Sub-track II –
Power & Energy Presentation
ST servo drive architecture and new LV & HV servo solutions

Liam PARK
Motor Control Competence Center
STMicroelectronics
1. Market information
2. ST products portfolios
3. Software ecosystem
4. IP
5. LV servo solutions
6. HV servo solutions
Motor control competence center mission

**SYSTEM R&D**
- Hardware reference design, application boards
- Firmware application modules for the ST MC Library
- System solutions

**CUSTOMER SUPPORT**
- Evaluation & training with ST tools
- ST kit product selection (in cooperation with TM)
- Schematics; layout review; tuning (in cooperation with FAE)

**PARTNERSHIP**
- Overall motor control system expertise
- Partnership & new algorithms;
- Customer’s IP porting to ST platforms

**NPP, NSP, GAP**
- Products validation in-application: feedback to divisions
- New product, new solution proposals: specification/roadmap
- Interdivisional/strategic MKT/Joint Labs: information & technology alignment

To **Create and Promote** innovative, convenient and mature motor control system Solutions;

To design and **Partner** with our Regional Customers in Asia

in order to leverage on the whole ST product portfolio for **Industrial Applications,**

in order to boost **revenues growth** in the market segment
Motor control competence center
major focus sectors

<table>
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<th>Home appliances &amp; Air con</th>
<th>Motor drives &amp; servo drives</th>
<th>Power tools &amp; high-end consumer</th>
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<td>High energy efficiency - high power</td>
<td>Position control</td>
<td>High speed motors</td>
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<tr>
<td>New algorithms - AI</td>
<td>Functional safety - predictive maintenance</td>
<td>High integration</td>
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</table>

**Market size**

- **Major home appliances:** 2022 TAM 4.2B$ *
- **Motor drive:** 2022 TAM: 5.1B$ *
- **Power tools:** 2022 TAM 1.2B$ *

* Source: OMDIA: Industrial Semiconductor Market Tracker Q32022
Motor drive market analysis
top CAGR in high end industrial

Motor drives shipment ($M) & CAGR 21-25 (%) *

- **Robotics**
  - CAGR 14.9%

- **Semiconductor machinery**
  - CAGR 9.1%

- **Machine tools**
  - CAGR 8.8%

*Source: Omdia 2022
How can ST help you innovate an industrial motor control system?

- New ST motor control solutions
- In each industrial application
ST product portfolios
STM32 for motor control

STM32H7
Arm® Cortex® -M7 up to 550 MHz
Most powerful Cortex core with double precision FPU
MPU, advanced DSP and L1 cache

STM32G4
Arm® Cortex® -M4 @240 MHz
Best in class core for real-time with single precision
FPU, DSP, MPU and ART Accelerator™

STM32G4
Pure 170 MHz CPU performance (Arm® Cortex®-M4)
with three accelerators

23% CPU load @16 KHz dual FOC @STM32G431
Leading the convergence of analog and digital in motion control

Motion control products & architectures

1. STDRIVE Discrete gate drivers
2. STSPIN32
3. STSPIN & PWD Motion control SiP
STSPIN32G4 SiP
5 ICs in 1, high integration motor control

High integration
STM32G4 + gate drivers + power management
~80% space reduction

High performance
3-phase gate driver
5.5V-75V
1A driving capability

Dual motor FOC Ready
+ STDRIVE101 6-in-1 gate driver

Ultralow power BOR
Down to 15uA lowest consumption

Smart driver
VDS monitoring of the power stage
Programmable VCC output
Protections: SC, UVLO, OL, thermal

Area reduction
up to 80%

STSPIN32G4 vs Discrete Solution

DCDC Converter VFDFPN10
LDO SO8
Gate Driver SO8

MCU LQFP48
1ch Comparator SOT23-5L
4ch Operational Amplifier TSSOP14

STSPIN32G4 QFN 9x9

QFN 9x9 mm
Up to 40 GPIO

4x4mm QFN
Power device technology portfolio overview

**High voltage power MOSFET**
- Planar and MDmesh
  - 250 V to 1700 V
- STripFET
  - -100 V to 200 V

**Low voltage power MOSFET**
- SiC MOSFET
  - 650 V, 1200 V, 1700 V
- GaN-on-Si
  - 100 V, 650 V
- LDMOS, DMOS
  - 28 V, 1000 V

