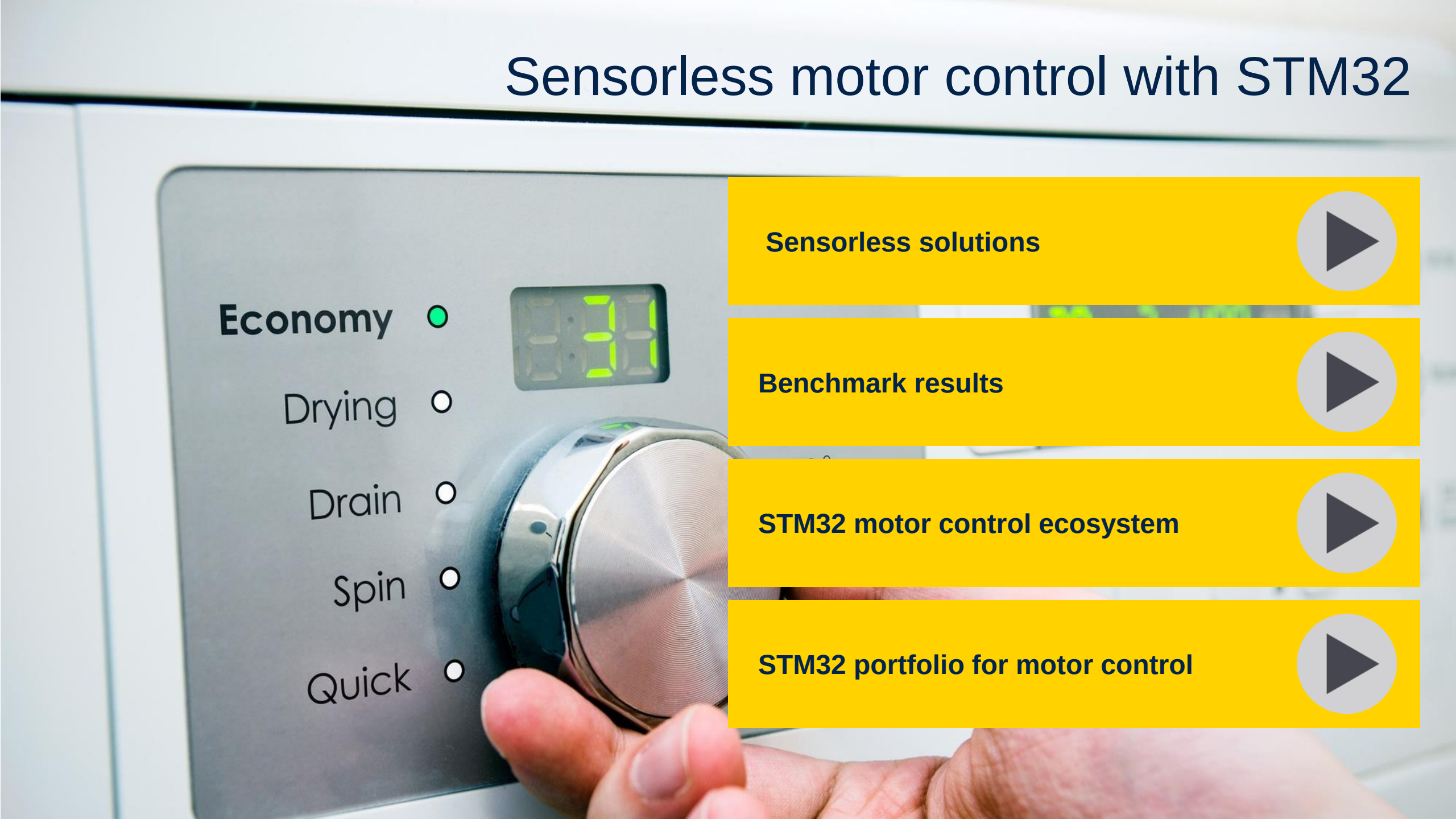
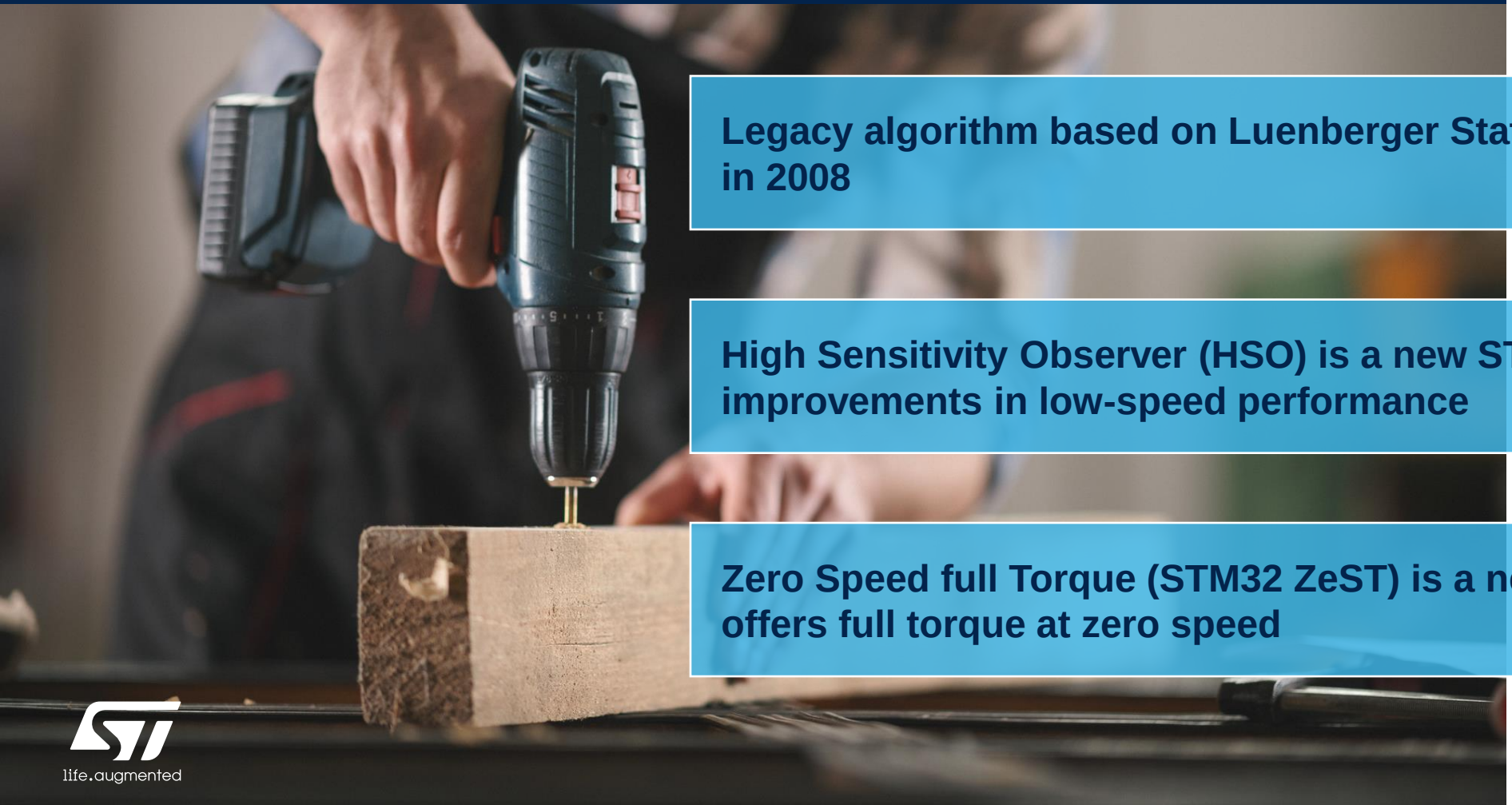
Sensorless motor control with STM32



- **Sensorless solutions**
- **Benchmark results**
- **STM32 motor control ecosystem**
- **STM32 portfolio for motor control**

Sensorless solutions

Sensorless field oriented (FOC) control for 3 phase motors offers benefits in cost and quality with the elimination of sensors and wiring



Legacy algorithm based on Luenberger State Observer introduced in 2008

High Sensitivity Observer (HSO) is a new ST algorithm that offers improvements in low-speed performance

Zero Speed full Torque (STM32 ZeST) is a new ST algorithm that offers full torque at zero speed

