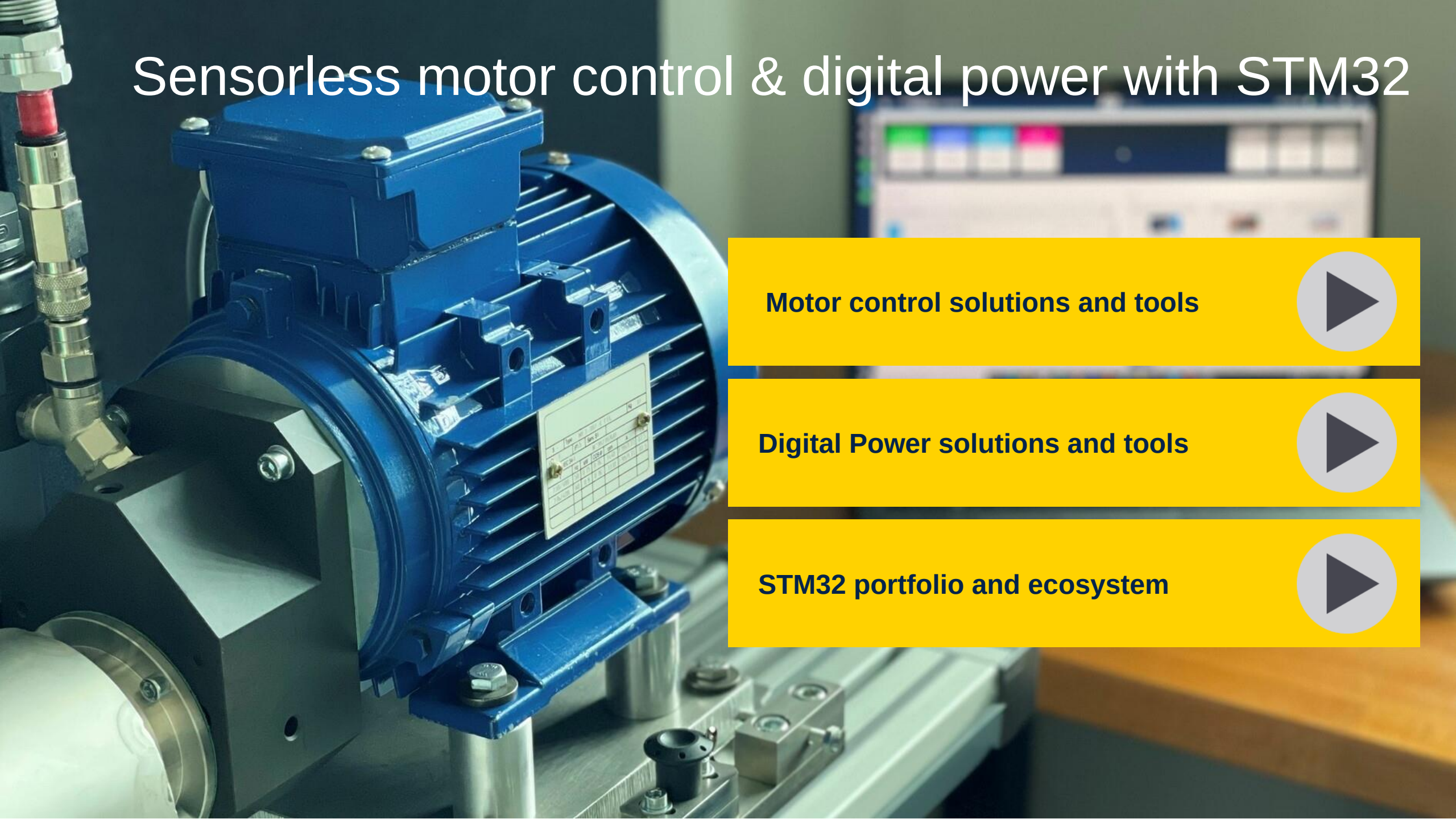
Sensorless motor control & digital power with STM32



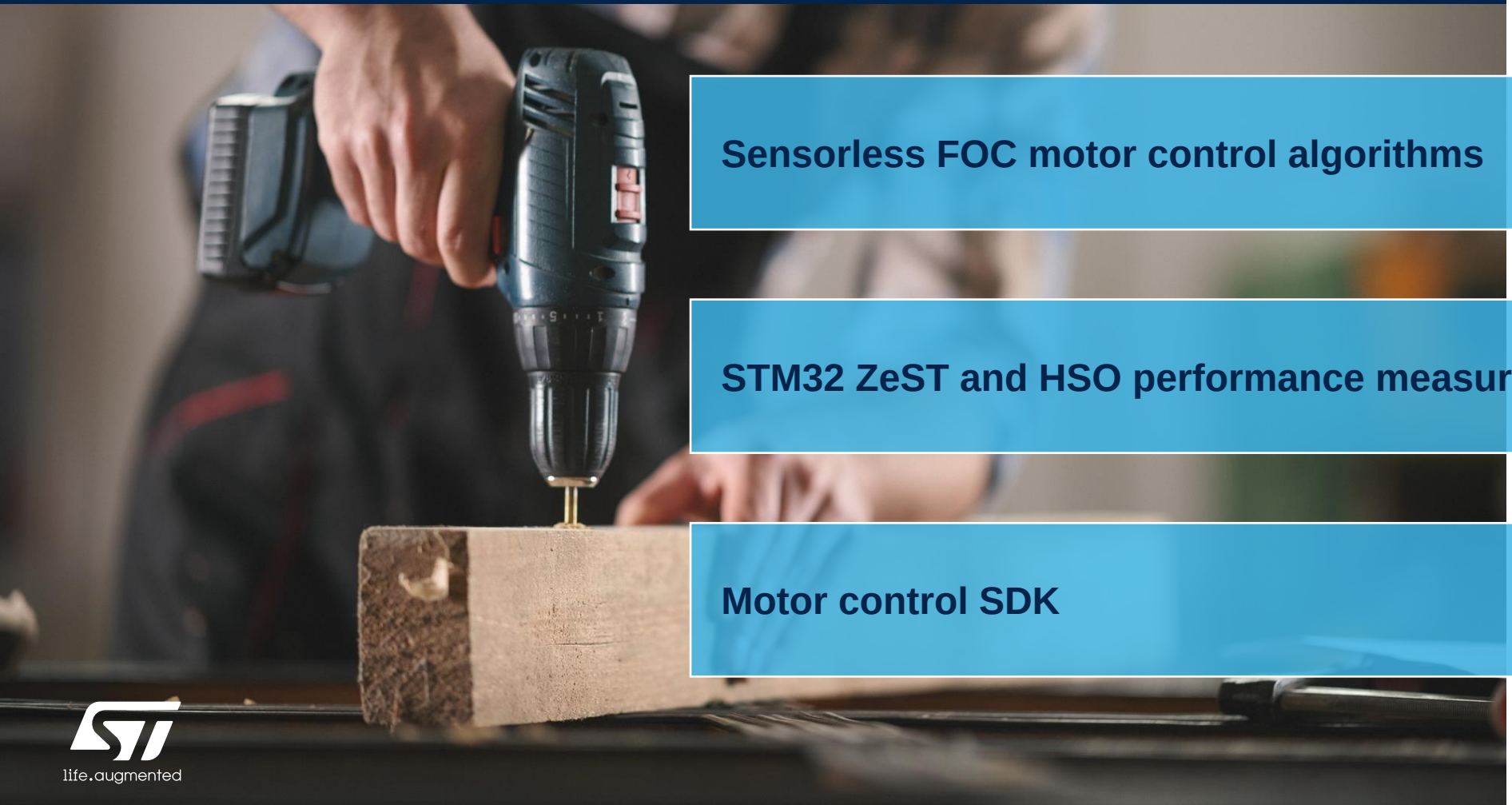
Motor control solutions and tools

Digital Power solutions and tools

STM32 portfolio and ecosystem

Sensorless motor control solutions

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



- **Sensorless FOC motor control algorithms**
- **STM32 ZeST and HSO performance measurements**
- **Motor control SDK**

