Modeling, Design and Control of the μWalker, a MEMS-based Storage Medium for μSPAM[1]

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(Field used for informations on processing by the editors)

Abstract

One of the necessary components in probe array memory storage devices is an actuator that aligns and moves the probes with respect to the medium in order to be able to read and write data. In the μSPAM project, the desired working speed should be above 10 mm/s in order to achieve access times below 10 ms and the precision, or tracking error, should not exceed 10 nm in order to enable densities up to 1 Tbit/in^2. The tracking function is being performed by an inchworm device (Figure 1), from hereon called the μWalker [1]. It has proven to be able to deliver relatively high forces for a range that can in principle be unlimited. In order to better understand the behaviour of the μWalker, to optimize its performance and as a basis for the design of a feed-back controller a model of this device is needed. This abstract presents a model based on a power-conservative port-based approach. The model has been implemented in the 20-Sim [2] simulation package.

Modeling as a tool for device optimization and control

Figure 2 sketches the walking sequence that completes one step to the left. By applying the indicated voltage signals as a function of time, one can proceed through the states q_0 through q_5 and back to q_0. By repeating this sequence, one can move a deliberately number of steps for a desired total stroke. When all inputs are set to zero, the structure goes back to steady-state, or minimum total system energy, due to the four long springs at the corners which electrically and mechanically connect the μWalker to the supporting structure.
In order to optimize the μWalker structure in terms of force delivered, speed, acceleration, step accuracy, total weight and more, a model that is closely related to the physical parameters of the μWalker is needed. Bond-graph models are well suited for this purpose. The bond-graph representation [3] of the μWalker model is presented in Figure 3. Besides for optimization of the structure, the model can be used for controller design, or even more, for an integrated design of the controlled structure, allowing for a true micro-mechatronic approach. Because of the inevitable uncertainties in the system, a controller is absolutely necessary in order to let the μWalker accurately move along a desired trajectory. Using a competent model in parallel with device development can accelerate both the development of the μWalker device and of the control system.
Figure 4 gives a simulation: five sequential steps are made. The position of the contact legs increases five times, followed by convergence to steady-state. Special attention is paid to the contact model between the contact legs and the walking surface —a Stribeck-curve [4] that simulates stick-slip has been implemented. The stick-slip model is shown in Figure 5, in a simplified context. Simulations show friction as function of the mass velocity.
One of the advantages of using physical models in 20-Sim is optimization of certain design features without the need for a new prototype. There are several parameters that can be used to influence the step size, amongst others time-shifting of certain input voltages. The effects of changing one or more parameters that influence the step size can easily be simulated with parameter sweeps. In general, parameters that barely influence the step size shall be set constant, while parameters that have much influence will be used for deliberately varying the step size. Note that in practice, making certain parameter sweeps can be very tedious because it involves changing physical properties. As an example, Figure 6 shows the effect of introducing a small time-shifting to the actuation plate. Future work will concentrate on finding optimal parameters, improving the device properties and control design.

References

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[1] μSPAM is the main project and stands for: Micro Scanning Probe Array Memory

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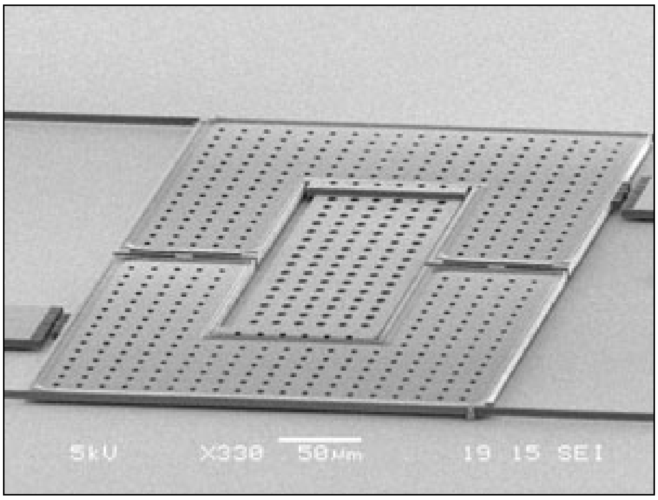

Figure 1: *1D-version of the µWalker used for modeling.*

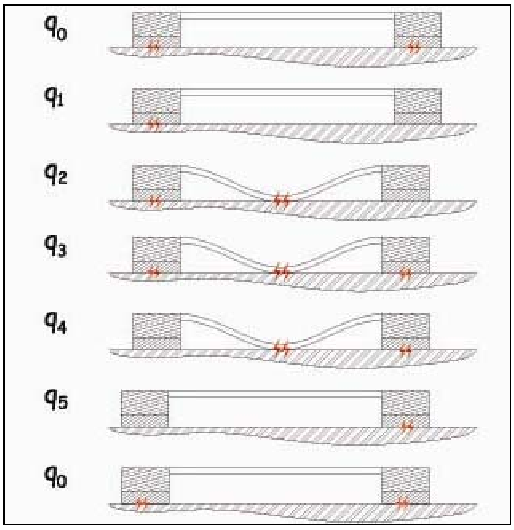

Figure 2: Step sequence of the µWalker.

