Piezo-based servomotor for demanding applications

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- The PAD principle
- Practical implementation
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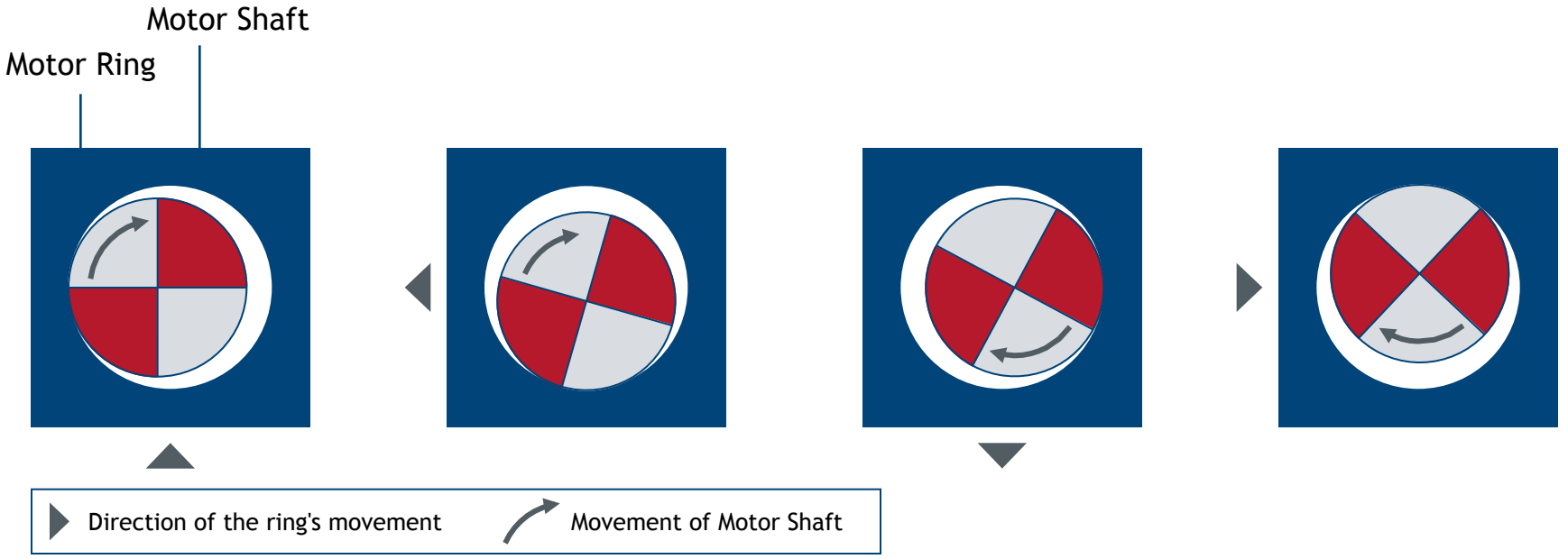
PAD technology transfer

- PAD technology developed in Siemens from 2000
- A partner was needed for commercialisation
- Noliac A/S acquired the PAD technology from Siemens AG in 2010
  - Patents
  - Fully equipped test laboratories
  - Training sessions

- Read full press release: http://www.noliac.com/News-22.aspx

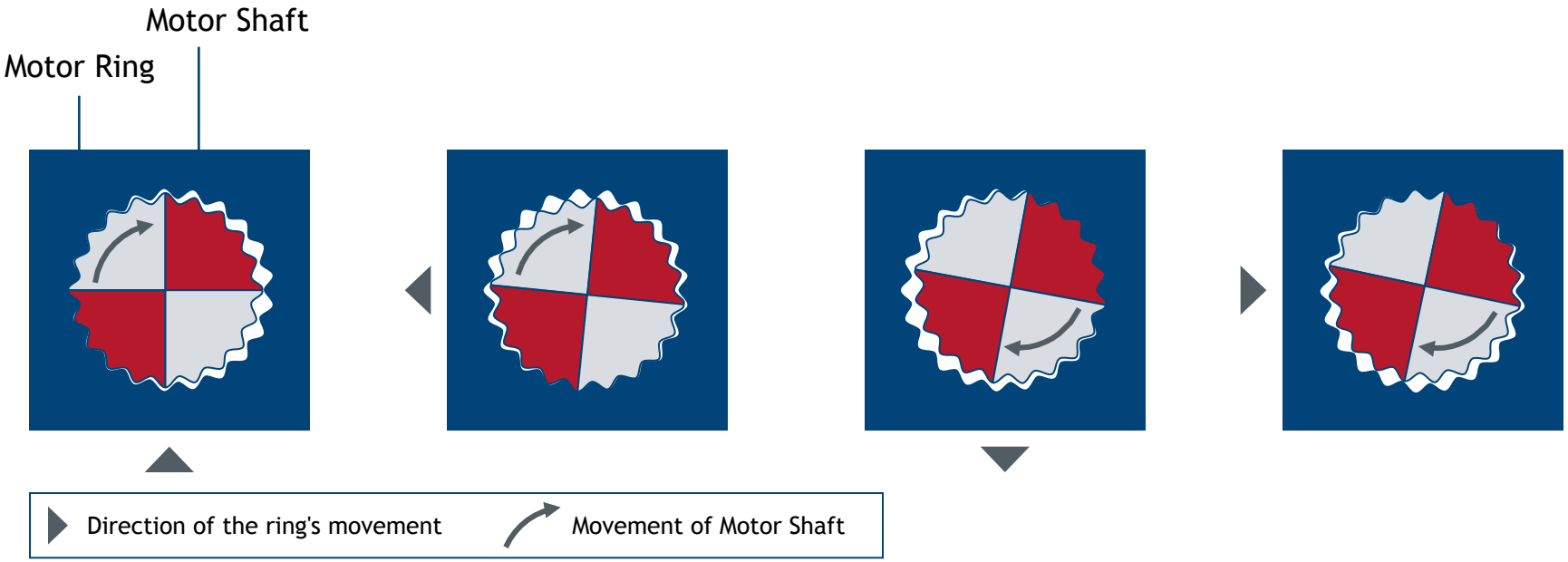
The PAD (Piezo Actuator Drive) principle

