MOTOR CONTROL SOLUTIONS BASED ON S32K1 MCUS

The S32K1 family of 32-bit AEC-Q100 qualified MCUs combines a scalable family of Arm® Cortex®-M0-based microcontrollers built on long-lasting features with a comprehensive suite of production-grade tools. S32K1 MCUs are included in NXP’s Product Longevity Program, guaranteeing a minimum of 15 years of assured supply.

S32K1 VALUE PROPOSITION FOR MOTOR CONTROL

SCALABLE MCU PLATFORM

- Hardware- and Software- compatible MCU family
- 48 MHz Arm Cortex-M0+ core or up to 112 MHz Arm Cortex-M4F core
- Flash memory: from 128 KB up to 2 MB
- QFN, LQFP, MAPBGA packages, from 32 to 176 pin count
- CAN FD, FlexIO, and QSPI Ethernet and serial audio interfaces
- AEC-Q100 qualified:
  - Grade 0 = -40° C to +150° C
  - Grade 1 = -40° C to +125° C
  - Grade 2 = -40° C to +105° C
- Functional Safety compliant: ISO 26262 up to ASIL B
- Cryptographic Services Engine compressed (CSEc) security engine: AES-128 and SHE compliant

MOTOR CONTROL COVERAGE

- Engineered tools for Brushed DC motors, 3-phase PMSM, and 3-phase BLDC motor control targeting body and chassis
- Dedicated peripherals set for rapid motor control loop implementation: FlexTimer (FTM), TRGMUX, Programmable Delay Block (PDB), Analog to Digital Converter (ADC), and Analog Comparator (CMP)

COMPREHENSIVE MOTOR CONTROL ECOSYSTEM

- Diverse hardware solutions supporting motor control applications
- S32K1 software ecosystem with production-ready algorithm library:
  - AMMCLIB set
  - FreeMASTER and MCAT tool
  - Model-Based Design Toolbox (MBDT)
- Dedicated technical support and on-line community

nxp.com/S32K1MCdevKits
**S32K1 PRODUCT OVERVIEW**

S32K1 provides a scalable platform with high hardware and software compatibility to address various motor control techniques and applications.

### S32K116 vs. S32K118 Common Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>S32K116</th>
<th>S32K118</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm® Cortex®-M0+</td>
<td>128 KB Flash</td>
<td>256 KB Flash</td>
</tr>
<tr>
<td></td>
<td>17 KB SRAM</td>
<td>24 KB SRAM</td>
</tr>
<tr>
<td>I/Os</td>
<td>up to 42 I/Os</td>
<td>up to 58 I/Os</td>
</tr>
<tr>
<td>eDMA</td>
<td>4 channel eDMA</td>
<td>1 x FlexCAN with 1 x FD</td>
</tr>
<tr>
<td>SRAM</td>
<td>17 KB SRAM</td>
<td>24 KB SRAM</td>
</tr>
<tr>
<td></td>
<td>32 KB SRAM</td>
<td>64 KB SRAM</td>
</tr>
<tr>
<td></td>
<td>128 KB SRAM</td>
<td>256 KB SRAM</td>
</tr>
<tr>
<td></td>
<td>256 KB SRAM</td>
<td>512 KB SRAM</td>
</tr>
</tbody>
</table>