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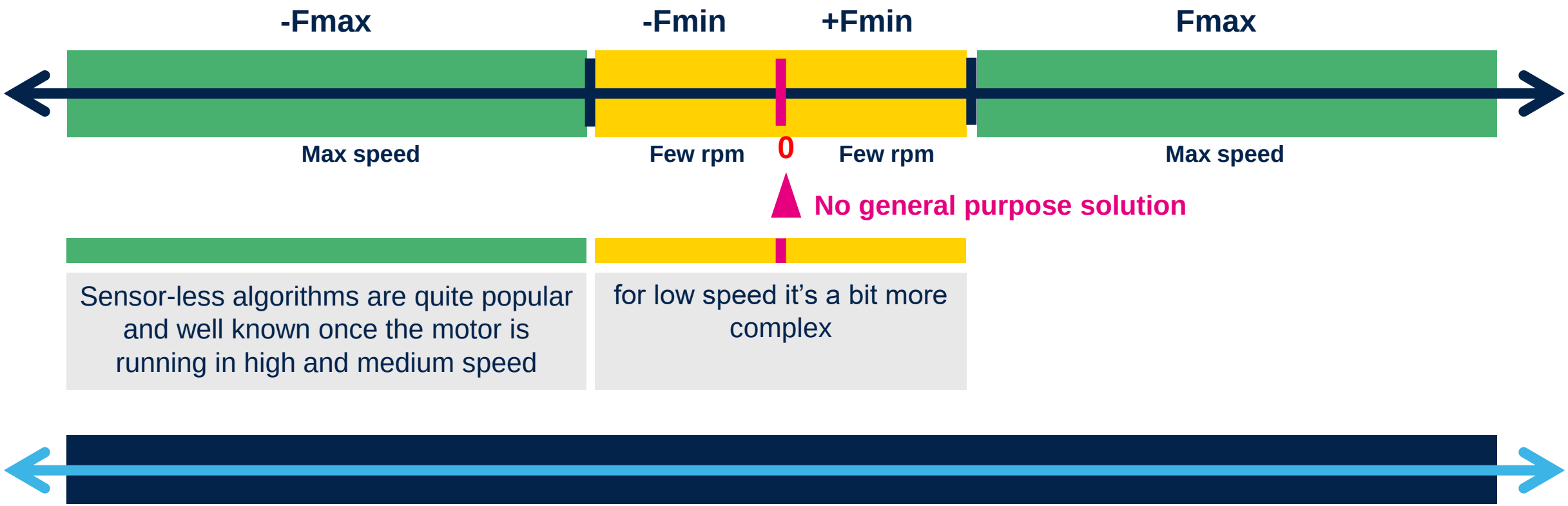
FOC sensorless challenge
Cold starting BLDC / PMSM motors with full torque



ZeST + HSO

New solution from ST !!

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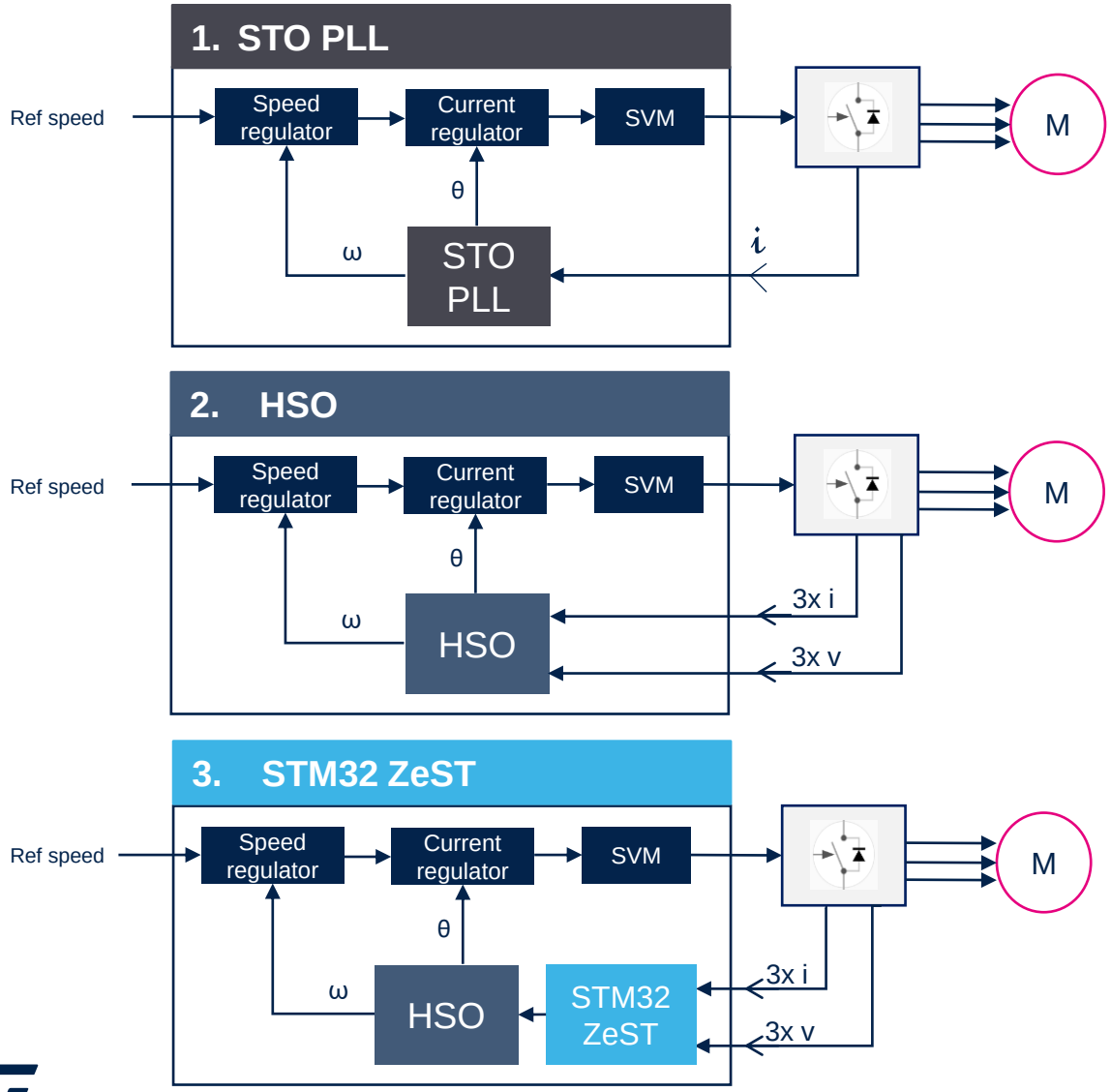
Sensorless FOC algorithms



1. Legacy solution with Luenberger State

- Observer PLL – (STO PLL)
- available in MCSDK since 2008

2. High Sensitivity Observer (HSO)

- Now available in MCSDK release 6.2
- Improved performance at low speed
- Improved startup performance for reduced current consumption

3. HSO in combination with STM32 ZeST

- STM32 ZeST is only available for selected customers under NDA
- Only solution to provide Zero Speed Full Torque without sensors

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Benchmark results

- Benchmark demonstrator
- HSO low speed performance and efficiency improvements
- STM32 ZeST torque curve
- STM32 ZeST and HSO efficiency example