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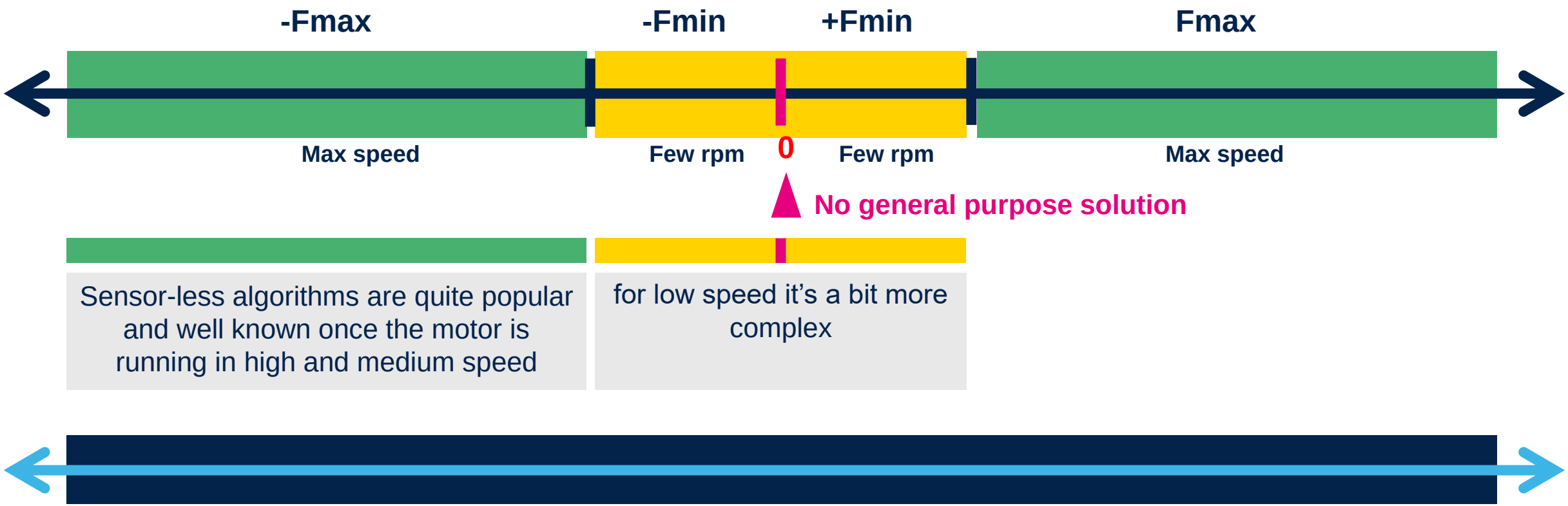
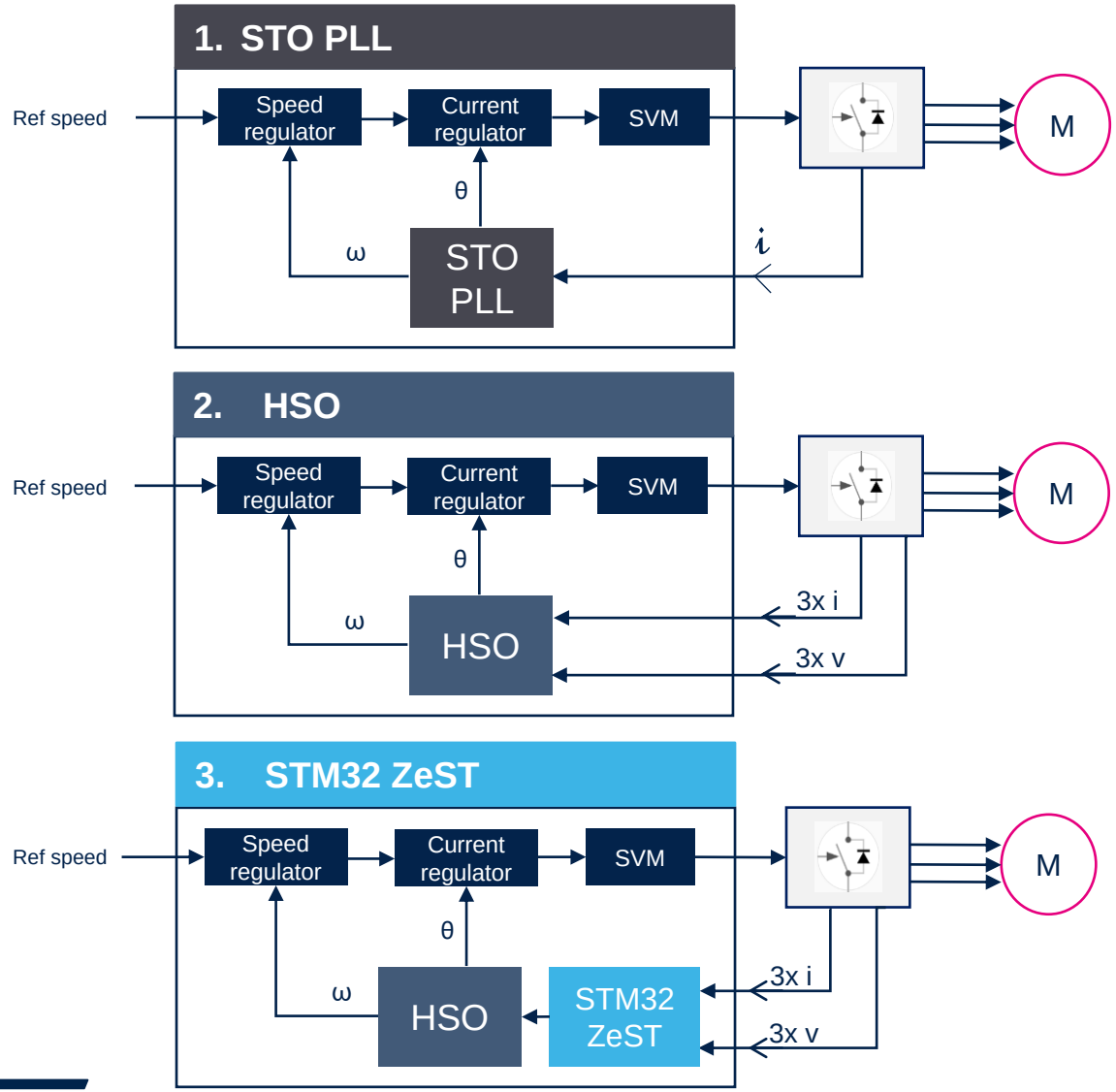
FOC sensorless challenge
Cold starting BLDC / PMSM motors with full torque



ZeST + HSO

New solution from ST !!

Sensorless FOC algorithms



1. Luenberger State Observer (legacy)

- 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 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-ZEST1S)

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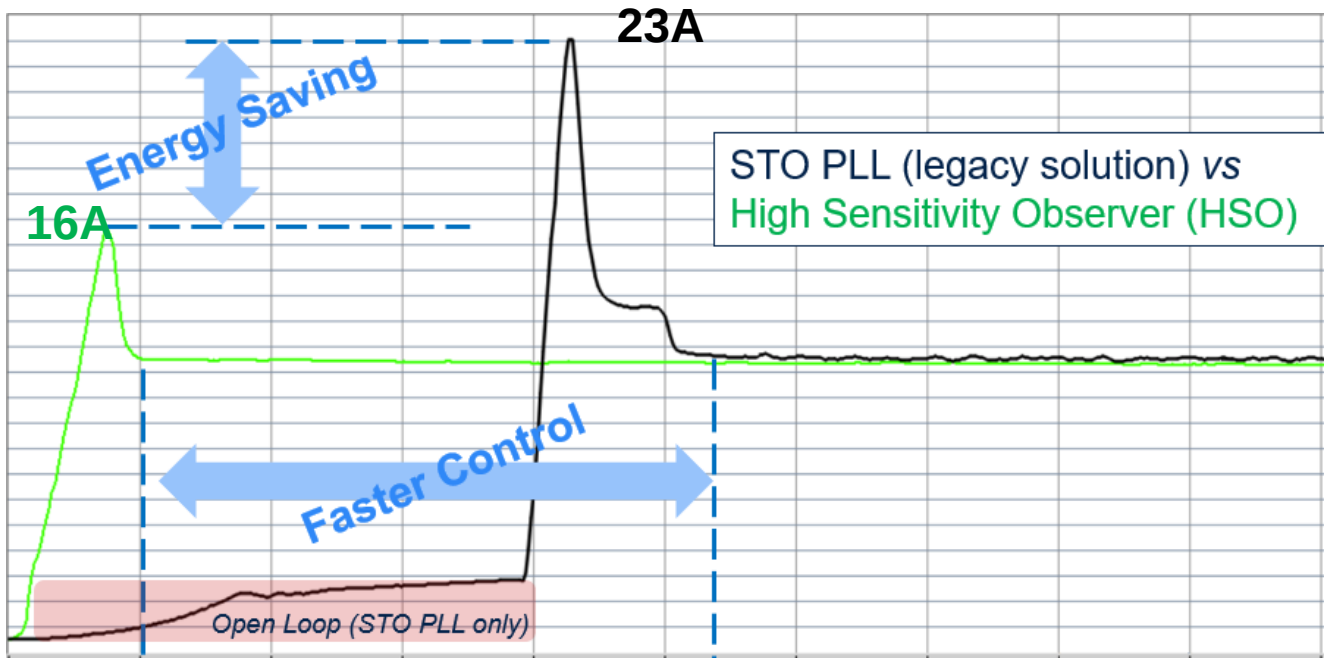
HSO – high sensitivity observer

Improvements in low-speed performance and efficiency



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

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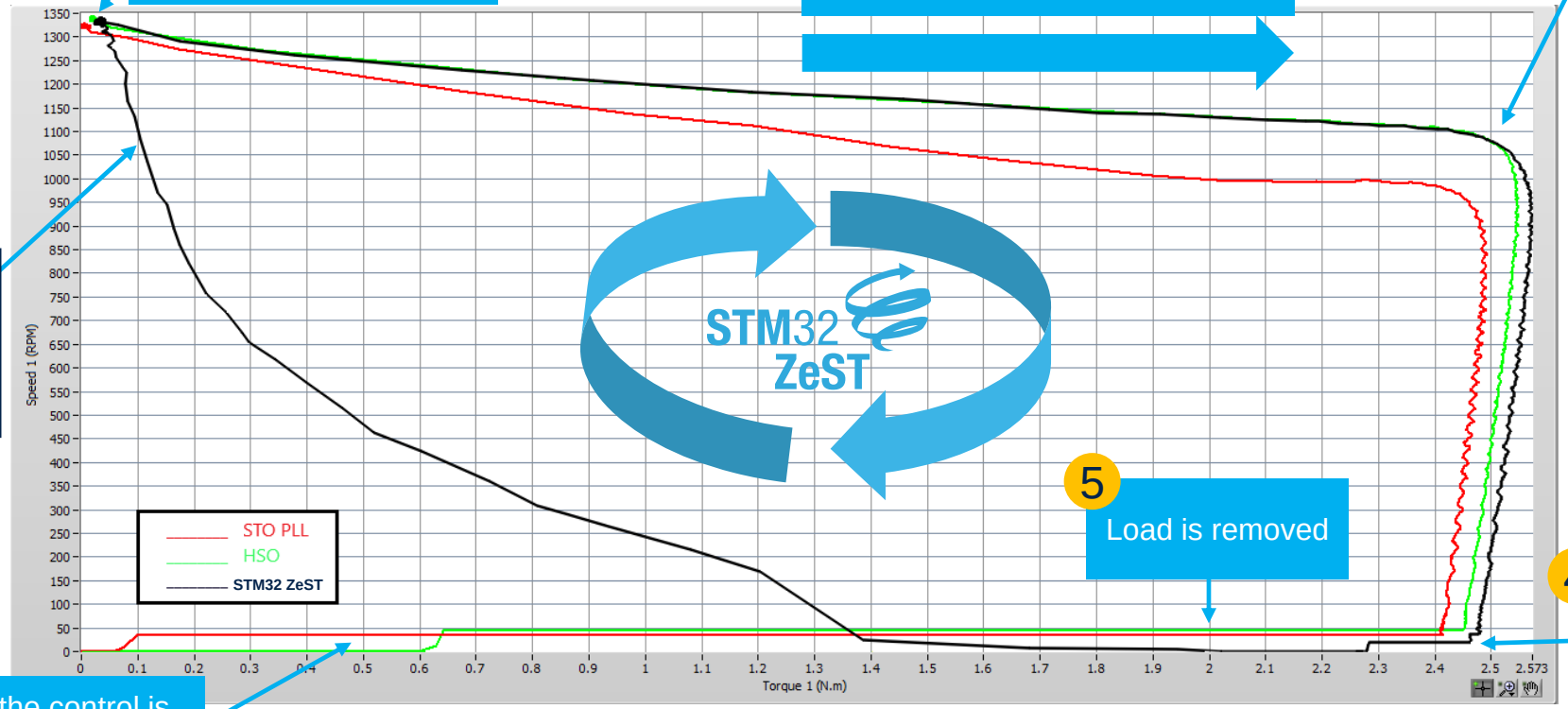
From full speed to stall torque (max torque, max load)