- Mechanical amplification
- Convert a circular translation into a rotation



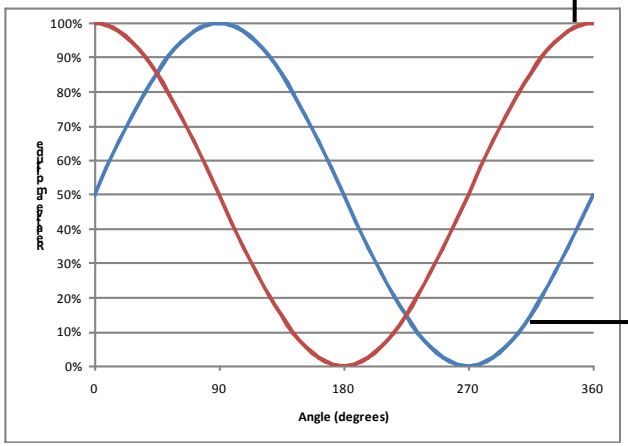
The PAD (Piezo Actuator Drive) principle

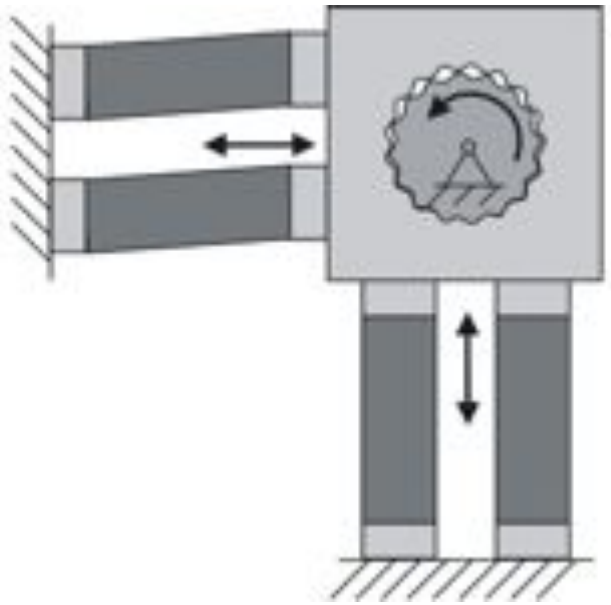
- Toothed ring/shaft for ”form-fit” principle



The PAD (Piezo Actuator Drive) principle

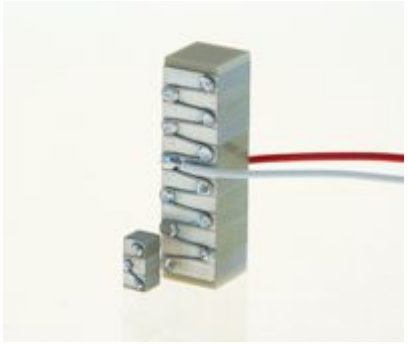
- Implementation:
  - Microtoothing for ”positive” actuation
  - Displacement generated by piezo elements
  - Signals with 90° phase



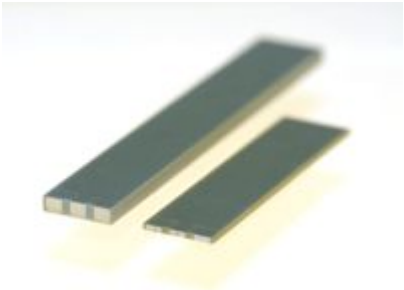


Scalability

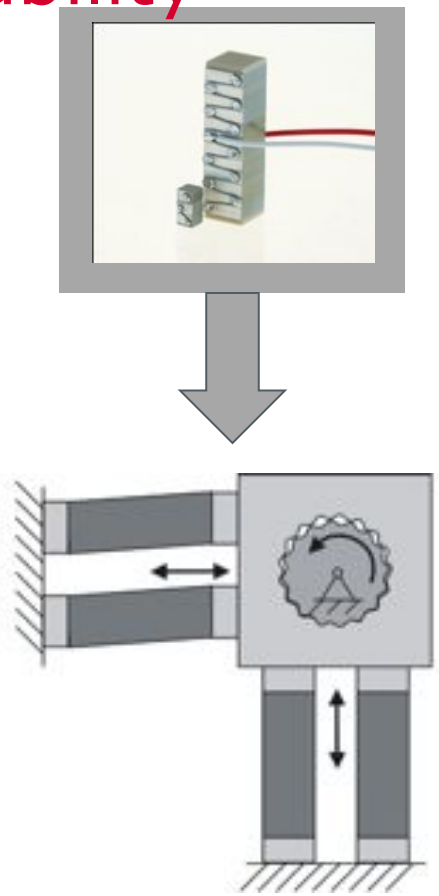
- Piezo actuation
  - Stacks
    - Large force capability
    - Small displacement (100s of µm)



