Simplify Motor Control Development with S12 MagniV

FTF-AUT-F0079

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Agenda

- Introduction to S12 MagniV Mixed-signal MCUs
- Target motor control applications
- Solutions for DC and BLDC/PMSM motors
- Summary
Introduction to S12 MagniV

S12 MagniV solutions deliver optimal **system cost and physical footprint** for sensor and actuator applications.

- **Reduces PCB Space**
  through Analog and MCU integration

- **Reduces assembly and test cost**
  through fewer components to pick and place

- **Simplifies HW and SW design for motor control applications**
  through production-ready software enablement
A Technology Sweet Spot for Sensor and Actuators

Digital Logic
S12, PWMs, Timers,
SRAM, SPI, SCI, GPIO,
Watchdogs, etc.

High-Voltage Analog
Low Side & High Side Drivers,
Voltage Regulator
LIN/CAN Phy. etc.

Non-Volatile Memory
Flash, EEPROM

High volume
Low leakage 180nm CMOS+NVM

40V UHV devices
Integration Beyond the MCU

Our **S12 MagniV** portfolio simplifies system design with the integration of High-Voltage (HV) analog features onto MCUs for automotive applications.

- **MM912/S12VR** Window Lift
- **S12ZVM** BLDC Motor Control
- **S12ZVH** Instrument Cluster
- **S12ZVL** LIN Slave Nodes

**Reduced BOM**
**Reduced PCB size**
**Improved manufacturing and quality**
**Efficient motor control**
Shrink Your Application

Traditional Solutions

- Standard MCU
- Multiple analog IC

System in Package

- Saves up 30% space
- Simplifies manufacturing
Manufacturing Benefits

• PCB space typically defines module size
  - Board space savings means less molding/cast

• Fewer components to mount
  - Saving $0.02 to $0.07 per IC depending on pincount, package and tooling

• Fewer test points necessary
  - Integration offers a pre-tested subsystem

• Fewer solder joints
  - Improves quality
Target Motor Control Applications

Or where S12 MagniV solutions are most optimal

- **Automotive or any operating range between 3.5V and 20V**
  - 50W to 1kW motors
  - LIN and CAN communication

- **Relay based DC motors**
  - With S12VR

- **FET-based DC or 3-phase BLDC/PMSM motors**
  - With S12ZVM
## Motor Categories

<table>
<thead>
<tr>
<th>Power Stage</th>
<th>Mechanical Construction</th>
<th>Commutation &amp; Control Technique</th>
<th>Topology Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relay-driven DC motors</td>
<td>Relay-driven DC motors</td>
<td>H-Bridge driven DC motors</td>
<td>Brushless DC Motors (BLDC)</td>
</tr>
<tr>
<td>H-Bridge driven DC motors</td>
<td>Relay</td>
<td>H-Bridge</td>
<td>Permanent Magnet synchronous Motors (PMSM)</td>
</tr>
<tr>
<td>Permanent Magnet synchronous Motors (PMSM)</td>
<td>H-Bridge</td>
<td>H-Bridge</td>
<td>3-phase</td>
</tr>
<tr>
<td>3-phase</td>
<td>3-phase</td>
<td>3-phase</td>
<td>3-phase</td>
</tr>
<tr>
<td>Permanent magnets placed on stator</td>
<td>Permanent magnets placed on rotor</td>
<td>Current conducted coils in stator generate changing magnetic flux vector</td>
<td>Mechanical commutation by brushes in the rotor</td>
</tr>
<tr>
<td>Magnetic poles in rotor generated by current conducted coil</td>
<td>Electronic Commutation takes place in the stator</td>
<td>6-step / block commutation to produce trapezoidal Phase voltage</td>
<td>Sinusoidal / vector control to produce sinusoidal phase voltage</td>
</tr>
</tbody>
</table>