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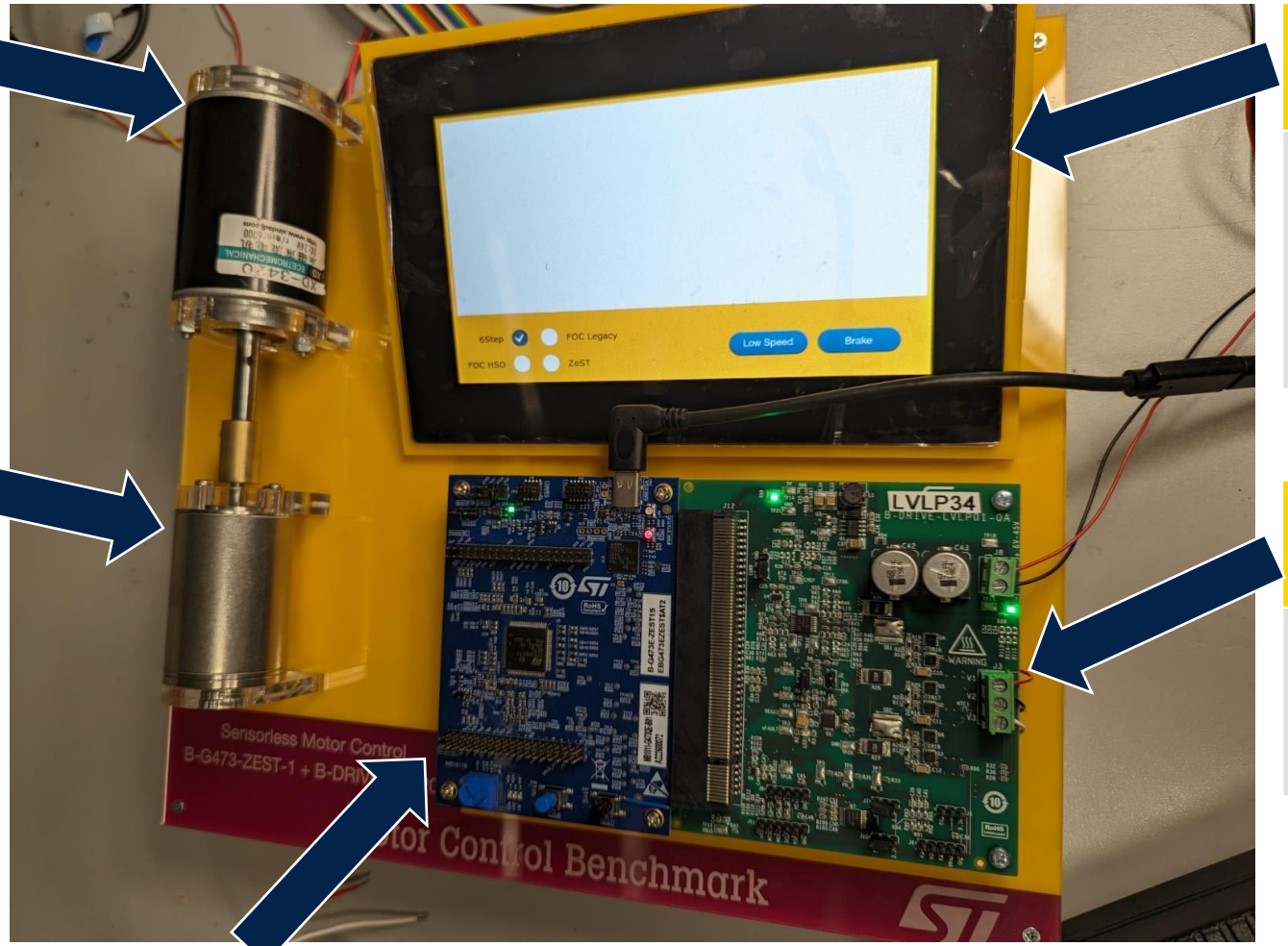
Benchmark demonstrator

Brake

DC motor coupled to the motor under test to simulate a load

Motor

PMSM motor subject to different control algorithms



HMI display

STM32H7 based display module for input selection and results display

Power board

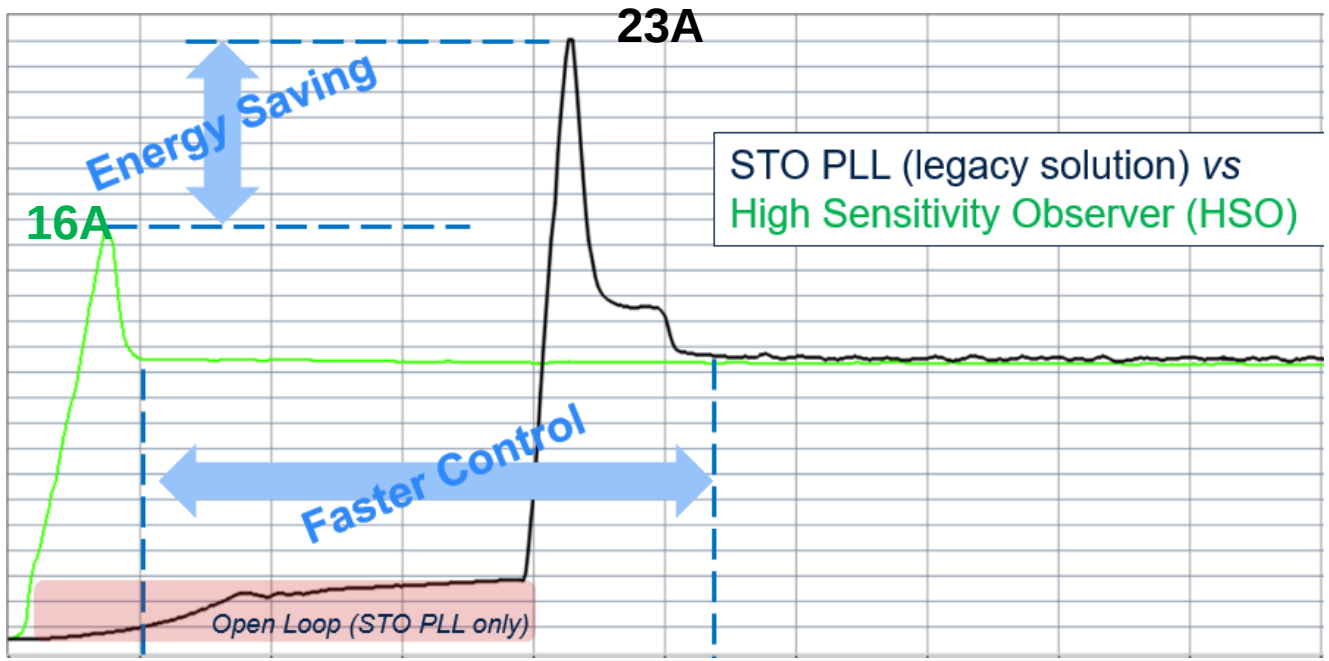
Low voltage, low power board (STEVAL-LVLP01)

Control board

STM32G473 MCU based control board (B-G473E-ZESTS1)

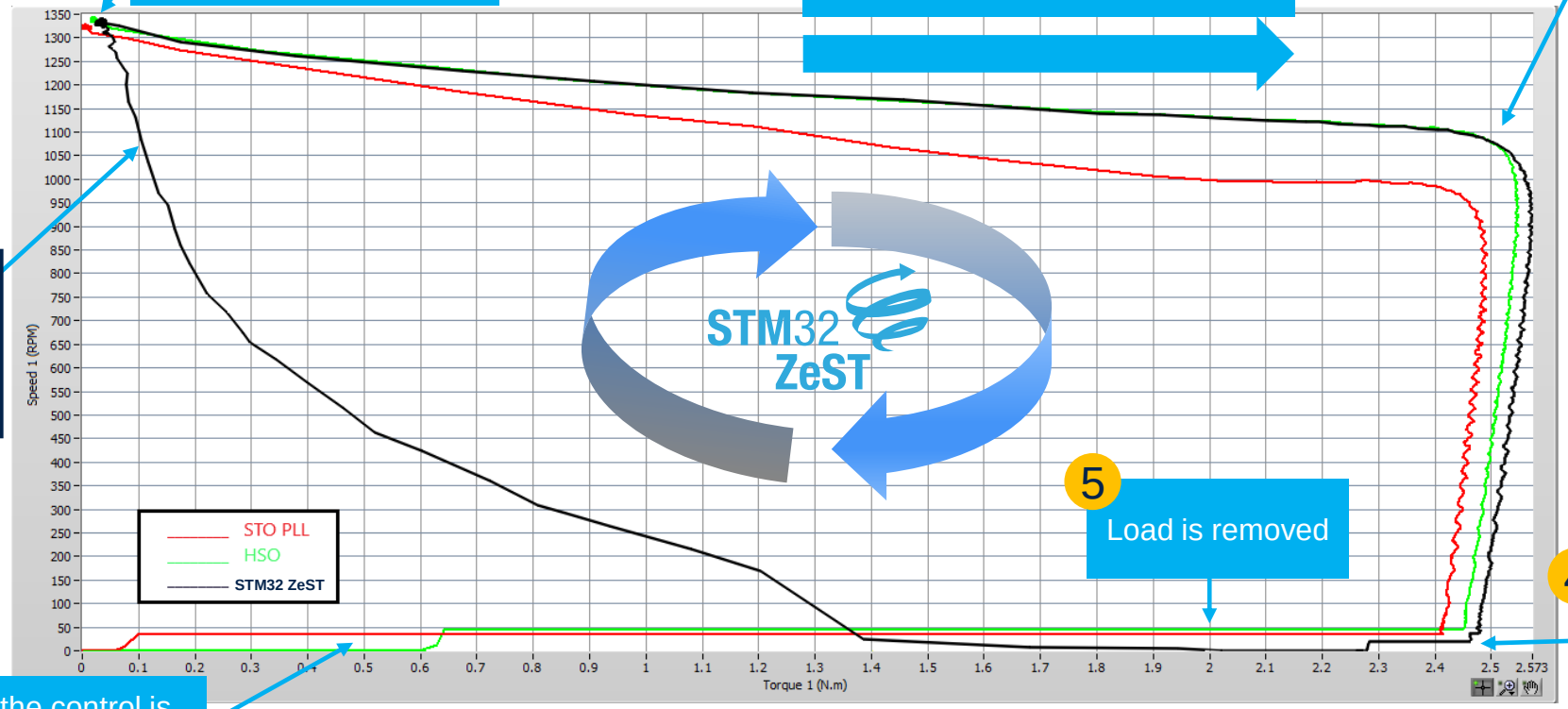
HSO – high sensitivity observer

Improvements in low-speed performance and efficiency



Current consumption during startup phase
Comparison between **STO PLL** and **HSO**

