

# ST 电机控制创新技术中心 电机解决方案

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Industrial Motor Control Competence Center  
AP Region, STMicroelectronics

Motor Control  
Competence  
Center





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电机控制创新技术中心：  
使命, 组织架构, 实验室

2

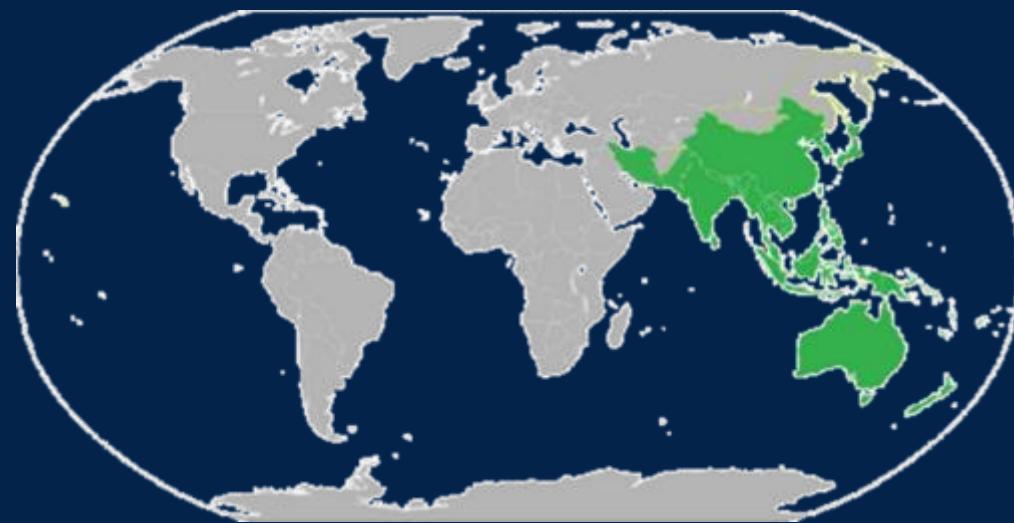
ST 用于电机控制的产品及架构

3

ST参考解决方案

# 电机控制创新技术中心使命

创建和推广创新的、便捷的以及成熟的**电机控制系统解决方案**;  
设计和**伙伴**和当地的客户  
增加**工业应用的全部ST产品**影响  
提高细分市场的**收入增长**



## • 系统级研发

- HW Reference Design, Application Boards
- FW Application Modules for the ST MC Library
- System Solutions

## • 客户支持

- Evaluation & Training with ST Tools
- ST Kit Product Selection (in cooperation with TM)
- Schematics; Layout review; Tuning (in cooperation with FAE)

## • 伙伴关系

- 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
- Inter-divisional / strategic MKT / Joint Labs: information & technology alignment