### S12ZVM Target Area

- **Lowest cost**: No mechanical component (reliability, electrification), No Relay noise, PWM speed regulation
- **High Efficiency**: Power to weight ratio, Reliability, Noise
- **Best noise behavior**: High speed & precision, Highest efficiency & torque, Power to weight ratio
<table>
<thead>
<tr>
<th>DC Motors</th>
<th>Relay-driven DC motor</th>
<th>FET-driven DC motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun-roof</td>
<td>Antipinch</td>
<td>No Antipinch</td>
</tr>
<tr>
<td>Window lift</td>
<td>Driver door</td>
<td>Antipinch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Antipinch</td>
</tr>
<tr>
<td></td>
<td>Passenger door</td>
<td>Antipinch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Antipinch</td>
</tr>
</tbody>
</table>
BLDC/PMSM Motors: Market Segmentation

- Cooling Fan
- HVAC Blower
- Liftgate
- 200+W motors
- Water pump
- Sliding doors
- Fuel pump
- Oil pump
- 50-200W motors
- Reduced GDU drive
- S12ZVML/C128/64/32
- CAN
- PWM
- S12ZVM32/16
S12VR Family Concept

- **< 200W Motors**
  - **S12ZVM**
    - 16/32KB; 64pin; 50nC
  - **S12ZVML**
    - 32-128KB; 64pin
      - LIN with PHY, 100nC
  
- **> 200W Motors**
  - **S12ZVMC**
    - 64-128KB; 64pin
      - 2nd 5V VREG for ext CAN, 100nC
  - **S12ZVML**
    - 32-128KB; 64pin
      - LIN with PHY, 100nC
  - **S12VR**
    - 48K-64KB; 32/48pin
      - LIN with PHY; LS drivers
  - **S12VR**
    - 32/16kB, 32pin
      - LIN with PHY; LS-driver

- **H-Bridge driven DC-motors**
- **Brushless DC Motors**
- **Relay-driven DC-motors**

**LIN applications**
**CAN applications**
**PWM controlled apps**

**High temp option (AEC Grade 0)**

**Switch panel interface**

**Production** | **Execution** | **Planning** | **Proposal**
S12 MagniV Solutions

Complete hardware and software ecosystem to simplify evaluation, development and validation for production

- **S12VR Family**
  For **Relay** driven **DC** motors

- **S12ZVM Family**
  For **BLDC/PMSM FET** driven **Motors**

- **S12ZVM Ecosystem**
  Production-ready software enablement
S12VR for Bi-directional DC Motors

Pinout representing functionality,
Physical pins location is not correct
# S12VR Package & Feature Options

<table>
<thead>
<tr>
<th>Product Name</th>
<th>S12VR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Package</strong></td>
<td>32-LQFP</td>
</tr>
<tr>
<td><strong>Status</strong></td>
<td>In design</td>
</tr>
<tr>
<td>Flash Memory</td>
<td>32/16kB</td>
</tr>
<tr>
<td>EEPROM</td>
<td>128B</td>
</tr>
<tr>
<td>RAM</td>
<td>2kB</td>
</tr>
<tr>
<td>High side drivers</td>
<td>1</td>
</tr>
<tr>
<td>Low side drivers</td>
<td>2</td>
</tr>
<tr>
<td>HV inputs</td>
<td>2</td>
</tr>
<tr>
<td>Sensor supply (Evdd)</td>
<td>1</td>
</tr>
<tr>
<td>A/D ext. channels</td>
<td>2 (+2HVIs)</td>
</tr>
<tr>
<td>PWM channels</td>
<td>8 x 8-bit (4x16-bit)</td>
</tr>
<tr>
<td>Timer channels</td>
<td>4 x 16 Bit</td>
</tr>
<tr>
<td>SCI modules</td>
<td>1</td>
</tr>
<tr>
<td>SPI modules</td>
<td>-</td>
</tr>
<tr>
<td>Max. 5V GPIOs</td>
<td>16</td>
</tr>
<tr>
<td>Interrupt/wakeup inputs</td>
<td>8</td>
</tr>
<tr>
<td>Package body size</td>
<td>7x7 mm²</td>
</tr>
<tr>
<td>Pin pitch</td>
<td>0.8 mm</td>
</tr>
</tbody>
</table>

