MATLAB EXPO 2019

Sviluppare controlli digitali per convertitori elettronici di potenza

Aldo Caraceto
Power Electronic Systems
Power Electronics Applications

- Electric vehicles and charging stations
- Rail
- Renewable energy
- Lighting
Power Converter Control Design Workflow Tasks

- Size inductor, capacitor and understand the behaviour in continuous and discontinuous mode
- Determine power losses and the thermal behaviour of the converter
- Design control algorithm based on time/frequency domain specification
- Implement power electronic controls on an embedded processor
Challenges for Power Electronics Engineer

- Understanding the impact of the power source and load on the operation of the power converter
- Testing embedded software for a complete range of operating and fault conditions
- Designing and implementing digital controls using only SPICE simulator tools
- Catching errors late in a program during software-hardware integration testing
- Qualifying designs to meeting regulatory and industry standards for efficiency, power quality, and safety
Why Simulink for Power Electronics Control?

- Extensive library of sources and loads
  - PV arrays, batteries, motors
- Broad range of power electronics models
  - Average value, fast ideal switching, physics-based
- Advanced control design capabilities
  - Auto-tuning in time & frequency domains for single and multiple loops
- Generation of readable, compact and fast code from models
  - C for microprocessors, HDL for FPGAs
Our Project Today

DC/DC LED Developer's Kit

LED Head Lamp

Fig 1: TMDSDCDCLEDKIT

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Let’s get to it!
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Simscape model for DC-DC Sepic Converter
Simscape model for DC-DC Sepic Converter
Simscape model for DC-DC Sepic Converter
DC/DC Sepic Converter
Open Loop Duty
Recap: Size Inductor, Capacitor and Understand the Behaviour in Continuous and Discontinuous mode.

What we did:
- Use simulation to design DC to DC converters
- Optimize component sizing using simulation driven analysis
Power Converter Control Design Workflow Tasks

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DC-DC Sepic converter with Non-Linear Switching Dynamics
Comparison of N-Channel MOSFET Characteristics With Datasheet
Comparison of N-Channel MOSFET Characteristics With Datasheet
Recap: Determine Power Losses and Simulate Thermal Behaviour of the Converter.

What we did
• Use semiconductor blocks from Simscape Electrical to model the non-linear switching behavior of SEPIC converter
• Leverage the multi-domain simulation capability of Simscape in understanding the thermal dynamics
Recap: Determine Power Losses and Simulate Thermal Behaviour of the Converter.

What we did

• Use semiconductor blocks from Simscape Electrical to model the non-linear switching behavior of SEPIC converter
• Leverage the multi-domain simulation capability of Simscape in understanding the thermal dynamics
New: Convert SPICE models into Simscape components

- Incorporate manufacturer specific behavior into simulation
- Easily parameterize the model
- Combine existing electronic models with other domains (such as thermal), control algorithms, signal processing, all in a single environment
Power Converter Control Design Workflow Tasks

▪ Size inductor, capacitor and understand the behaviour in continuous and discontinuous mode

▪ Determine power losses and the thermal behaviour of the converter

▪ **Design control algorithm based on time/frequency domain specification**

▪ Implement power electronic controls on an embedded processor
DC/DC Sepic Converter
Voltage Mode Control (VMC)
Controlling PID parameters
Step Plot: Reference tracking

**Identified Plant Structure:** Underdamped Pair

Controller was re-tuned using the new plant "Plant1"
Recap: Design Control Algorithm Based on Time/Frequency Domain Specifications

What we did
- Identify plant model from input output simulation data
- Use auto tuning algorithms to tune the control gains
New: Autotune PID Controllers in Simulation or on Hardware

- Use Closed-Loop PID Autotuner block to generate autotuning code and deploy to embedded software

- Estimation experiment is performed without opening the feedback loop

- Use to tune PID controller gains for a plant model in Simulink or for a physical plant
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Fast Code Generation Using Embedded Coder Quick Start

SIMULINK MODEL

QUICK START – 7 Simple Steps

GENERATED CODE
Digital DC/DC Sepic Converter
Voltage Mode Control (VMC)
## Code Generation Report for 'DC_DC_LED_External_2'

### Model Information

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Author</td>
<td>vivekr</td>
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<tr>
<td>Last Modified By</td>
<td>vivekr</td>
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<tr>
<td>Model Version</td>
<td>1.252</td>
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<td>Tasking Mode</td>
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### Configuration settings at time of code generation

### Code Information

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>System Target File</td>
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<td>Hardware Device Type</td>
<td>Texas Instruments-&gt;C2000</td>
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<td>Simulink Coder Version</td>
<td>8.14 (R2018a) 06-Feb-2018</td>
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<td>Timestamp of Generated Source Code</td>
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<td>Location of Generated Source Code</td>
<td>C:\Users\vivekr\Desktop\DC_DC_LED_External_2_ert_rtw\</td>
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<tr>
<td>Type of Build</td>
<td>Model</td>
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<tr>
<td>Objectives Specified</td>
<td>Execution efficiency, RAM efficiency, ROM efficiency</td>
</tr>
</tbody>
</table>
Control Algorithm deployment to TI controller and Parameter Tuning using External Mode
Recap: Implement Power Electronics Control on an Embedded Processor

What we did:
• Verify the controller for various test cases
• Generate code from MATLAB and Simulink models optimized for embedded controllers
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How We Addressed The Challenges

- Understand the impact of the power source and load
- Testing for a complete range of operating and fault conditions
- Designing and implementing digital controls using only SPICE simulator tools
- Catching errors during software-hardware integration testing
- Compliance to industry standards
- Development Time

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Customers routinely report 50% faster time to market
Murata Used Simulink to Model the EMS Controller and Power Electronics, Run simulations, and Generate Production Code

Challenge
Reduce time-to-market for the company’s first energy management system product trial

Solution
Use Model-Based Design with Simulink to model the controller and power electronics, run simulations, and generate production code implemented on Piccolo™ and Delfino™ 32-bit microcontrollers made by TI

Results
- Control software development time reduced by more than 50%
- Defect-free code generated
- Project ramp-up time shortened

Model-Based Design with Simulink enabled us to reduce time-to-market, which was a significant advantage for us. Because we were not expert programmers, modeling and simulating our control design and then generating quality C code from our models was essential to produce a working system as quickly as possible.”

- Dr. Yue Ma, Murata Manufacturing Co., Ltd.
Maggiori Informazioni

- Partecipate alla masterclass “Sviluppo di un sistema di gestione delle batterie con Simulink»

- Visitate la pagina mathworks.com/solutions/power-electronics-control

- Scaricate power electronics control design trial package con il software necessario per effettuare desktop modeling, simulazione e control design