Speed vs torque

STM32 ZeST vs STO PLL vs HSO - Performance & behavior

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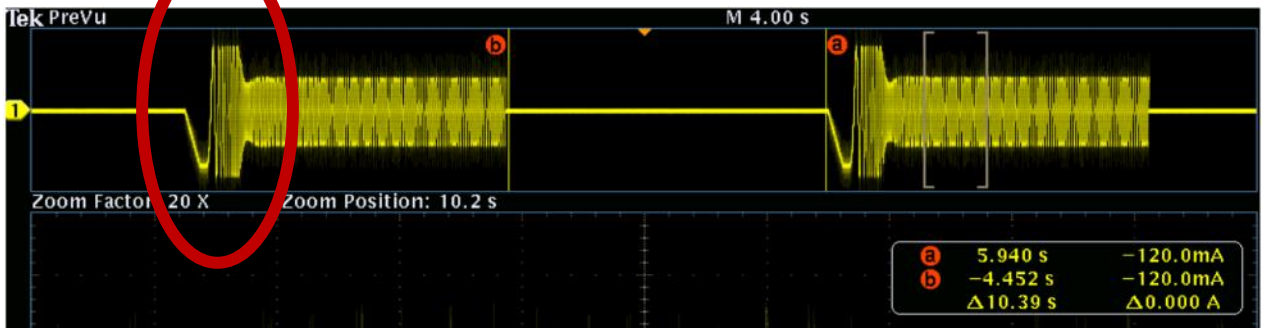
Using STM32 ZeST to run a smart, power-efficient washing machine

Zero Speed full Torque sensor-less algorithm

Energy saving per washing cycle ~ 15-40%

Standard (open loop) sensorless startup

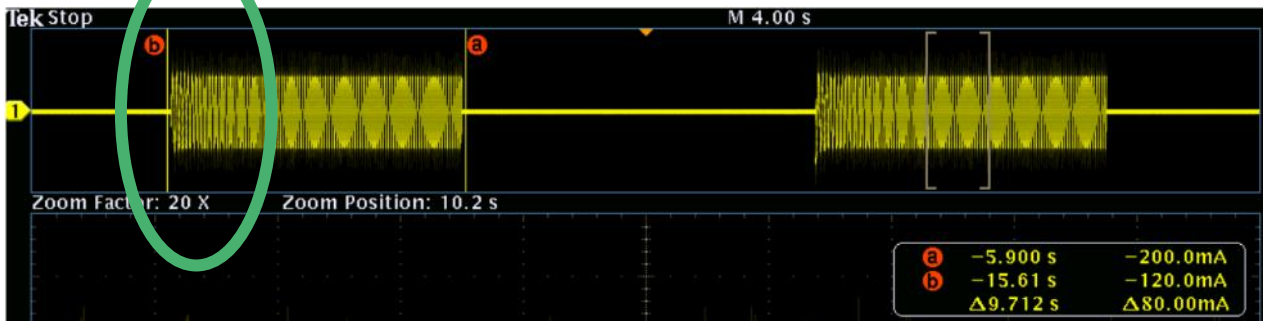
High peak current



STM32 ZeST start-up

Energy saving !

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



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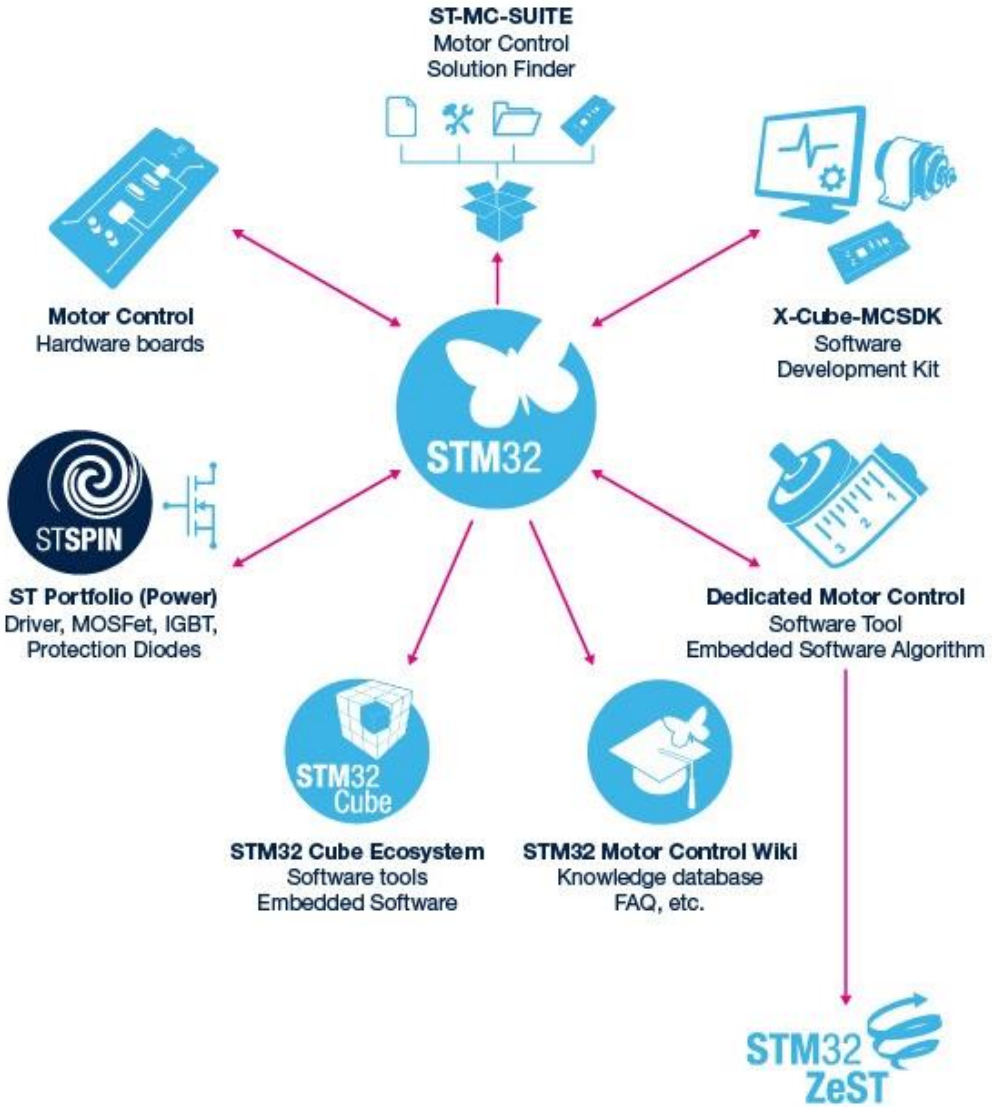
STM32 motor control ecosystem



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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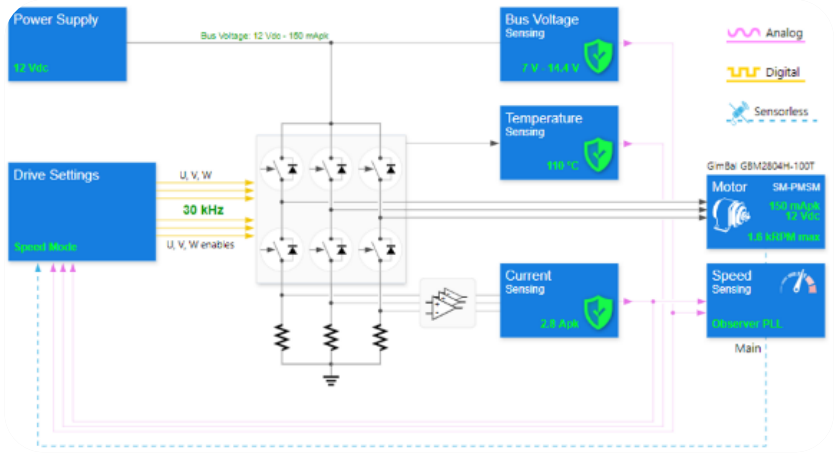
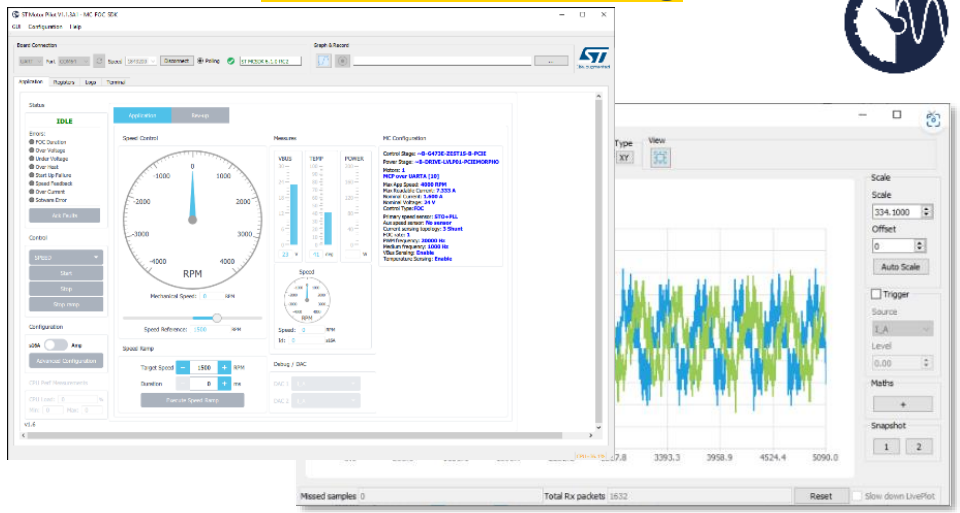
X-CUBE-MCSDK: tools and software

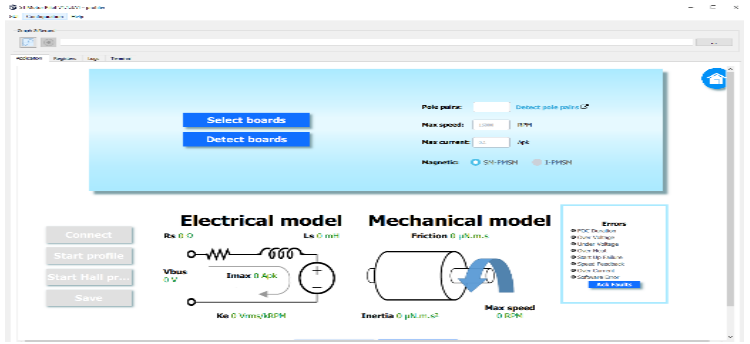
Motor Control Workbench: **System configuration**



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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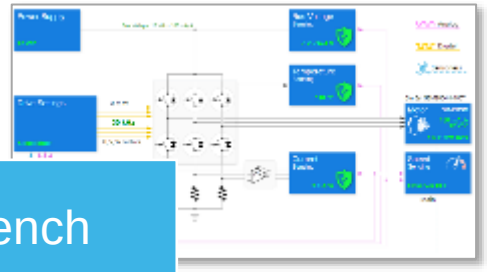
Motor control development flow and tools