**IGBT**
- SLLIMM
  - 500 V, 600 V
- ACEPACK
  - 650 V, 1200 V

**Power bipolar**
- Power bipolar
  - 15 V to 1700 V

**SiC MOSFET**
- 600 V, 650 V, 1200 V, 1250 V

**SLLIMM**
- 500 V, 600 V

**ACEPACK**
- 650 V, 1200 V

**GaN**
- 100 V, 650 V

**Power RF**
- Rad-hard bipolar and MOSFET
  - 60 V, 200 V

**Hi-Rel & Space**
- LDMOS, DMOS
  - 60 V, 200 V

**Intelligent power module**
- SLLIMM
  - 500 V, 600 V

**Power module**
- ACEPACK
  - 650 V, 1200 V
Isolated interface product portfolio

**ISOSD61**
- 16-bit SD
- TTL Version
- 86dB SNR
- 25MHz External Clock
- SO16

**ISOSD61L**
- 16-bit SD
- LVDS Version
- 86dB SNR
- 25MHz External Clock
- SO16

**STISO621W**
- 1/1 channels
- SO8 8mm Wide Body
- 6kVp Viotm
- 100Mpbs

**STISO621**
- 1/1 channels
- SO8 Narrow Body
- 4.8kVp Viotm
- 100Mpbs

**STISO620**
- 2/0 channels
- SO8 Narrow Body
- 4.8kVp Viotm
- 100Mpbs

**6kV galvanic isolated high-accuracy and robust sensing devices for industrial market**

**Up to 6kV galvanic isolated high speed standard digital isolators for a wide range of applications**
Functional safety for industrial automation
IEC 61508

Galvanically isolated drivers and interfaces, sigma-delta converters, intelligent power switches

STGAP/ISOSD/IPS

1.2 kV Galvanic Isolation
6kVpk Galvanic isolated Single & Dual channel

100 V / ns
Transient Immunity

Current capability
4A sink / source
Ready for SiC power

Fast Switching Frequency
(Prop. Delay 80ns)

Stand by, SD pin, Brake pin,
Thermal shutdown

Ecosystem and full support availability

SIL ready enabled by native hardware features and safety libraries

• IEC 60747-5
  (Optoelectronic devices, ratings, and characteristics)
• UL 1577
  (Optical isolators)
• IEC 60747-17 (VDE 0884-10)
  (Magnetic and capacitive couplers for isolation)
The breakthrough and updates of X-CUBE-MCSDK
X-CUBE-MCSDK embedded SW and SW tools

Motor Pilot...

Motor Control Workbench

System configuration

Motor drive tuning

… including Motor Profiler

Custom hardware board description

Embedded SW

```c
#include "MC.h"
{
  CMCI oMCI = GetMCI(M1);
  MCI_ExecSpeedRamp(oMCI, final speed, ramp duration);
  MCI_StartMotor(oMCI);
}
```

Motor characterization

Hardware board features and parameters

JSON file
X-CUBE-MCSDK new delivery: top additions

- Improved sensor-less algorithm
- STM32 large support
- Dual motor capability
- Support for customer boards
- Monitoring and debugging capabilities

Available in www.st.com
X-CUBE-MCSDK v6.2
Improved sensor-less algorithm

- Current consumption during startup procedure between STO PLL and HSO:
  - STO PLL: Current peak = 23A
  - HSO: Current peak = 16A

Hardware requirement:
- Voltage input + 2 ADC min
- Necessary for HSO algorithm

Working configuration:
- 3 shunts
- STM32G4
HSO: increasing low-speed performance