### S32K142 vs. S32K144 vs. S32K146 vs. S32K148

<table>
<thead>
<tr>
<th>Feature</th>
<th>S32K142</th>
<th>S32K144</th>
<th>S32K146</th>
<th>S32K148</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm® Cortex-M4F</td>
<td>256 KB Flash</td>
<td>512 KB Flash</td>
<td>1 MB Flash</td>
<td>2 MB Flash</td>
</tr>
<tr>
<td></td>
<td>32 KB SRAM</td>
<td>64 KB SRAM</td>
<td>128 KB SRAM</td>
<td>256 KB SRAM</td>
</tr>
<tr>
<td>I/Os</td>
<td>up to 49 I/Os</td>
<td>up to 89 I/Os</td>
<td>up to 128 I/Os</td>
<td>up to 156 I/Os</td>
</tr>
<tr>
<td>eDMA</td>
<td>16-channel eDMA</td>
<td>2 x FlexCAN with 1 x FD</td>
<td>3 x FlexCAN with 2 x FD</td>
<td>3 x FlexCAN with 3 x FD</td>
</tr>
<tr>
<td>SRAM</td>
<td>32 KB SRAM</td>
<td>64 KB SRAM</td>
<td>128 KB SRAM</td>
<td>256 KB SRAM</td>
</tr>
<tr>
<td></td>
<td>256 KB SRAM</td>
<td>512 KB SRAM</td>
<td>1 MB SRAM</td>
<td>2 MB SRAM</td>
</tr>
</tbody>
</table>

### Motor Control Peripherals

<table>
<thead>
<tr>
<th>Feature</th>
<th>S32K142</th>
<th>S32K144</th>
<th>S32K146</th>
<th>S32K148</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADCs</td>
<td>1 x 13-ch. 12-bit ADC</td>
<td>2 x 16-ch. 12-bit ADC</td>
<td>2 x 16-ch. 12-bit ADC</td>
<td>2 x 16-ch. 12-bit ADC</td>
</tr>
<tr>
<td></td>
<td>1 x 16-ch. 12-bit ADC</td>
<td>2 x 16-ch. 12-bit ADC</td>
<td>2 x 24-ch. 12-bit ADC</td>
<td>2 x 32-ch. 12-bit ADC</td>
</tr>
<tr>
<td></td>
<td>1 x PDB</td>
<td>2 x PDB</td>
<td>4 x 16-bit FTM (32-ch.)</td>
<td>6 x 16-bit FTM (48-ch.)</td>
</tr>
</tbody>
</table>

### S32K1 MOTOR CONTROL LINE-UP

#### S32K1 vs. MC Techniques Line Up

- 3ph PMSM FOC Sensorless
- 3ph PMSM FOC Encoder / Resolver
- 3ph BLDC 6-step Sensorless
- 3ph BLDC 6-step HALL
- Dual DC motor servo
- DC and Stepper Motor Dual Direction

#### S32K1 vs. Typical MC Applications Line Up

- Belt Starter Generator
- Crankshaft Motor Generator
- Transmission Actuators
- Pumps
- Engine Cooling
- HVAC Blower
- Window Lift (3ph PMSM)
- Sunroof (3ph PMSM)
- Trunk Opener (Dual DC motor)
- Window Lift (DC motor)
- Seat Control (DC motor)
- Mirror Control (Stepper motor)

**nxp.com/S32KMCdevKits**
AUTOMOTIVE MATH AND MOTOR CONTROL LIBRARY (AMMCLIB) SET
- Precompiled software library including NXP-patented control math algorithms
- Automotive production-ready software (SPICE Level 3, CMMI and ISO 9001/TS 16949)
- Delivered as bit-accurate models for MATLAB®/Simulink® and C code
- Single API across NXP MCUs, simple migration across platforms

MODEL-BASED DESIGN TOOLBOX (MBDT)
- Model-based design environment in MATLAB/Simulink for motor control software on S32K MCUs
- Automatic code generation for S32K1xx peripherals and applications prototyping
- Extensive online community and tutorials available
- Model-based design approach helps to save R&D time and test efforts

FREEMASTER (LITE)
- Real-time data visualization tool for debugging and tuning embedded algorithm during development
- Graphs, tabular grids, and web views embedded directly in the desktop application
- FreeMASTER Lite supports JSON RPC protocol and is able to run on Windows® or Linux® host PC, enabling custom UI on web browsers

MOTOR CONTROL APPLICATION TUNNING (MCAT)
- HTML-based graphical user interface tool, plug-in to FreeMASTER and fully compliant with AMMCLib set API
- Real-time tuning and updating of control parameters