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

1 **Hardware setup**

2 Motor Control Workbench

MC configuration



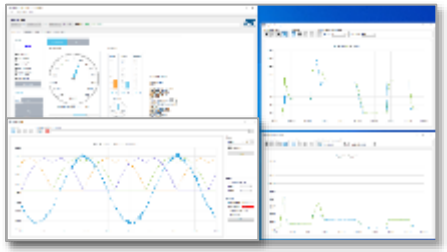
3 **Added configuration Project build**

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

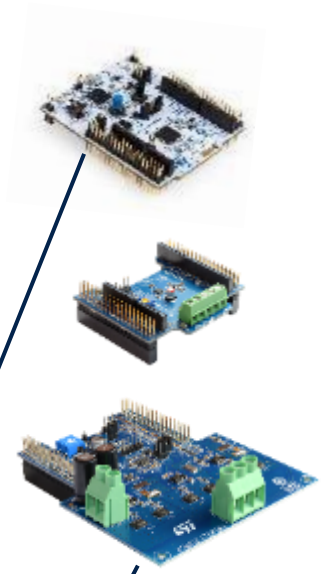
Control + power

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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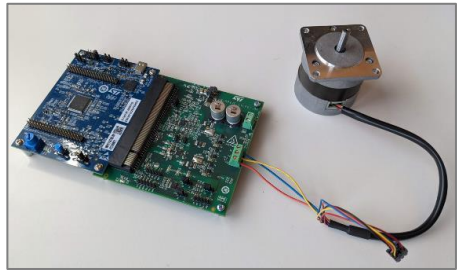
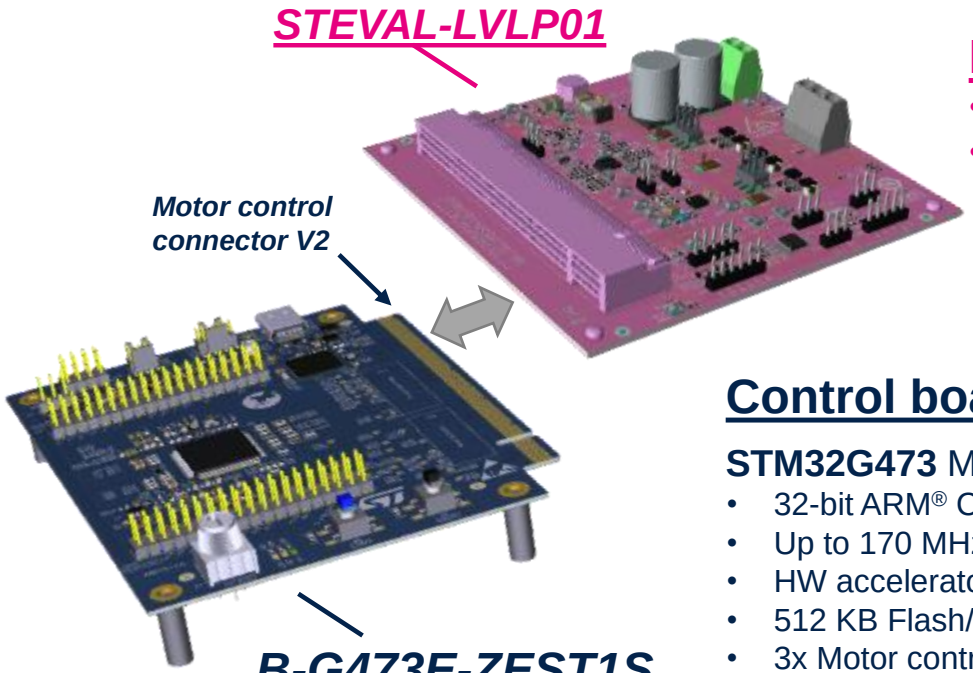
STM32 ZeST and HSO specific boards

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 and HSO 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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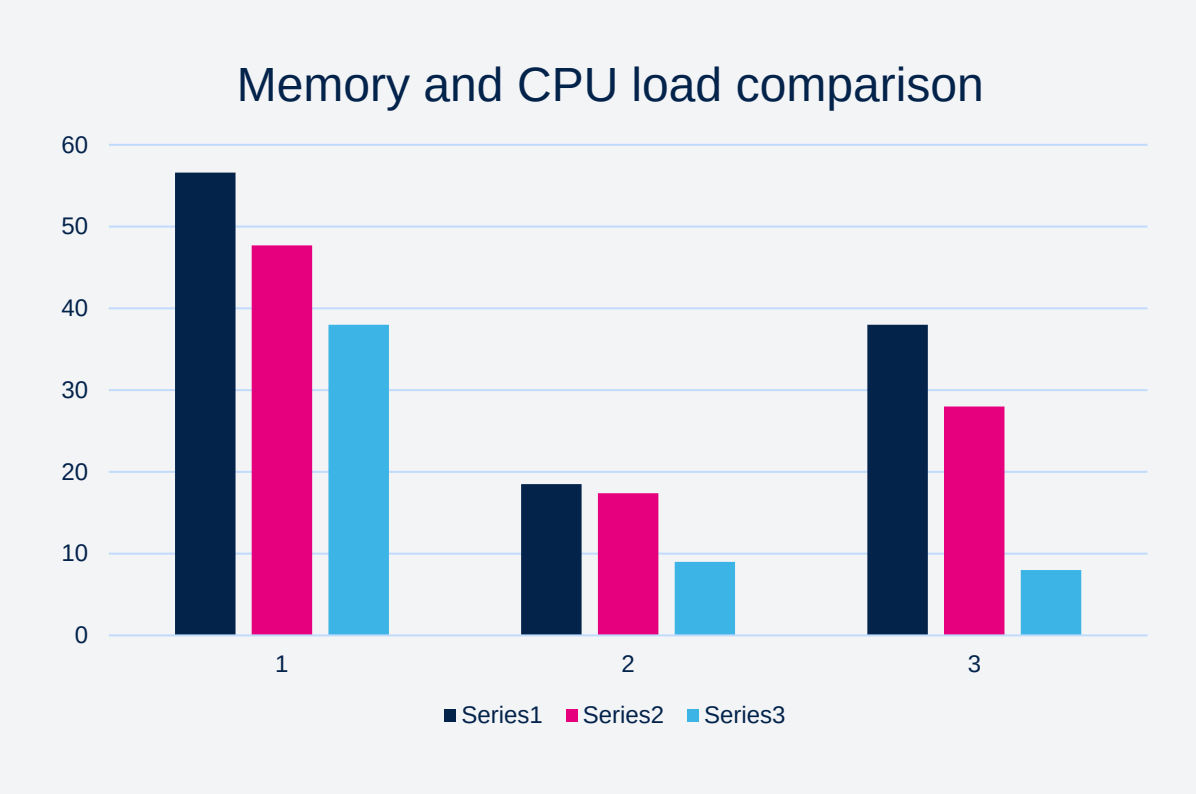
STM32G4 memory & CPU load



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	1 or 2	2
Advanced control timer	1	1
General purpose timer	**0**	**1**
Comparator	3	3
Operation amplifiers	3	3
DMA	**0**	**1**

Making edge AI more accessible with STM32 solutions

- 3 products for embedded developers and data scientists

AD + LOD
SENSING

NANOEDGE AI STUDIO

User-friendly Auto-ML tool for STM32 MCUs

SENSING
AUDIO
VISION

STM32 Cube.AI

AI model optimizer and code generator for STM32 MCUs

SENSING
AUDIO
VISION

X-LINUX-AI

A complete AI framework for STM32 MPUs

- Covering a broad variety of applications

ANOMALY DETEC. + L.O.D.

- Anomaly detection
- Predictive maintenance
- Learning on device

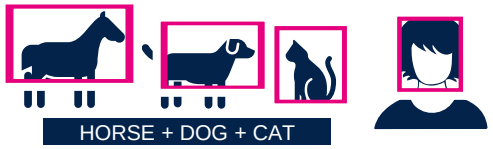
SENSING

- Sensor analysis
- Activity recognition (motion sensors)
- Stress analysis or attention analysis

AUDIO

- Audio (key word, scene detection)
- Speech (sentences) recognition
- Speech synthesis

VISION

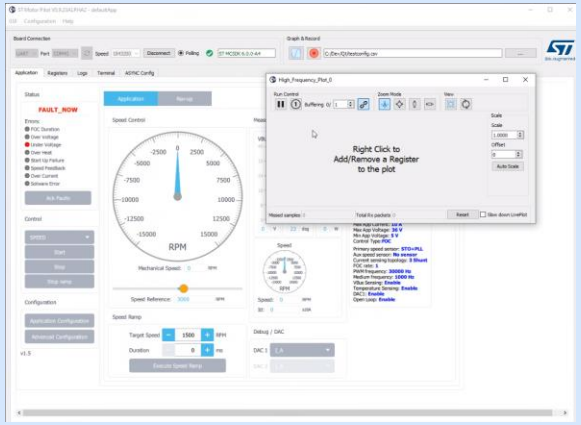


- Multiple object detection
- Face/object analysis (face detection)

Condition monitoring with X-CUBE-MCSDK

How to access to these new features and evaluate / create a PoC

Motor Pilot from MCSDK v6 with **record feature**



NanoEdge Studio Library generation

NANOEDGE AI STUDIO

NEAI libraries free of charge on STM32G4 dev boards

Integrate next to MC algorithm

CODE

Run MC and anomaly detection

MCSDK | NanoEdge AI Studio | IDE

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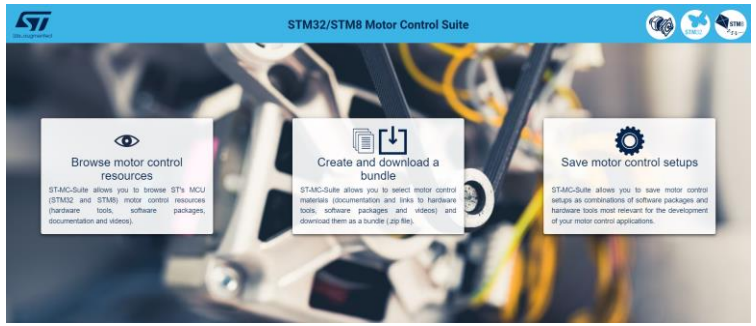
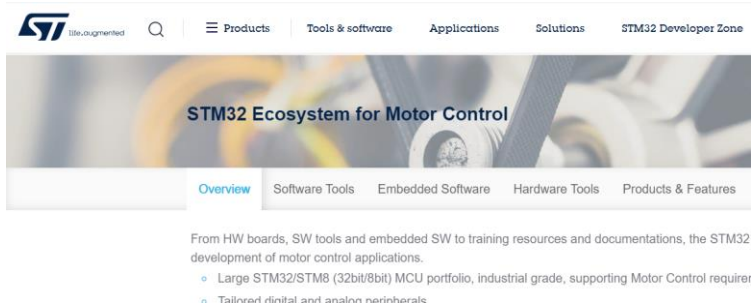
STM32 motor control resources