Improved sensor-less algorithm

With STO PLL, the control is lost below 70 RPM

1. 1st speed command set to 60 rpm: STO PLL lost at this step
2. 2nd speed command set to 20 rpm: HSO still running until this step

30% load applied here

With HSO, the control is maintained at 20 RPM

Speed curves comparison STO PLL vs HSO control at 30% load
STM32 support

STM32 large support

STM32F0
STM32F0
STM32F4
STM32L4
STM32F3
STM32F7
STM32G0
STM32G4
STM32G4
STM32C0
STM32H7
STM32H5
Dual motor application is back

Support for STM32F3, STM32F4, and STM32G4

Dual motor capability
Monitors and debugging: Motor Pilot

Control, monitor, tune, and debug your real-time applications

Real-time monitoring: each sample can be plotted and recorded

GUI customization: any developers can easily customize motor Pilot GUI to fit application needs

Motor Profiler included and profiling possible with custom boards
Motor pilot customizable UI

Monitoring and debugging capabilities

MCSDK FOC  MCSDK position control  MCSDK 6-Step

Preparing Chinese version of motor Pilot user interface
STM32 X-CUBE-MCSDK designed for you!

Why to use STMicroelectronics X-CUBE-MCSDK?
- New FOC sensor-less algorithm: high sensitivity observer
- Possibility to tune code for YOUR hardware design
- Great SW tools = MC Workbench + Motor Pilot

Visit the STM32 motor control dedicated web page:
www.st.com/content/st_com/en/stm32-motor-control-ecosystem.html
IPs
New single shunt current sensing: breaks all barriers of state-of-art

Achieves:
• no PWM distortion!
• Simultaneous sampling of two phase currents!

New (patent pending)
Multimotor shared current sensing with shunt resistors/ICS

Achieves:
• Savings on current sensors & network
• Savings on PCB space
• Savings on MCU pinout assignment
STM32G4 accelerators

ST US multimotor drive patents

ADCS apparatus & sequence arbiter for multi-motor sampling sync

Achieves:
- No dead-band (max MI)
- No IRQ & CPU load for peripherals reconfig
- Robust, hardware based, peripherals transitions
LV servo solutions
ST LV servo drive solution roadmap

- **Quad drive**: STSPIN32G4/STM32G4 dual drive solution
- **GaN based Multi-Drive**: NextSTM32 Multi-Motor servo drive solution

High end

- STEVAL-ETH001V1
- STSPIN32G4 LV servo drive with EtherCAT

Mainstream

- EVSPN32G4
- STSPIN32G4/LV servo drive solution V2 & disty variants
- NextSTM32 Multi-Motor drive solution

Access

- EVALKIT-ROBOT-1
- STSPIN32G4 LV servo IPC version
- GaN based Multi-Motor drive solution

- STSPIN32G4 LV servo IPC version
- Inverter

Timeline:
- 2022
- 2023
- 2024
- 2025
EVALKIT-ROBOT-1
compact brushless servo control kit

Position control loop based on FOC

STSPIN32F0A
45 V fully integrated 3-phase BLDC driver (600 mA gate current) embedding Cortex®-M0 MCU

STL7DN6LF3
60 V, 35mΩ Dual N-channel MOSFETs in PowerFLAT 5x6 dual Island

Maxon EC-i40
100 W 3-phase BLDC with 1024-pulse incremental encoder

• 36 V and 6 \( A_{\text{PEAK}} \) power stage
• Encoder + Hall sensors supported
• MODBUS com. protocol via RS-485
EVSPIN32G4/NH general purpose evaluation board

Key features

- Up to 75 V and output current up to 20 $A_{\text{rms}}$
- Three shunt topology
- Embedded OPAMPs used for current sensing
- BEMF sensing circuitry for sensorless driving
- Digital Hall sensors input management
- PCB temperature monitoring (NTC)
- Bus voltage monitoring
- CAN bus mounting option
- Embedded STLINK V2-1
- **Fully integrated in X-CUBE-MCSDK 6.x**