0.8mm pitch allows routing signals between pins for PCB space- & layer-savings
S12ZVM for BLDC Motor Control

**Discrete Solution**

- **VREG (8pin)**
- **LIN phy (8pin)**
- **MCU or DSC (48pin)**
- **Gate Driver (48pin)**
- **Op-amps**

**S12ZVM Solution:**

- ~ 50 fewer solder joints
- - 4 to 6 cm² PCB space

**64pin**

**4cm ~1 ½ in.**
S12ZVML Application Schematic

- **S12Z core**
  - 128 kB Flash
  - 8 kB RAM
  - 512Bytes EEPROM
  - Dual 12bit ADC
- **Temp Sense**
- **Charge Pump**
- **GDU**
  - 3 phase H-Bridge Predriver
  - Current Sense (2 x Op-Amp)
- **LIN Physical Interface**
- **PMF 6-ch PWM**
- **PTU**
- **BDM**
- **Vregs (5V VDD, VLS, VDD sensor)**

**Optional Components**:
- External Oscillator (XTAL/EXTAL)
- 5+4ch Ext. Mux’d with Op-Amps
- +8ch Int. Mux’d with Op-Amps

**Other Important Components**:
- **Power Supply** (+11V, 0V)
- **IO**
  - MISO, MOSI, SCLK, RXD0, TXD0, KWP0, KWP1, IOC0, IOC1, IOC2, IOC3
- **Hallout**
- **AMR/Hall Sensor**
- **Lin GND**
- **BDM**
- **Charge Pump**
- **AMPM0, AMPP0, AMPM1, AMPP1**
- **Shunt0, Shunt1**

**Miscellaneous**:
- **XTAL/EXTAL**
- **VSS1, VSS2, VSSX1, VDDX1, VDDA, VDDF**
- **H0, H1, H2, S0, S1, S2**
- **LG0, LG1, LG2, LS0, LS1, LS2**
- **AMP0, AMP0, AMP1, AMP1, AMP2, AMP2, AMP3, AMP3**
- **VDD, BKGD, VSS1, VSS2, VSSX1, VDDX1, VDDA, VDDF**
- **BCTL**
- **Current Sense**
- **VBS0, VBS1, VBS2**
- **VCP, VHD, EVDD**
- **Hallout**
- **AMR/Hall Sensor**
- **optional**
# S12ZVM Family Feature Set Summary

<table>
<thead>
<tr>
<th>Flash /RAM Size</th>
<th>128 / 8 KB</th>
<th>64 / 4 KB</th>
<th>32 / 2 KB</th>
<th>32 / 2 KB</th>
<th>16 / 2 KB</th>
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<tbody>
<tr>
<td>Connectivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIN</td>
<td>S12ZVML128</td>
<td>S12ZVMC128</td>
<td>S12ZVML64</td>
<td>S12ZVMC64</td>
<td>S12ZVML32</td>
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<tr>
<td>CAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIN count</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>EEPROM (bytes)</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
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<tr>
<td>LIN PHY</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<tr>
<td>2nd VREG</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>GDU (HS / LS)</td>
<td>3 / 3</td>
<td>3 / 3</td>
<td>3 / 3</td>
<td>3 / 3</td>
<td>3 / 3</td>
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<tr>
<td>PWM channels</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>ADC (ext. channels)</td>
<td>4 + 5</td>
<td>4 + 5</td>
<td>4 + 5</td>
<td>4 + 5</td>
<td>4 + 5</td>
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<tr>
<td>MSCAN</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>SCI</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>SPI</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>TIM (IC/OC channels)</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<tr>
<td>External FET Nominal Total Gate Charge (nC)</td>
<td>100-150</td>
<td>100-150</td>
<td>100-150</td>
<td>100-150</td>
<td>50-80</td>
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<tr>
<td>Samples availability</td>
<td>Now</td>
<td>Now</td>
<td>Now</td>
<td>Now</td>
<td>Now</td>
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<tr>
<td>Production release</td>
<td>Q1 2014</td>
<td>Q1 2014</td>
<td>Q1 2014</td>
<td>Q1 2014</td>
<td>Q4 2015</td>
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</table>
S12ZVM Ecosystem – The Complete Solution

