Precision positioning system with high-speed FPGA based closed loop control

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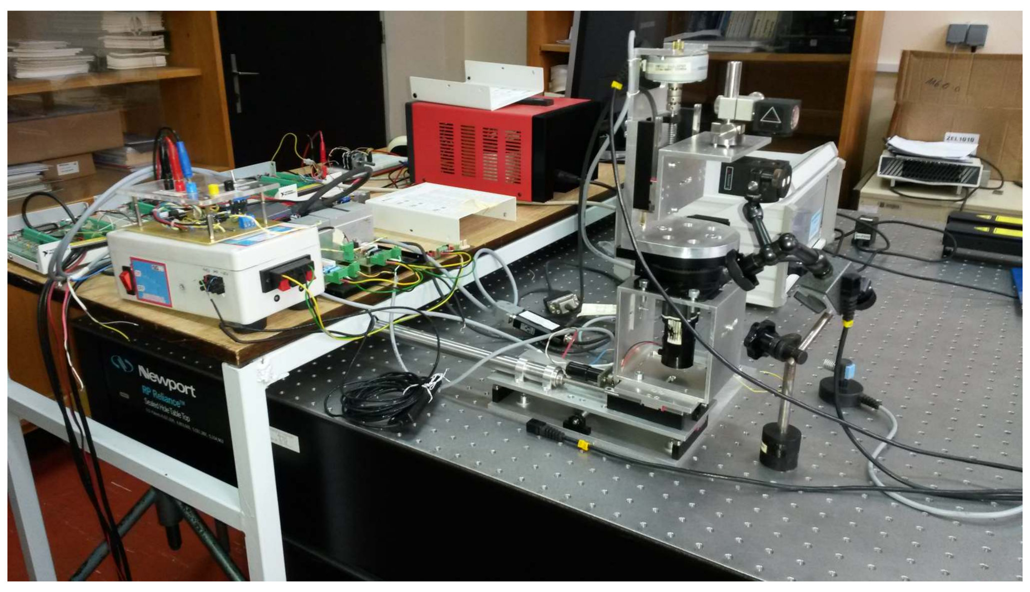
Precision positioning

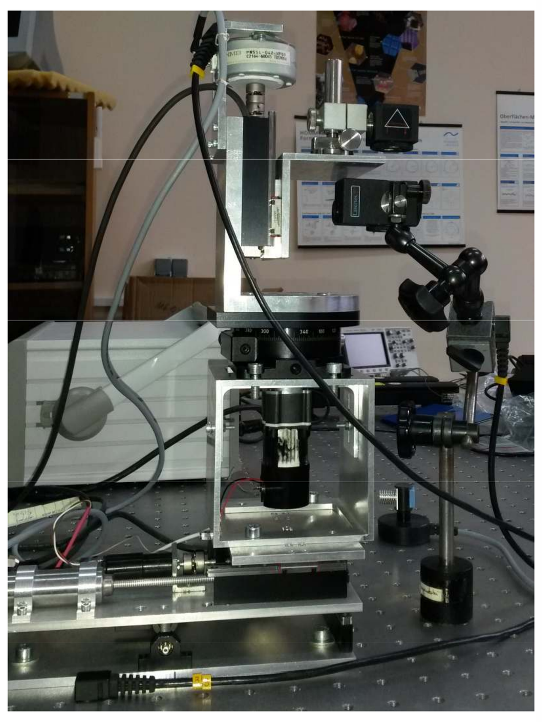
- **Precision positioning systems** are often used for manipulation of small structures.