# 电机控制创新技术中心关注焦点



## 电机控制



家用电器  
空调

自动化伺服驱动器

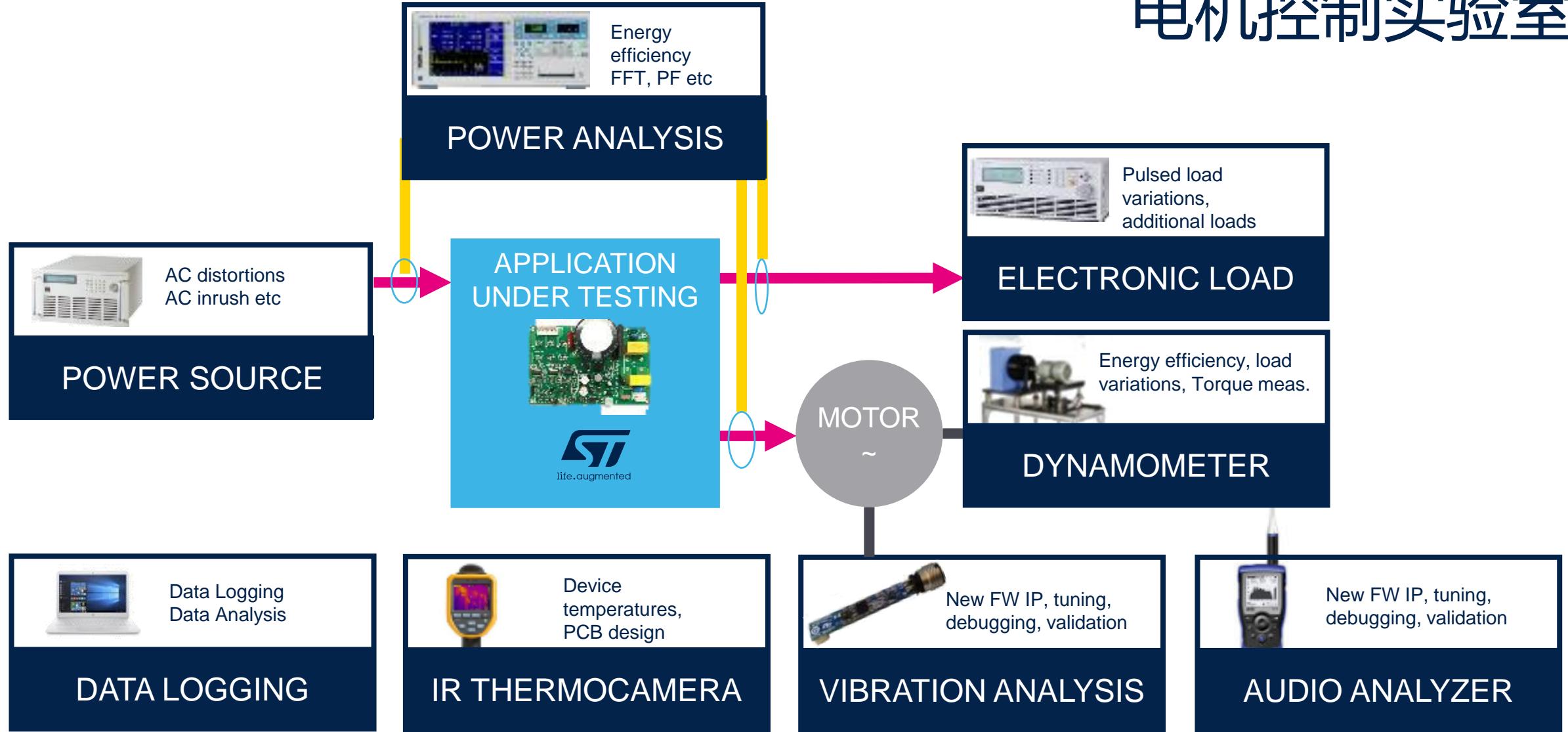
工业  
运输

电动 & 园林  
工具

消费类  
电机控制

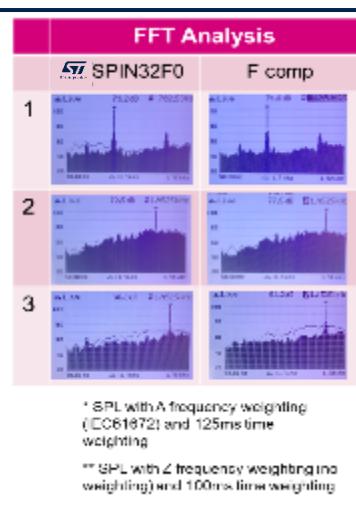
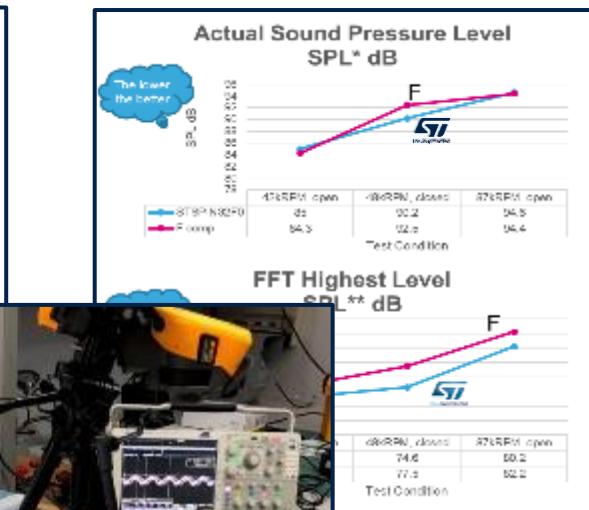
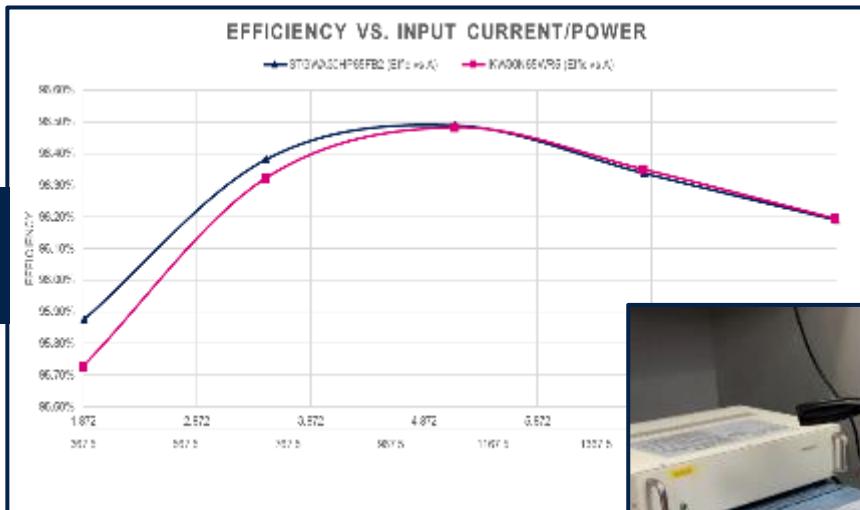


# 电机控制实验室



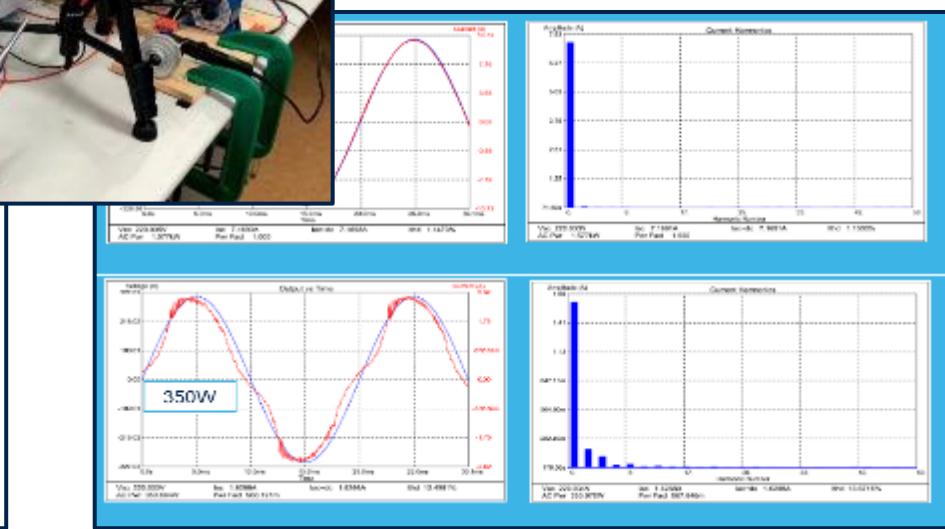
# 电机控制实验室 测试项目

Energy efficiency



Audio Analysis

Thermal analysis



PF, THD Measurement

# 电机控制 技术, 架构, 生态系统

Extensive Motor Control ecosystem based on high technology and STM32 MC SDK for higher efficiency and reliability



IGBT, HV SJ Power MOSFETs, Power Modules



STM32G4, STSPIN32F0, Microcontroller



Gate driver ICs, AC-DC converters, Power Management, Signal conditioning and interface



