Design Methodology for an Embedded System for High-Performance Computing

Wolfgang Fengler, Bernd Däne, Vesselka Duridanova

Ilmenau Technical University, Germany
Where is Ilmenau?

[Map showing locations of Frankfurt, Hamburg, Berlin, Munich, and Ilmenau in Germany]
Topics

1. Introduction and Overview
2. Design of the Computer System
3. Example Model
4. Simulation Results
5. Summary

Parts of this work were and are supported by the Thuringian Ministry of Science, Research and Art (FKZ B509-00002) and by the German Research Council (SFB 622).

Most figures are taken from: MLDesigner, Copyright (c) 2003 MLDesign Technologies, Inc. All rights reserved.
1. Introduction and Overview

- **Nano positioning and measuring machines:**
  - Machines for fast positioning and position determination with nanometer and subnanometer resolutions

- **Examples of application:**
  - Manufacturing and assembly of very small parts
  - Measurement on semiconductor wafers
  - Atomic Force Microscopes (AFM)
Principle of an Atomic Force Microscope
(From a project team at Ilmenau Technical University)
Operation Details

- Position measurement by laser beam interference (multiple axis)
- Closed loop control of position
- Very fast calculation of filter and control algorithms by embedded DSP system
Picture of the Machine
Simplified Flow of Signals

Mechanical/optical system

- Sensors
- Controlled system
- Actuators

Computer system

- Setpoints
- Control algorithms
- Preprocessing
- Filtering and formatting
- Output
2. Design of the Computer System

- Multi processor system with very fast DSPs (Texas Instruments TMS320C67xx)
- Proprietary real time operating system (with multiple scheduling strategies)
- Management of high sample rates
- Model based design methodology
Model based design methodology

- Includes embedding environment
- Multi domain modelling
- Combination of different models
- Continuous design flow towards implementation
- Modular design
- Integration into design tool suite
Model Structure

Simulation model (all domains possible)

Mechanical/optical system

Computer system

„Instrumentation“

(Stimulation and display)

Implementation model (domains restricted)
Steps in the Design Process

- Signal flow model of whole system
- Behavioral model of operating system
- Generating software from the model
- Verification and validation

Modelling tool under consideration:
**MLDesigner®** from MLDesign Technologies, Inc.

*MLDesigner: Copyright (c) 2003 MLDesign Technologies, Inc. All rights reserved.  www.mldesigner.com*
MLDesigner Basics

- Hierarchical multi domain modeling framework
- Covers module, system and strategy („mission“) levels
- Combines numerous modeling domains (discrete and continuous paradigms)
- Capabilities for simulation, design check, code generation, export
- Derived from well-known Ptolemy tool (University of Berkeley)
MLDesigner Sample Workspace
3. Example Model

First result: Example model for an Atomic Force Microscope

- Modelled with MLDesigner
- Combines discrete and continuous parts
- Detailed dynamical simulation
- Equipped with elements for stimulation and display
Top Level of Model
Module 'nano_scanner'
Module 'laser_noise'
Module 'filter_dig_pos'
Module 'dig_interpolator'

The diagram illustrates the connections and calculations involved in the module 'dig_interpolator'. It includes inputs 'Sin_in' and 'Cos_in', and outputs 'dig_Sin_out' and 'dig_Cos_out'. The module performs operations such as sine, cosine, and XOR calculations to generate the outputs.

1. **sin 0°**
   - Connected to 'testlevel#1' and 'xor'
   - 'testlevel#1' connected to 'dig_Sin_out'

2. **cos 90°**
   - Connected to 'testlevel#2' and 'xor'
   - 'testlevel#2' connected to 'dig_Cos_out'

3. **sin 45° + cos 45°**
   - Through 'Gain#5' and 'Add.input=2#3'
   - Connected to 'testlevel#3' and 'xor'
   - 'testlevel#3' connected to 'dig_Sin_out'

4. **-sin 135° - cos 135°**
   - Through 'Gain#7', 'Add.input=2#4', 'Gain#3'
   - Connected to 'testlevel#4' and 'xor'
   - 'testlevel#4' connected to 'dig_Cos_out'

This diagram showcases the complex interconnections and calculations that are part of the module 'dig_interpolator' for high-performance computing.
Module 'up_down_count'
Module 'position_arctan'
4. Simulation Results

- Validation of overall function
- Visualization of the behavior of control loops
- Examination of the influence of different error sources
- Simple variability
Position Values vs. Time
Enlarged Detail
Reconstructed Surface Topology
Detail Including Noise Error

![Graph showing position values over time with different axes and time intervals.](image)
Position Values With Phase Error
5. Summary

Modelling of the whole system has been demonstrated.

Next steps:

- Methodology for software implementation
- Support for multiprocessor systems
- Consideration of limited resource such as computing power
- Inclusion of models for the operating system
- Inclusion of models from external sources
- Validation and verification methods
Contact

Prof. Dr. Wolfgang Fengler  
Ilmenau Technical University  
Dept. of Computer Architectures  
P.O. Box 100565  
98684 Ilmenau, Germany  

Phone: +49-3677-69-2825  
Wolfgang.Fengler@tu-ilmenau.de  
http://tin.tu-ilmenau.de/ra/