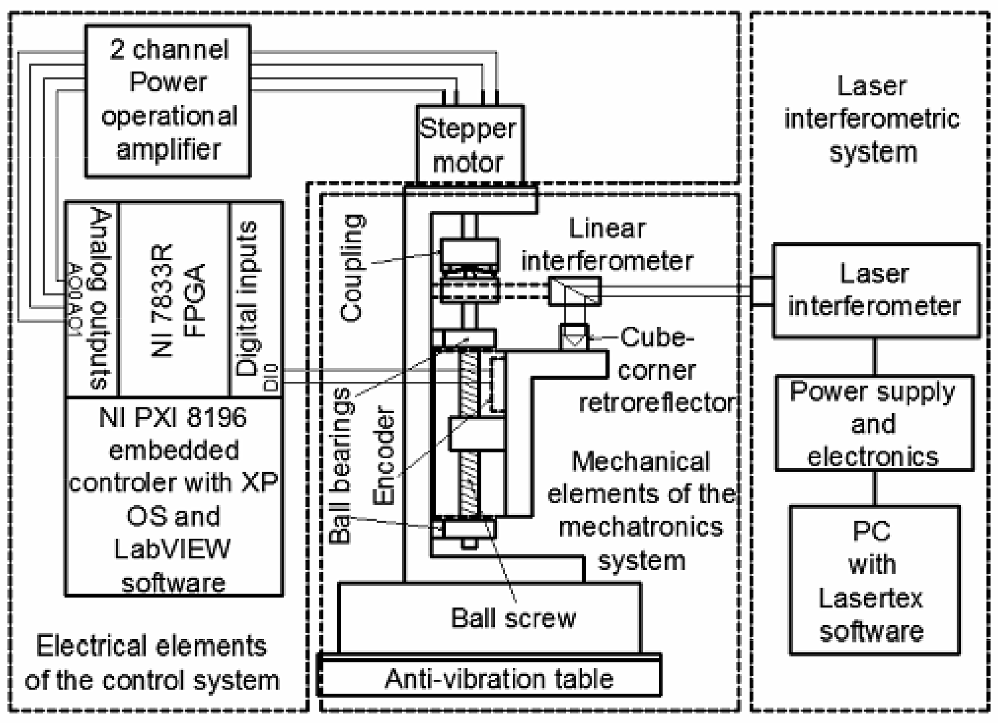
Other applications are:

- Positioning of optical devices,
- Handling and assembly of microsystems,
- Focusing mechanism for telescopes,
- Micro and Nano manipulation,
- Semiconductor industry,
- MEMS devices,
- …



Experimental Set-up





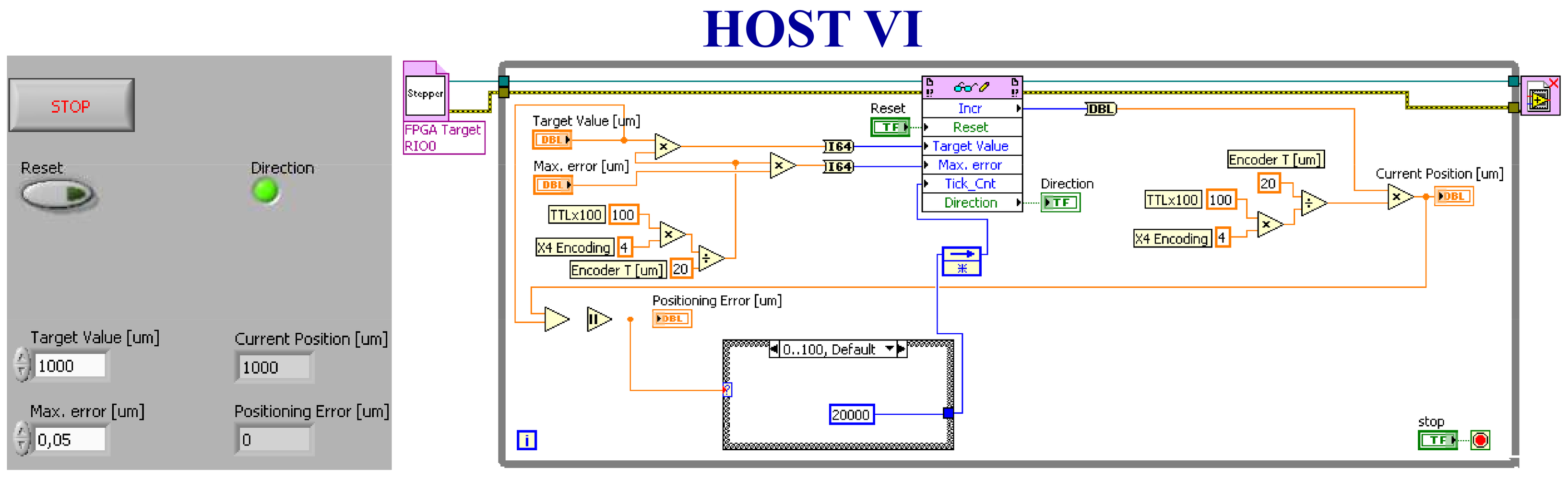
- The experiments are conducted on the vertical axis of an experimental system, composed of a stepper motor, a feedback sensor, mechanical elements and control system.
- National Instruments hardware is used to implement control system.
- NI PXI 1050 chassis, NI PXI 7833R FPGA Real-Time (RT) module, NI PXI 8196 Host controller.