From full speed to stall torque (max torque, max load)



Speed vs torque

STM32 ZeST vs STO PLL vs HSO - Performance & behavior

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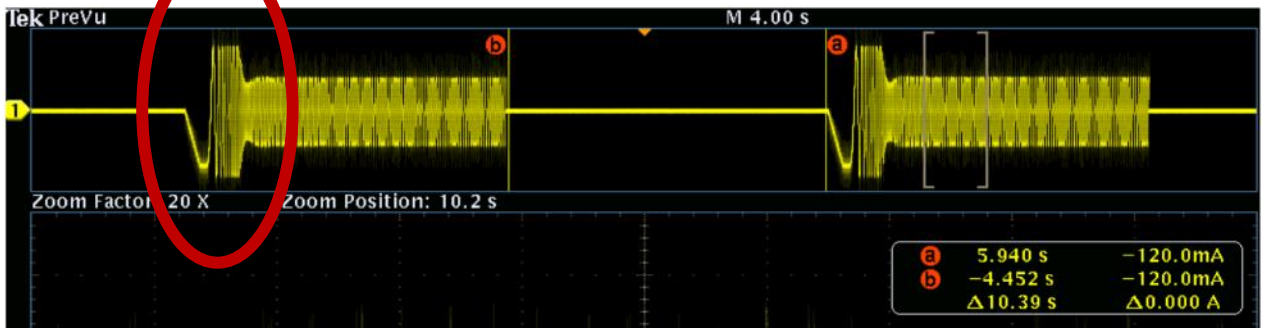
Using STM32 ZeST to run a smart, power-efficient washing machine

Zero Speed full Torque sensor-less algorithm

Energy saving per washing cycle ~ 15-40%

Standard (open loop) sensorless startup

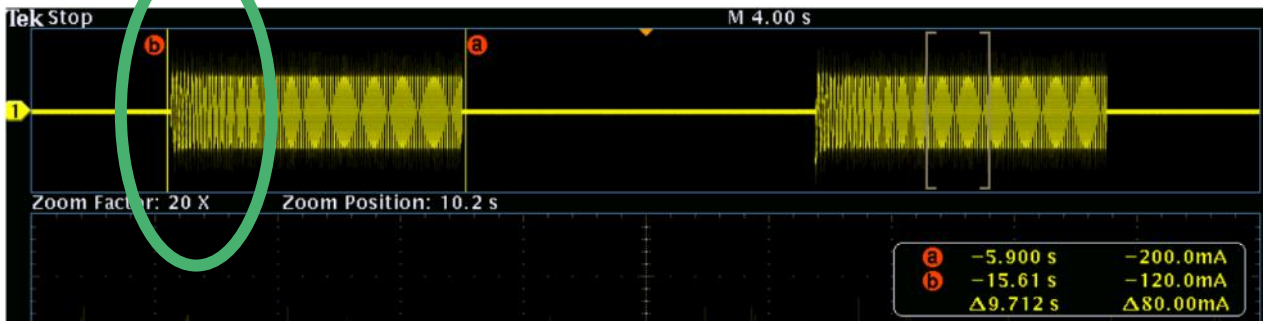
High peak current



STM32 ZeST start-up

Energy saving !

- ✓ No high peak current
- ✓ Shorter start-up



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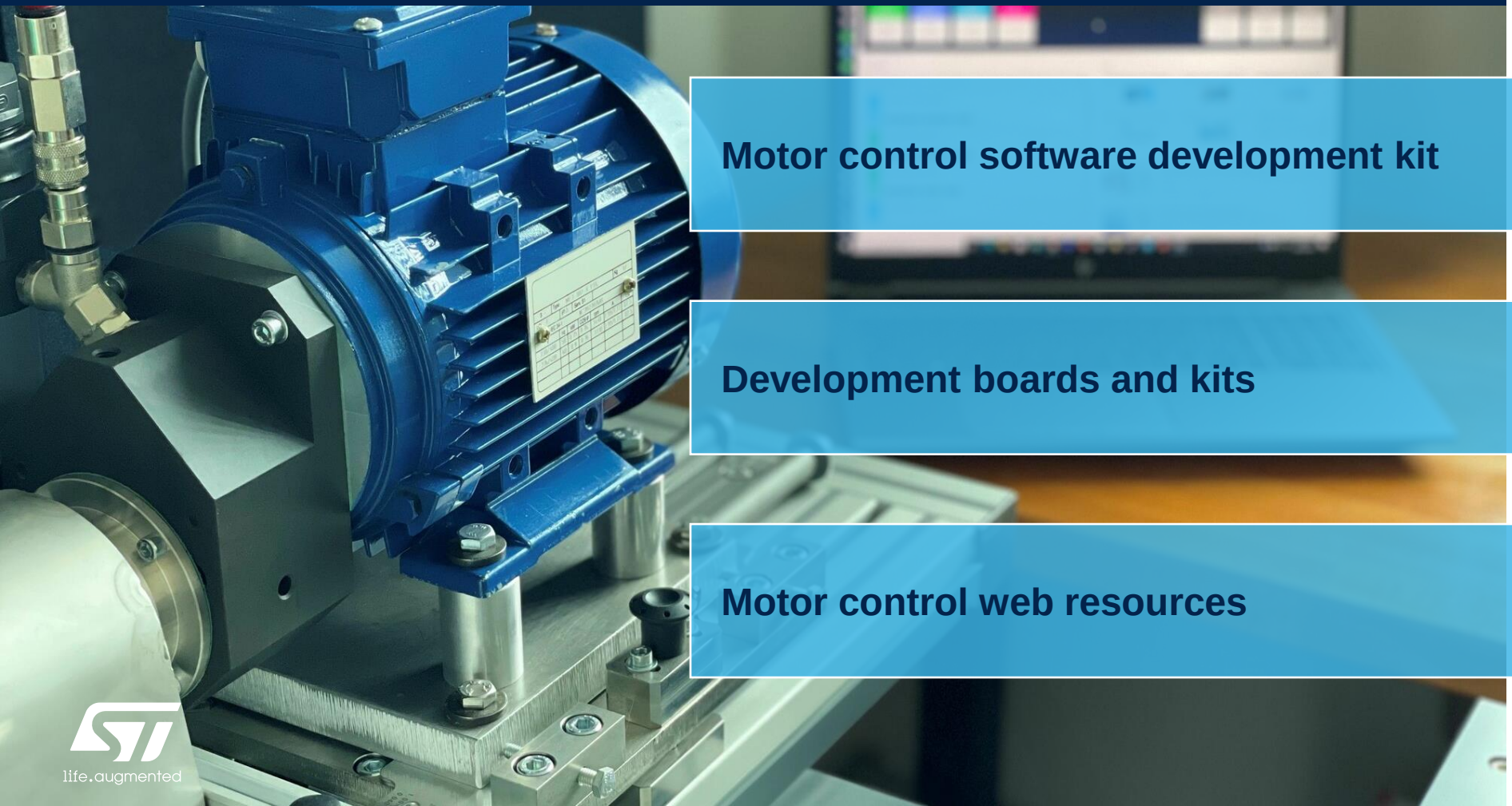
STM32 ecosystem for motor control

Full ecosystem for 3 phase motor control development



- Motor control software development kit
- Development boards and kits
- Motor control web resources

