

The background of the slide is a photograph of a sailboat on the water. The sailboat's white sail is prominent on the left side, with a small red logo visible. The sea is dark blue with whitecaps, and the sky is blue with scattered white clouds. In the top left corner, the Siemens logo is displayed in teal. A semi-transparent grey bar at the bottom contains the main title and footer text.

**SIEMENS**

Siemens AG

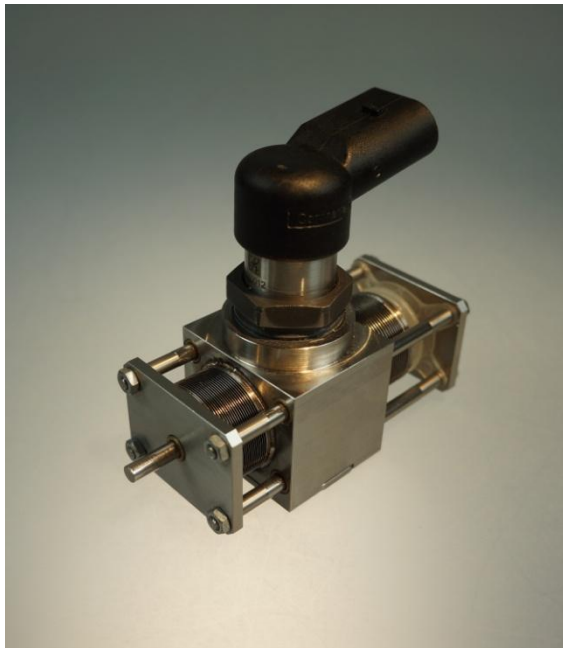
# Searching for applications for novel piezohydraulic actuator

# Background

Currently used actuation principles have serious deficiencies when it comes to inherent safety and/or harsh environment applications.

Drive Technology		Characteristics
Electromagnetic Drive	+	• Low cost
	-	• Low force density • Challenging thermal management • Low efficiency at low power levels • No inherent safety (due to reflected inertia when combined with gearbox)
Hydraulic/ Pneumatic Drive	+	• High torque and power density
	-	• Loss of efficiency over time • Low bandwidth capabilities limited to less than 20 Hz • No inherent safety (due to very high output stiffness)
Piezoelectric Drive	+	• Superior efficiency compared to electromagnetic drives at low power regions
	-	• Limited to very short displacements (typically strains of 0.15%) • Unsuitable for static applications due to self-discharge

## Researchers at Siemens have developed a small but powerful piezohydraulic actuator

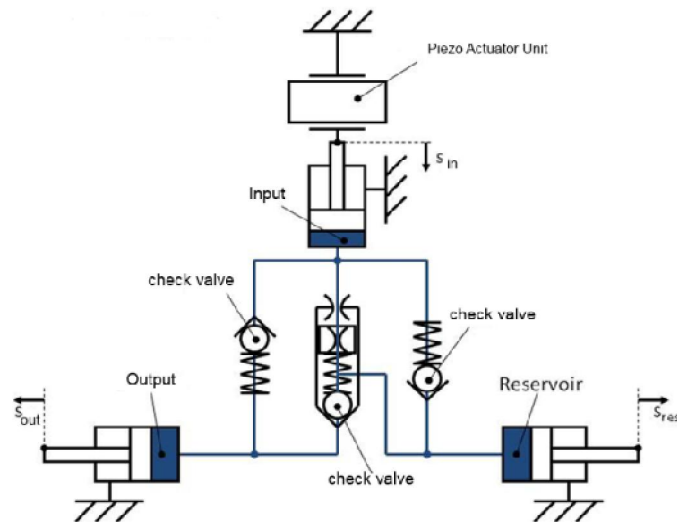


Picture of first laboratory model

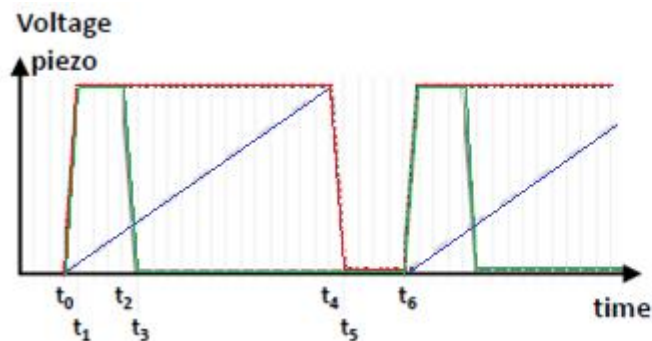
### Key characteristics

- High force density
- Low power region (around 20 W)
- Variable impedance
- Human-like force/velocity characteristic
- Intrinsic passive safety
- Low intrinsic inertia
- High accuracy in  $\mu\text{m}$  range
- High efficiency in ranges up to 30W
- High robustness e.g. in case of impact or vibrations
- Use in harsh environment possible (metal encapsulated system)

# The concept combines piezomechanics with hydraulics



Schematic concept of piezohydraulic actuator



Operation modes:

- I. Low force – high velocity —
- II. High force – low velocity —
- III. Highest force – no velocity (blocking force) —

## Working principle

- Hydraulic amplifying system is used as a stroke integrator of the piezo.
- Damping factor of the system is improved due to viscous damping of the fluid providing high robustness.
- Basic function of the actuator is similar to micro pump principle: pumping of fluid resulting in piston/bellow displacement.
- By adjusting the input voltage three different operation modes can be distinguished:
  - I: Low force - high velocity
  - II: High force - low velocity
  - III: Highest force - no velocity (blocking force)
- This results in a muscle-like behavior: maximum force at zero velocity and low force for movements with high velocity

# The piezohydraulic actuator at a glance

## What is the technology about?

- A novel piezohydraulic actuation principle able to mimic human muscle behavior has been developed.
- In order to accomplish this muscle performance a piezo actuator unit is combined with an hydraulic system of throttles and check valves .
- Different velocity-force relations can be achieved by adjusting the duty cycles of the piezo voltage

## What is the benefit of the technology?

- Variable impedance possible by adjusting duty cycle of the piezo voltage signal.
- Passive safety: for the protection of other creatures and objects as well as actuator itself, the system operates with low forces at high velocities and has a low impact energy. The maximum force is reached at zero velocity.
- High robustness: in addition to high impact robustness, the system is highly damped by the fluid, which enables applications at high vibrations.

## What is your challenge?

- We are convinced that applications of this technology widely surpass our current scope of business.
- We are therefore looking for new ideas of other possible applications and/or potential customers to incorporate their requirements in the further development process

## Exceptional proposals will be rewarded



### What can we offer?

- All submitted proposals have the chance to further influence our prototype/ development process towards your need/application requirements.
- Additionally, **exceptional contributions** can benefit from:
  - joint evaluation of cooperation opportunities in commercial areas, technology development, manufacturing, integration et al.
  - open discussion of licensing opportunities
  - cross-functional workshop to further develop joint business opportunity.