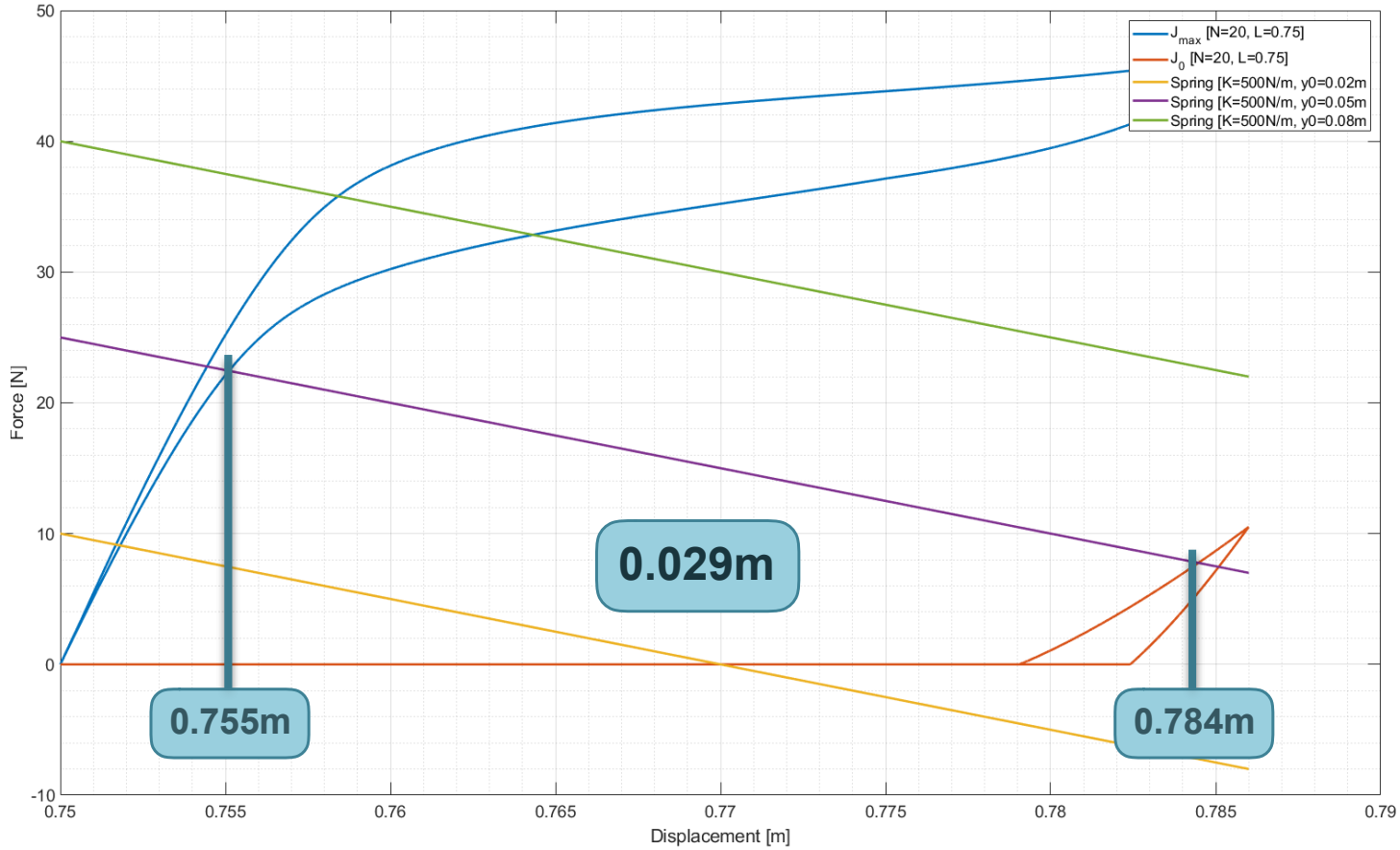
*Force-Displacement plot of an SMA bundle (**N=1**) with a length of **0.1m** against a spring (**K=500N/m**)*

task 2 - SMA against spring



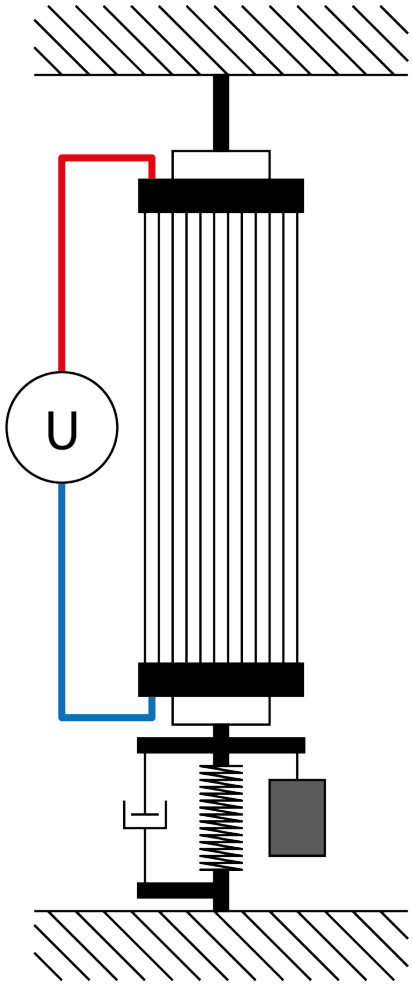
*Force-Displacement plot of an SMA bundle (**N=1**) with a length of **0.75m** against a spring (**K=500N/m**)*

task 2 - SMA against spring



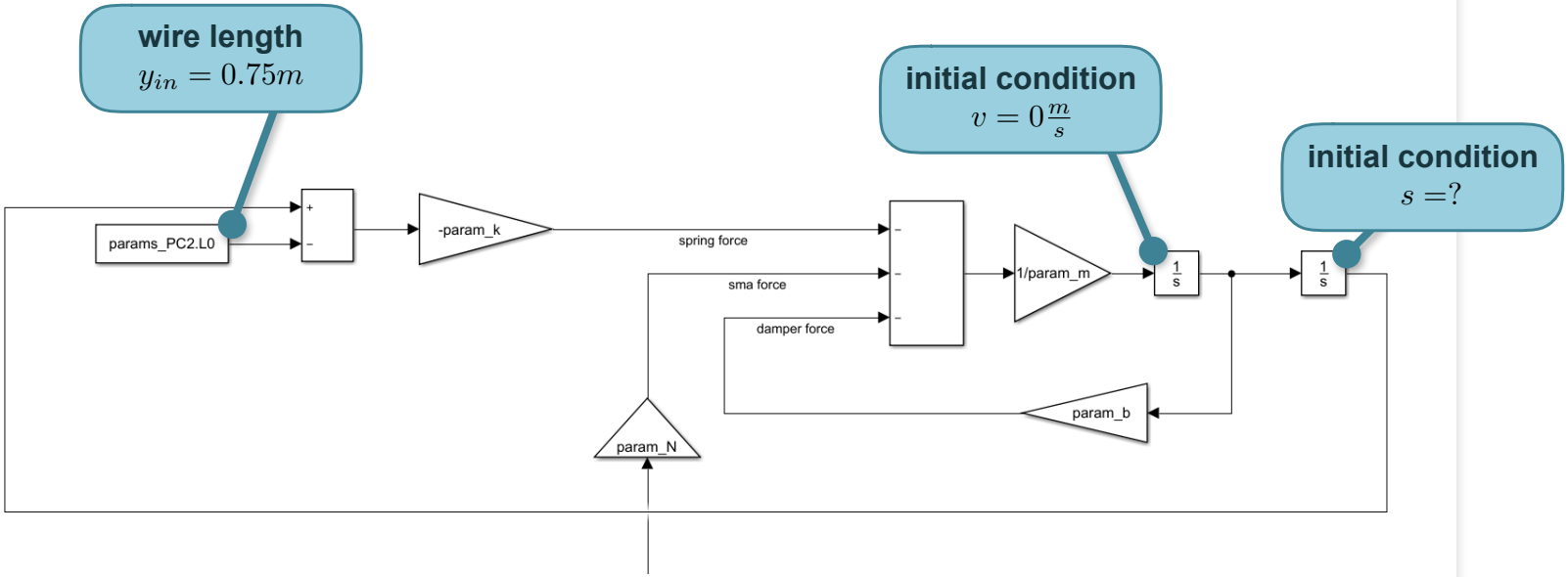
*Force-Displacement plot of an SMA bundle (**N=20**) with a length of **0.75m** against a spring (**K=500N/m**)*