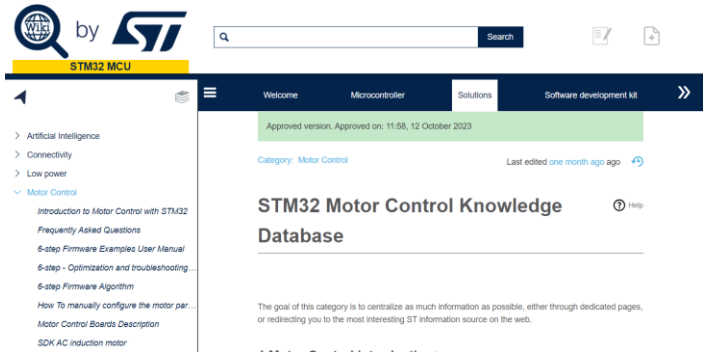
ST-MC-SUITE

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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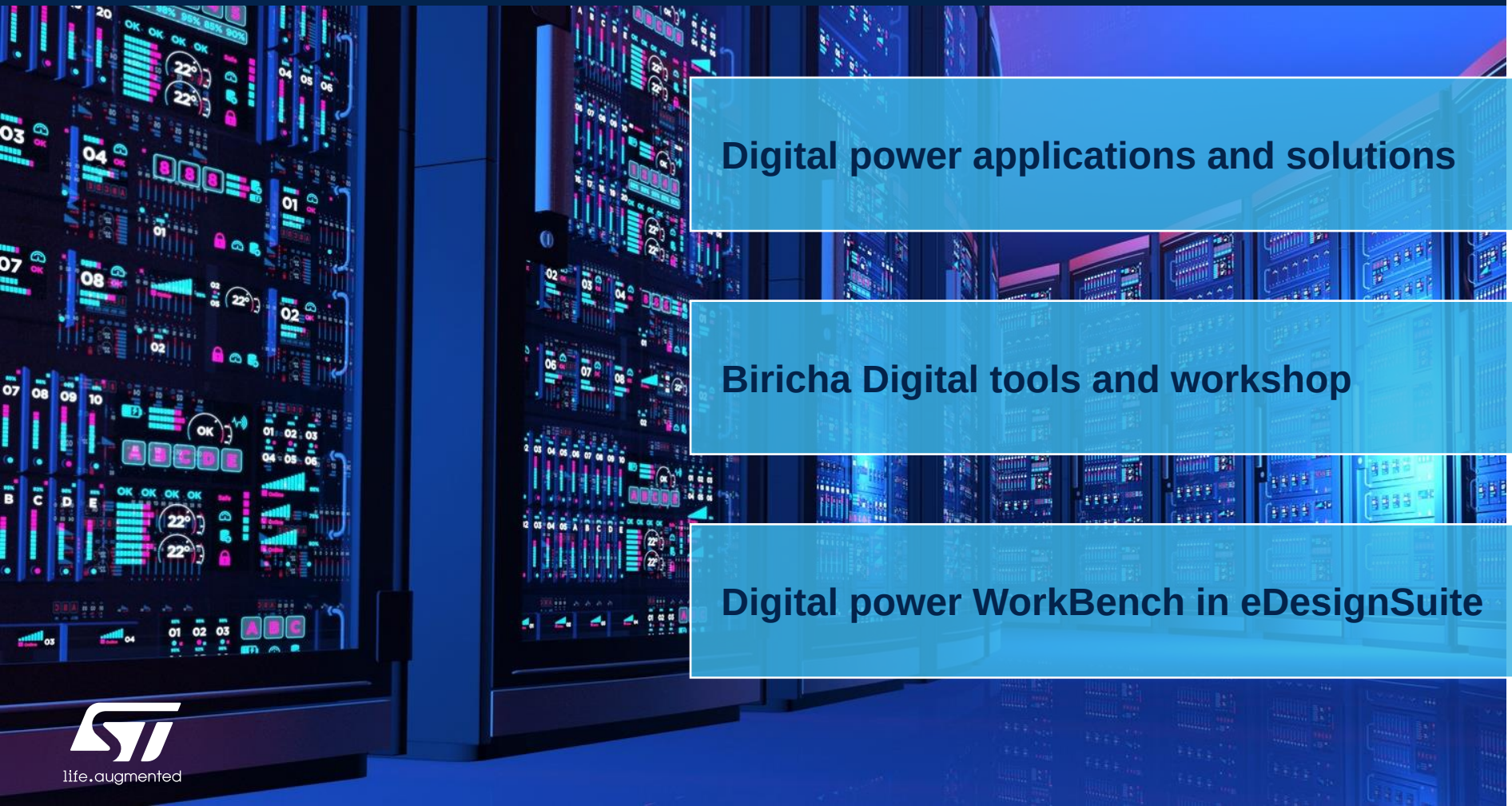
Digital power solutions and tools

Digital switch mode supplies and power factor correction



Digital power applications and solutions

Biricha Digital tools and workshop

Digital power WorkBench in eDesignSuite

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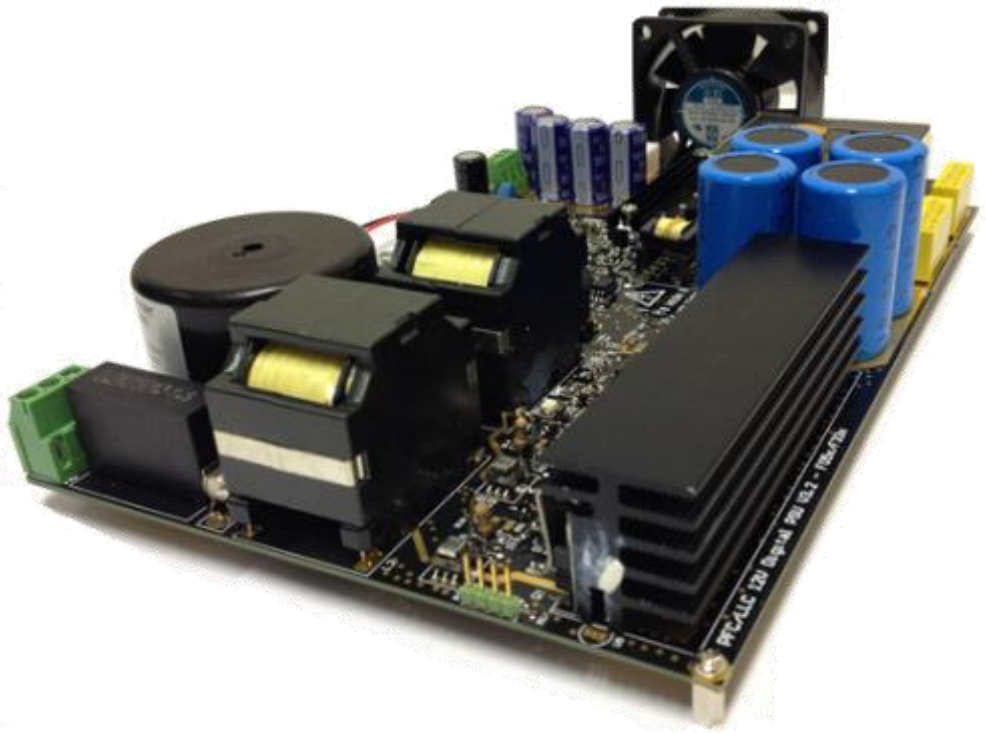
Why use digital power control?



- Less sensitive to environmental conditions (temperature, aging, etc.)
- Software programmable for a more flexible solution, single design for different solutions (e.g. output voltage)
- Advanced control possible (non-linear, type III compensator)
- Failure prevention (diagnostic monitoring and logging)
- Communications (fault reporting, firmware update)

STM32 Digital Power: a scalable ecosystem

Expert level

5 Dedicated boards (PSU + PFC)

Expert level

4 STM32 D-Power SDK (ST-WDS/ST-PLD + STM32CubeMX)

Partnership

3 Biricha workshops

2 STM32 D-Power Discovery Kits

1 D-Power for beginners

Basics of digital power in 2 videos by Biricha

Biricha design tools for STM32

ST WDS free digital power supply design tool available from Biricha Digital for all STM32 MCUs

ST PLD free digital power faction correction design tool from Biricha Digital available for all STM32 MCUs

download at biricha.com

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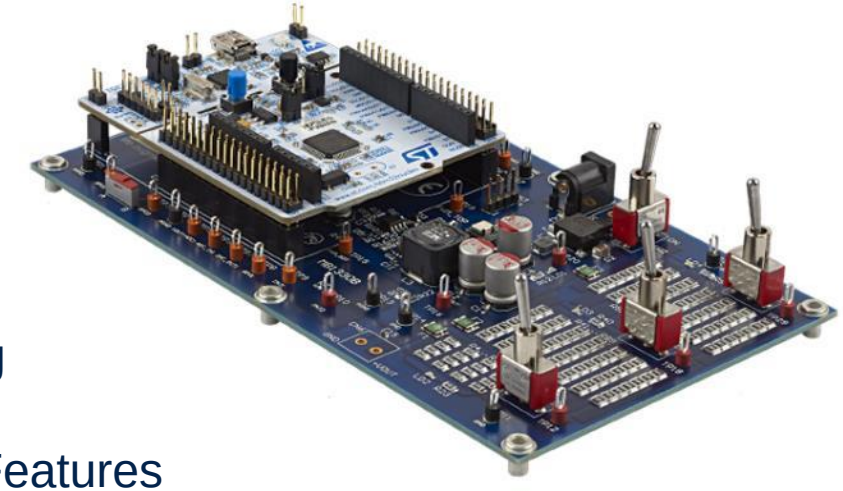
Biricha Digital 4-day hands on workshops

Digital Power Supply and PFC Design Workshop with STM32
April 23-26, 2024
Austin, TX
USA

STM32 PSU/PFC design workshop



Agenda:
Day 1: Introduction to Digital Power Programming
Day 2: Digital Power Supply Design
Day 3: Peak Current Mode and Advanced MCU Features
Day 4: Digital PFC Design & Implementation

register at biricha.com

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BIRICHA DIGITAL

Digital power WorkBench in eDesignSuite

Fully graphical user interface for high power solutions

Power stage optimizer

Digital control loop designer

STM32 FW generator

Evaluation board selector

Supported topologies (AC/DC, DC/DC)

- ZVS&CCM Interleaved Totem-Pole, Vienna Rectifier, 3-Level T-Type Converter
- FB LLC, DAB

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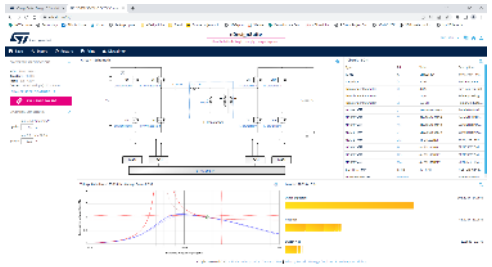
eDesignSuite

Digital Power WorkBench supported topologies

FB LLC
(500 – 5000 W)