Documentation:
- Data brief: DB4420
- User manual: UM2850

Suitable for FOC and 6-STEP driving

Tested in high-speed applications with FOC 1 shunt up to 130 Krpm

**EVSPIN32G4** eval board with heatsink
**EVSPIN32G4NH** eval board without heatsink
STSPIN32G4 LV servo drive solution

Solution dedicated for AGV, robotic

• Specs:
  • 50x100x50mm dimension
  • 1000 W output power without cooling fan
  • 20~60 VDC supply, 20 Arms, 50 A peak

• Features:
  • EtherCAT onboard
  • Capable of embedded to motor shell
  • Isolated pulse input
  • Isolated digital input x2
  • Isolated digital output x2

Key products:
  • STSPIN32G4
  • STL90N10F7 * 12
  • ST26C32 * 2
  • VIPER319HDTR
  • LDK320ADU33R
  • LDK320ADU50R
STSPIN32G4 dual motor control topology

Key features

- Embedded DC-DC converter for driver supply and others
- Embedded LDO for MCU supply and others
- Embedded CAN controller for system bus communication
- Small PCB size and simple routing

Very compact
Easy design
### STSPIN32G4 dual drive solution V2

#### Example: SIL 3 architecture/1.5 kW/310 VDC 220V

<table>
<thead>
<tr>
<th>Component</th>
<th>Price (Average Price for 10KU)</th>
<th>Standard architecture servo motor drive x 2 (pcs/total price)</th>
<th>New ST solution dual servo drive (pcs/total price)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RJ-45</td>
<td>$3</td>
<td>4/$12</td>
<td>2/$6</td>
</tr>
<tr>
<td>Protection device</td>
<td>$1</td>
<td>4/$4</td>
<td>2/$2</td>
</tr>
<tr>
<td>Isolation</td>
<td>$1</td>
<td>4/$4</td>
<td>2/$2</td>
</tr>
<tr>
<td>EtherCAT target controller</td>
<td>$7</td>
<td>2/$14</td>
<td>1/$7</td>
</tr>
<tr>
<td>MCU</td>
<td>$10</td>
<td>4/$40</td>
<td>2/$20</td>
</tr>
<tr>
<td>IPM + gate drivers</td>
<td>$10</td>
<td>2/$20</td>
<td>2/$20</td>
</tr>
<tr>
<td>Power rails</td>
<td>$6</td>
<td>4/$24</td>
<td>2/$12</td>
</tr>
<tr>
<td>Shunts/ICS</td>
<td>$1</td>
<td>6/$6</td>
<td>3/$3</td>
</tr>
<tr>
<td><strong>Total~</strong></td>
<td><strong>$124</strong></td>
<td></td>
<td><strong>$72</strong></td>
</tr>
</tbody>
</table>

**Lower cost**  **Higher reliability**  **More compact**  **Higher performance**  **SDK ready**

~40% COST SAVING
STSPIN32G4 dual drive solution

ToF sensor board

VL53L3CX-SATEL

IMU sensor board

STEVAL-MKI207V1(6 axis)

OR

STEVAL-MKI217V1(9 axis)
STSPIN32G4 dual drive solution V2

- **Specs:**
  - 130x130mm dimension
  - 1000 W output power each
  - 20 ~ 60 VDC supply, 20 Arms rating, 50 A peak

- **Features:**
  - Shared current sensing network
  - 2 switches in parallel per switch arm
  - EtherCAT or CAN onboard
  - RS232 onboard
  - Multiple selectable configurations:
    - Dual differential ABZ + Hall encoder
    - Dual ABS encoder
    - Isolated digital output x2
    - Isolated digital input x2

- **Applications:**
  - Robotic, AGV, or other position control applications
High performance LV servo drive solution

Order code for SPM interface: STEVAL-ETH001V1

Application board with DPM interface: AB0035.B.01(*)