task 3 - SMA against msd-system



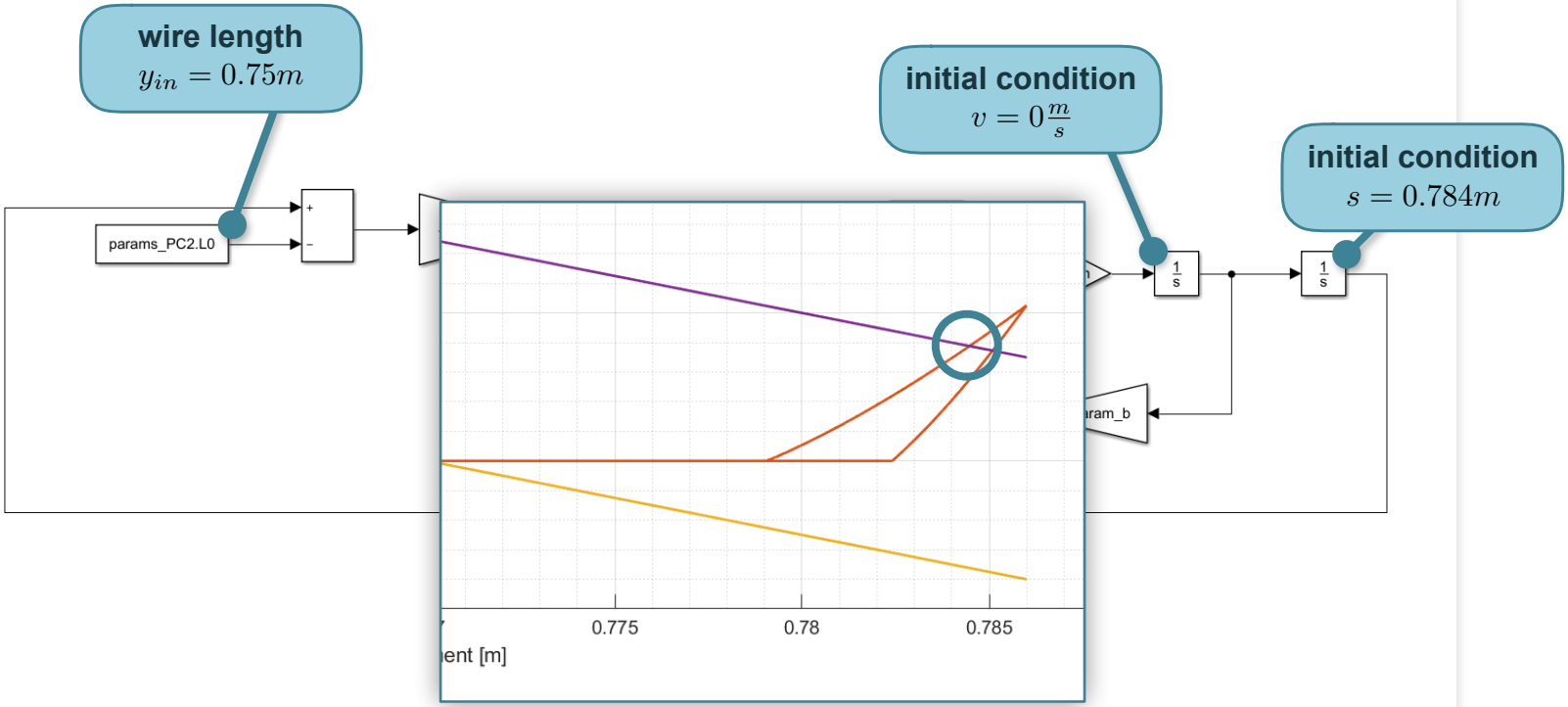
- plot SMA actuator against a mass-spring-damper system with parameters determined in task 2

