Optimized Motor Control Applications: from idea to deployment with NXP Model-Based Design Toolbox

Razvan Chivu

Stefan Cinipeanu

MATLAB EXPO
AGENDA

1. **NXP Software and Tools** Enablement

2. **NXP’s Model-Based Design Toolbox** Introduction

3. **NXP’s Motor Control Solution with S32K39x**

4. Model-Based Design Toolbox for **Motor Control Applications**
From Virtual Vehicle to All-Electric Off-Road UTV in Less Than a Year

Going Green with an All-Electric Utility Task Vehicle

Vanderhall Motor Works’ Brawley™ is an all-electric utility task vehicle (UTV). Also known as side-by-sides, UTVs are off-road vehicles popular with recreational users, farmers, and hunters. With 303 horsepower and a 140-mile driving range, the Brawley is designed to give users a powerful yet environmentally friendly ride over sand dunes and rocky terrain.

The Vanderhall team faced its own bumps and obstacles when it started its design process. Vanderhall’s conventional gasoline-powered vehicles were based on a General Motors® powertrain. The engineers started by swapping the internal combustion engine with another vendor’s electric powertrain hardware and software. Although EV powertrains are simpler with fewer components—just the battery, inverter, and electric motor—integrating the separate systems did not work out as the engineers anticipated.

“We needed the electric powertrain to communicate with all the other modules and controls from General Motors, such as the power steering and the anti-lock brakes,” says Christopher Johnson, CTO of Vanderhall. “None of the components communicated well. We ended up with a vehicle that was hard to drive.”
A POSITION OF STRENGTH TO BETTER SERVE OUR 26,000+ CUSTOMERS

We accelerate breakthroughs that advance the world through our semiconductor technology leadership.

EMPLOYEES IN

30+ COUNTRIES

$13.21B
Annual Revenue ¹

~31,000
EMPLOYEES

9,500
Patent Families

~11,000
Engineers

60+
Year History

~31,000
Headquartered in Eindhoven, Netherlands

¹ Posted revenue for 2022 – Please refer to the Financial Information page of the Investor Relations section of our website at www.nxp.com/investor for additional information.
Documentation
- Reference Manuals
- Application Notes

Real-Time Drivers
- AUTOSAR MCAL
- Non AUTOSAR SDK

SW Libraries
- ex. AMMCLIB

Reference Designs

Tools
- Debugger
- Toolchains
- Configuration Tools
- Real-time Monitoring

NXP SOFTWARE AND TOOLS ENABLEMENT – THE ECOSYSTEM
Images presented are for illustration purposes only and may not be an exact representation of the product – their purpose is just exemplification of a concept.
S32 DESIGN STUDIO IDE – CAPABILITIES AND TOOLS

S32 Design Studio IDE

Pins Tool

Clocks Tool

Peripherals Tool
Images presented are for illustration purposes only and may not be an exact representation of the product – their purpose is just exemplification of a concept.
FREEMASTER - DATA VISUALIZATION
NXP SOFTWARE AND TOOLS ENABLEMENT

Documentation
- Reference Manuals
- Application Notes

Real-Time Drivers
- AUTOSAR MCAL
- NXP AUTOSAR SDK

SW Libraries
- eM CLI

Tools
- IDE, Debugger
- Toolchains
- Configuration Tools

Reference Designs

S32 Design Studio – IDE – Debugger - Toolchains

Pins Tool
Clocks Tool
Peripheral Tool
FreeMASTER Lite

FreeMASTER MCAT

Images presented are for illustration purposes only and may not be an exact representation of the product – their purpose is just exemplification of a concept.
Images presented are for illustration purposes only and may not be an exact representation of the product – their purpose is just exemplification of a concept.
NXP SOFTWARE AND TOOLS ENABLEMENT

MathWorks ECOSYSTEM – MATLAB / Simulink

REAL-TIME MONITOR + DEMO TOOLS

CONFIG-BUILD-DEBUG TOOLS

REAL-TIME DRIVERS

HARDWARE

S32 Design Studio
IDE – Debugger - Toolchains

Model-Based Design Tools for Simulink

FreeMASTER MCAT

FreeMASTER Lite

Images presented are for illustration purposes only and may not be an exact representation of the product – their purpose is just exemplification of a concept.
CODE GENERATION FLOW

Build

.mdl/*.slx

EBtresos .mex

MBDT

*Config/generate

*Config

RTD (drivers, linker …)
AMMCLIB
FreeMASTER

BUILD

*_ert_rtw

Simulink model > C src
MakeFile

*Config

RTD (drivers, linker …)
AMMCLIB
FreeMASTER

*.elf/*.bin
NXP SOFTWARE AND TOOLS ENABLEMENT - MBDT SOFTWARE AND TOOLS

- MathWorks ECOSYSTEM – MATLAB / Simulink
- MBDT MODEL-BASED DESIGN TOOLS
- REAL-TIME MONITOR + DEMO TOOLS
- CONFIG-BUILD-DEBUG TOOLS
- REAL-TIME DRIVERS
- HARDWARE