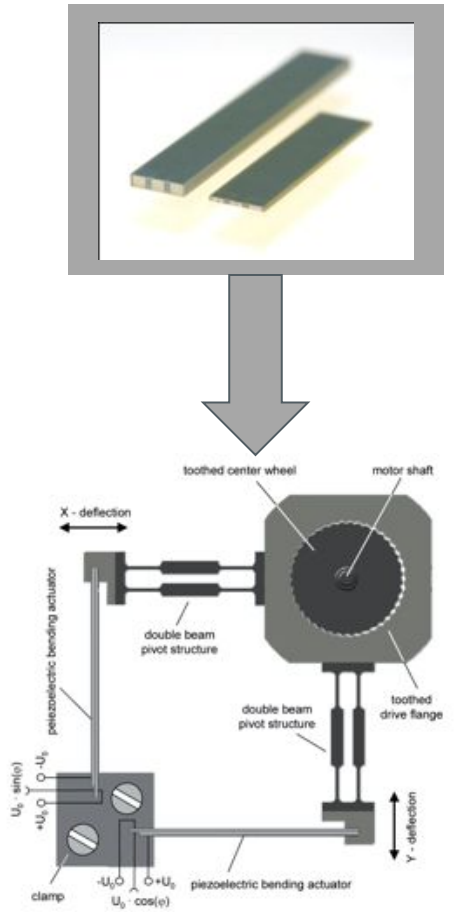
  - Bending actuators
    - Amplified movement
    - Lower force (10s of N)