► Diodes and Protections, Thyristors



MEMS Sensors & Actuators, Time of Flight

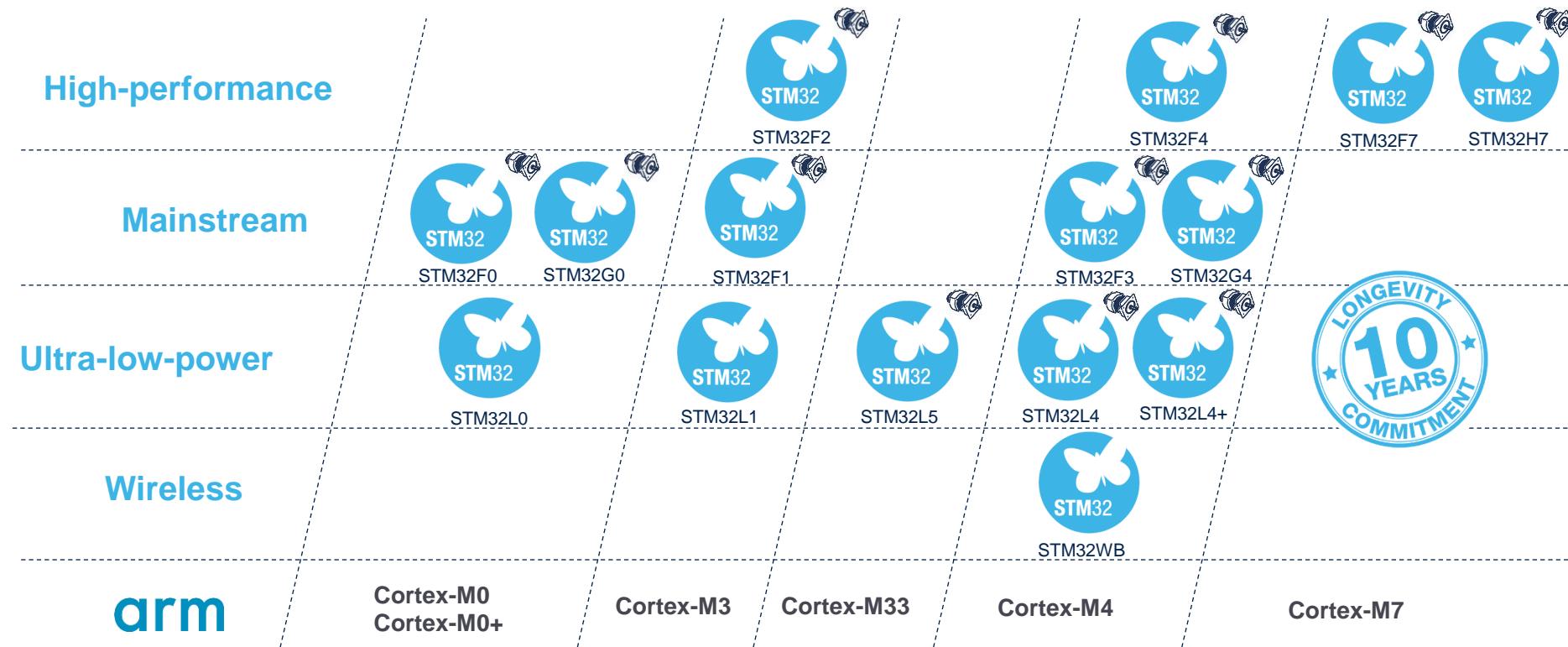


Bluetooth LE and Sub-1GHz processors, chip and modules



# STM32 电机控制组合 – 橄榄

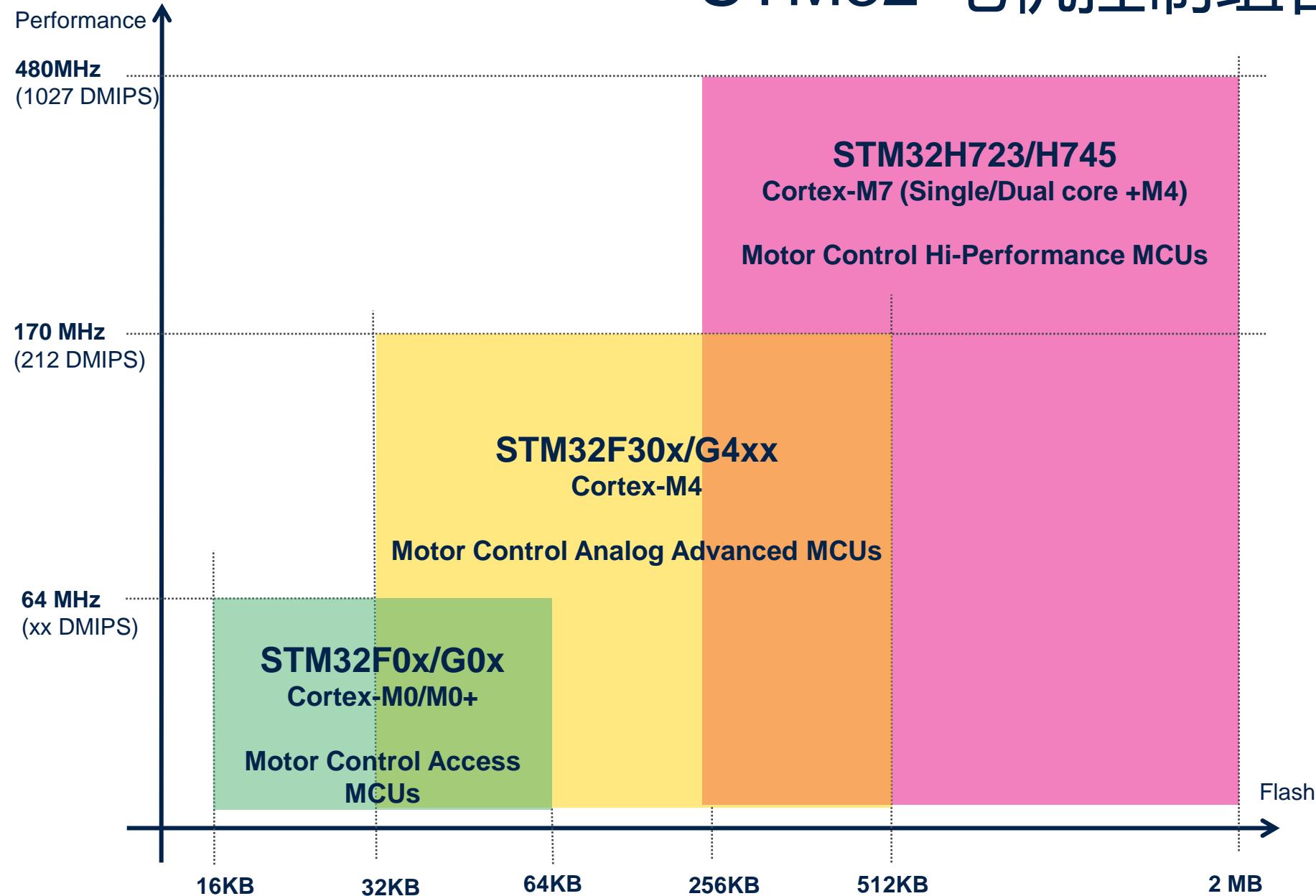
Large choice of STM32 with embedded Advanced Motor Control PWM timers



: STM32 series with Advanced PWM Motor Control timer(s)



