Nanometer Precise Hybrid Actuator in Positioning Mechanism with long Travel Range

Nano technology demands extreme high resolution and accuracy and at the same time long travel range, which requirements normally are hard to combine. New mechatronic hybrid systems can overcome this gap by applying an integrated piezo-flexture approach in a motorised stage and a one sensor parallel control structure.

Design Principle of a Hybrid System

PIEZO SYSTEM

Resolution 0.00002 [µm]

Range 2 to20 [µm]

SERVO MOTOR SYSTEM

Resolution 0.2 [µm]

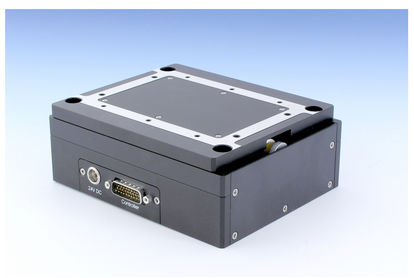
Range 4 to 300 [mm]

SENSOR

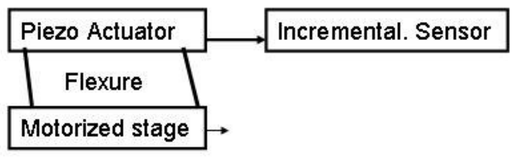
1 incremental sensor

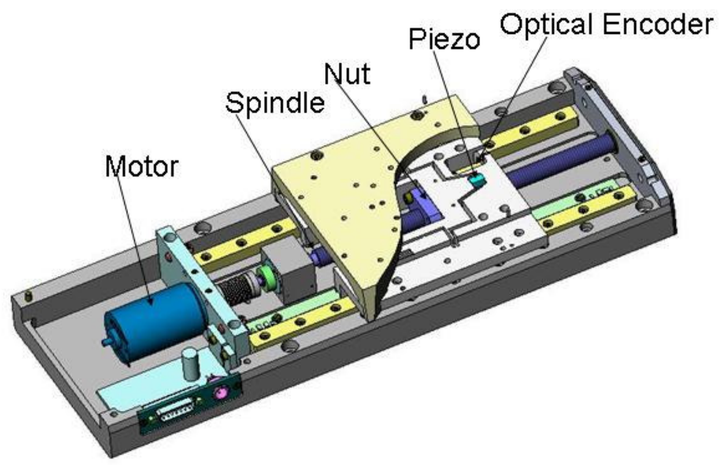
Power Dissipation

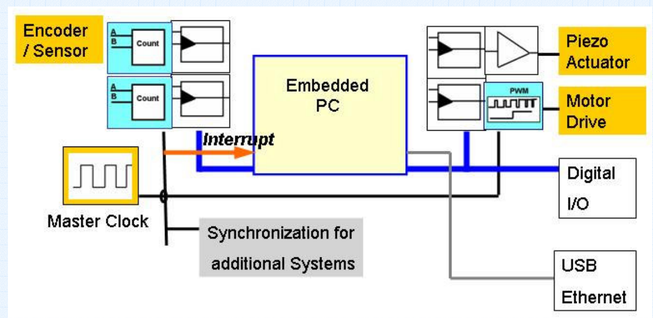
Close to zero for
static position control