Scalability



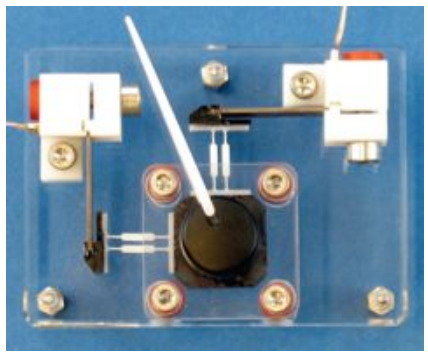
- PowerPAD



- MiniPAD

Scalability

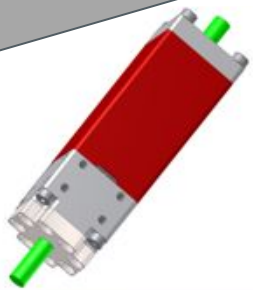
- Demonstrated range



1,5 N.mm

30 N.mm

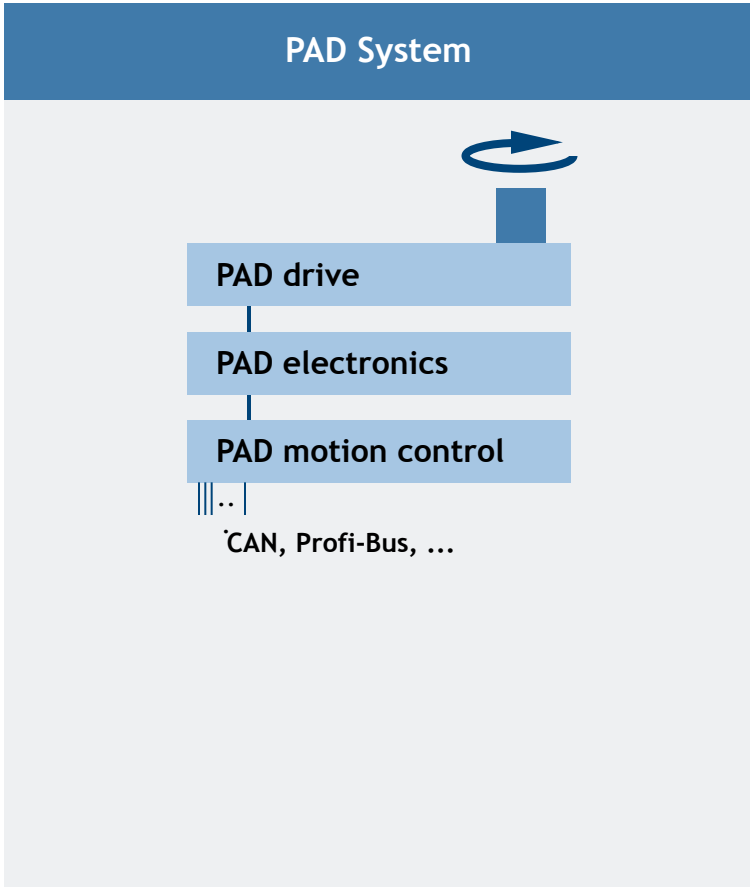
5 N.m

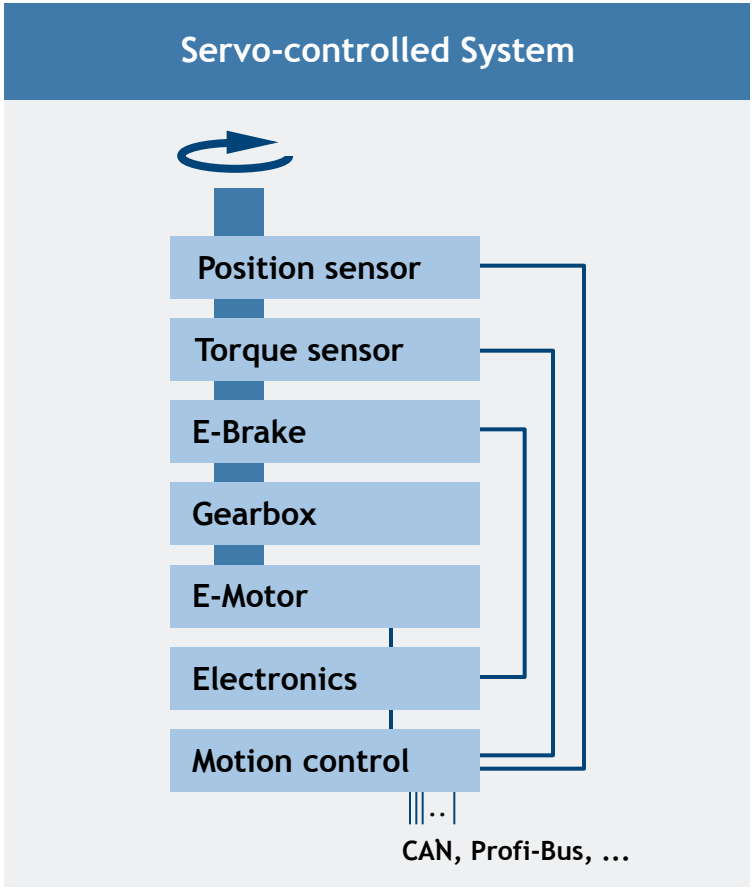


Advantages of the technology

- No gearing
  - Low inertia
  - High dynamics
  - Low backlash
- Self-locking
- High resolution
- Non-magnetic

An integrated technology





Servomotor application

- Take advantage of:
  - Open-loop positioning capability
  - Force feedback capability
- Example: Delta3 robot

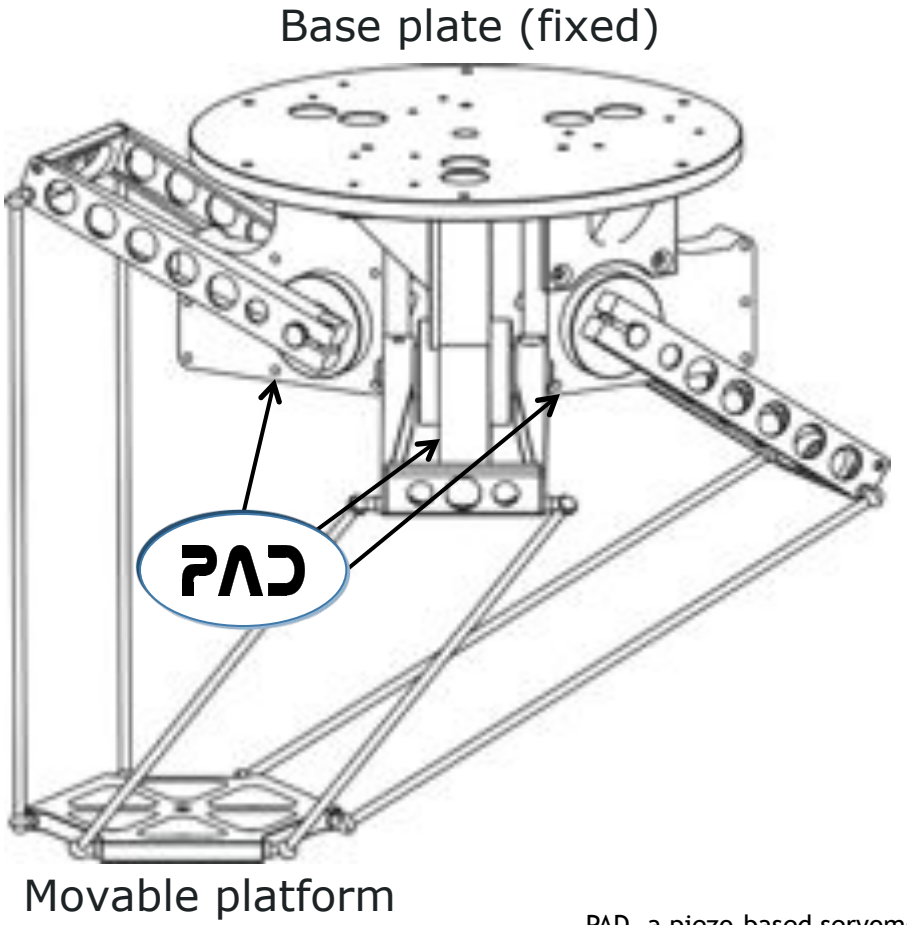
"Synchronously Controlled Piezoelectric Actuator Drives (PAD) as Motors of a Delta-3 Robot"