task 3 - SMA against msd-system



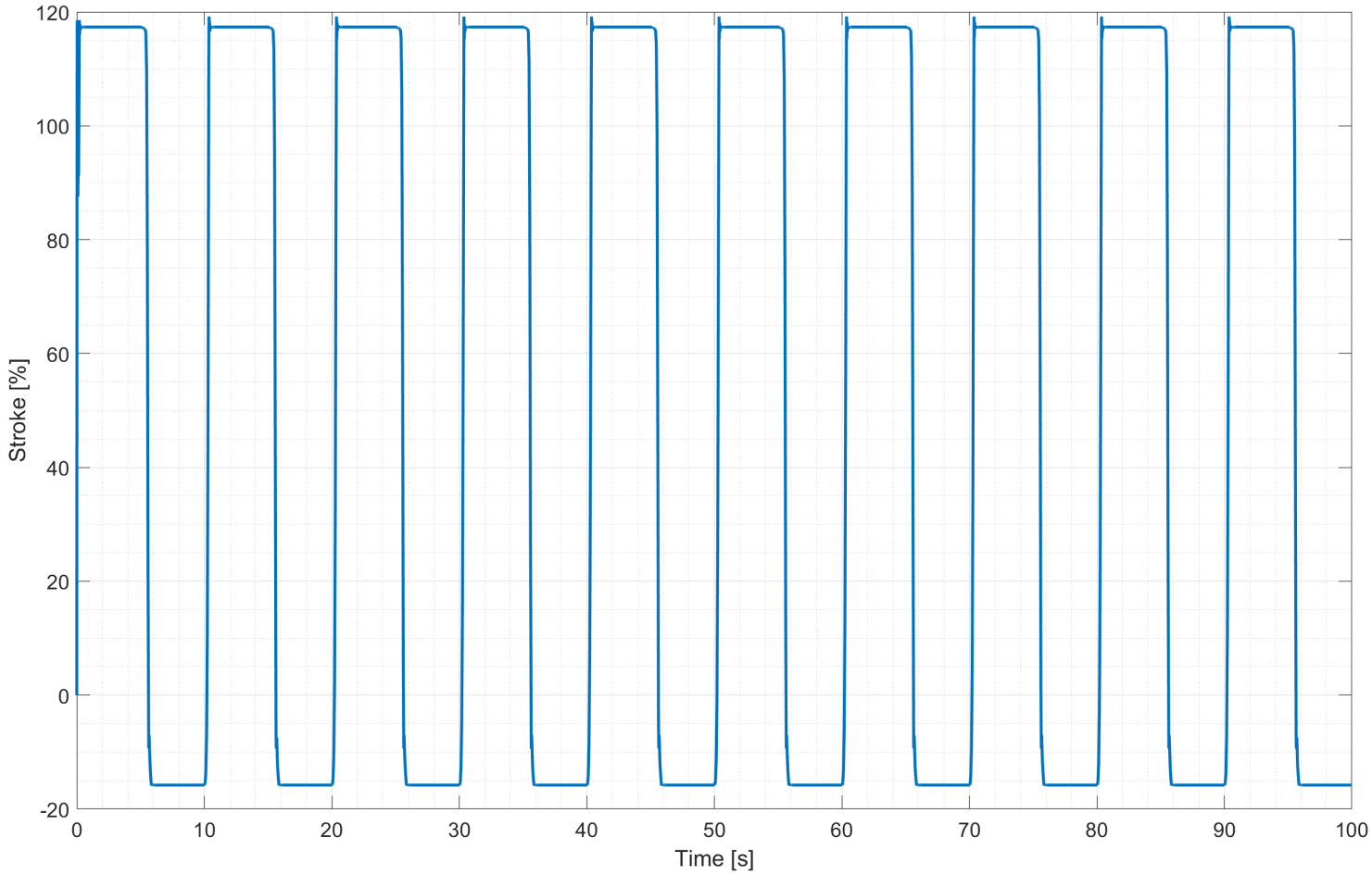
Simulink block diagram of the mass-spring-damper-system

task 3 - SMA against msd-system



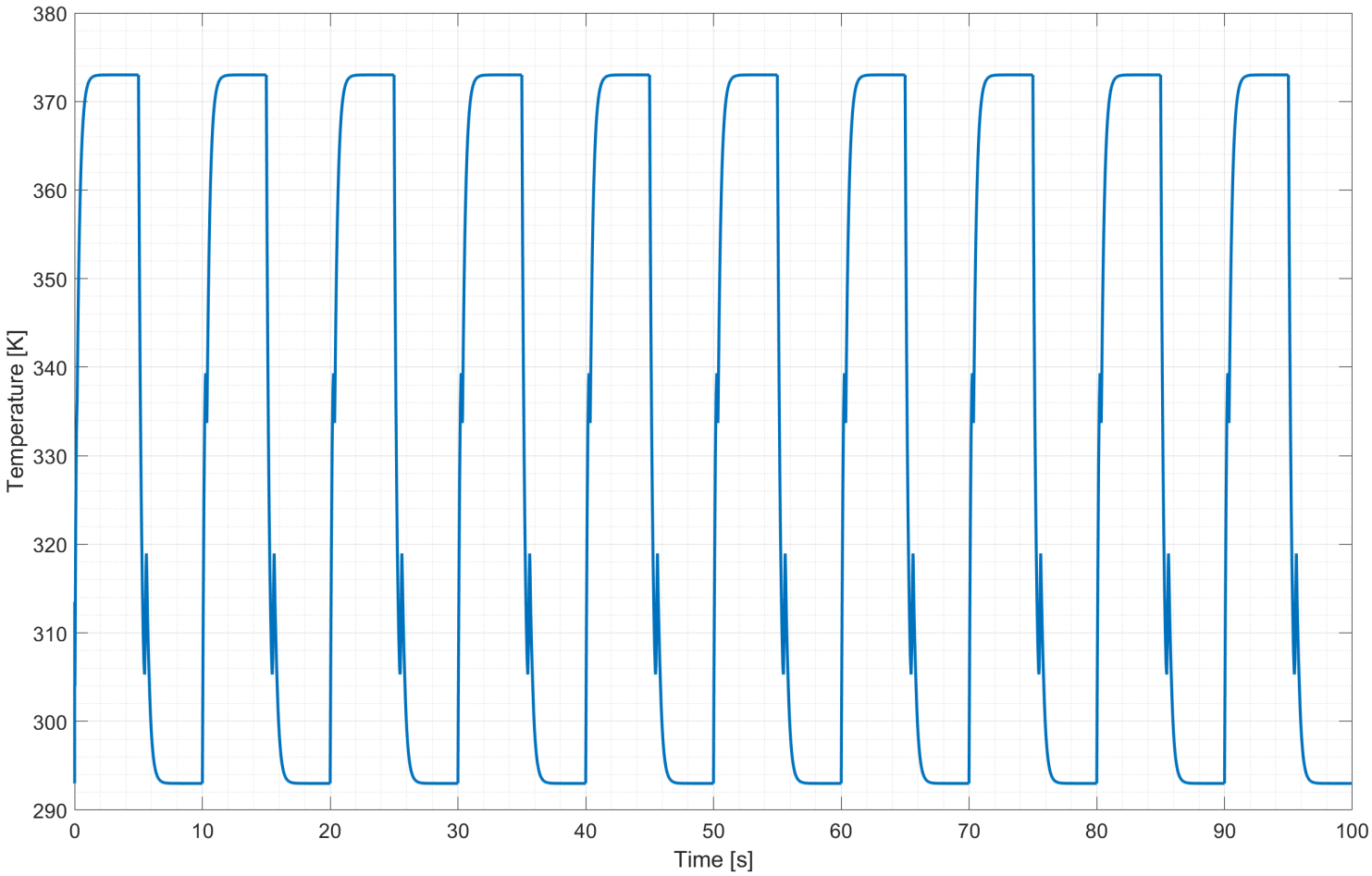
Simulink block diagram of the mass-spring-damper-system