S32K1 ADDITIONAL SOFTWARE
- S32 Design Studio IDE: Eclipse, GCC, and debugger
- Production-grade S32 Software Development Kit (S32 SDK): SPICE Level 3 compliant, MISRA tested
- NXP AUTOSAR® MCAL (QM and ISO 26262 compliant) and OS
- Security firmware – NXP provided
- Core Self-Test Library for functional safety applications
- Production-grade ASIL compliant Real Time Drivers (RTD) support
- Third-party ecosystem support to reduce time-to-market
### PRODUCTS

<table>
<thead>
<tr>
<th></th>
<th>3-Phase Low-Power Motor Control Development Kits</th>
<th>3-Phase High-Power Motor Control Development Board</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MCU</strong></td>
<td>S32K116</td>
<td>S32K144</td>
</tr>
<tr>
<td><strong>Analog</strong></td>
<td>UJA1169 – Mini high-speed system basis chip</td>
<td>TJA1021 – LIN PHY TJA1043 – CAN PHY GD3000 – MOSFET gate Driver for 3-phase motor</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td>3-phase BLDC motor with Hall sensor</td>
<td></td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Up to 100 W</td>
<td>Up to 800 W</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>12 V (10-18 V)</td>
<td>12/24 V (10-36 V)</td>
</tr>
<tr>
<td><strong>Current sensing</strong></td>
<td>Single-, dual-, and triple-shunt</td>
<td></td>
</tr>
<tr>
<td><strong>Position sensing</strong></td>
<td>Hall, encoder</td>
<td></td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td>CAN (FD), LIN, UART, PWM</td>
<td></td>
</tr>
</tbody>
</table>

### HARDWARE

**Motor**
- 3-phase BLDC motor with Hall sensor
- 24 VDC, 9000 RPM, 95 W
- 24 VDC, 4000 RPM, 40 W
- N/A

**Power**
- Up to 100 W
- Up to 800 W

**Voltage**
- 12 V (10-18 V)
- 12/24 V (10-36 V)

**Current sensing**
- Single-, dual-, and triple-shunt

**Position sensing**
- Hall, encoder

**Communication**
- CAN (FD), LIN, UART, PWM

### MOTOR CONTROL SOFTWARE APPLICATION

**PMSM FOC**
- 3-phase field-oriented control (FOC) with field weakening (FW)
- Sensor (Encoder) or sensorless control (back-EMF observer)
- Single-shunt and dual-shunt current sensing and 3-phase stator current reconstruction

**BLDC Six-step**
- 3-phase 6-step commutation control
- Sensor (Hall) or sensorless control based on back-EMF zero-cross detection method

### TOOLS

**Integrated development environment**
- S32 Design Studio for Arm®

**MCU peripherals settings and control**
- S32K1 SDK and software configuration tool

**Motor control library**
- Automotive Math and Motor Control Library

**Visualization and motor control tuning**
- FreeMASTER and Motor Control Application Tuning (MCAT)
S32K1 MOTOR CONTROL BLOCK DIAGRAMS

FIELD ORIENTED CONTROL (FOC) FOR PMSM MOTOR

S32K1xx

Current Loop

Field Weakening

Current q PI Controller

Current d PI Controller

Inverse Park Transformation d, q → α, β

Forward Clark Transformation α, β → d, q

Back-EMF and Angle Tracking Observer

Sensorless Encoder Sensor

Overall Speed

Overall Torque

Overall Current

Overall Power

S32K1 RESOURCES

S32K1 MCUs
nxp.com/S32K1

S32 Motor Control Development kits
nxp.com/S32KMCdevKits

S32 Design Studio IDE
nxp.com/S32DS

Model-Based Design Toolbox
nxp.com/MBDT

FreeMASTER
nxp.com/FreeMaster

Automotive Math and Motor Control Library
nxp.com/AMMCLib

S32K online support
nxp.com/S32K1community

MBDT online support
nxp.com/MBDTcommunity

nxp.com/S32KMCdevKits

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