R. Zeichfüßl, B. Gottlieb, C. Wallenhauer, A. Kappel, Siemens AG, Corporate Technology, Munich, Germany

M. Vogl, T. Kraus, T. C. Lüth, Institute of Micro Technology and Medical Device Technology (MIMED), TU Munich, Germany

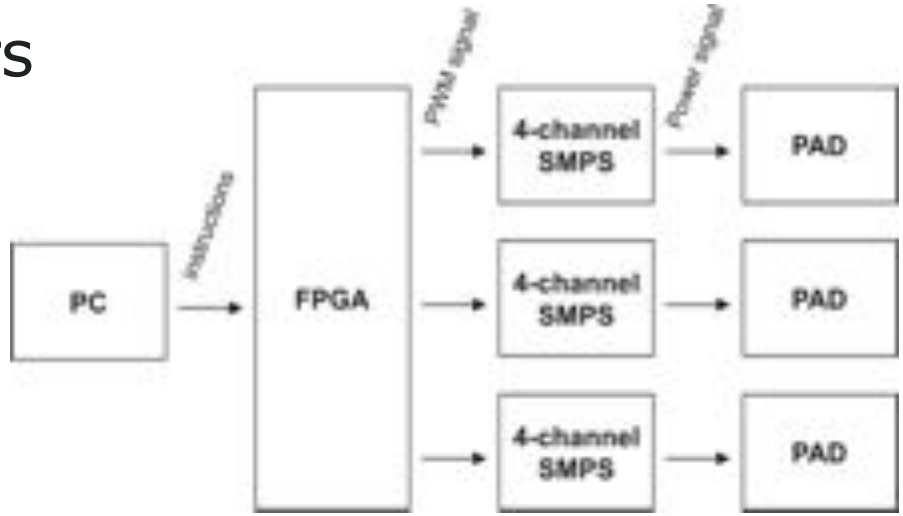
Delta3 robot

- Parallel kinematics
- 3 translational axes
- 3 PAD drives



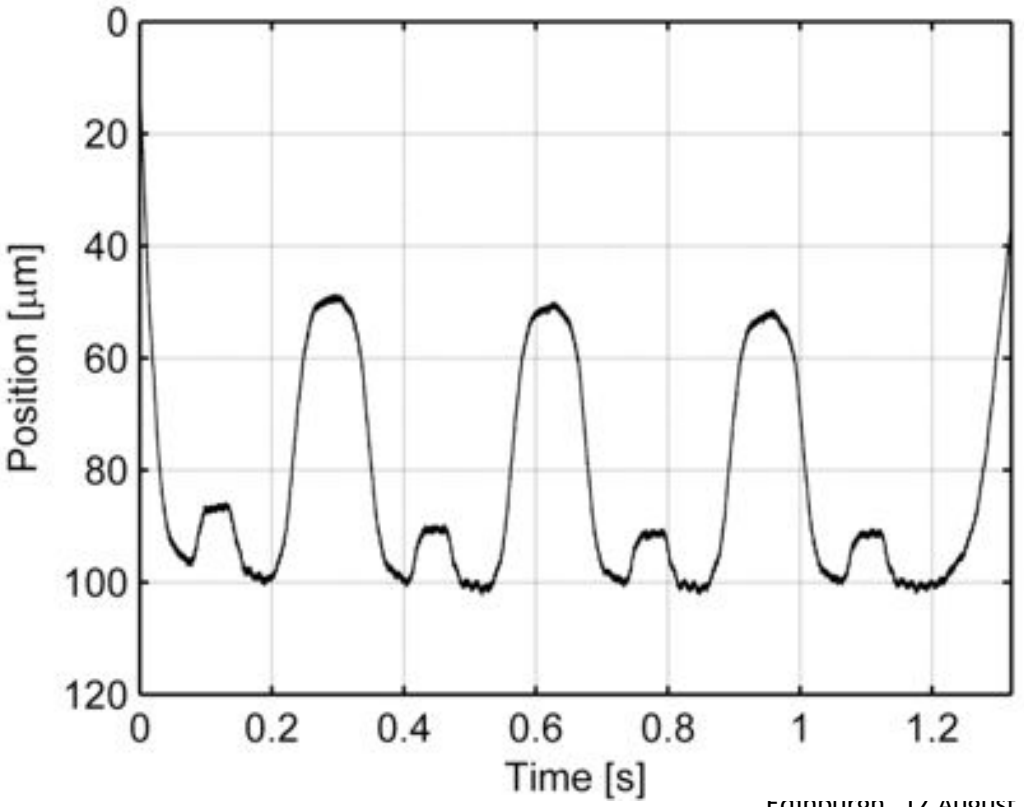
Delta3 robot control

- 1 FPGA
  - Position calculation
  - Signal generation
- Multi-channel amplifiers
- No position feedback