task 3 - SMA against msd-system



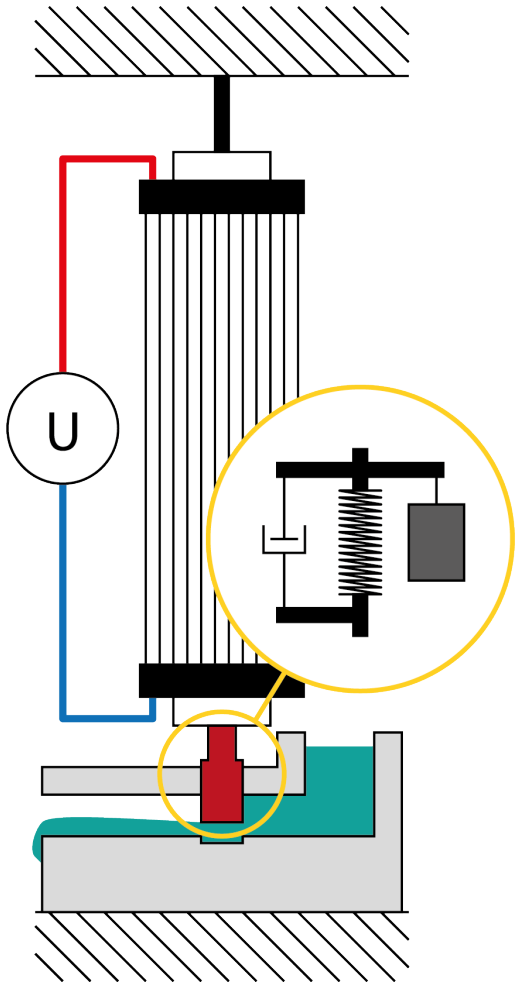
Time-Stroke plot

task 3 - SMA against msd-system



Time-Temperature plot

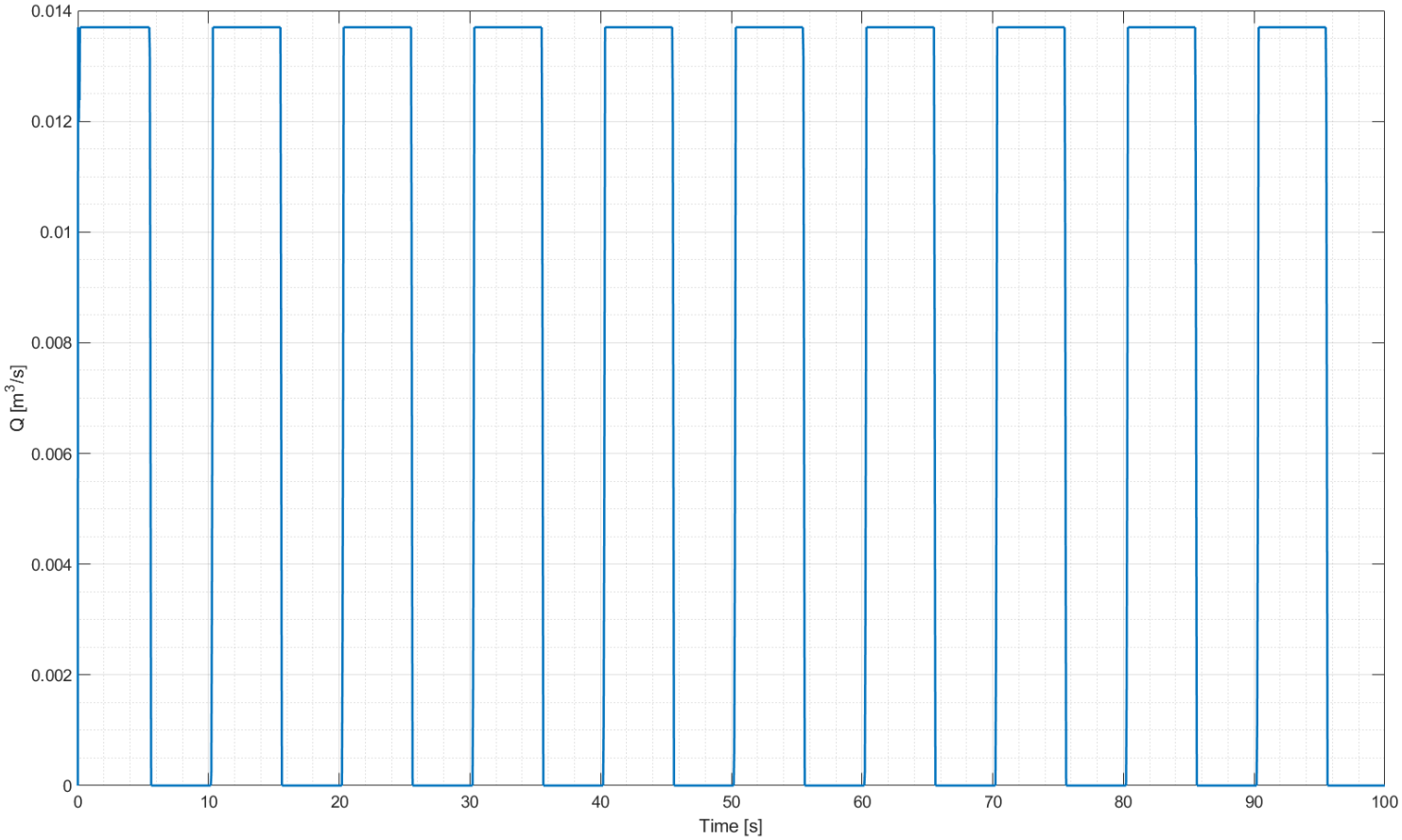
task 4 - SMA driving a valve



- deflect a valve represented in a mass-spring-damper system and plot the resulting flow
- flow is defined as:

$$q(s) = sat(s) \cdot A \cdot \eta \cdot \sqrt{\frac{2 \cdot \Delta P}{\rho}}$$

task 4 - SMA driving a valve

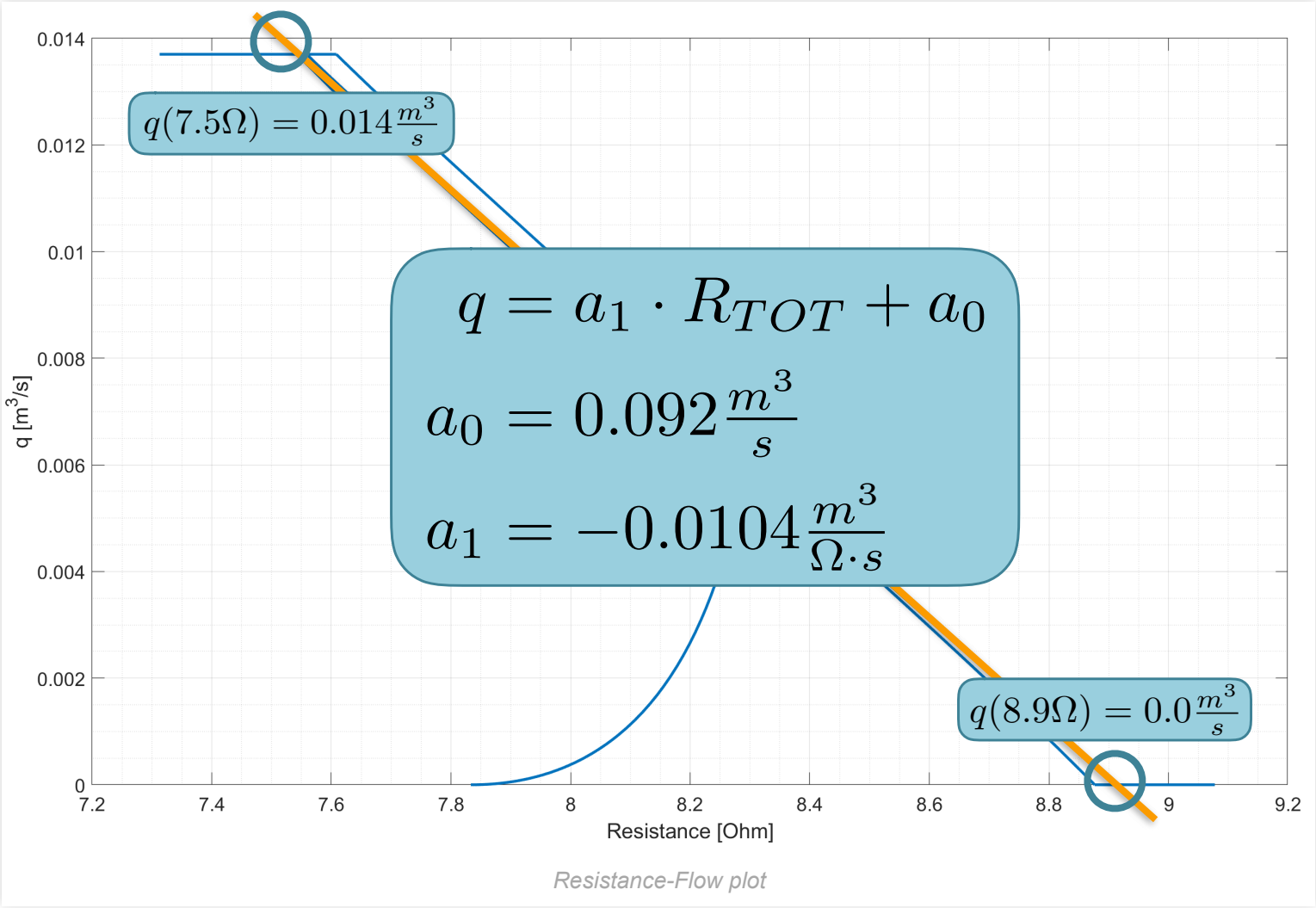


Time-Flow plot

task 5 - plot approximation

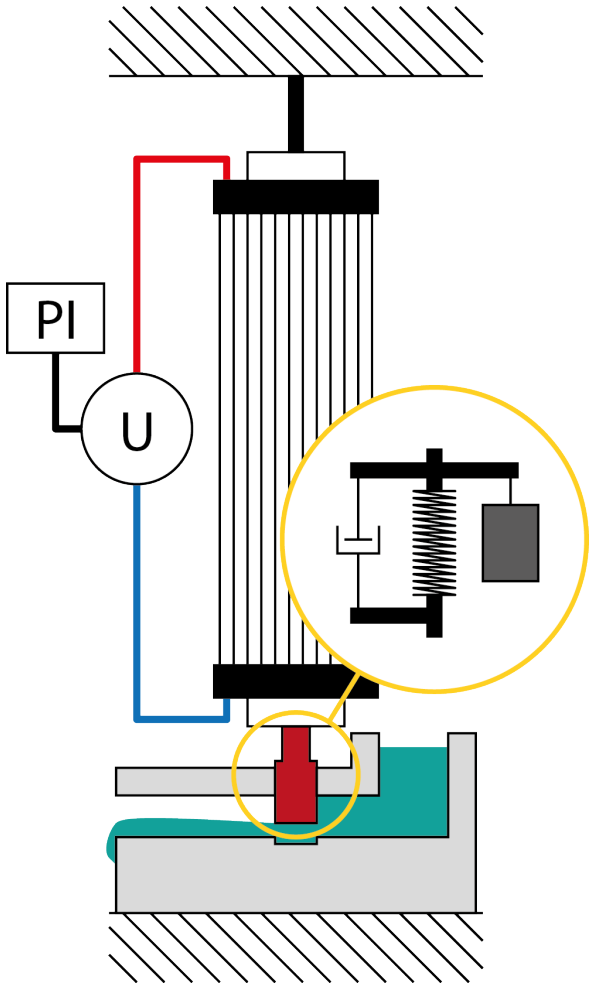
- plot the flow against the resistance
- find a linear approximation for the relationship between the flow and the resistance