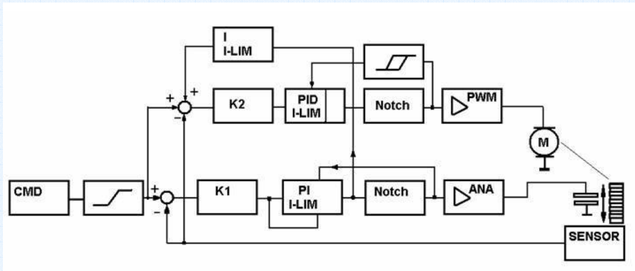
M-714 stage





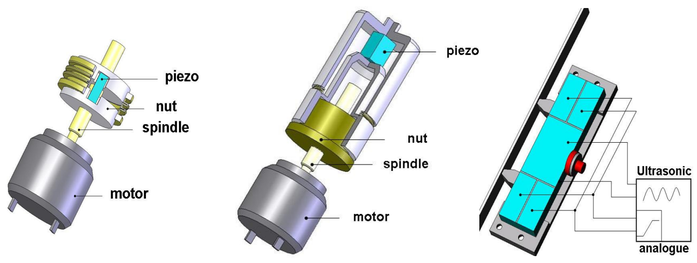


Controller structure



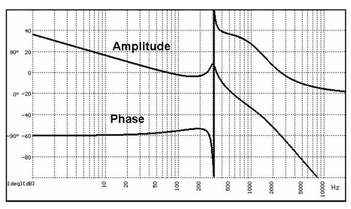
Firmware algorithm structure

Hybrid Drives



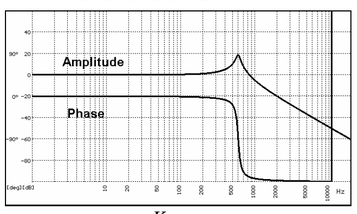
- Spindle/nut or ultrasonic piezo drives & PZT linear actuators in the strut
- Spindle/ nut & PZT linear actuators in the nut (stack or tube)
- Piezo ultrasonic drives with additional analogue mode

Motor driven



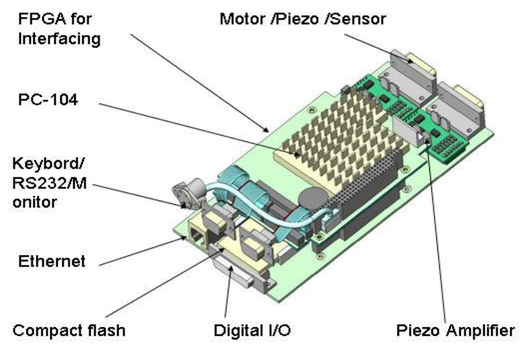
$$T_m(p) = \frac{K_m}{Ti * \left[p + \frac{2D}{\omega_m} p^2 + \frac{p^3}{\omega_m^2} \right]}$$

Piezo actuator



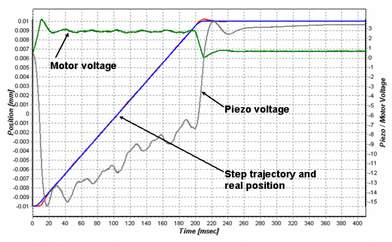
$$T_z(p) = \frac{K_p}{1 + \frac{2 \cdot D}{\omega_0} p + \left(\frac{p}{\omega_0} \right)^2}$$

Hybrid Stage / Controller Design



Hybrid Controller

The controller splits the frequency response between the piezo actuator and the motorized stage. The piezo actuator is driven at a higher bandwidth than the motorized actuator.



Simultaneously control loop for PZT and Motor

Test Results: Step Response of Hybrid Actuators

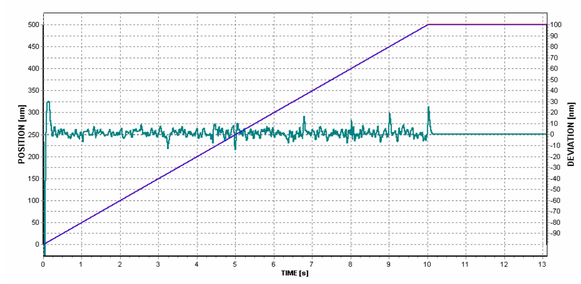
Sensor resolution : 2nm (Test with 0.02nm are done)

Step performance: < 2nm

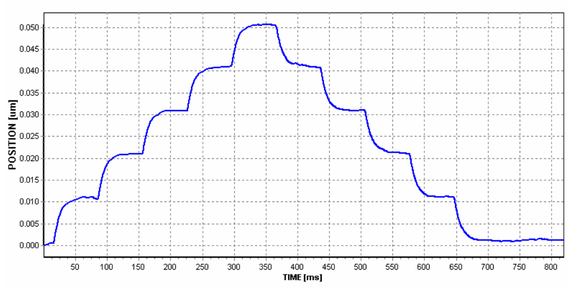
Dynamic distortion: < 10nm

PZT output resolution: 24bit (4µm stroke)

Motor counter : unlimited



1mm movement
Deviation less than 10nm



0.01µm step size
The system has no hysteresis effects

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