Power stage optimizer

STM32F3

- Full SJ solution

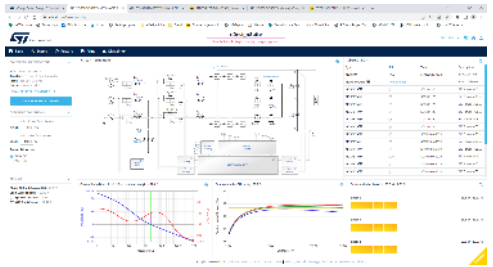
Vienna PFC Rectifier Bidir 3L T-type PFC
(6 – 20 kW)

DPC compatibility with STM32Cube, signal conditioning eDSim simulation

STM32G4

- Full SiC solution

ZVS Totem-Pole PFC
(330 – 3300 W)

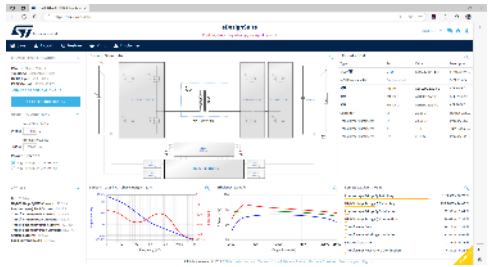


DPC compatibility with STM32Cube, signal conditioning eDSim simulation

STM32G4

- Full SJ solution

Dual Active Bridge
(6 – 30 kW)



DPC Bidirectional power flow, STPOWER Studio connection

STM32G4

- Full SiC solution

Bidirectional Totem-Pole
(3 – 11 kW)

SiC/SJ solution

Bidirectional CLLC
(3 – 11 kW)

SiC/SJ solution

3-phase bridge PFC – B6
(11 – 22 kW)

Full SiC solution

AVAILABLE SOON

2021 2022 2023

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eDesignSuite

D-power @ eDesignSuite

GUI

- Schematic view, BOM, Bode Diagrams, Power losses (for Power Transistors and Diodes)
- Wizard based design customization

Hardware sizing

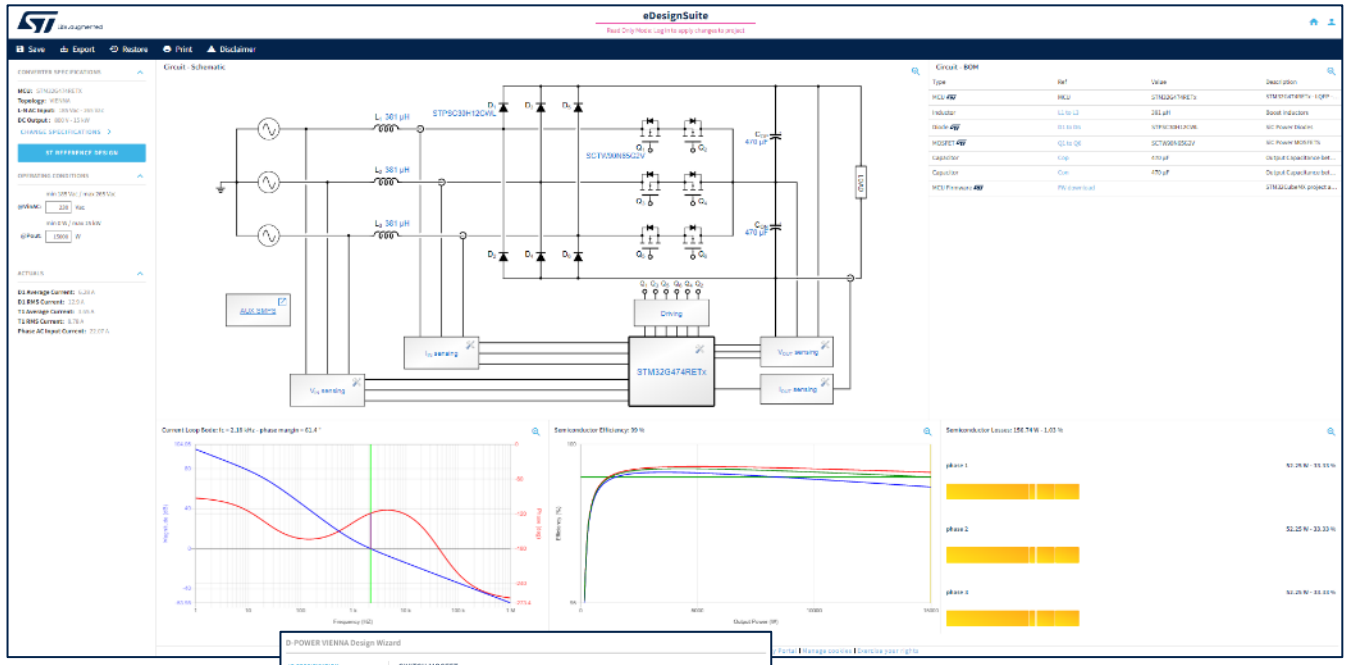
- Magnetics, power switch selection, diodes selection, current Loop and voltage loop compensation

Firmware customization

- Sensing, protections, voltage control and Current Control

Firmware delivery

- Compatibility with STM32Cube tools: delivery of custom STM32Cube expansion pack for the selected topology + STM32CubeMX project (.ioc file) reflecting all current solution customization



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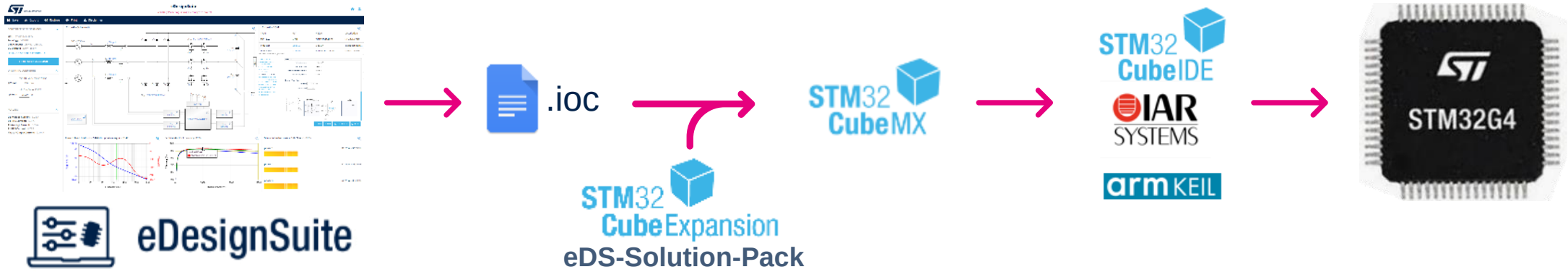
DPWB D-power firmware

FW generation and delivery workflow



Firmware delivery

Compatibility with STM32Cube tools: delivery of custom STM32Cube expansion pack for the selected topology + STM32CubeMX project (.ioc file) reflecting all current solution customization

eDesignSuite

eDesignSuite

Digital Power Workbench

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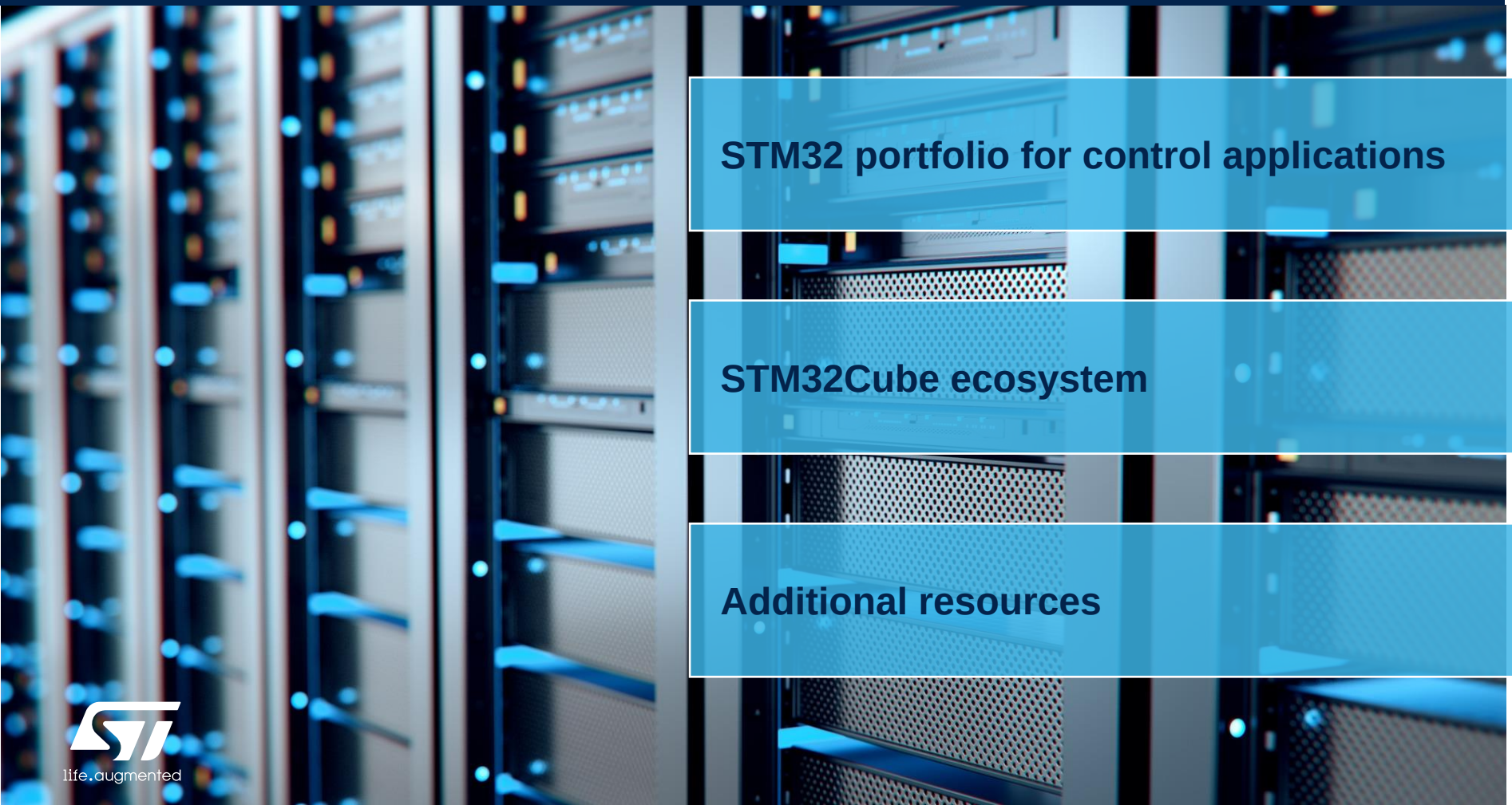
STM32 portfolio and ecosystem

Large and scalable MCU portfolio and rich ecosystem



- STM32 portfolio for control applications
- STM32Cube ecosystem
- Additional resources

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STM32 portfolio

MPU

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

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

High Perf MCUs

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

Mainstream MCUs

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

Ultra-low Power MCUs

STM32L0
75 CoreMark
32 MHz Cortex-M0+

STM32U0
134 CoreMark
56 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

Wireless MCUs

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
Pre-announcement (coming in 2024)