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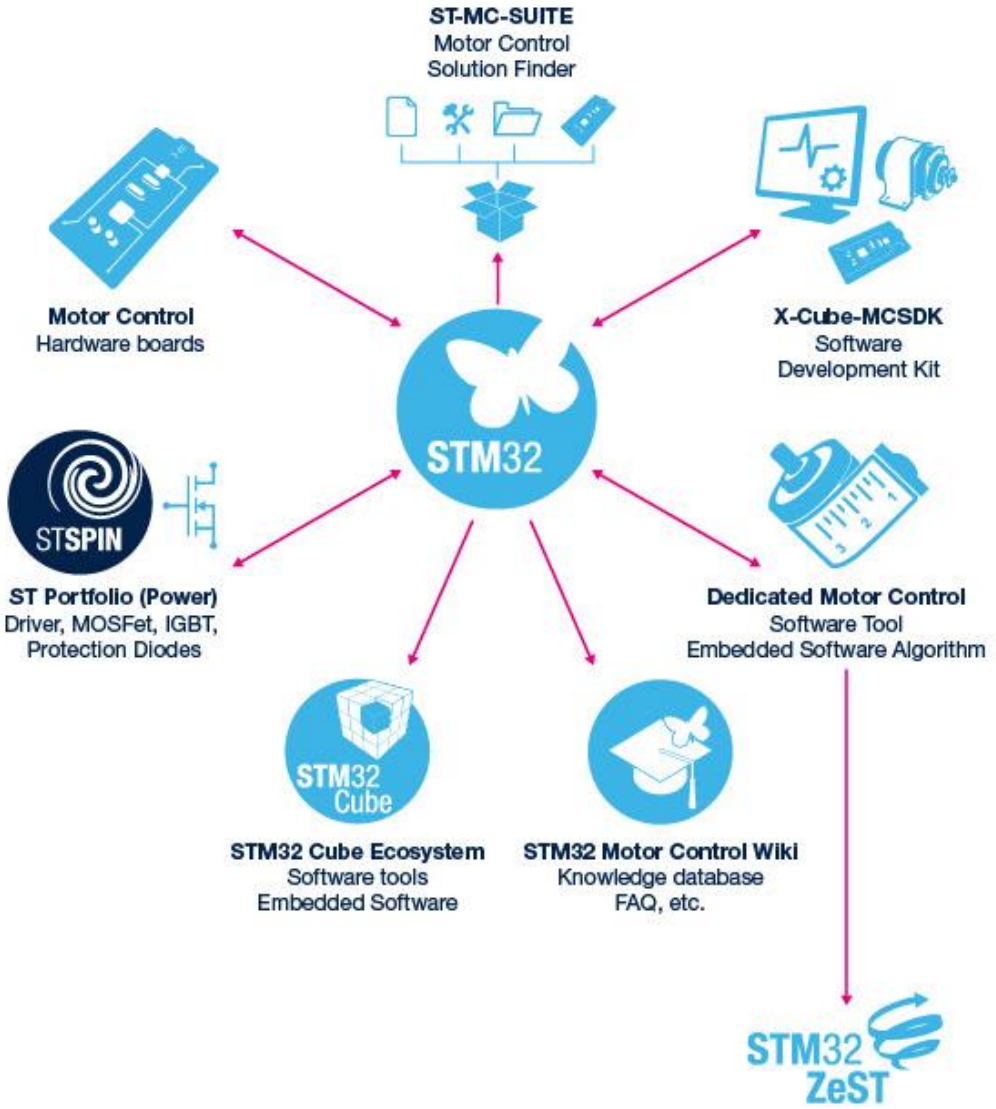
STM32 motor control ecosystem



STM32 MCUs	Portfolio of STM32 products for scalable performance and features
X-CUBE-MCSDK	Motor control software development kit offering a collection of tools and software
Boards & kits	Wide range of development boards and kits to support motor control development

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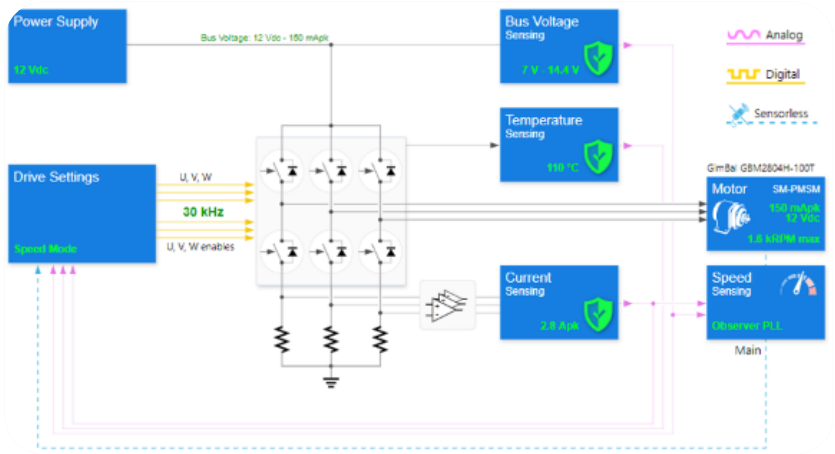
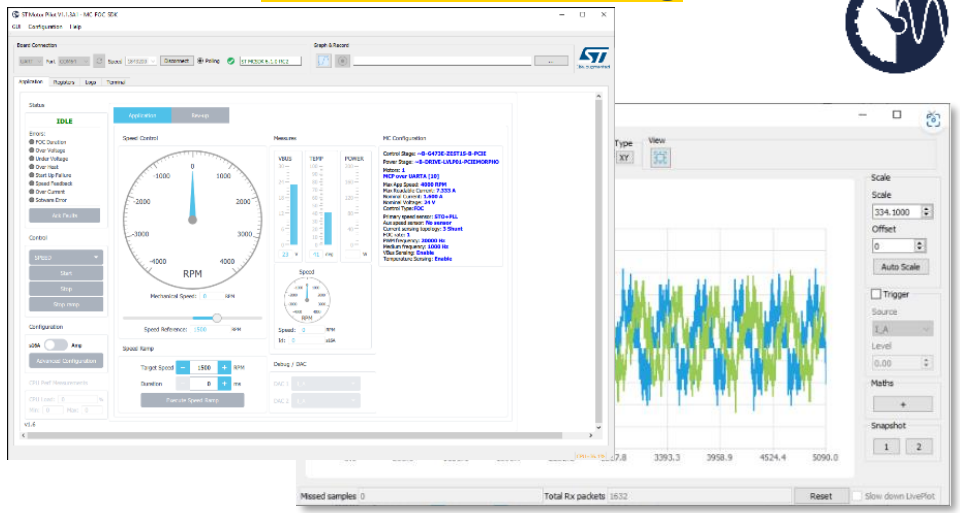
X-CUBE-MCSDK: tools and software

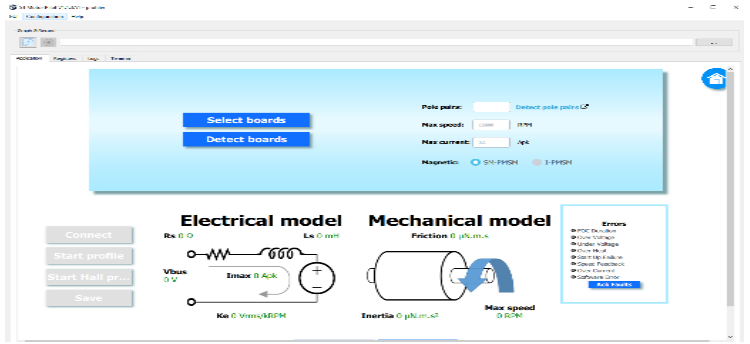
Motor Control Workbench: **System configuration**



Motor Pilot: **Motor drive tuning**



Motor Profiler: **Motor characterization**



Custom HW board description

Board features & parameters
Json file

Firmware library

Embedded SW

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

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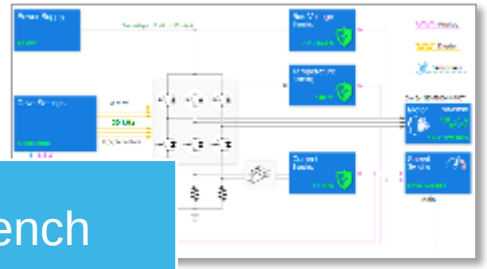
Motor control development flow and tools