Element	Type	Manufacturer	Parameters	
Ball screw	SHS6X2R	SKF	d_0 = 6 mm, p = 2 mm, B = 50 mm, h_p = 94%	
Ball bearings	618/4	SKF	d = 4 mm, D = 9 mm, b = 2.5 mm	
Coupling	MCGS13-3-3	Misumi	D_C = 16 mm, d_1 = d_2 = 3 mm, l_C = 13 mm	
Stepper actuator	PM55L-048	NMB Technologies Corp.	48 steps/revolution	
Feedback sensor	MS 30.03	RSF Elektronik	20 μm period and 1 V_{PP}	50 nm resolution
Interpolation unit	APE 371	Heidenhain	TTL x 100 max. Interpolation	

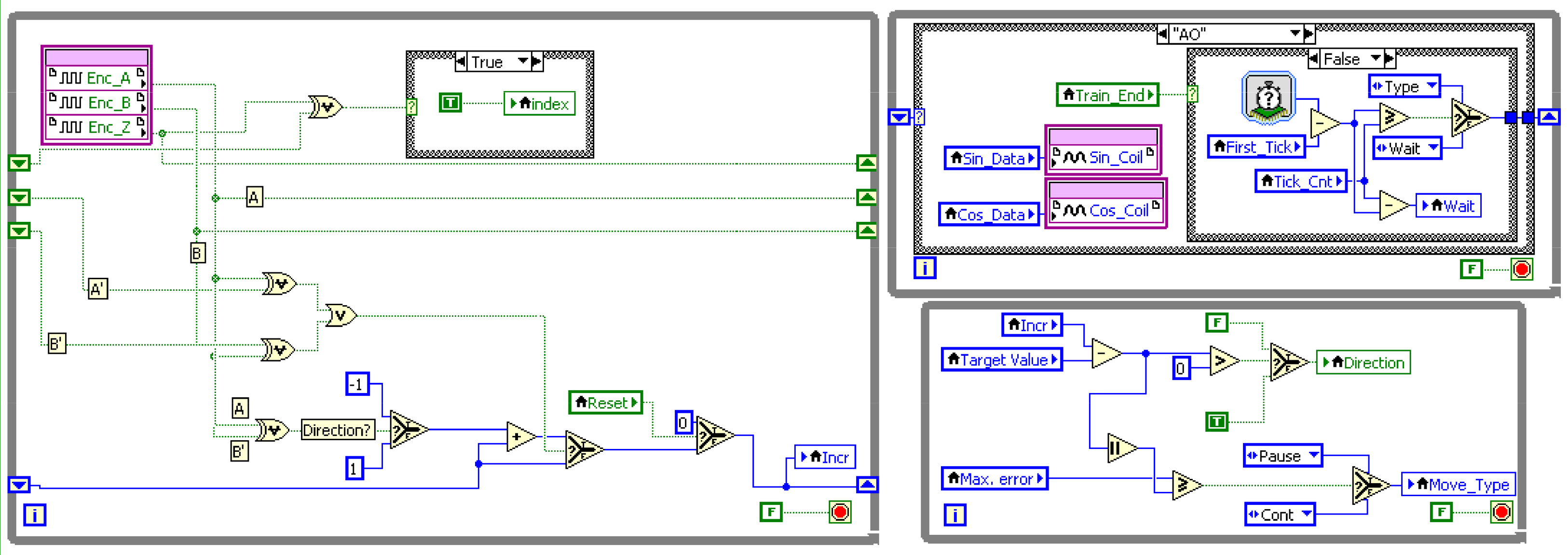
Control system

- Microstepping control is established using *sin* and *cos* voltages and each of actuator's 48 steps is divided into 1024 sub-steps (approx. 50k μsteps/revolution).
- The algorithm consists of two LabVIEW® virtual instruments (VIs); **FPGA VI** written to the **RT target** and **HOST VI** running on the MS Windows based PC.

HOST VI



FPGA VI



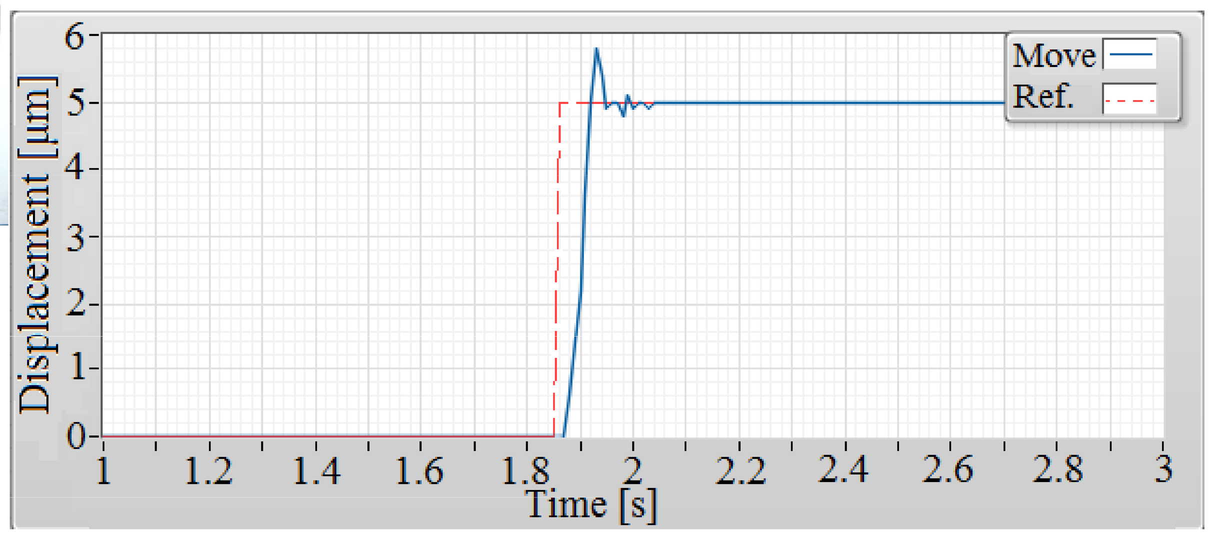
- **HOST VI** enables the conversion of the digital representation of the variables to engineering units and, by converting users' inputs to FPGA VI digital values, it is used to communicate with the VI running on the RT target.
- It consists of a case structure (with defined positioning intervals; from 0 to 100 μm, from 101 to 500 μm and > 500 μm) used to define the time between micro steps and proportionately the velocity for each interval – this algorithm is used to reduce the overshoot in output signal.
- Left while loop of the **FPGA VI** reads the interpolated **TTL** encoder signals and, depending on the direction of motion, increments or decrements the *incr* variable. Every transition from logic "0" to "1" and vice versa is counted for both channels (X4 encoding).
- The while loop in the upper right corner represents actuator's driving signal. It consists of *if* statements of which the most important are: *Move type (*pause / continuous), *sin* and *cos* for reading the value of the signal from the memory block, *Scale* for scaling the voltage levels and *AO* for generating the analog output.
- The third loop of the FPGA VI in the lower right corner compares the actual and the reference position, define the maximum allowable error and alter the direction of motion. Micro steps are generated (motion type *continuous*) until the system reaches its final position. When the error is lower than the allowable one, motion type *pause* is activated but the motor coils are still powered to preserve the reached position.