Hardware (Evaluation board, target application)

Freescale production software

Freescale enablement software

Third party production software

Customer Application Software

MC ToolBox: Rapid prototyping with Matlab Simulink

FreeMASTER: -Graphical User Interface -Instrumentation

MCAT Tuning Tool

MC Dev Kit Reference Software

LIN 2.1 Drivers

NVM Drivers

CAN/LIN Stack

Autosar OS

Math and Motor Control Libraries:
- Standard optimized math functions and motor control algorithms
- Includes Matlab Simulink Models

Compiler and Debugger

Graphical Init Tool

NVM Drivers

Freescale production software

Freescale enablement software

Third party production software
# S12ZVM Hardware Tools Overview

<table>
<thead>
<tr>
<th>Type</th>
<th>Evaluation Board</th>
<th>Motor Control Development Kit</th>
<th>Mini Eval Board</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>Evaluation and software development for either CAN or LIN target device</td>
<td>Spin a BLDC motor within minutes, for demo and training purposes</td>
<td>Low cost and small 5x9cm board for evaluation and training purposes.</td>
</tr>
<tr>
<td><strong>HW Features</strong></td>
<td>- LIN and CAN interfaces</td>
<td>- <strong>S12ZVML12EVBLIN</strong> with pre-programmed <strong>S12ZVML128</strong> part</td>
<td>- <strong>S12ZVML128</strong> part</td>
</tr>
<tr>
<td></td>
<td>- Onboard BDM-to-USB</td>
<td>- <strong>BLDC motor with Hall-effect sensors mounted on Plexiglas</strong></td>
<td>- LIN connector</td>
</tr>
<tr>
<td></td>
<td>- SCI-to-USB interface</td>
<td>- <strong>PMSM version will also be available</strong></td>
<td>- Onboard BDM-to-USB debug interface</td>
</tr>
<tr>
<td></td>
<td>- Freemaster</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Hall sensor interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Resolver interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- <strong>6 N-channel FET with 10-15A drive capability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Software Package</strong></td>
<td><strong>MTRCKTSBNZVM128_SW</strong></td>
<td><strong>MTRCKTSBNZVM128_SW</strong></td>
<td><strong>MTRCKTSBNZVM128_SW</strong></td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Prototypes now (XS12ZVMx12EVB)</td>
<td>Now for BLDC Q2 14 for PMSM</td>
<td>25FEB14 on Element14 and Freescale websites</td>
</tr>
<tr>
<td><strong>Partnumbers</strong></td>
<td><strong>S12ZVML12EVBLIN</strong> <strong>S12ZVML12EVBCAN</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td><strong>$349</strong></td>
<td><strong>$789</strong></td>
<td><strong>$69</strong></td>
</tr>
</tbody>
</table>
Summary: Simplify Your Design

- One single-chip solution
- One S12 MagniV platform for multiple applications
- Complete hardware and software solution

Please visit the following related sessions:

- FTF-AUT-F0232: Sensorless Field Oriented Control of a PMSM Motor Using S12 MagniV S12ZVM Mixed-Signal MCUs
- FTF-AUT-F0076: Hands-On Workshop: Motor Control Toolbox Overview (Reserved Seat Required)
- FTF-AUT-F0014: Overview of FreeMASTER and RAppID Bootloader