BLDC Motor Controller Development with solidThinking EMBED™
Agenda

• solidThinking EMBED™ Overview
  • Model Based Development Steps
  • EMBED Key Capability
  • Unique Functions

• Motor Driver Development with EMBED
  • Sensorless FOC (InstaSPIN™)
  • BLDC Motor Driver Development with EMBED

• Processor-in-the-Loop
Model Based Development Steps

### Simulation
- **Plant Model**: $\frac{10}{s^2 + 5s + 100}$
- **Controller Model**

### Processor In The Loop (PIL)
- **Plant Model**: $\frac{10}{s^2 + 5s + 100}$
- **Controller Code Gen**
- **Interactive Gains**: 4.2

### Hardware In The Loop (HIL)
- **Plant Model**: $\frac{10}{s^2 + 5s + 100}$
- **Controller Code Gen**
- **Sensors, Actuators, Partial Plant**

**Design the Difference with Digital twin**
solidThinking EMBED™ key Capabilities

✓ Rapid Development of Control Systems
  - Embed’ provide a complete toolchain for embedded control systems development
solidThinking EMBED™ key Capabilities

✓ No Hand-Coding required
  - Embed’s code generator allows user to easily develop target system WITHOUT the need of hand-coding

[Diagram of diagram to code process]
solidThinking EMBED™ key Capabilities

✓ Affordable & Easily Configurable Development Environment

- Providing TI’s C2000 Motor control, InstaSPIN-FOC/MOTION, on-chip peripherals, fixed point & motor block libraries including Motion block libraries
Unique Functions

✓ Extensive Block Libraries for Embedded Systems

- C2000 Motor Control
- InstaSPIN
- On-chip peripherals
- Fixed-point & Motor block libraries
Unique Functions(2)

✓ Diagram-to-Code

- Embed generates efficient & compact ANSI C code for discrete, continuous and hybrid systems. Eg) Code generated for closed-loop motor control runs at 300 KHz on a 150 MHz F28355 MCU with very little memory footprint.
Unique Functions(3)

✓ Scaled, Fixed-Point Algorithms

- Overflow and precision loss effects are easily seen and corrected at simulation time. Auto-scaling speeds fixed-point development, while in-line code generation provides faster target code.
Unique Functions (4)

✓ Target Hardware Support
- Comprehensive target-specific block library lets you easily program on-chip devices
- Support Most of TI C2000 and MSP MCU
Interactive Hardware-In the Loop Simulation

- Plant runs on the host computer in Embed while the control algorithm runs in real-time on the target MCU. Real-time communication is performed via a JTAG hotlink. Embed also supports PIL-synchronous communication mode that runs the target in lock-step with the simulation for easy verification of embedded algorithms.
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What is FOC?

Field Oriented Control (or FOC) is a technique which allows you to precisely orient the stator magnetic field w.r.t. the rotor magnetic field, usually in an attempt to achieve maximum torque per amp. Control the amplitude and direction of phase current w.r.t rotor flux.
What is FOC?

Low Torque
Medium Torque
High Torque

Torque = \frac{3}{2} P \left[ \lambda_{dr} I_{qs} \right] \uparrow

Constant (for now)

Adjustable

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Commanded \( i_d = 0 \)

Commanded (torque) \( i_q \)

Forward Clarke-Park Transform

\( \theta_d \) Speed

Sensorless Observer

Sensorless FOC

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What is InstaSPIN™-FOC?

- A new advanced field oriented control technique for sensorless control of permanent magnet (salient and non-salient) and Induction motors
- Comprehensive self-commissioning capabilities
- On-line estimation of key variables
- Relatively easy to use by inexperienced users

What are the components of InstaSPIN™-FOC?

- 'FAST': a universal FOC control technique that provides
  - Flux: amplitude of the rotor flux vector
  - Angle: angle of the rotor flux vector
  - Speed: shaft speed of the motor
  - Torque: shaft torque of the motor
- 'Motor ID': a comprehensive 'self-commissioning Technique that gives:
  - Stator resistance estimate (on-line and off-line)
  - Stator inductance estimate
  - Current controller parameter estimates
- 'EPL' (power-warp): a control technique for IM to optimize motor efficiency during partial load operation
InstaSPIN-FOC with Servo Driver

- Immediate fault detection
- Functional limp mode
- Controlled stop instead of coast

PMSM or ACIM

Control Software

Encoder Fault

\[ \Delta \]

\[ \frac{d}{dt} \]

\[ \theta \]

\[ V_a \]

\[ V_b \]

\[ V_c \]

Redundant Failsafe Operation

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Typical architecture of InstaSPIN™-FOC
FOC Simulation

- 10000: Frequency
- 36: Ybus
- 20: Current Limit
- 12: ADC Resolution
- 2000: Speed Reference
- 2048: Encoder tics

Simultaneously Sampled 12-Bit ADCs

Sample

Forward Clarke Transform

Speed Reference

Speed

Initial Speed (RPM)

Motor Load Plot

RPM Plot vs. Time

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Target MCU Core Configuration

Pre-Scaling

Drive controller with FAST

ADC Sim

F28x Config: F28069M@90MHz
TI XDS100v2 USB

CPU:
F28069M

Enable Interactive Peripheral Mode

CPU Speed (MHz):
90

Clock Source:
Internal Oscillator 1

Multiple of Crystal Freq:
9x

HSPCLK:
1/4SYSCLK

LSPCLK:
4/4SYSCLK

JTAG connection:
TI XDS100v2 USB

Control Clk Src:
32 bit timer 2

EPWM Interrupt Event:
CTR = 0

Control Clk Prescale:
1

Ctrl Clk Count Mode:
Down

DLL/xd Version:
VisSim/EDC for F280X v140 Build 320

OK  Cancel  Help
Target MCU Peripherals Configuration

[Diagram of MCU peripherals configuration with various connections and properties configurations.

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Code Generation & Compiler
FOC Based BLDC Motor Speed control

measured phase current 1A/div
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Thanks.