# STM32 电机控制组合- 旗舰





# ST 电机控制驱动组合

Broad portfolio with > 130 products and > 1.5 Billion units sold

## Motor Driver ICs 1.8V – 600 V

Extra-Miniaturized  
STSPIN2 Series

High-performance  
STSPIN8, L62 Series

High-Power / Voltage  
PWD SiP Series

## Gate Driver ICs + MOS / IGBT / SiC / GaN 600V – 6KV

Half-Bridge  
3-Phase Bridge  
L638, L639 Series

High-Current  
L649 Series

Galvanic Isolated  
STGAP Series

Motor drivers with embedded MCU: STSPIN32 Series

Below 10 W

Up to 100 W

Up to 500 W

Up to 1 kW

Up to tens of kW



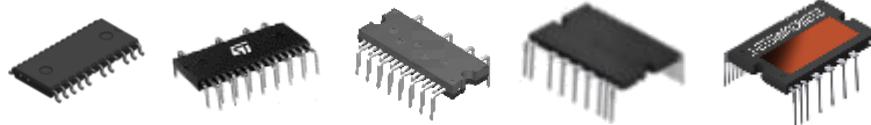


# 完整的功率模块

## Intelligent Power Module SLLIMM

(IGBT, Silicon MOSFET options)

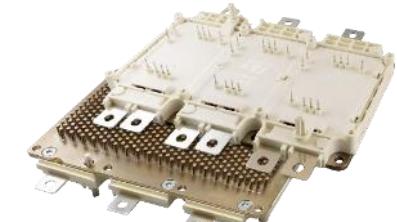
Higher current scalability to cover a wider power range



## Power Module ACEPACK

(Silicon MOSFET, IGBT, Silicon Carbide MOSFET option)

Adaptable Compact Easier Package



— 30W — 500W — 3kW — 5kW — 10kW — 30kW — 150kW — 250kW →

### Home Appliances

Roller shutter   Washing Machine   Fridge   Air Conditioning



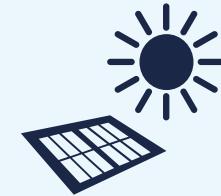
### Motor Drive, E-Mobility

Motor Pump   DC-DC, OBC   Electric Motor, Charging Station



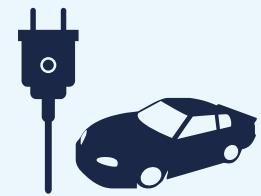
### Energy Conversion & Storage

Solar Inverter



### E-Mobility

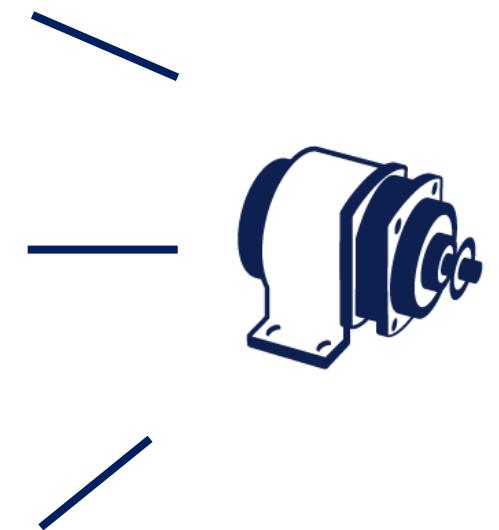
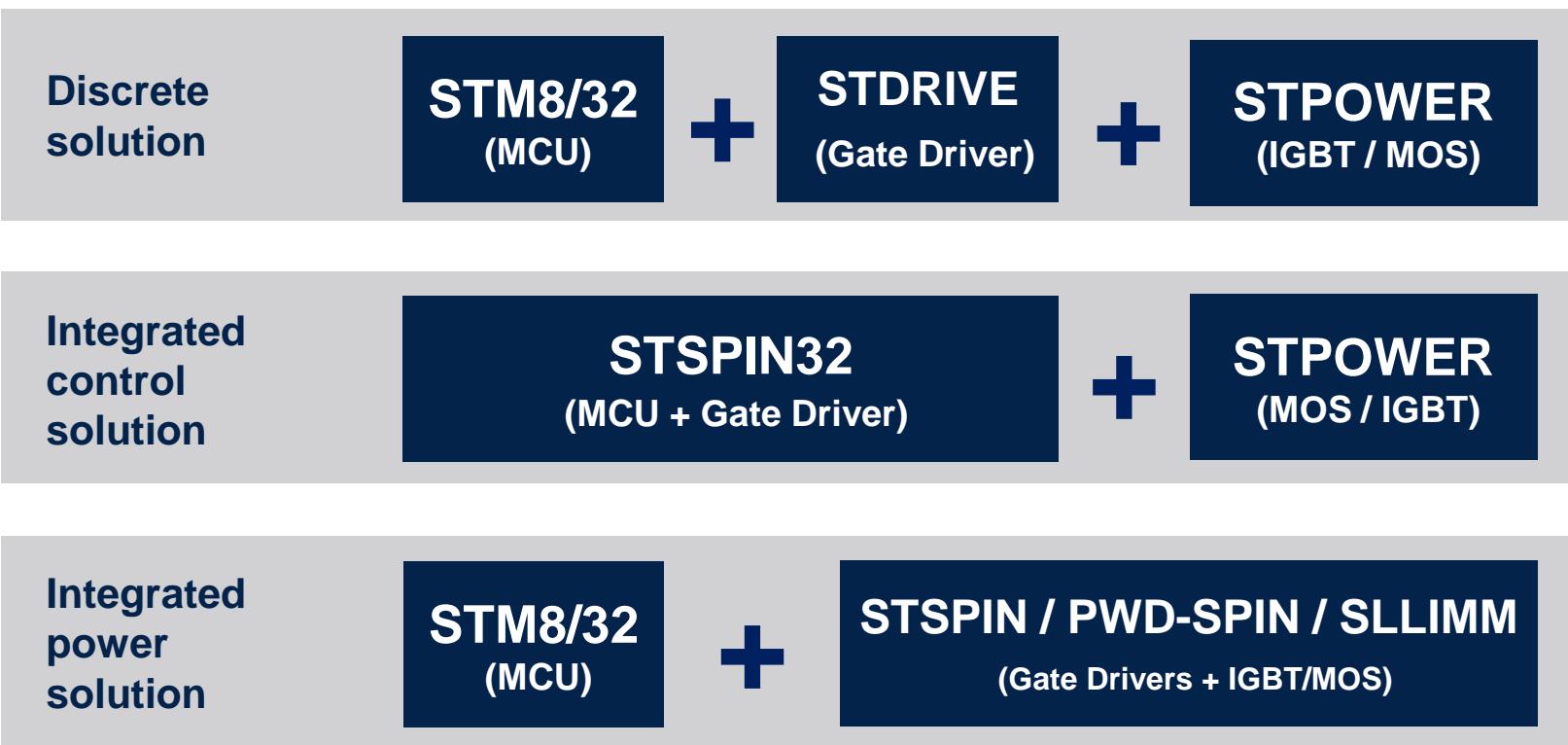
Traction