Use ST-MC-Suite on-line tool to identify your most appropriate HW board

1 **Hardware setup**

2 Motor Control Workbench

MC configuration



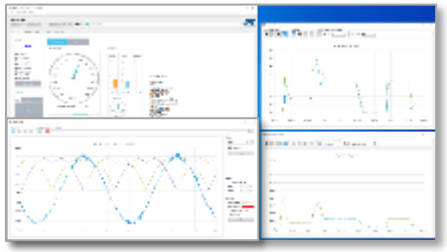
3 **Added configuration Project build**

STM32CubeMX & IDE

STM32 CubeMX

4 **Motor drive tuning**

Motor Pilot



5 **Final application development**

User code

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

STM32 CubeIDE

iar

KEIL Tools by ARM

Motor control boards and kits

Control + power

Eval / Nucleo + power / expension

Control stages

Power stages

MC Connector
Flat cable

NUCLEO-G431RB

X-NUCLEO-IHM16

Inverter (Complete drive)

B-G431B-ESC1

MC kits

P-NUCLEO_IHM03

Use ST-MC-SUITE on-line tool to select your HW boards

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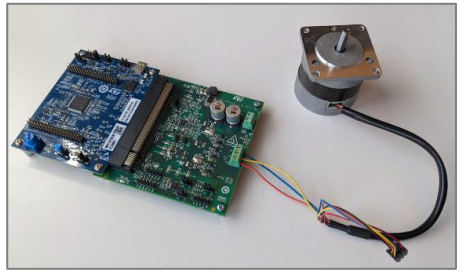
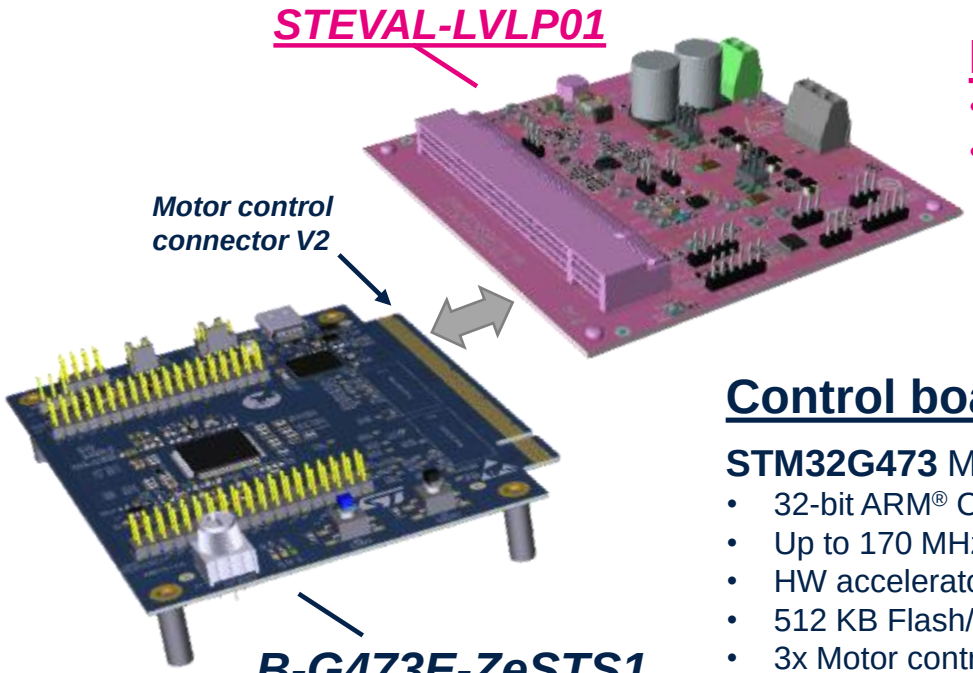
STM32 ZeST and HSO specific boards

New boards for evaluation and fast prototyping





Power board:

- **STDRIVE101** three-phase gate driver
- **STL110N10F7** power MOSFETs

HW type	CPN
Control board	**B-G473E-ZEST1S**
Motor + Power supply	**B-MOTOR-PMSMA1**
Power board LV/LP	**STEVAL-LVLP01**
Adapter board (for multiple MC)	**B-ZEST-ADAPT1**

Control board (Discovery)

STM32G473 MCU:

- 32-bit ARM® Cortex®-M4 Core
- Up to 170 MHz clock frequency
- HW accelerator (Cordic, FMAC)
- 512 KB Flash/96 KB SRAM
- 3x Motor control timers
- 5x 12-bit ADCs (19 channels)
- 7x Ultra-fast Comparators + DACs
- 6x OP-Amps

STM32 ZeST solution:

- Input voltage from 6V to 45 V
- Output current up to 5 A_{RMS}
- Three or single shunt configuration
- ST-LINK/V3 programmer embedded
- Digital hall sensor and quadrature encoder input

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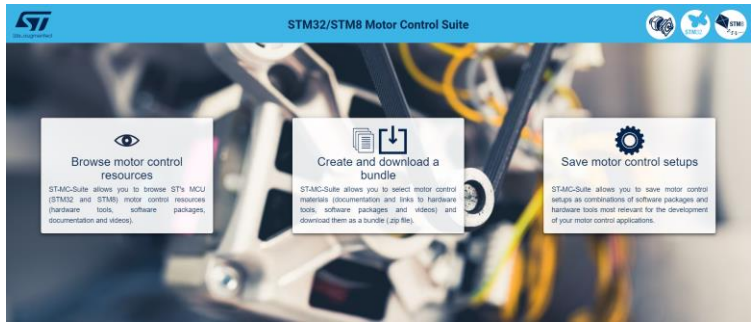
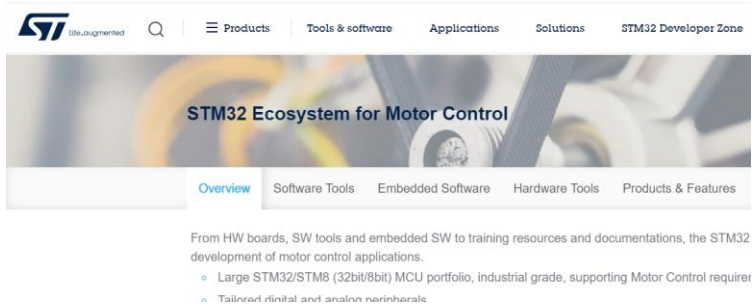
STM32 motor control resources



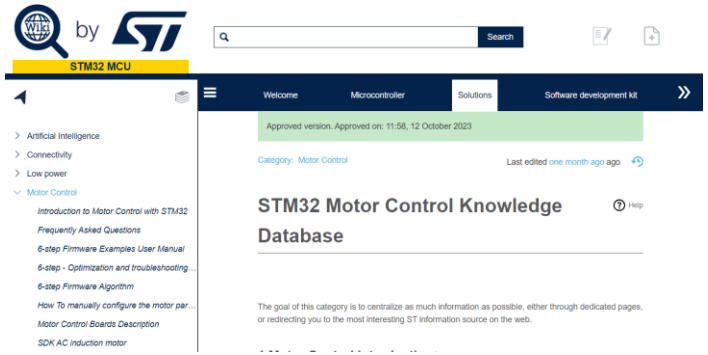
ST-MC-SUITE

Web based tool for board selection and resource bundling



STM32 motor control ecosystem

Web landing page for STM32 motor control resources



STM32 Wiki

Wiki for STM32 motor control technical information

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STM32 portfolio for motor control

STM32 portfolio MCUs targeted for 3 phase motor control

- Scalable offering from entry level to high performance
- STM32G4 mixed signal MCUs optimized for motor control
- STM32G4 for HSO and ZeST

