MATLAB EXPO 2019

Sviluppare controlli digitali per convertitori elettronici di potenza

Aldo Caraceto
Power Electronic Systems
Power Electronics Applications

Electric vehicles and charging stations

Renewable energy

Rail

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
Power Converter Control Design Workflow Tasks

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▪ Determine power losses and the thermal behaviour of the converter

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Let’s get to it!
Power Converter Control Design Workflow Tasks

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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

- 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 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

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Controlling PID parameters

PID Tuner: Step Plot: Reference tracking

Controller Parameters:
- P: 0.27328
- I: 38.0456
- D: n/a
- N: n/a

Performance and Robustness:
- Rise time: Tuned = 0.00864 seconds, Block = 0.00342 seconds
- Settling time: Tuned = 0.0382 seconds, Block = 0.0351 seconds
- Overshoot: Tuned = 5.6 %, Block = 32.9 %
- Peak: Tuned = 1.06, Block = 1.05
- Gain margin: Tuned = 47 dB @ 6.8e+05 rad/s, Block = 161 dB @ 3.14e+05 rad/s
- Phase margin: Tuned = 60 deg @ 169 rad/s, Block = 45.7 deg @ 349 rad/s
- Closed-loop stability: Stable, Stable

Controller was re-tuned using the new plant "Plant1"
PID Tuner (Sepic_new_closedloop_tune/MCU/Software/Discrete PID Controller) - Plant Identification

Step Plot: Reference tracking

- Tuned response, Plant1
- Block response, Plant1

Identified Plant Structure: Underdamped Pair

Controller was re-tuned using the new plant "Plant1"
Continuous-time
Discrete-time

Sample time (-1 for inherited): -1
Integrator and Filter methods:

Compensator formula

\[ P + I \cdot T_s \cdot \frac{1}{z - 1} \]

Controller parameters
Source: Internal
Proportional (P): 0.29875551672997
Integral (I): 37.8468024852967

Automated tuning
Select tuning method: Transfer Function Based (PID Tuner App)
Enable zero-crossing detection
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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- **Implement power electronic controls on an embedded processor**
Fast Code Generation Using Embedded Coder Quick Start

SIMULINK MODEL

GENERATED CODE

QUICK START – 7 Simple Steps
Code Generation Report for 'DC_DC_LED_External_2'

Model Information

<table>
<thead>
<tr>
<th>Author</th>
<th>vivekr</th>
</tr>
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<tbody>
<tr>
<td>Last Modified By</td>
<td>vivekr</td>
</tr>
<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

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<thead>
<tr>
<th>System Target File</th>
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<tr>
<td>Hardware Device Type</td>
<td>Texas Instruments-&gt;C2000</td>
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<tr>
<td>Simulink Coder Version</td>
<td>8.14 (R2018a) 06-Feb-2018</td>
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<tr>
<td>Timestamp of Generated Source Code</td>
<td>Thu Jul 12 18:43:08 2018</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>
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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

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