Hardware Generation from Simulink Models

Subject: Elektro- und Kommunikationstechnik
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This thesis presents an environment for rapid prototyping on Field Programmable Gate Arrays (FPGAs) from Simulink models. Its main purpose is to allow students to implement control designs in FPGA hardware without the need for a deep understanding of hardware specific languages or toolchains. The developed environment is used to implement a Model Predictive Controller for a PMDC motor. The tremendous computing capacity of the FPGA is used to reach high sampling frequencies which yield a controller operating close to the theoretical optimum.

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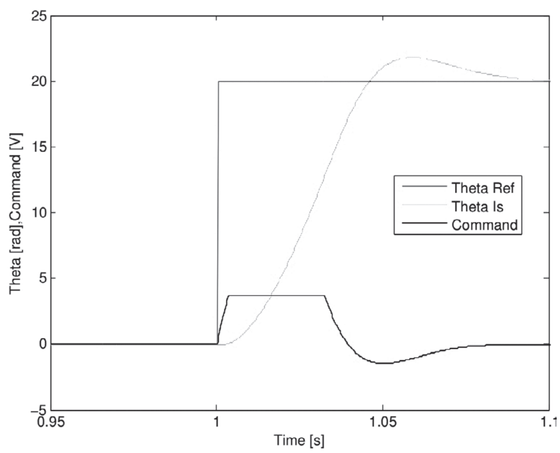
FPGAs realize custom hardware in reconfigurable logic and reach enormous computing capacity through the high level of specialization and parallelism. The design process however requires specialized knowledge in concepts, languages, and tools.

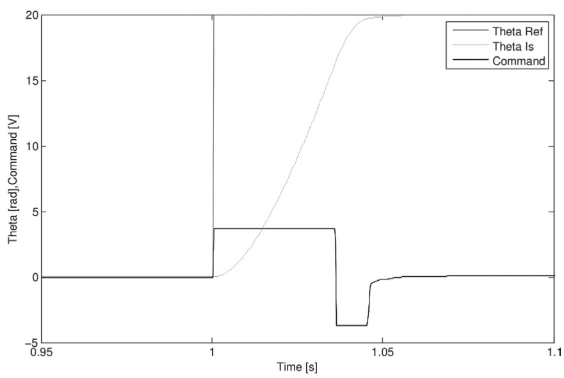
We implement an automated design flow from Simulink models down to the Gecko FPGA platform, which is a design of the HuCE – microLab. The system is used in control courses to allow the implementation of controller designs in custom hardware at the touch of a button.

The system bases on the code generation capabilites of the Simulink HDL – coder product. With our custom Simulink library we provide a set of prepared functionalities and model templates. Based on these library elements, the student can focus on the main task – the controller design. The Simulink model builds the interface to the automated implementation flow: Code generation, integration in the runtime environment, synthesis, and finally the download to the hardware are completely hidden behind a single ‹Run› button. The provided datalogger is able to capture signals in the design with up to 6 MSamples / s and uploads data to the host where it is analyzed with Matlab. Our system therefore enables an iterative design process: Design and simulation in Matlab, test on real hardware, offline data analysis and refinement of the initial design based on the test results. In a second part of this thesis we use this system to implement a novel position controller for a PMDC motor:

Model Predictive Control (MPC) is a comparatively new approach in control theory which takes a model of the plant to be controlled to predict its future behavior based on measured inputs and the known control output. An online constrained optimization is performed to minimize the position error, yielding the optimal feasible voltage output to the motor on each timestep. The observer, controller, and optimization parts are all formulated as matrix mulitplications which can be computed very efficiently with custom hardware. Our design performs 35 prediction and optimization steps in every cycle and runs at 400 kHz. Figure 2 illustrates the results of the given MPC implementation, Figure 1 shows the results of a state-space controller in comparison. One clearly sees that the prediction gives very fast controller response while at the same time guarantees a zero overshoot.



Step response state-space Controller



Step response Model Predictive Controller