Prototyping Electric Drive Control
Maximum Performance and Quick Design
Michael Strugholz, Munich, November 20, 2019
Agenda

1. Introduction
2. Processor-Based Prototyping
3. FPGA-Based Prototyping
4. Customers application
5. Summary
Controller Prototyping – Identified Trends

- **Enhanced energy density** by means of miniaturizing power electronics
- **Increased switching frequencies**
  - DC/DC Converters $f_{SW} > 100$ kHz
  - Drive Inverters $f_{SW} > 20$ kHz
- **Increased complexity of applied topologies** requires more switches
  - Parallel and interleaved structures
  - Multilevel architectures
- **Increased controller complexity**
  - Stricter fail-safe requirements
  - Failback routines e.g. Limp Home mode
Electric Motor Control – Real Environment

- **Controller**
- **Power module**
- **Motor**
- **Sensors**
  - Measurement signals
  - Voltage
  - Current and position

*Picture: Infineon, LEM, Heidenhain*
Electric Motor Control – Rapid Control Prototyping (RCP)

Controller

Power module

Motor

Sensors

TargetLink

Measurement signals

Voltage

Current and position

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Electric Motor Control – Rapid Control Prototyping (RCP)

Control signals

Power module

Voltage

Motor

Measurement signals

Sensors

Picture: Infineon

Picture: LEM, Heidenhain

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Electric Motor Control – Rapid Control Prototyping (RCP)

- Control signals
- Voltage
- Power Module
- Power Grid
- Measurement signals
- Current and voltage
- Sensors
- Picture: Infineon
- Picture: LEM
Electric Motor Control – Rapid Control Prototyping (RCP)
Processor based prototyping
SCALEXIO-Based System: Development Process

Design, simulation, and analysis processor and FPGA models on a PC

I/O connection via ConfigurationDesk®

Monitoring, tuning

Implementation on RT hardware

Real-time simulation and verification in a real environment
Why Rapid Control Prototyping?

- Test and run new ideas in a realistic environment
- Use a high-performance system with virtually no restrictions
- Implement your Simulink®/Stateflow® model at the click of a button
- Get convenient access to all relevant data during validation
Implementation Software – ConfigurationDesk

Separate model implementation and I/O configuration

- Simulink, FMI, V-ECU, etc.
- golden model
- reuseable I/O configuration
- better overview, multiselection
Model Function View Set
Rapid Control Prototyping Systems

- MicroLabBox
- MicroAutoBox
- AutoBox
- SCALEXIO LabBox
- Solutions

Off-the-shelf

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Full Range of Products – Development

Development of electric motor and power electronics controls

- In-vehicle and laboratory use
- Variety of interfaces
- Flexible PWM generation
- High computation power
- Powerful FPGAs
- Signal conditioning and power stages
- Comprehensive software support
FPGA based prototyping
How to increase Control Performance?

- No delay for task handling
- No communication delay
- Calculate in the nanoseconds range
- Real parallel computing
- Customized I/O behavior
FPGA Technology - Architecture
The Xilinx DSP Blockset

Slice
AddSub
Mult
Delay
Rotational
Convert
Single Port RAM
Shift
Gateway In
System Generator
Gateway Out
Electric Motor Control – Rapid Control Prototyping (RCP)
Xilinx blockset based library for add on functionality
Control Algorithm for FPGA Implementation

Slow speed control loop (e.g., 1kHz)

Fast current control loop (e.g., 200 kHz)

Processor → BUS → FPGA

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FPGA-Based RCP - XSG Libraries for Prototyping

- XSG Utilities
- XSG AMC
- User Design
- RTI FPGA
- MicroAutoBox II/III
- MicroLabBox
- SCALEXIO
Customers application
Model-Predictive Control (MPC) of Electric Drives Using Parallel Computing on FPGAs

Finite-control set MPC:
Find optimal switching pattern

\[ J(e, u) = \sum_{i=0}^{n} f(e, u) \to \min \quad u_{\text{max}}, i_{\text{max}} \]

Possible voltage vectors \(2^3 = 8\)
Model-Predictive Control (MPC) of Electric Drives Using Parallel Computing on FPGAs

- **dSPACE processor board**
  - Cycle time: 100 µs
  - Rotor position measurement
  - State-model calculation
  - Providing of the state-model

- **dSPACE FPGA board**
  - Cycle time: 5 µs
  - Measurement of motor current and DC-link voltage
  - Calculation of the best voltage vector
  - Gate signal output to the inverter

- **Plant model updates for accurate control**

- **Parallel processing on FPGA**

- **dSPACE processor board**
  - IOCNET

- **dSPACE FPGA board**
  - Calculation of the best voltage vector
Model-Predictive Control (MPC) of Electric Drives Using Parallel Computing on FPGAs

### dSPACE processor board
- **Cycle time:** 100 µs
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- Setpoint
- Vector-MPC
- PI

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Power Electronics and Electrical Drives
Professor Dr.-Ing. Joachim Böcker
Electric Motors – Rapid Control Prototyping (RCP)

**Implementation Software**
Advanced I/O functions for AC motor control design (position encoder, multichannel PWM)

**XSG AC Motor Control Library**
IP library for FPGA-based AC motor control design

**XSG Utils Library**
Essential base functions for enhanced FPGA programming

**Real-Time Hardware**
- Scalable product portfolio for laboratory and in-vehicle use
- Latest processor and FPGA technology

**Rapid Pro**
- In-vehicle power stages *(for electrification purpose)*
  - High-current half-bridge driver modules
    - 6 V…30 V
    - Up to 60 A peak

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**Controller embedding**

**Signal conditioning**
**Key Takeaways**

- dSPACE offers powerful function libraries for processor-based as well as for FPGA-based designs.
- The tool chain provides easy implementation and excellent debug options.
- The channel set is tailored for e-drive control.
- Demo models are available to speed up your work.
- The dSPACE hardware portfolio provides compact systems and modular systems as well as for in-vehicle and laboratory use cases. For the FPGA of the modular system further I/O features are planned.
With us, mobility switches to electric even faster.