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STM32 MC-SDK support

LONGEVITY 10 YEARS COMMITMENT

STM32MP1
Up to 1 GHz Cortex-A7
209 MHz Cortex-M4

STM32MP2
Dual 1.5 GHz Cortex-A35
400 MHz Cortex-M33

STM32F7
1082 CoreMark
216 MHz Cortex-M7

STM32H7
Up to 3224 CoreMark
Up to 550 MHz Cortex -M7
240 MHz Cortex -M4

STM32N6
MCU with neural processing unit

STM32F2
Up to 398 CoreMark
120 MHz Cortex-M3

STM32F4
Up to 608 CoreMark
180 MHz Cortex-M4

STM32H5
Up to 1023 CoreMark
250 MHz Cortex-M33

STM32F3
245 CoreMark
72 MHz Cortex-M4

STM32G4
569 CoreMark
170 MHz Cortex-M4

Mixed-signal MCUs

STM32C0
114 CoreMark
48 MHz Cortex M0+

STM32F0
106 CoreMark
48 MHz Cortex-M0

STM32G0
142 CoreMark
64 MHz Cortex-M0+

STM32F1
177 CoreMark
72 MHz Cortex-M3

STM32L0
75 CoreMark
32 MHz Cortex-M0+

STM32L4
273 CoreMark
80 MHz Cortex-M4

STM32L4+
409 CoreMark
120 MHz Cortex-M4

STM32L5
443 CoreMark
110 MHz Cortex-M33

STM32U5
651 CoreMark
160 MHz Cortex-M33

STM32WL
162 CoreMark
48 MHz Cortex-M4
48 MHz Cortex-M0+

STM32WB0
216 CoreMark
64 MHz Cortex-M0+

STM32WB
216 CoreMark
64 MHz Cortex-M4
32 MHz Cortex-M0+

STM32WBA
407 CoreMark
100 MHz Cortex-M33

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Latest product generation
Radio co-processor only
Supported in latest MC-SDK
STM32 ZeST + HSO supported

STM32G4 features for control applications

High performance
ARM Cortex-M4 + FPU @ 170Mhz
ART Accelerator, Routine Booster(CCM)
Math Accelerators (FMAC, CORDIC)

7x Comparators
Down to 19ns propagation delay

5x ADC
5x12-bit, 16-bit oversampling
4 MSPS (0.25µs)

7xDAC
12-bit DAC 15 Msps

Motor control Timer
& High-resolution Timer
12 channels up to 184 ps resolution

STM32G4

Power Supply Unit
Power Factor Correction

USB Type-C Power Delivery

High robustness
Highly immune to fast transients
Robust IOs against negative injections

Safety
Checksum by hardware
ECC on Flash, **Parity** on RAM
FuSa SW library (SIL)

FD CAN
Up to 3 instances
Payload bit rate 8 times bigger than standard CAN

High temperature
from -40°C
up to + **125°C**

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Extensive & innovative peripheral set

Unit parameters	STM32G474 Hi-Resolution line	STM32G473 Performance line	STM32G431 Access line	STM32G491 Access line
Core, frequency	ARM Cortex-M4, 170 MHz			ARM Cortex-M4, 170 MHz
Flash (max)	512 Kbytes (2x256 KB dual bank)		128 Kbytes single bank	**512** Kbytes single bank
RAM (up to)	96 Kbytes		22 Kbytes	96 Kbytes
CCM –SRAM (code-SRAM)	32 Kbytes		10 Kbytes	16 Kbytes
12-bit ADC SAR	5x 12-bit 4 MSPS		2x 12-bit 4 MSPS	3x 12-bit 4 MSPS
Comparator	7		4	**4**
Op Amp with 4 built-in gain values with 1% accuracy	6		3	**4**
12-bit DAC	7		4	**4**
Motor Control timer	3x (170 MHz)		2x (170 MHz)	**3x** (170MHz)
CAN-FD	3x		1x	**2x**
12 channel Hi-resolution Timer	1x	-	-	-
Power supply	1.72 to 3.6 V			1.72 to 3.6 V

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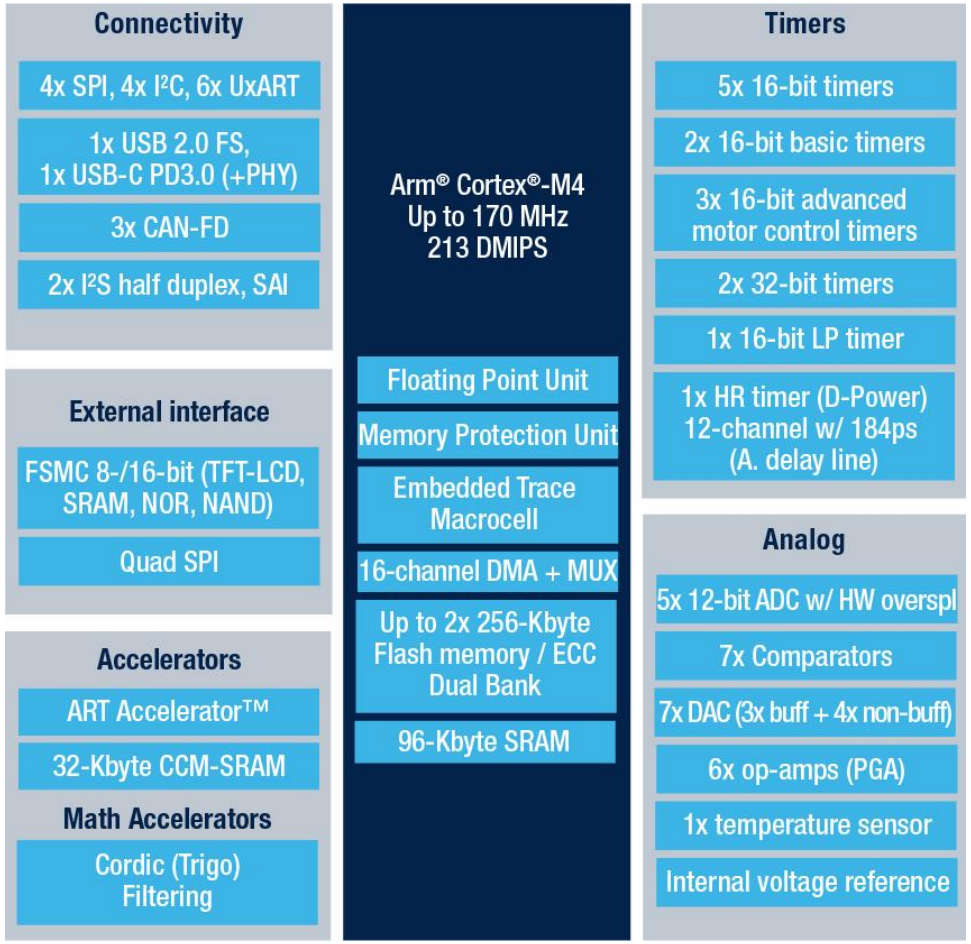
STM32G474/3 block diagram

High resolution and performance lines [128KB .. 512KB]

- 32-bit Arm Cortex-M4 core with FPU
- ART + CCM-SRAM + mathematic accelerators
- Dual-bank Flash with ECC
- SRAM with parity bit
- +/- 1% internal clock
- 1.72 to 3.6V power supply
- Up to 125°C



- High resolution timer *(G474 only)*
- 3x advanced motor control timers
- Rich advanced analog
- 3x CAN Flexible Data rate
- USB-C Power Delivery3.0
- Advanced security and safety features
- Robustness: highest level 5 / FTB/ESD - IEC 61000-4-4