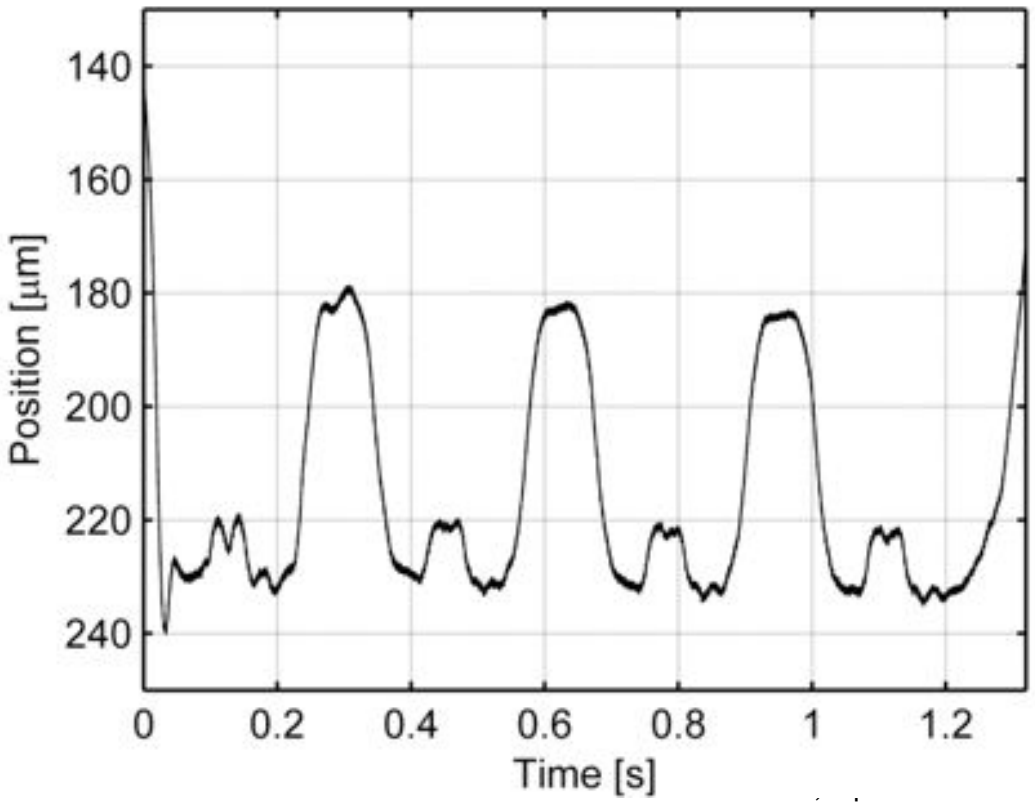
Test results

- Z steps of 10 and 50µm
- Fast movements
- External LVDT sensor
- No load



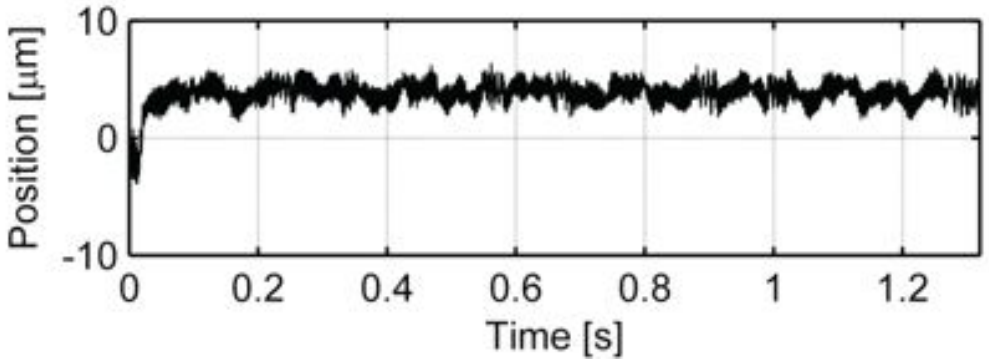
With load

- Same test with 2kg load

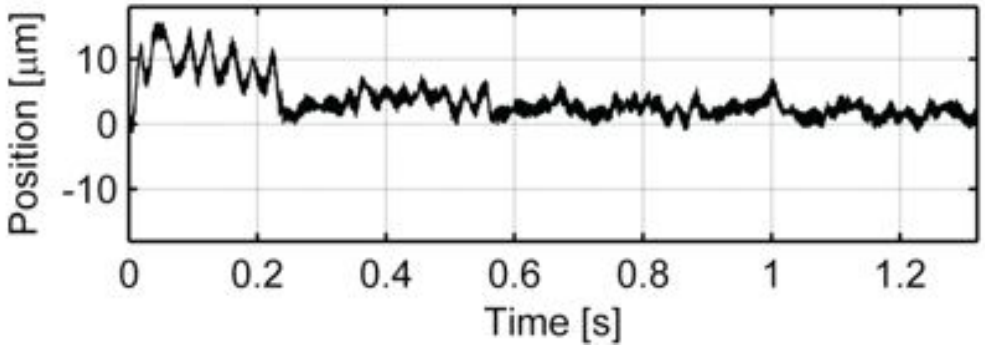


Repeatibility results

- Difference between first and last experiment



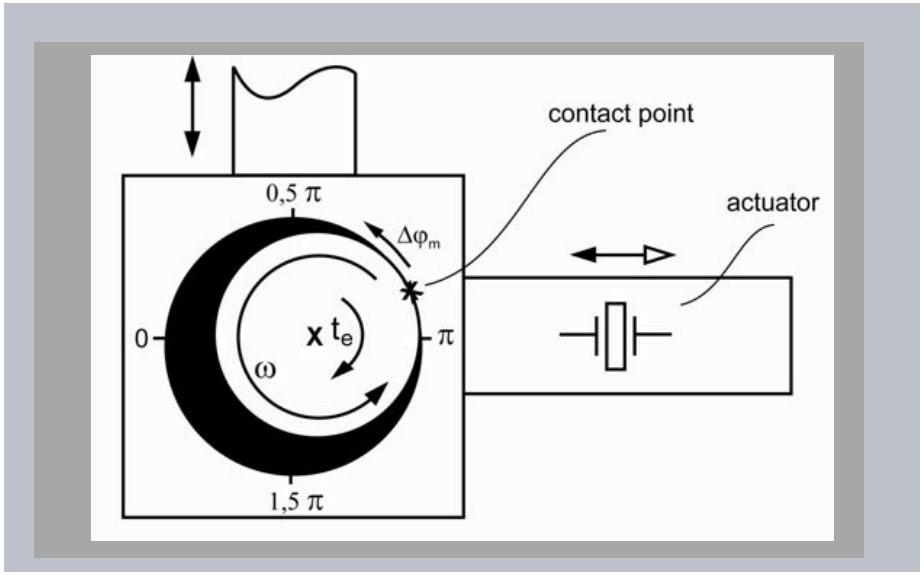
No load



2 kg load

Force feedback principle