- Design
- Prototype
- Deploy
- Integrate
- Test

✓ FAST – Time To Market
✓ Hardware independent simulations
✓ Easy To Use-Reuse
ENHANCED TIME PROCESSOR UNIT

Cortex M7 CPU

- eTPU
- SW Resolver
- Analog Sensing
- FOC
- PWMM
S32K39X MOTOR CONTROL CONFIGURATION USE-CASES

CPU – Cortex M7

FOC

eTPU

SDADC

SAR-ADC

PWM

eFlex PWM

SW resolver

currents, bus voltage, resolver signals

PWM

CPU – Cortex M7

FOC

eTPU

SDADC

SAR-ADC

PWM

SW resolver

currents, bus voltage, resolver signals

CPU – Cortex M7

FOC

eTPU

SDADC

SAR-ADC

PWM

SW resolver

currents, bus voltage, resolver signals
S32K39X MOTOR CONTROL ETPU RESOLVER – HARDWARE CONFIGURATION

3PHLV PWR Board

MC33937 predriver

PWM commands

SAR-ADC

BCTU

eFlexPWM

LCU

eDMA

FOC

Cortex M7

SW RESOLVER eTPU

CoolFlux® DSP SD-ADC

SGEN

XS32K396-BGA-DC

Phase currents
DC bus voltage

Resolver
S32K39X MOTOR CONTROL ETPU RESOLVER – HARDWARE CONFIGURATION

FOC

Cortex M7

Actuate Motor Phases

Analog Sensing SW Resolver

Resolver

3-ph inverter
S32K39X MOTOR CONTROL ETPU RESOLVER – SOFTWARE ARCHITECTURE

FOC

Cortex M7

Flowchart diagram showing the software architecture with states INIT, READY, RUN, FAULT, CALIB, and ALIGN.
S32K39X MOTOR CONTROL ETPU RESOLVER – SOFTWARE ARCHITECTURE

FOC

Cortex M7

Analog Sensing ISR

Get Measurements

Fault Detection

State Machine Execution

Clear Interrupt

event = e_fault
NXP MOTOR CONTROL TOOLS WORKFLOW

S32 Design Studio IDE

Application Source Code

MBDT

Application static configuration

C Drivers Peripherals

Real-Time Drivers

Configuration Tools

AMMCLIB

Precompiled Library

C Drivers Configuration Structures

Auto Read Configuration Structures

C Drivers Peripherals

Real-Time Drivers

Configuration Tools

AMMCLIB

Precompiled Library

C Drivers Configuration Structures

Auto Read Configuration Structures

C Drivers Peripherals

Application static configuration

Application Simulink Model

Export generated code to S32DS

Flash

Real-Time Communication

NXP MOTOR CONTROL TOOLS WORKFLOW

MATLAB & Simulink

Model-Based Design Toolbox

FreeMASTER

Real-Time Communication

Complie

Generated Application Source Code
Images presented are for illustration purposes only and may not be an exact representation of the product – their purpose is just exemplification of a concept.
Explore all options:
1. Check HW and SW setup
2. Check this model setup
3. Generate Code, Build & Deploy on EVB
4. Open the FreeMASTER project

Initialization:
- Initialize

Device_Init

System Initialize
- MBD_State
- MBD_Event

Actions:
- Hardware Interrupt Callback
  - Peripheral: DMA
  - Interrupt All_ISR
  - IRQ Handler

AnalogSensing_Interrupt

Model Source
- PIT_ISR
- VariableDefinition

Model Source
- MCAT_Init
- FaultDetection

Model Source
- FocFastLoop
- FocSlowLoop

eDMA_ISR
ADDITONAL RESOURCES & SUPPORT

MBDT Beginner's Guide

W1: MBDT Introduction
W2: How-To SPI
W3: How-To CAN
W4: How-To PWM
W5: How-To LIN
W6: How-To PIL
W7: How-To Timers

Co-hosted Webinars
Motor Control: S32K
Motor Control: i.MX RT
Motor Control: BLDC/PMSM
Motor Control: Design Application
Code Generation and Verification
Speed Up Applications
Development with MBDT
AUTOSAR SW on S32K1/MPC
AUTOSAR SW on S32K3
Deploying BMS algorithm on S32K1
Deploying Deep Learning SOC algorithm on S32K3
Vision
FreeMASTER

PMSM Control Workshop
Course Main Page
M1: Environment Setup
M2: PMSM and FOC
M3: System Partitioning
M4: PWM Modulation
M5: V/f Scalar Control
M6: Current Sensing
M7: Torque Control
M8: Speed Control
M9: Position Observer
M10: Sensorless Speed Control

BLDC Control Workshop
Course Main Page
1. Introduction
2. Application Partitioning
3. Input Commands
4. BLDC Motor Theory
5. Hall Sensors
6. Commutation
7. Commutation Algorithm
8. Power Stage Config
9. Open Loop Control
10. Speed Estimator
11. Closed Loop Control
12. Motor Control System
Thank you