task 5 - plot approximation



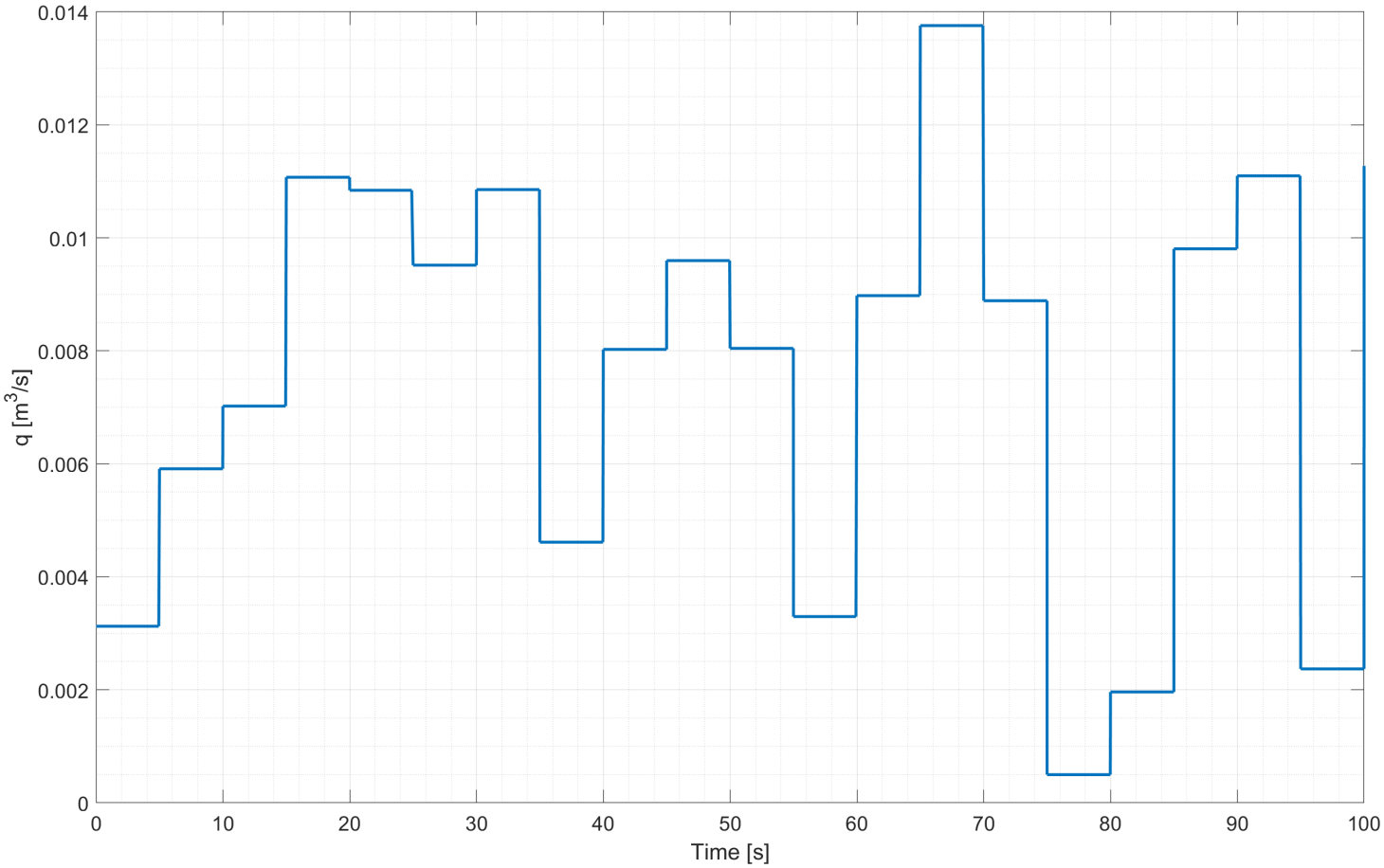
Resistance-Flow plot

task 6 - PI controller



- use a PI controller to regulate the flow based on adjusting power

task 6 - PI controller



reference flow plot

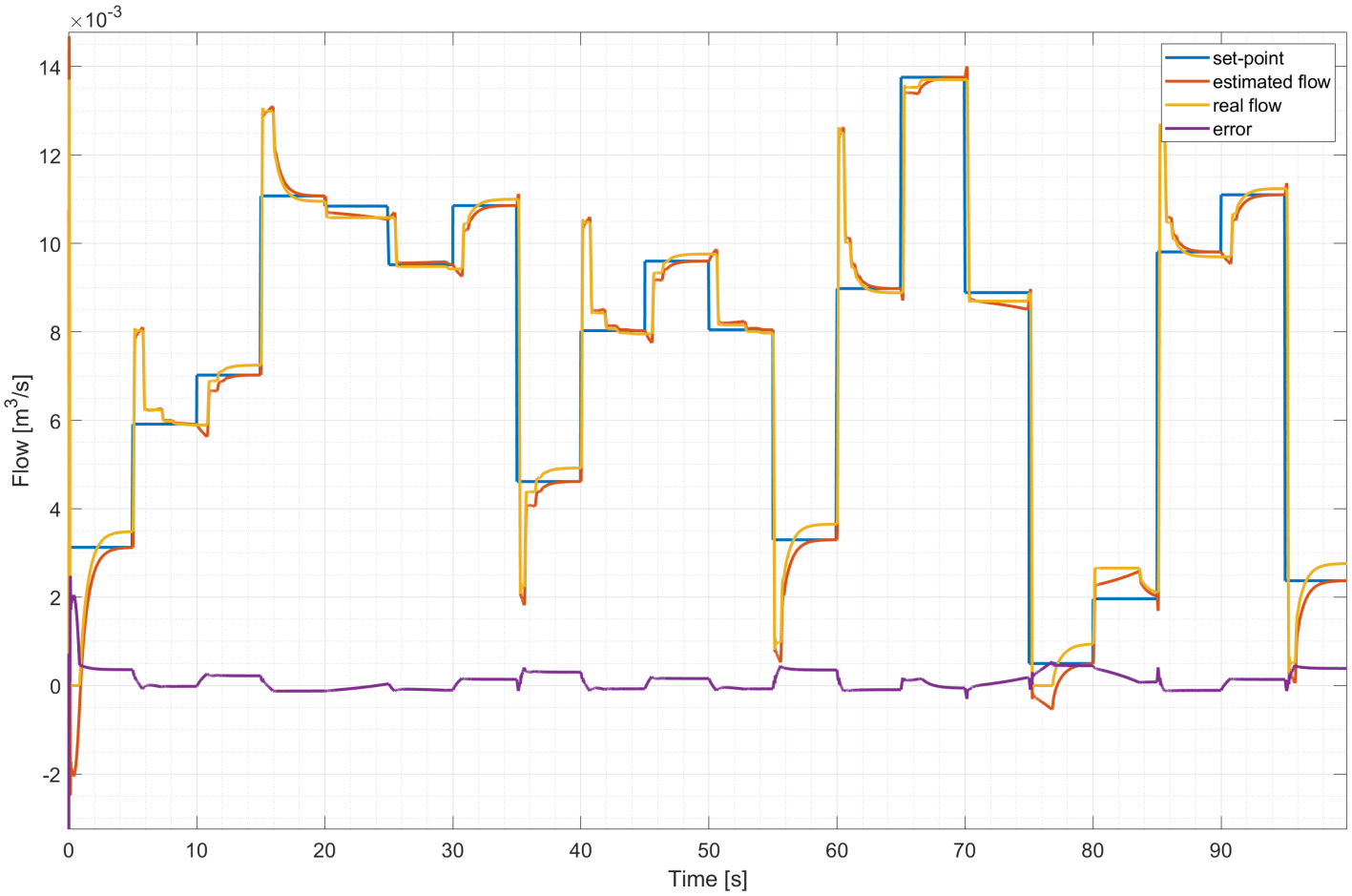
task 6 - PI controller (PI tuning)

- first step: increase P until the signal starts oscillating measure the oscillation time and the value for P
- calculate the real values for P and I

$$
\begin{aligned}
P_{krit} &= 2.2 \\
P &= 0.45 \cdot P_{krit} = 0.99 \\
T_{krit} &= 1.0 \\
T_n &= 0.85 \cdot T_{krit} \\
I &= \frac{P}{T_n} = 1.16
\end{aligned}
$$

- fine-tune the values by hand until the result is satisfactory

task 6 - PI controller



plot of all important controller signals

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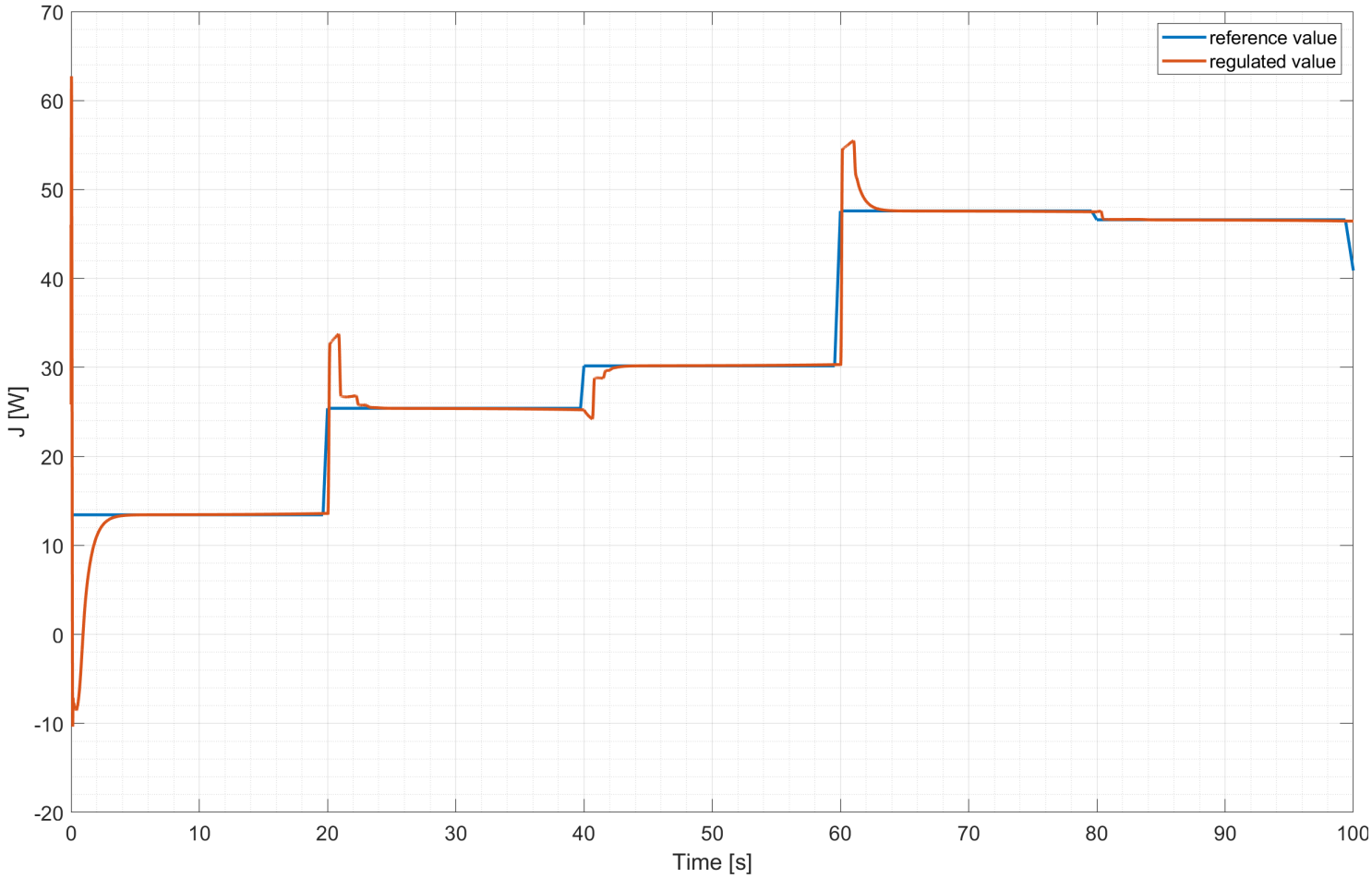
Thank you for your attention!
Questions?