- Mechanical load causes phase shift between actuator force and displacement



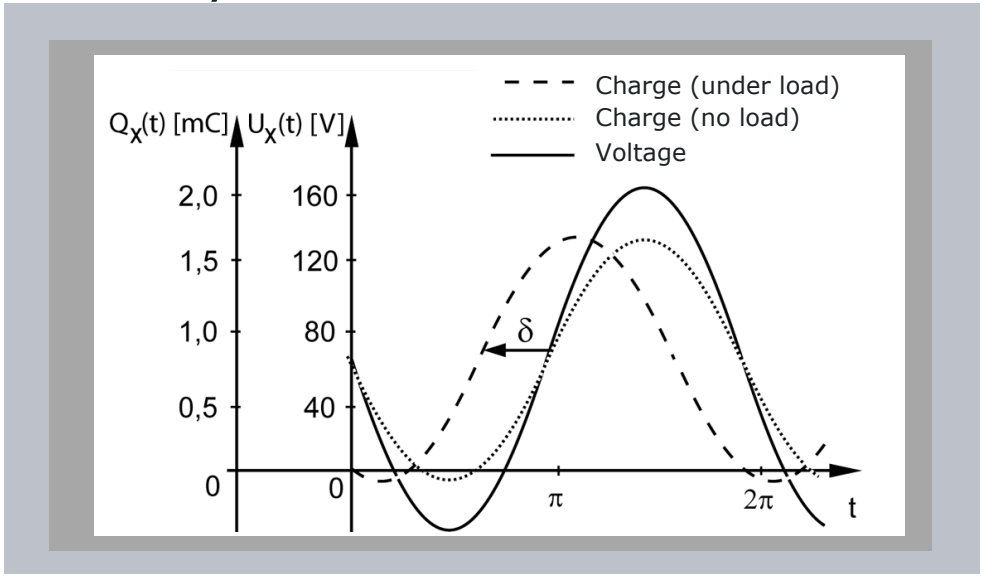
$$\Delta\varphi_m = \arcsin\left(\frac{2t_e}{d_{shaft}}\frac{1}{k \cdot D_{33} \cdot v_0}\right)$$

Force feedback principle

- Piezo charge depends on force and voltage
  - Mechanical load causes phase shift between electric charge and driving voltage
- Charge can be measured with Sawyer-Towes circuit