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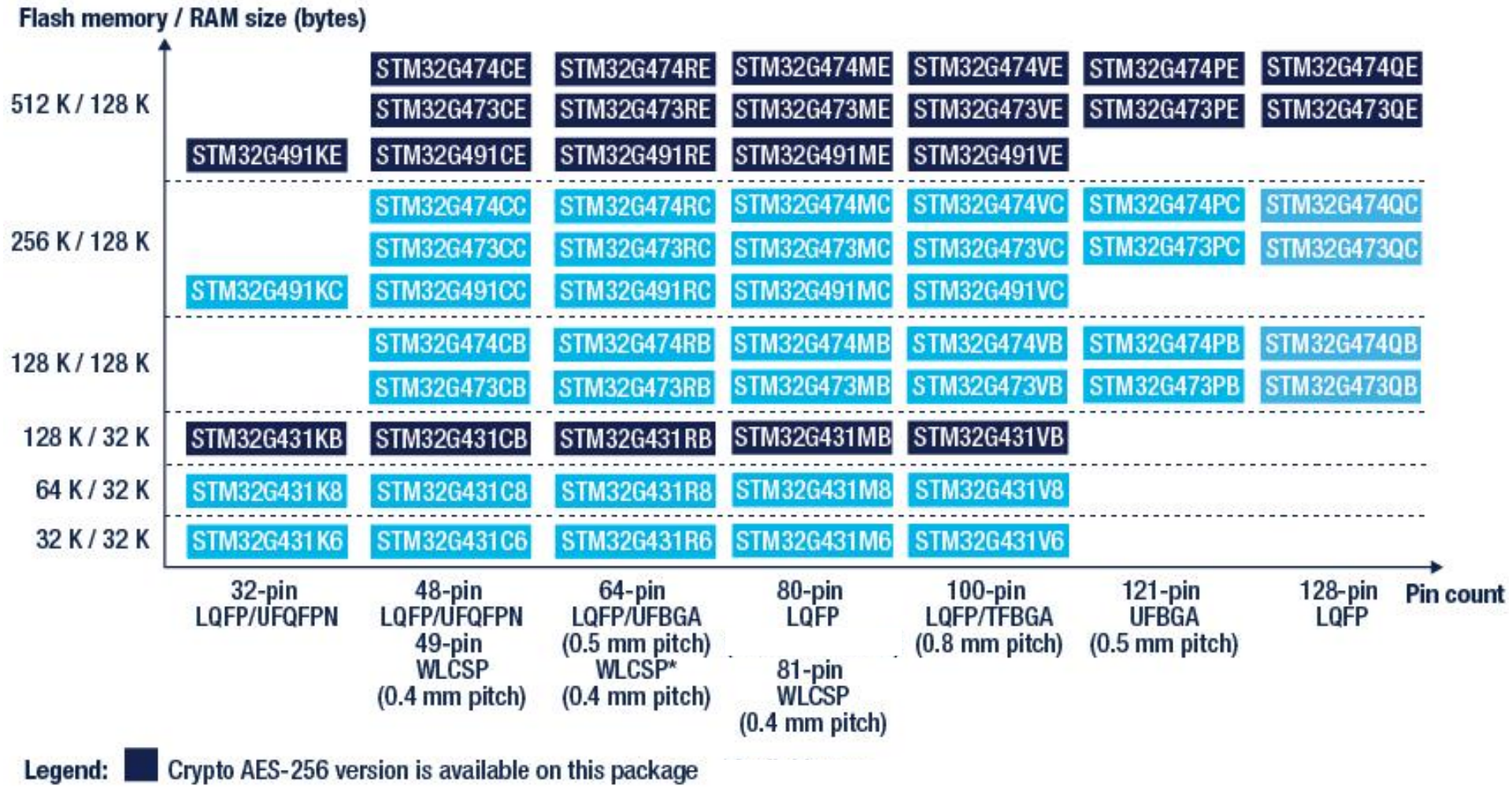
STM32G4 portfolio



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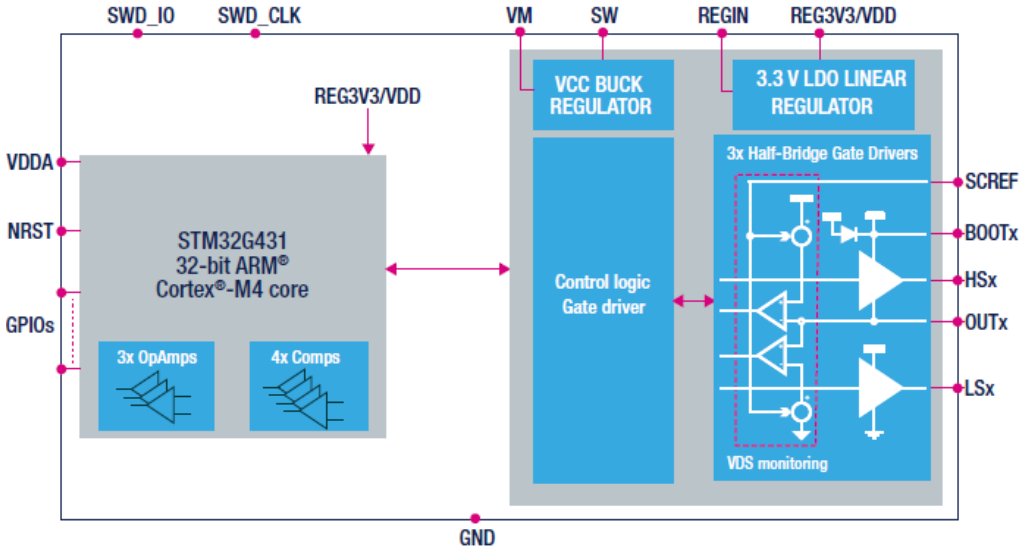
STSPIN32G4
Integrated STM32 and gate driver

STSPIN32G4 system integration – 5 ICs in 1

supported by MCSDK6.2



STSPIN32G4 also supports improved sensor-less algorithm

MCU	• ARM Cortex-M4 CPU @ 170MHz • 128kB Flash & 32k SRAM • 28 timer channels (2 adv. timers for PWM) • 4x fast comparators • 3x Op-Amp with built-in gain (PGA) • 2x 16-bit ADCs & 4x 12-bit DAC • I2C / UART / SPI / CAN • up to 40GPIOs • 6 step & FOC sensorless / sensored algorithms
Gate driver & power management	• 3 phase 75V gate driver with 1A driving capability • VS = 5.5V – 75V • Vcc 200mA buck converter • 3.3V 150mA linear regulator • MOSFET V_{DS} Monitoring protection • Fully protected (UVLO, Short-circuit, OCP) • Fully configurable by I2C

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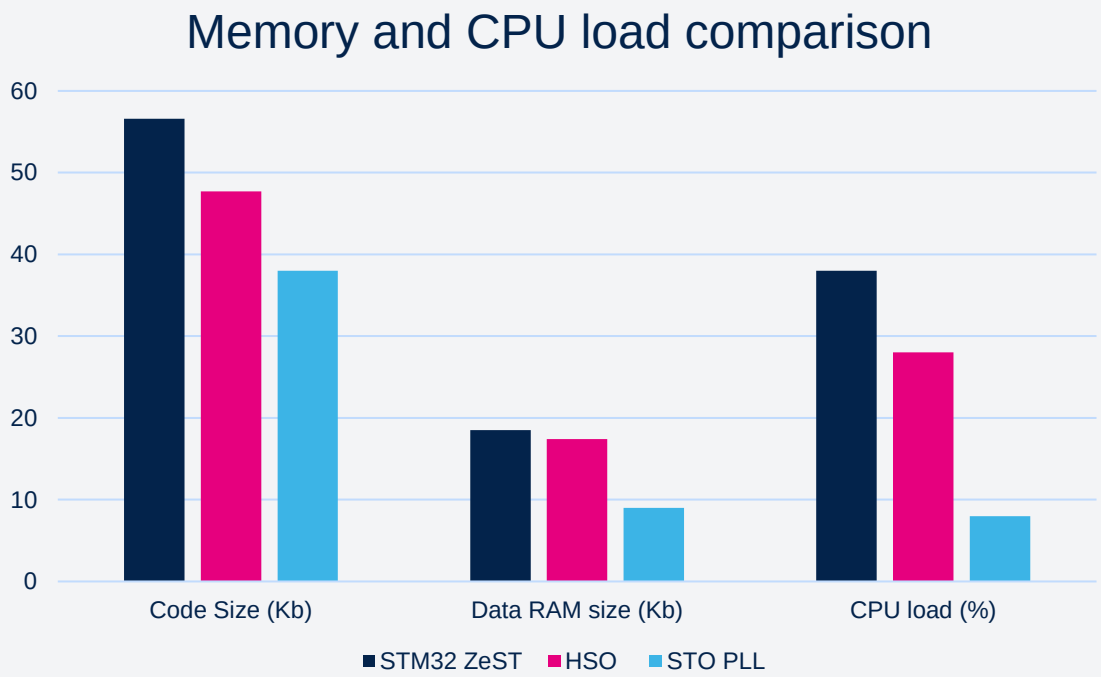
STM32G4 memory & CPU load



ST SW Motor control	FOC Code Size (Kb)	HAL Code size (Kb)	Data RAM size (Kb)	CPU load (%)
STM32 ZeST	45.6	11	18.5	38
HSO	36.7	11	17.4	28
STO PLL	27	11	9	8

Note:

1. *Total code size by considering HAL code and MCP interface.*
2. *PWM frequency set to 10KHz*

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STM32G4 algorithm requirements

Current sensing topology

	STO PLL	HSO / STM32 ZeST
1x Shunt	✓	✘
3x Shunt	✓	✓
Hall effect current sensor	✓	✓

Current and voltage sensing

	STO PLL	HSO/STM32 ZeST
Number of phase currents sensing	**2**	**3**
Number of phase voltages sensing	**0**	**3**
Analog low pass RC filter	**0**	**3**

Peripheral resources

IP	STO PLL	HSO / STM32 ZeST
ADC	2	2
Advanced control timer	1	1
General purpose timer	**0**	**1**
Comparator	3	3
Operation amplifiers	3	3
DMA	**0**	**1**