Typ. Application Examples

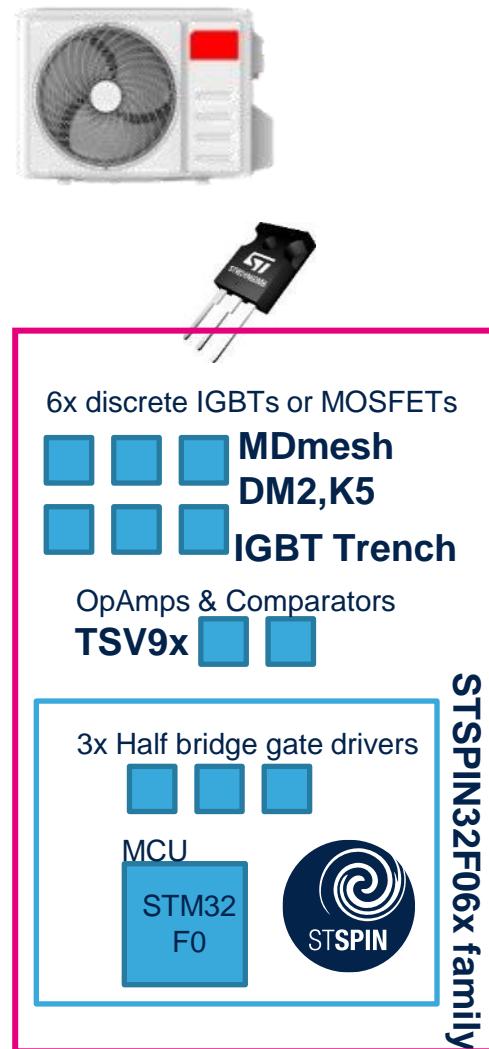
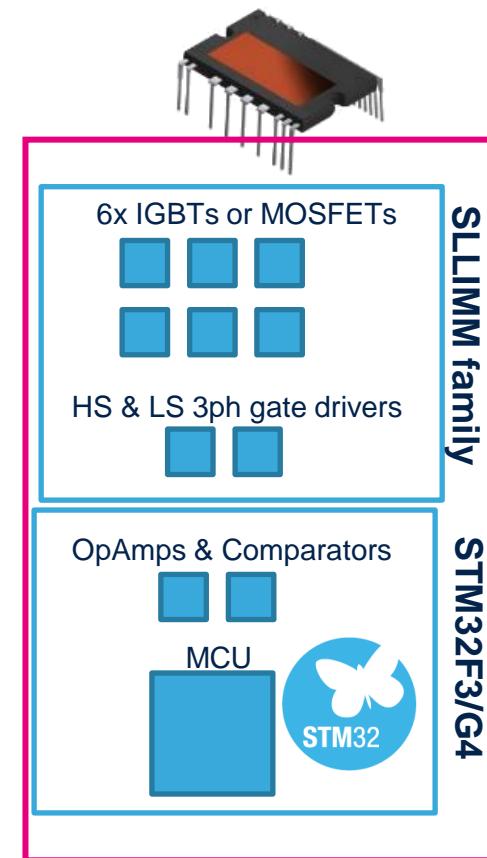
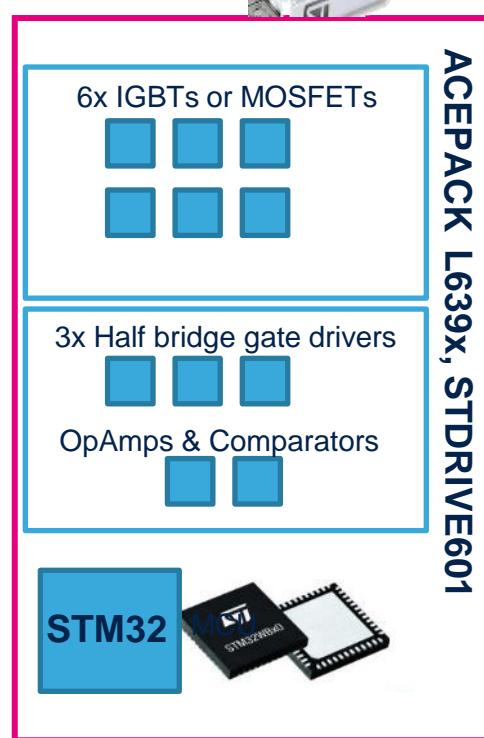
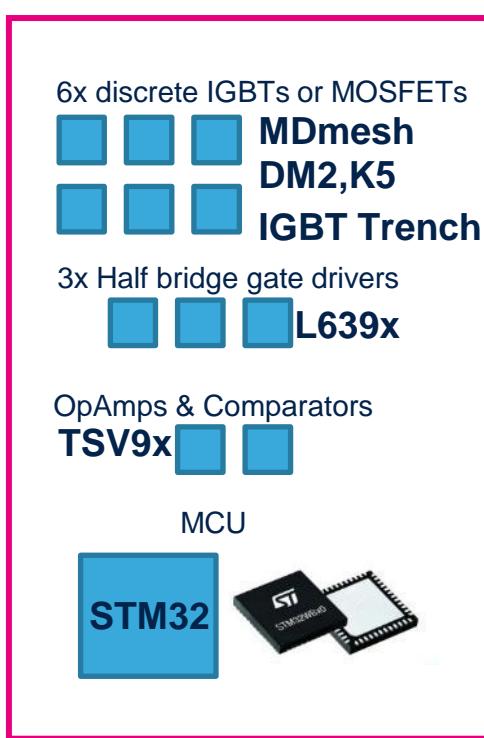
# ST 电机控制解决方案

Different low and high-voltage solutions allow motion control designers to adopt the best strategy for their design