$$q(t) = -D_{33}F(t) + C_p v(t)$$

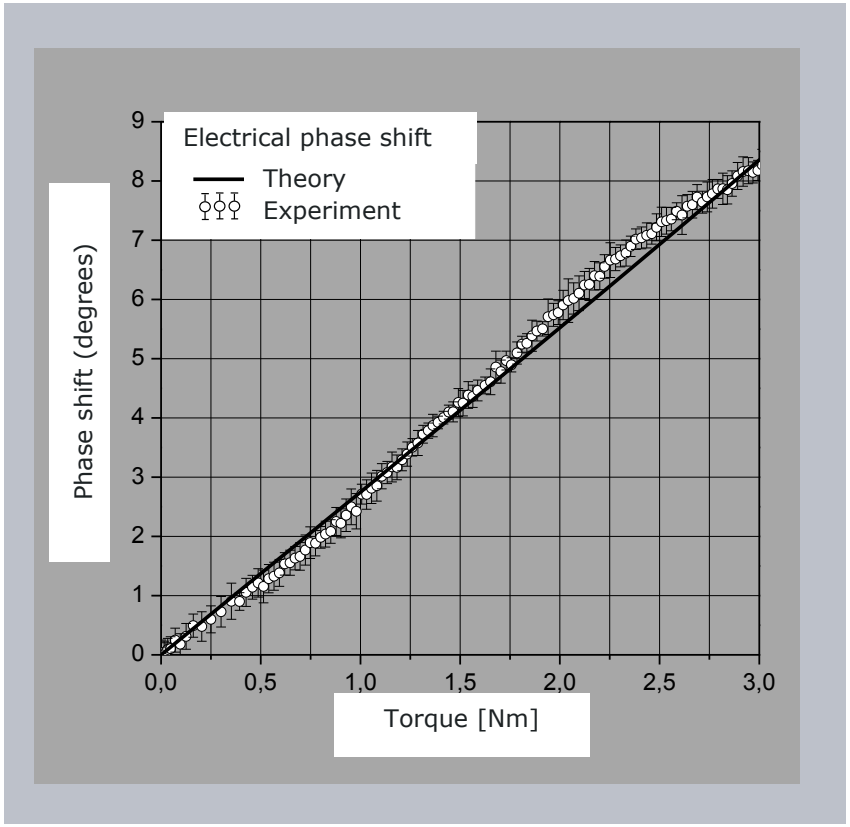
$$s(t) = -\frac{F(t)}{k} + D_{33}v(t)$$



Force feedback results

- Phase shift measurement using ”zero crossing”
- Good correlation
- No additional sensors required

$$\Delta\varphi_e(\Delta\varphi_m) = \arctan\left(\frac{D_{33}ks_0 \cdot \sin\Delta\varphi_m}{D_{33}^2 kv_0 - D_{33}ks_0\sqrt{1-\sin^2\Delta\varphi_m} + C_p v_0}\right)$$



Magnetic properties

- Publication: MRI device

  Development of a MRI-Safe Piezo Actuator Drive (PAD)

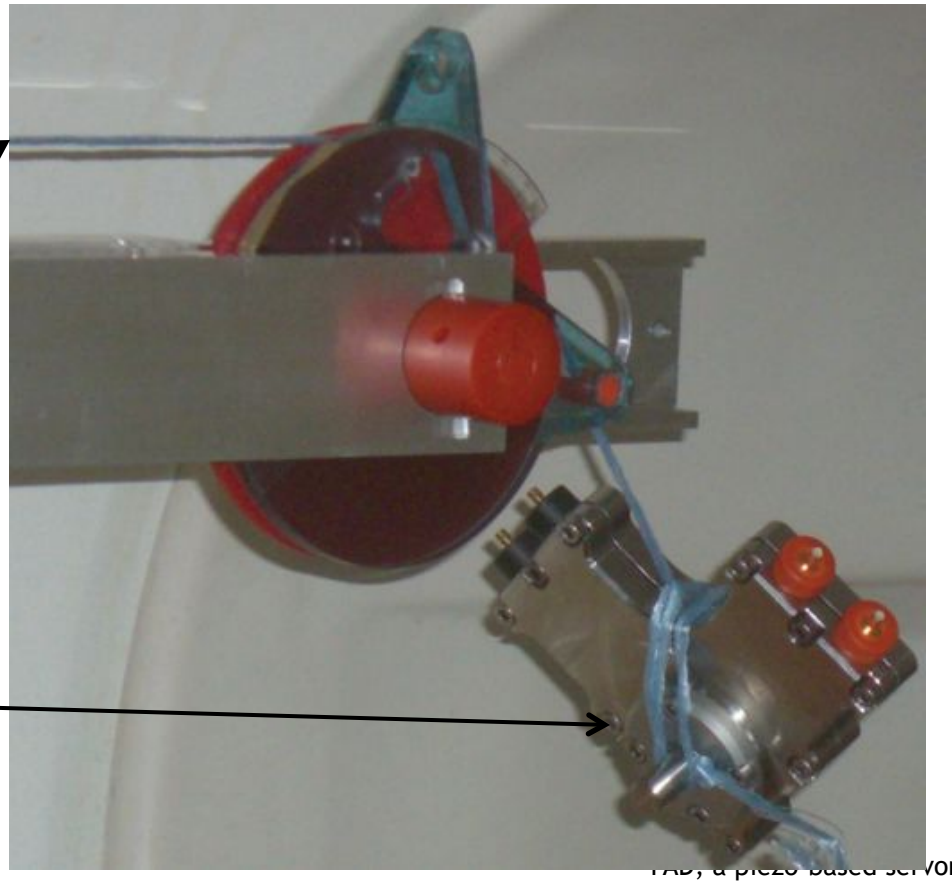
  Vogl, M.; Kraus, T.; Zeichfüßl, R.; Wallenhauer, C.; Gottlieb, B.; Kappel, A.; Lüth, T.C. Actuator 2008, Bremen, Germany, 09.-11. Juni 2008, pp. 576-579.

  ISBN: 3-933339-10-3.

Testing under strong magnetic field

- 1,5 T MRI device

Force amplitude and direction measurement



Test results

- Magnetic force 3,4N (1/2 the weight)
- Some materials still magnetic (housing, preload springs)
- Torque capability 1,75 N.m
- Potential for:
  - Immunity
  - Non interference

Conclusions

- Noliac can offer Siemens' PAD technology from 2011, after transition phase has been completed
- Scaleable technology
- Innovative servomotor with definitive advantages
  - Large torque capability
  - High dynamics
  - Torque feedback capability
  - No position feedback needed
  - No interference with magnetic fields

Thank you for your attention !

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