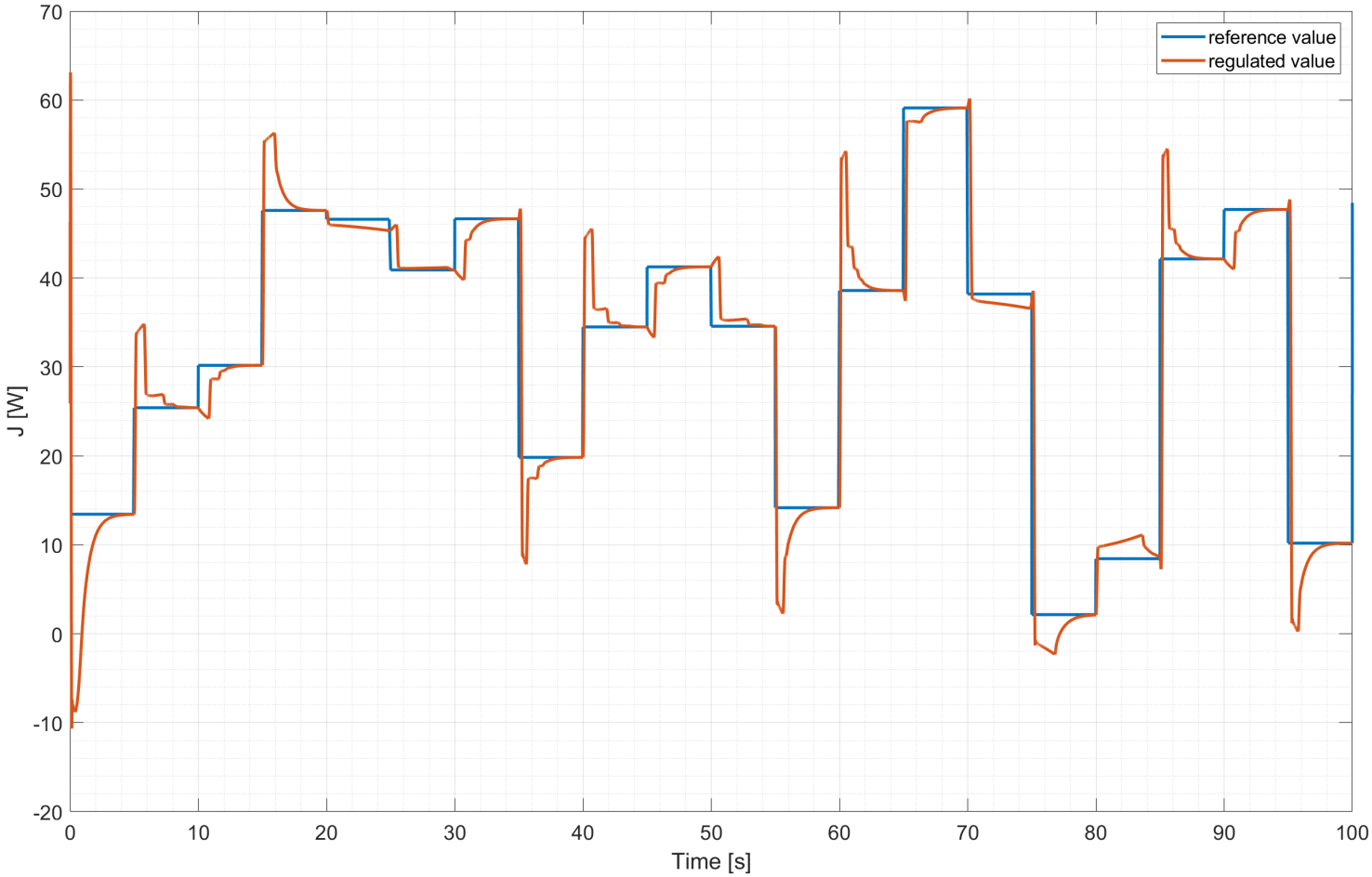
Cover picture: https://www.youtube.com/watch?v=ULvS3K3-QRM