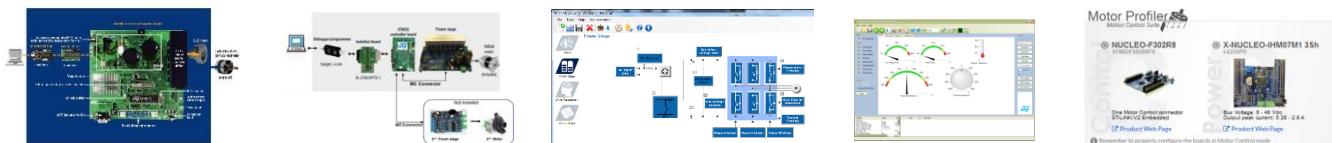
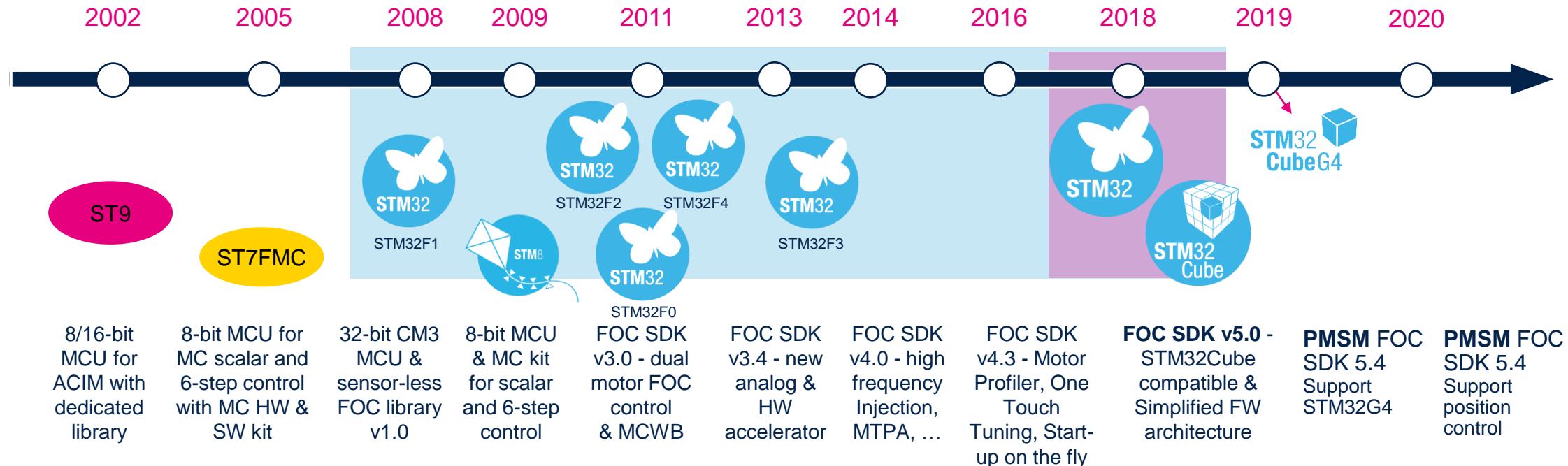