STM32 series support

MC-SDK support for STM32 microcontrollers

STM32F0	STSpin32F0	STM32F4	STM32L4	STM32F3
STM32F7	STM32G0	STM32G4	STSpin32G4	STM32H7
STM32C0	STM32H5			

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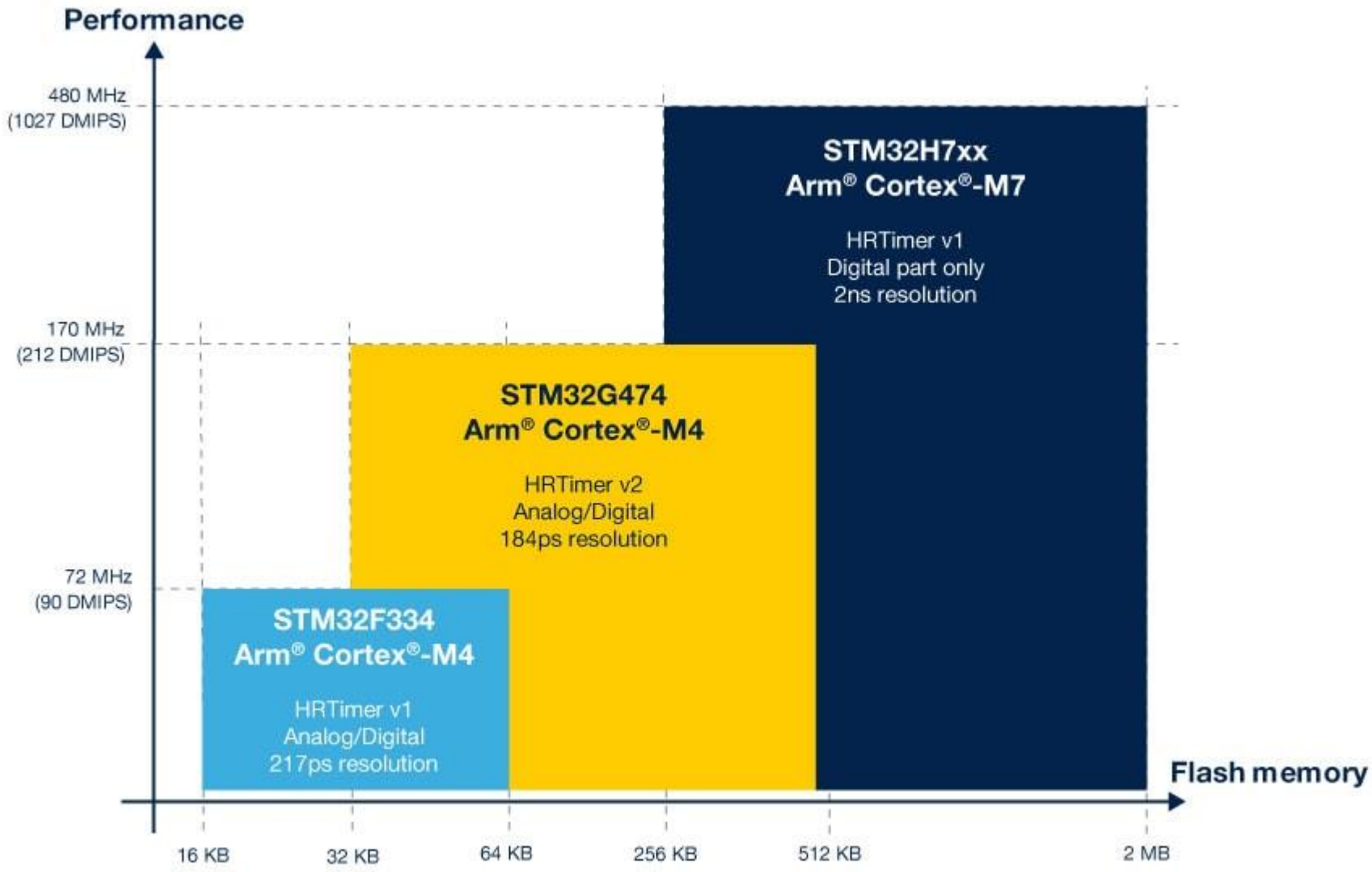
STM32 flagship products for digital power



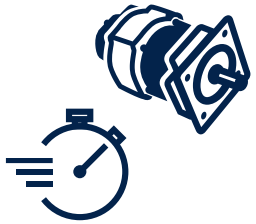
STM32G4 features for control applications

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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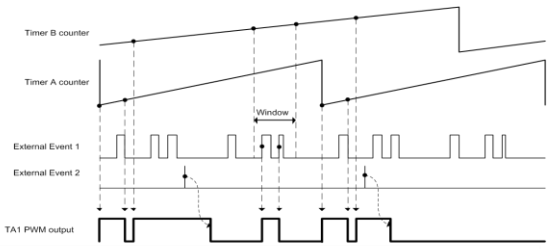
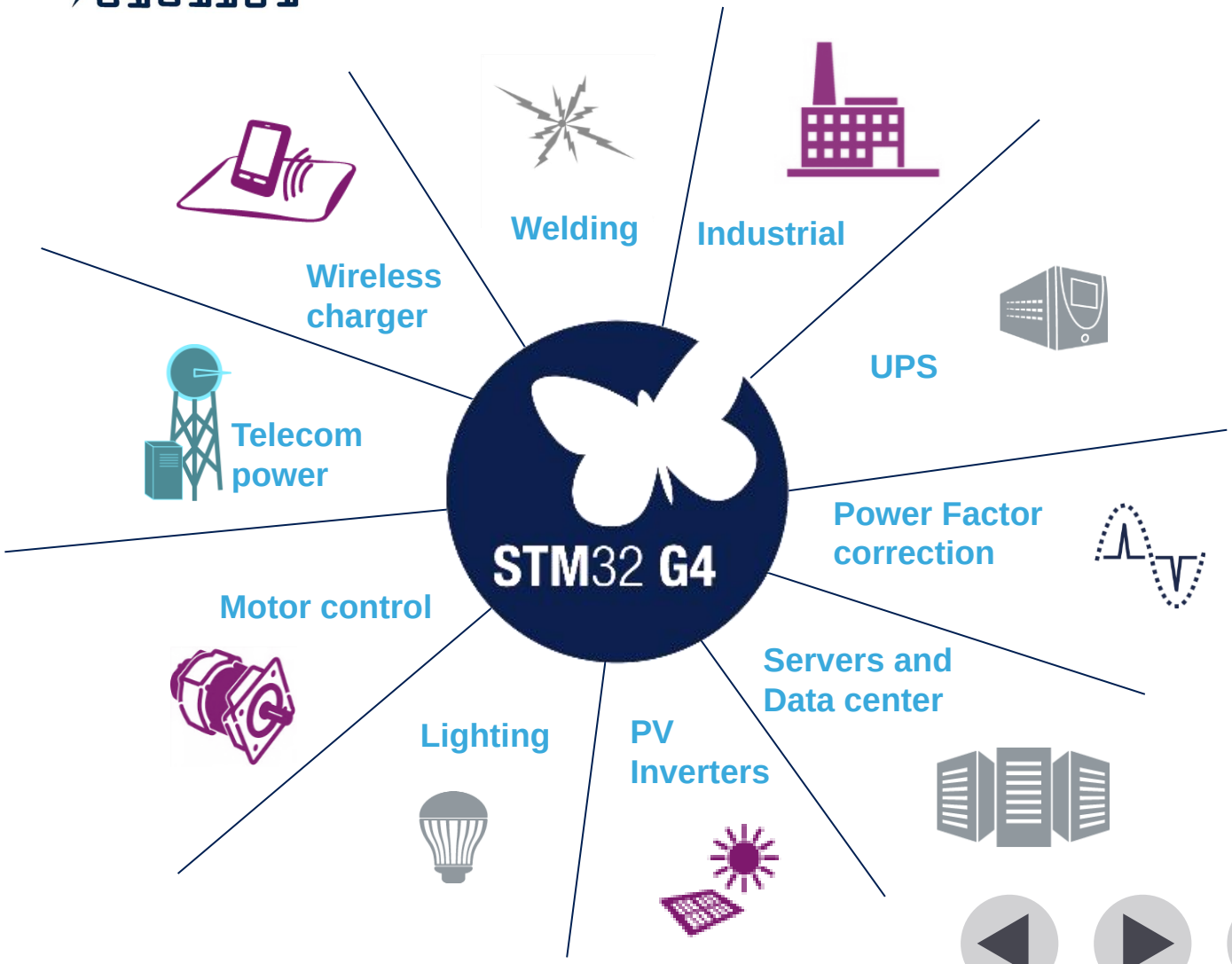
Digital power applications

Enhance your digital power solutions using the **High Resolution Timer (HRTIM)**

- ✓ 184ps resolution
- ✓ Flexible PWM generation





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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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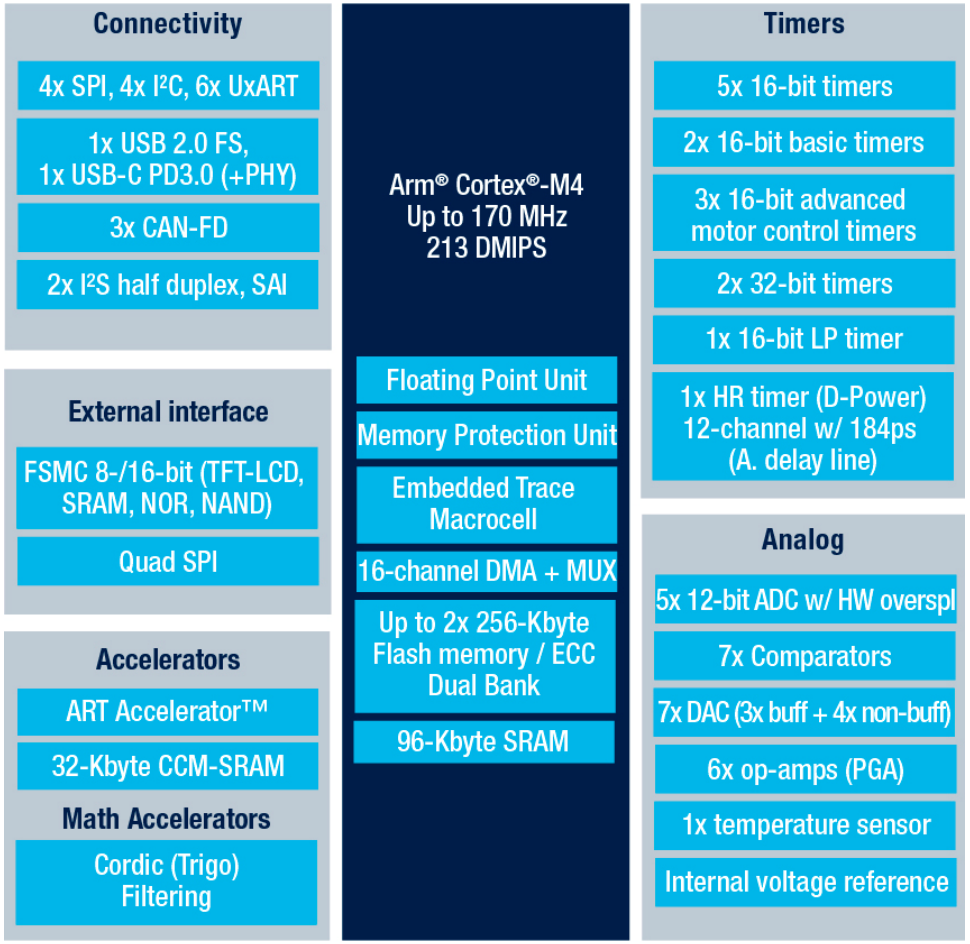
STM32G474/3 block diagram