Key products
- STM32F767ZI - microcontroller
- STDRIVE101 - three phase gate drivers
- STH270N8F7 - power MOSFETs
- STL6N3LLH6 - power MOSFETs
- L7987L DC/DC - converter
- LD39150DT33 - low drop linear regulator
- L7805CD2T - linear regulator
- IPS160H - digital output
- CLT03-2Q3 - digital Input
- NETX-90 - network Ethernet controller

• Supply voltage range 20 V up to 56 V
• **700 W max output power**
• STM32 platform powered by STM32F767ZI
• Multiaxial position control algorithm and real-time connectivity based on EtherCAT stack embedded in the application firmware
• Multiprotocol supported using NETX90 network controller (PROFINET, EtherCAT, Ethernet IP, TSN)
• DPM and SPM interface between NETX90 and MCU
• Motor control power stage, powered by STDRIVE101 and STH270N8F7 power MOSFET
• Power management circuit powered by L7987 switching converter
HV servo solutions
ST HV servo drive solution roadmap

**GaN augmented**

**Single axis**
- High voltage high power testing platform
  STM32H743 + ACEPACK, IGBT, SiC MOSFETs
  version 380 VAC 3 ph 10 kW

**Dual axis**
- ST2GaN-based high BandWidth & efficiency
  Servo control 220 VAC 600W

2021
- Cooperation with EMEA

2022
- STM32H7 dual axis + SLIMM 2nd/HP
  1PH/3PH 220 VAC 1.5 KW

2023
- High end servo drive with real-time connectivity and safety functions
  SIL2 750VDC 22KW
  STM32H743 + ACEPACKSMIT

2024
- STM32H5 Single axis + SLIMM 2nd/HP
  1PH/3PH 220 VAC 850 W~1.5 KW

2025
High end servo drive block diagram and ST BOM
High end servo drive with real-time connectivity and safety functions

Key products:
- STGSH50M120D 1200V, 50A Low Loss M series IGBT in ACEPACK SMIT (HB topology)
- STM32H743ZGT6 Arm® Cortex®
- STGAP2HD Galvanically isolated 4A gate driver
- ET1100 (ET11002) Ethercat ASIC slave device
- STM802RM6F – voltage supervisor
- STIS0621 – isolated UART
- L69861 - 38 V, 5W synchronous iso-buck converter
- ISOSD61 – isolated Σ-Δ modulator
- IPS1025H, IPS4200L, IPS160HF – Intelligent power switch
- CLT03-1SC3 – Digital Input

• Power stage IGBT based with ACEPACK™ SMIT package (1200V, 50A HB)
• DC input up to 800V
• Planar transformers for aux power supply
• Position sensors:
  • High-end serial encoder (EnDat 2.2, Hyperface, BISS)
  • Resolver
  • Hall sensors
  • Incremental encoder
• Current sensing: Σ-Δ modulator
• Connectivity: EtherCAT, Modbus RTU, CAN
• Position control supported
• Modular solution (stacked):
  • Power board 21x10 cm
  • Control board 21x12 cm

• Safety:
  • TUV assessment for SIL2 level ongoing
  • Diagnostic functionality for power supplies OV and UV detection
  • Voltage supervisor and Watchdog functionality
  • STL libraries for STM32H743ZG (not included in the example firmware)
  • Safe Torque Off (STO)
  • Safe Brake Control (SBC)
High-end servo drive power test @750 Vdc, 22 kW

NCTs values of two devices in parallel in the same leg → current well balanced

Testing conditions:

- DC BUS: 750V
- Power input: 22kW
- Ph current: 41 Arms
- Fsw: 8kHz
- dead time: 2.2us
- SPEED: 3200RPM
- T_NTC: 108°C
- Forced air cooling
- Heatsink Rth: 0.54 °C/W (natural convection)

Power stage with two 1200V HB ACEPACK SMIT IGBTs (with embedded NCTs only for phase W) in parallel for each leg

T_NTC = 108°C (Thermal steady state reached)
Our technology starts with You