# 灵活的架构 高压应用

Flexibility through undisputed widest product portfolio

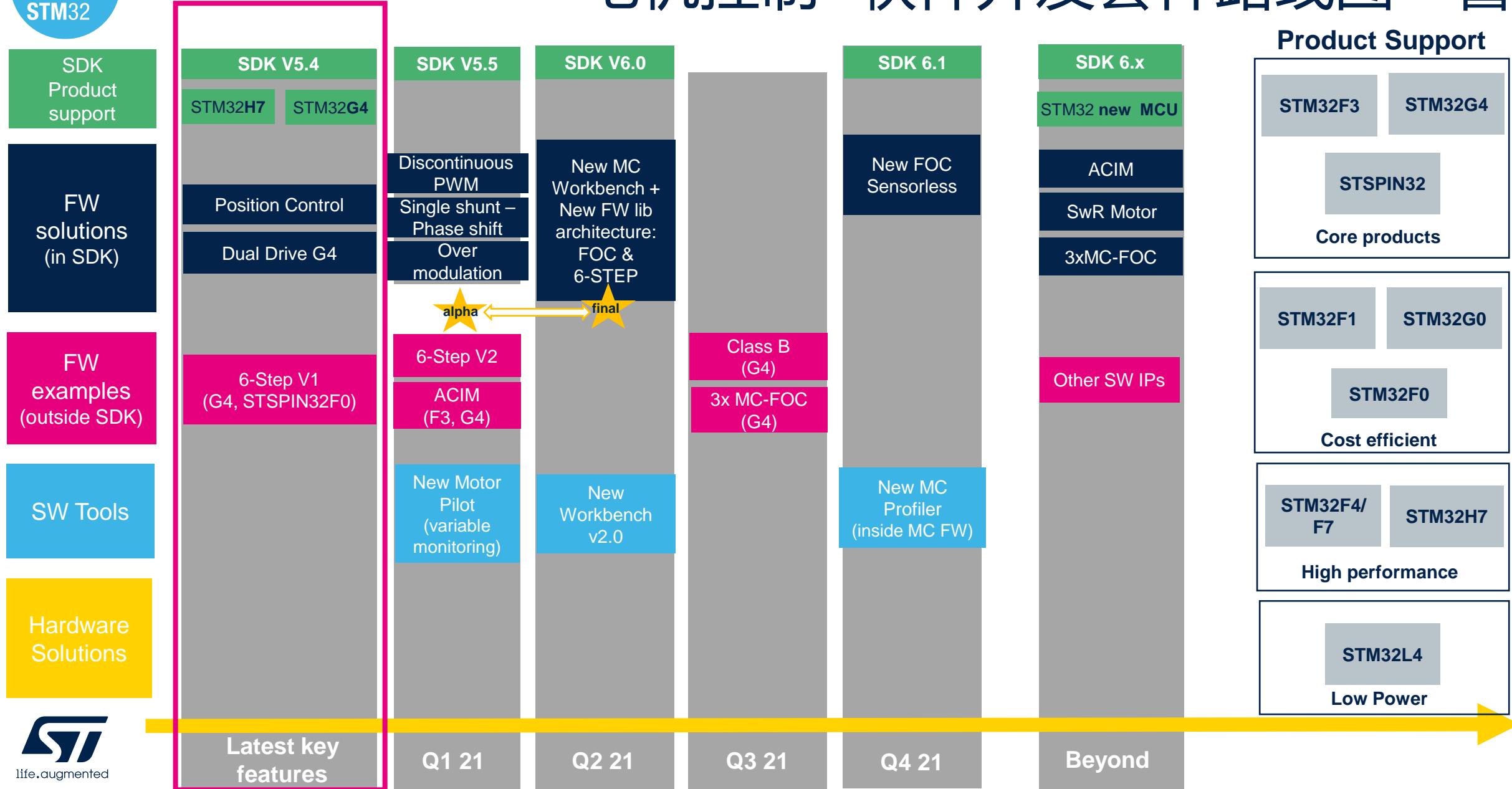


# 18 年三相电机控制经验 聚焦FOC 和 6step





# 电机控制- 软件开发套件路线图一瞥



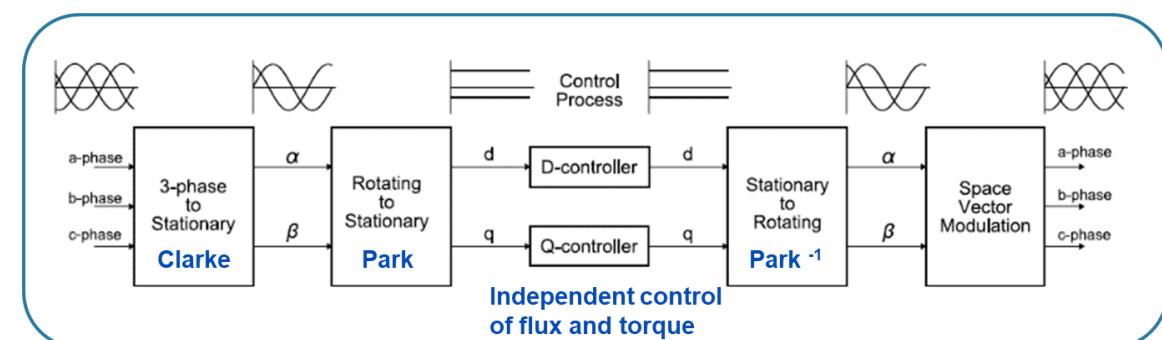
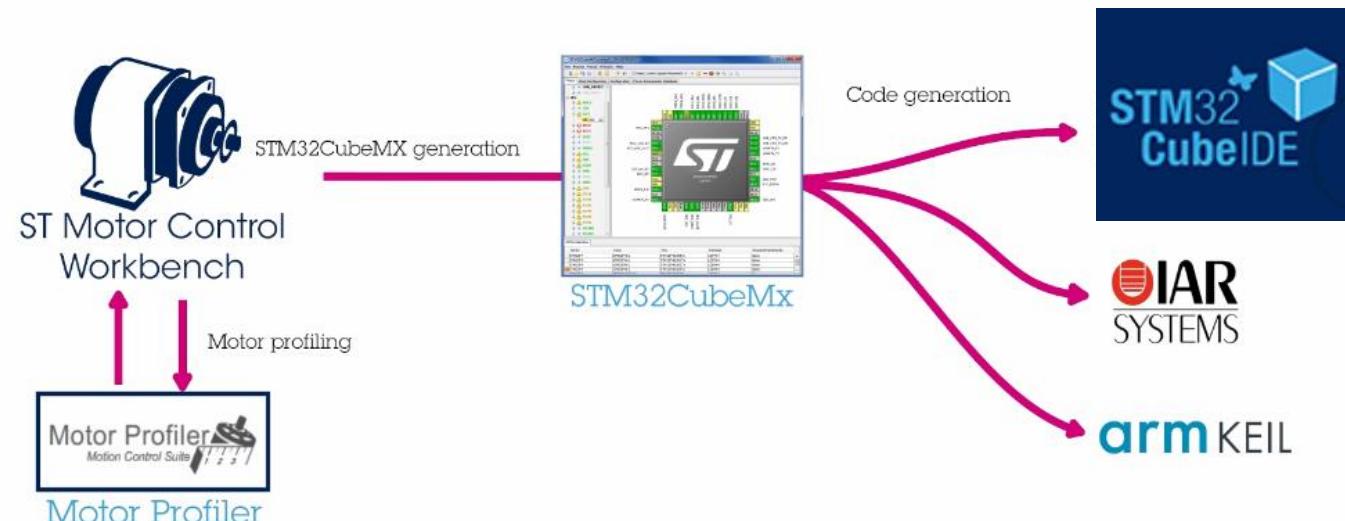


# STM32 电机控制FOC固件库

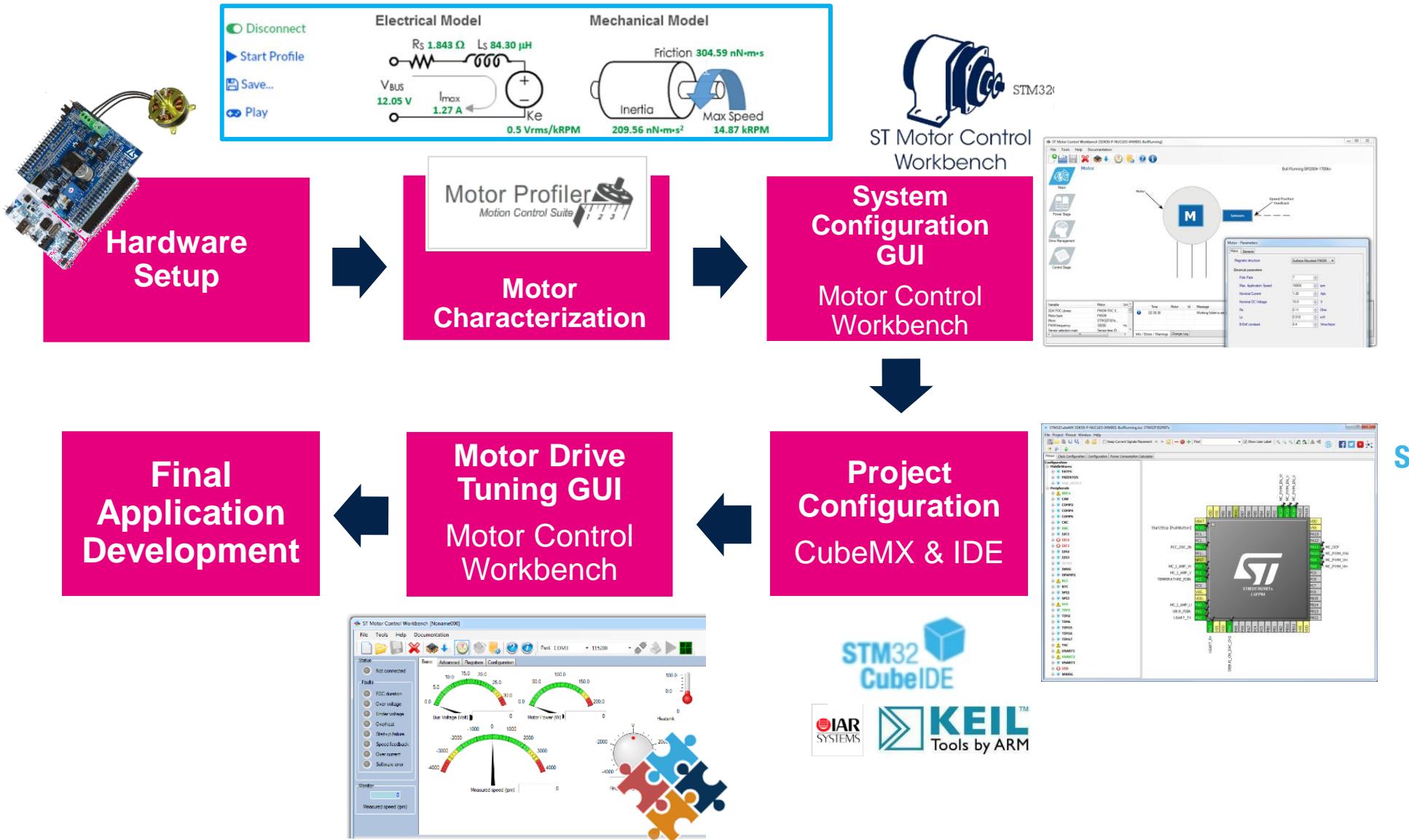
## STM32 Motor control Software Development Kit