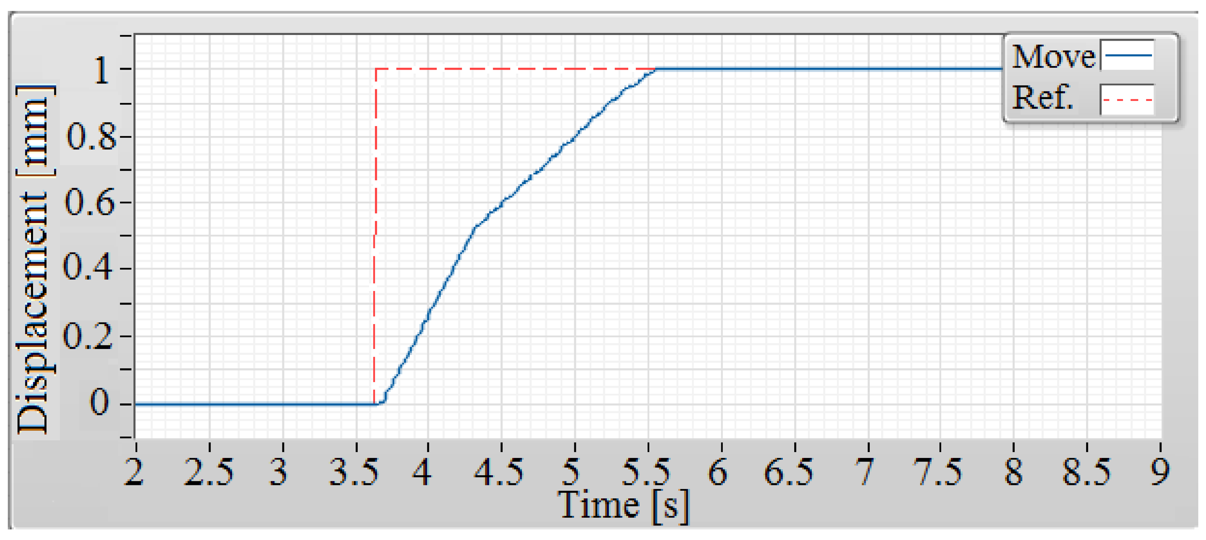
Experimental results

- Experimental validation of the positioning repeatability and accuracy is performed by using a Michelson-type laser Doppler interferometric system LSP 30-3D.

Positioning errors [μm]

Step size \ Point #	1	2	3	4	5
5 μm	0.17	0.01	-0.37	-0.22	0.3
1 mm	2.11	0.33	-0.93	0.33	-0.06





Conclusions and outlook

- A micropositioning mechatronics system, where closed loop feedback is obtained by using microstepping control, is described,
- Experimental validation is performed via a set of point-to-point positioning steps, for two types of movement: short (5 μm) and long (1 mm) range,
- Calculated positioning accuracy and repeatability for short steps are, respectively, 0.02 and 0.28 μm, while for the long steps these values are, respectively, 0.36 and 1.1 μm,
- Final configuration of the system, with 4 axes (6 DOFs) aimed at micromanipulation, will be designed and tested.

Acknowledgements

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