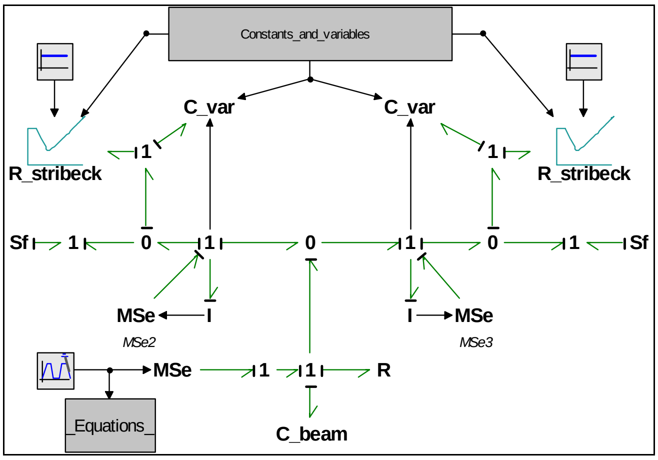

Figure 3: *20-SIM model of the µWalker*.

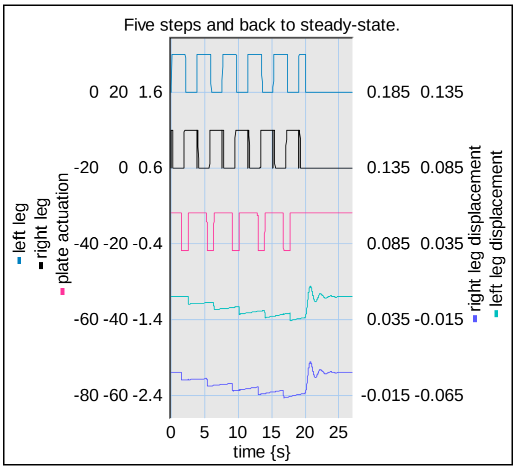

Figure 4: *Simulation of five sequential steps.*

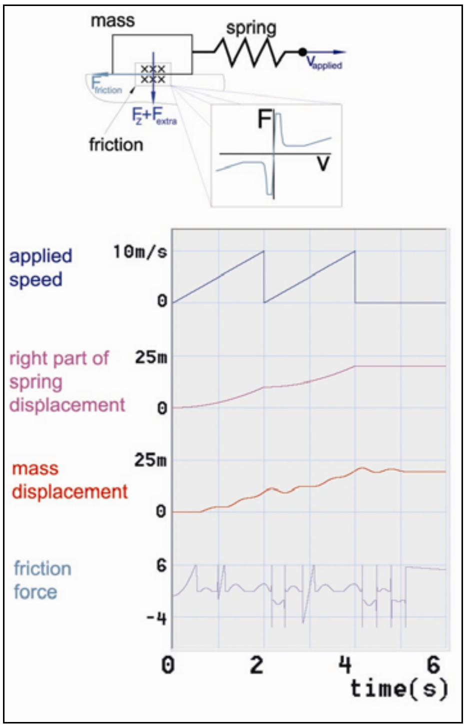

Figure 5: *Modeling of the stick-slip phenomenon.*

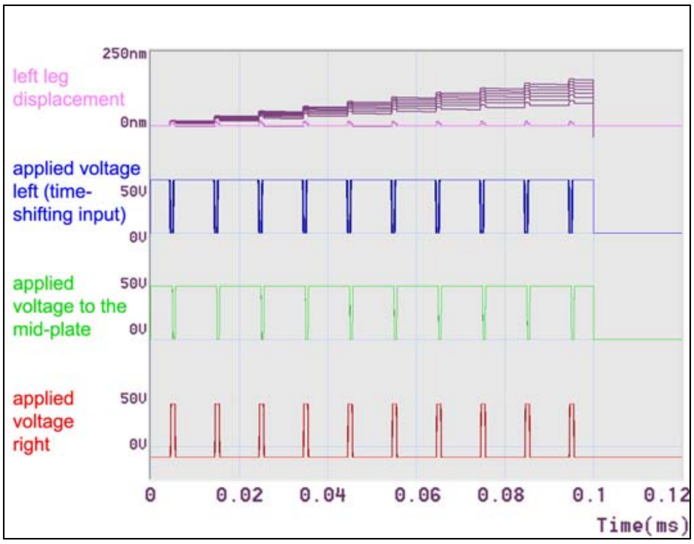

Figure 6: *Time-shifting of the input 'applied voltage left' is here used for step size control.*