ZeMA



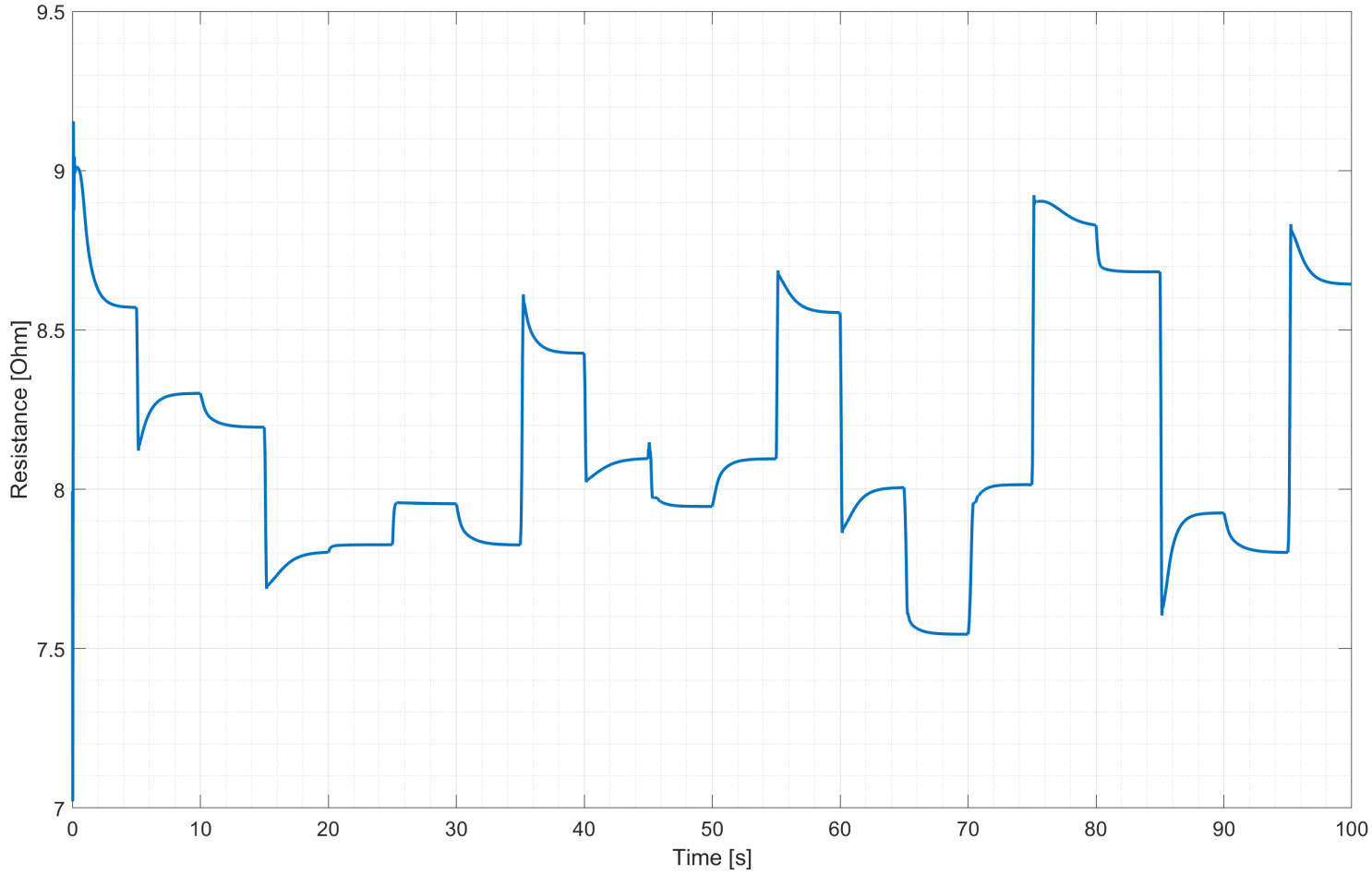
task6: PI controller with 5 different destinations for 20 seconds each

appendix



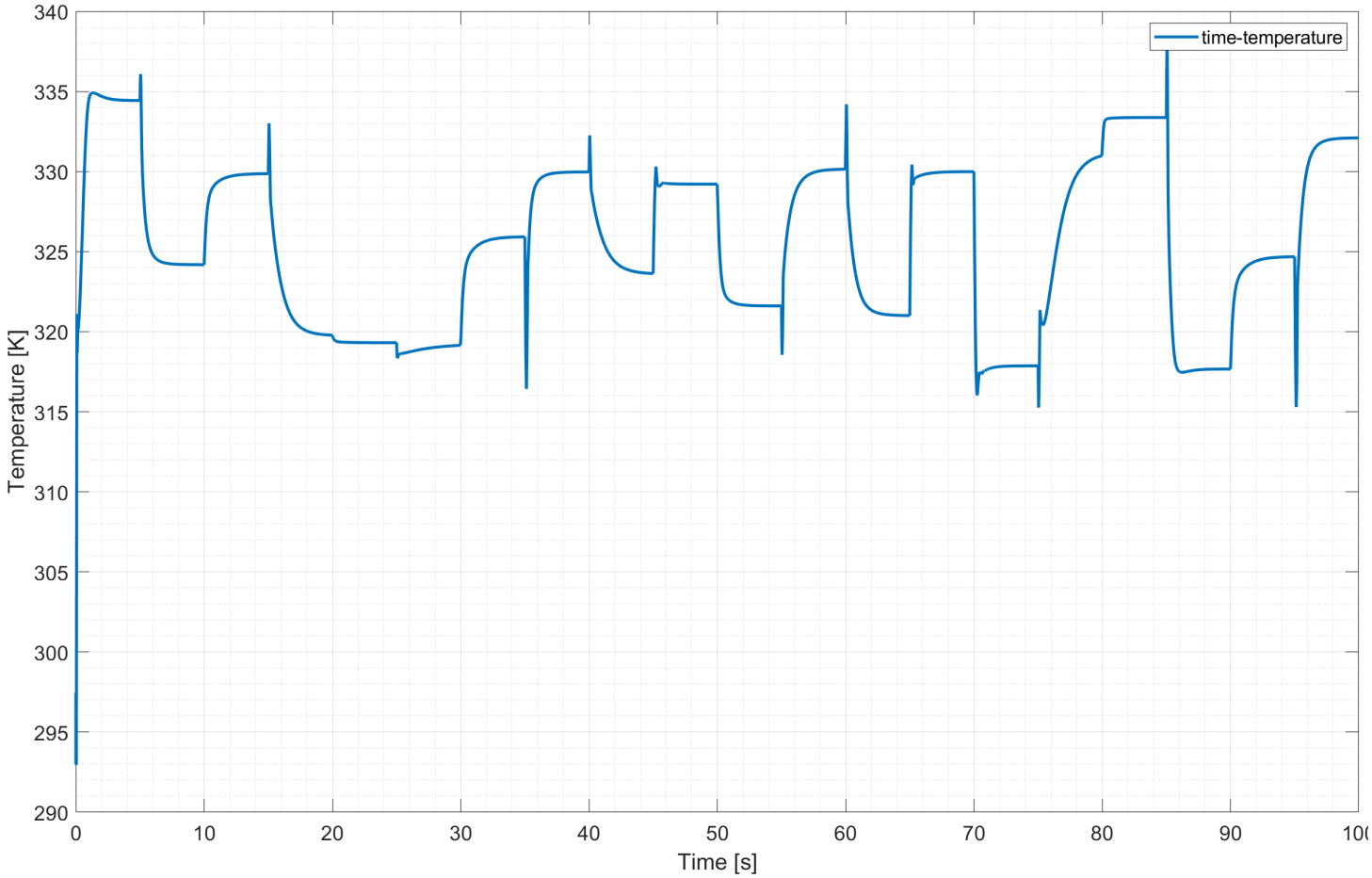
task6: PI controller with 20 different destinations for 5 seconds each

appendix



task6: PI controller; Time-Resistance plot

appendix



task6: PI controller; Time-Temperature plot

appendix

$$J_{max} = \alpha \cdot 2 \cdot \pi \cdot l_0 \cdot r_0 \cdot N \cdot \Delta T$$

$$0 = F_{TOT} + k \cdot (y - y_0) + b\dot{y} + m\ddot{y}$$

$$s = \frac{y_{in} - y}{0.0295}$$