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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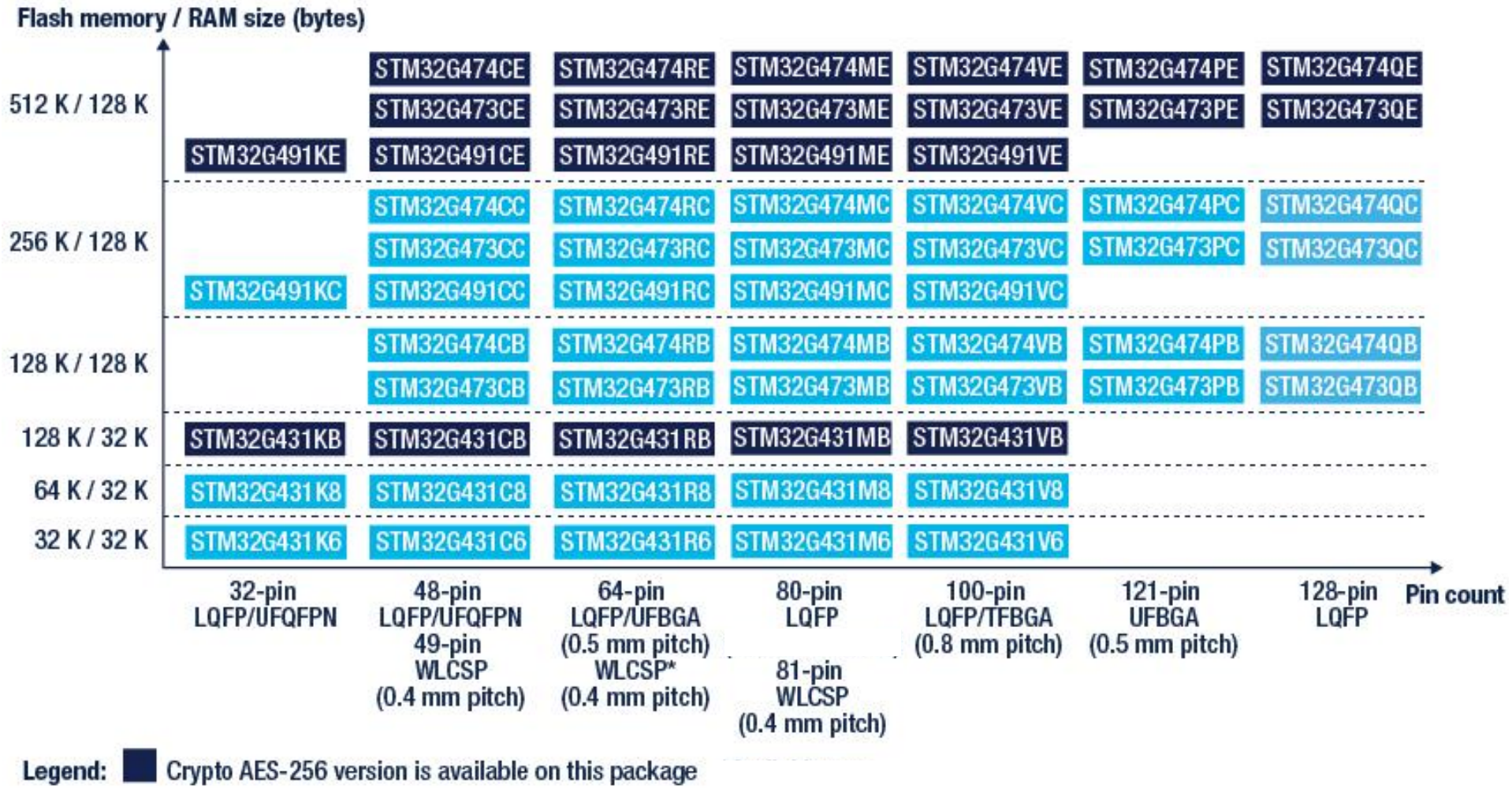
STM32G4 portfolio



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STM32 ecosystem overview

Software

Software Tools

- STM32 CubeMX — Configuration
- STM32 CubeIDE — Development
- STM32 CubeProgrammer — Programming
- STM32 CubeMonitor — Monitor

Embedded Software

- STM32 CubeMCU Packages — Packages
- STM32 Cube
- STM32 CubeExpansion — Expansions

Hardware



STM32 Nucleo	Discovery kits	Evaluation boards
Flexible prototyping	Key feature prototyping	Full feature evaluation

Customer support

FAE - Worldwide Customer Support

community.st.com

MOOC

Partner Program

new

wiki.st.com/stm32mpu

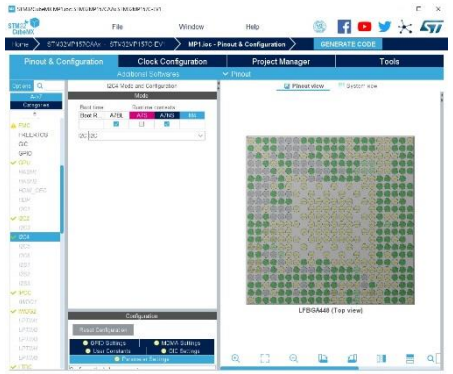
wiki.st.com/stm32mcu

github.com/STMicroelectronics

Software tools for STM32

Complete support of Arm Cortex-M architecture

STM32 CubeMX

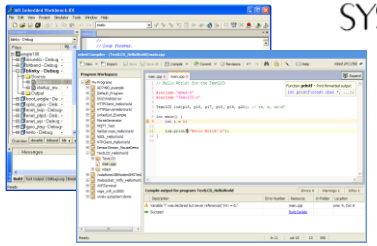


STM32 CubeIDE

arm KEIL

IAR SYSTEMS

eclipse



STM32 CubeProgrammer

STM32 CubeMonitor

STM32CubeMX

STM32CubeMX enhanced for Dual-core

- Configure and generate Code
- Multi-core resources allocation
- Peripherals configuration

IDEs
Compile and Debug

Multi-Core Solutions

- Partners IDE
- Free IDE based on Eclipse
- **Multi-core** debugging

STM32 Programming & Monitoring tools

STM32CubeProg
STM32CubeMonitor

- Program the application into the chip
- Sign the application and generate license
- Monitor variables at run-time

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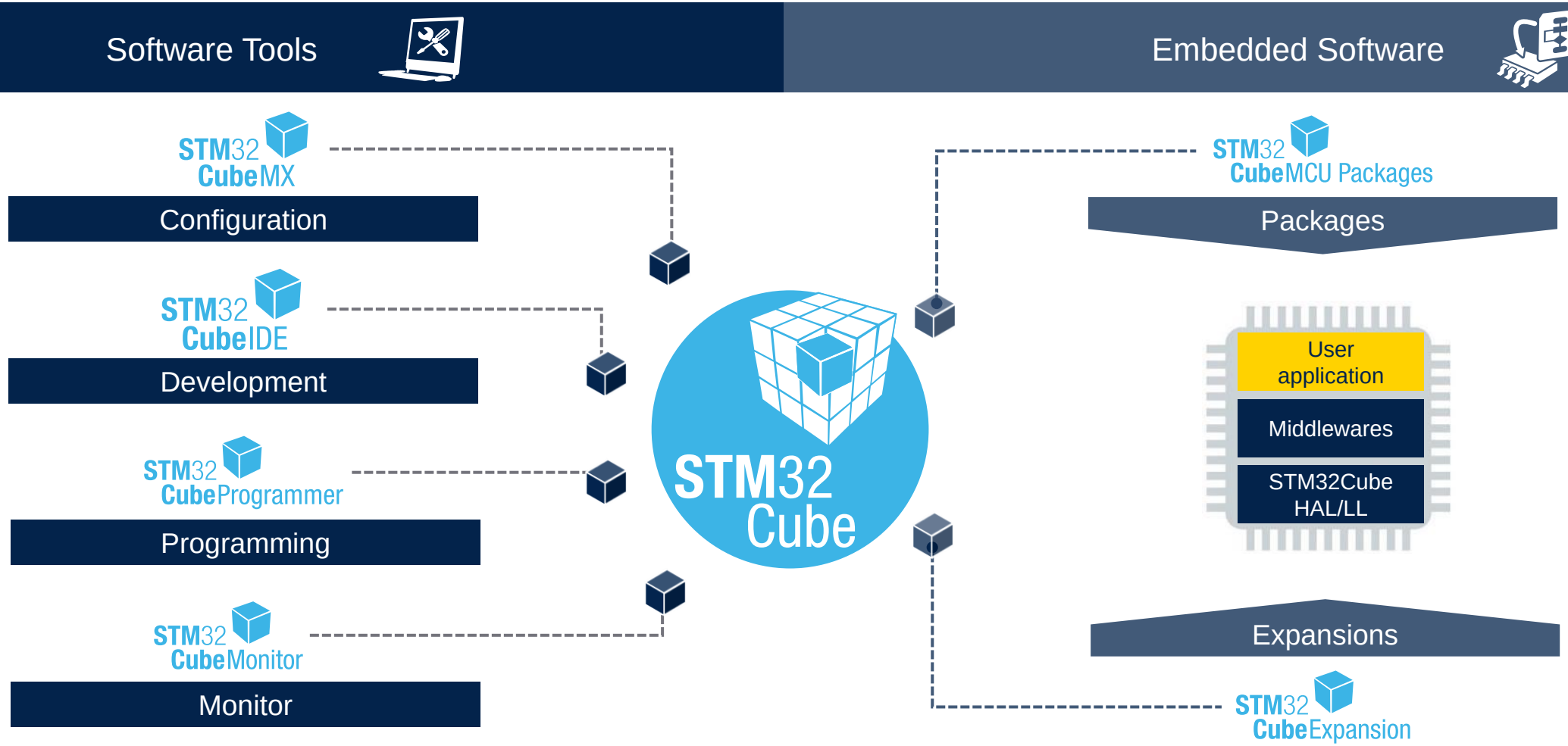
STM32Cube Software Suite Offer



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