### Benefits of FOC:

- **Best energy efficiency**  
even during transient operation, due to optimal current angle
- **Responsive speed control**  
to load variations, due to direct and decoupled control of electromagnetic torque and flux
- **Precise position control**  
due to direct and decoupled control of electromagnetic torque and flux;
- **Acoustical noise reduction**  
due to sinusoidal waveforms / optimized control
- **STM32 MC SDK advantage**  
Automatic code generation, single/dual motor sensorless, sensored, 1/3 shunt, position control, MTPA, etc etc



# MCSDK 工作流程



# 电机控制SDK v5.4 特性列表

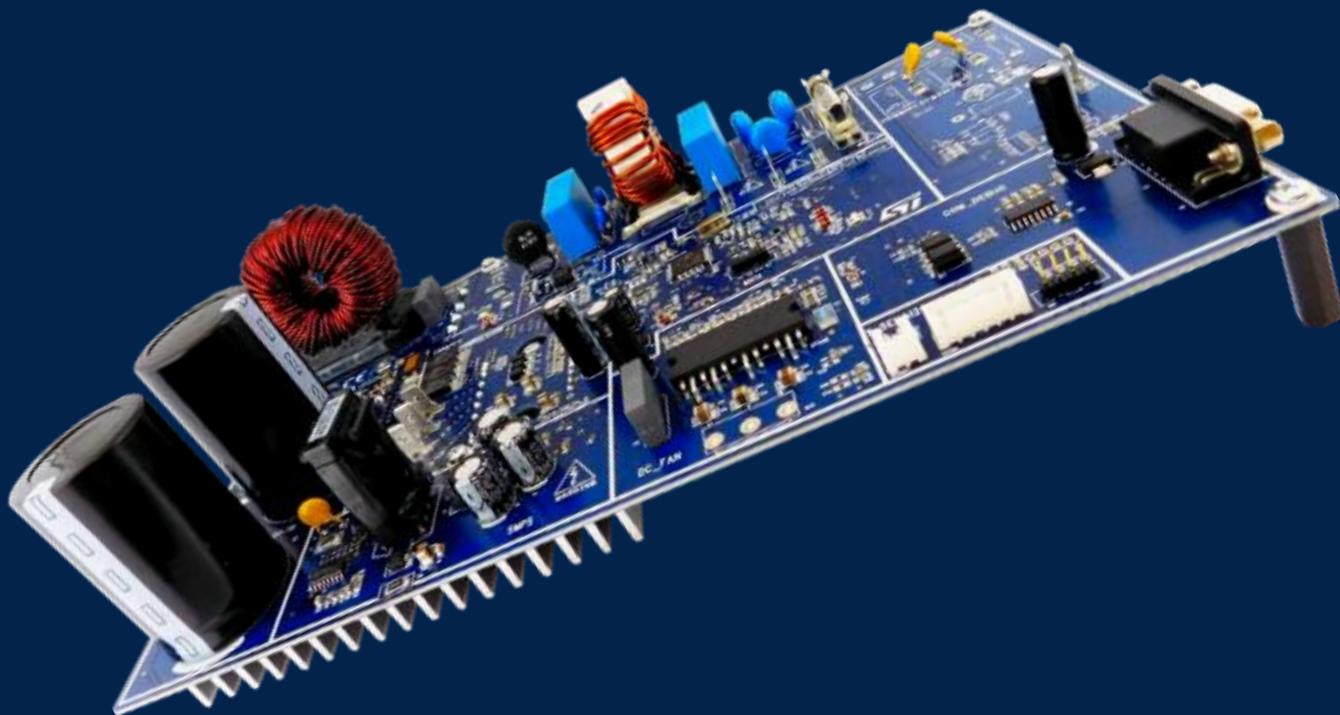
Full Integration / configuration in MC Workbench tools:

STM32 series	F0	F1	F3	F4	F7	L4	G0	G4
• 1 Shunt	✓	✓	✓	✓	✓	✓	✓	✓
• 3 Shunt	✓	✓	✓	✓	✓	✓	✓	✓
• Hall sensors	✓	✓	✓	✓	✓	✓	✓	✓
• ICS	✗	✓	✓	✓	✓	✓	✗	✓
• Flux weakening	✓	✓	✓	✓	✓	✓	✓	✓
• MTPA	✓	✓	✓	✓	✓	✓	✓	✓
• Sensorless (PLL / Cordic)	✓	✓	✓	✓	✓	✓	✓	✓
• Feed Forward	✓	✓	✓	✓	✓	✓	✓	✓
• Single FOC	✓	✓	✓	✓	✓	✓	✓	✓
• Dual FOC	✗	✓/✗	✓	✓	✓/✗	✗	✗	✓
• FreeRTOS	✗	✓	✓	✓	✓	✓	✗	✓
• Position Control	✓	✓	✓	✓	✓	✓	✓	✓

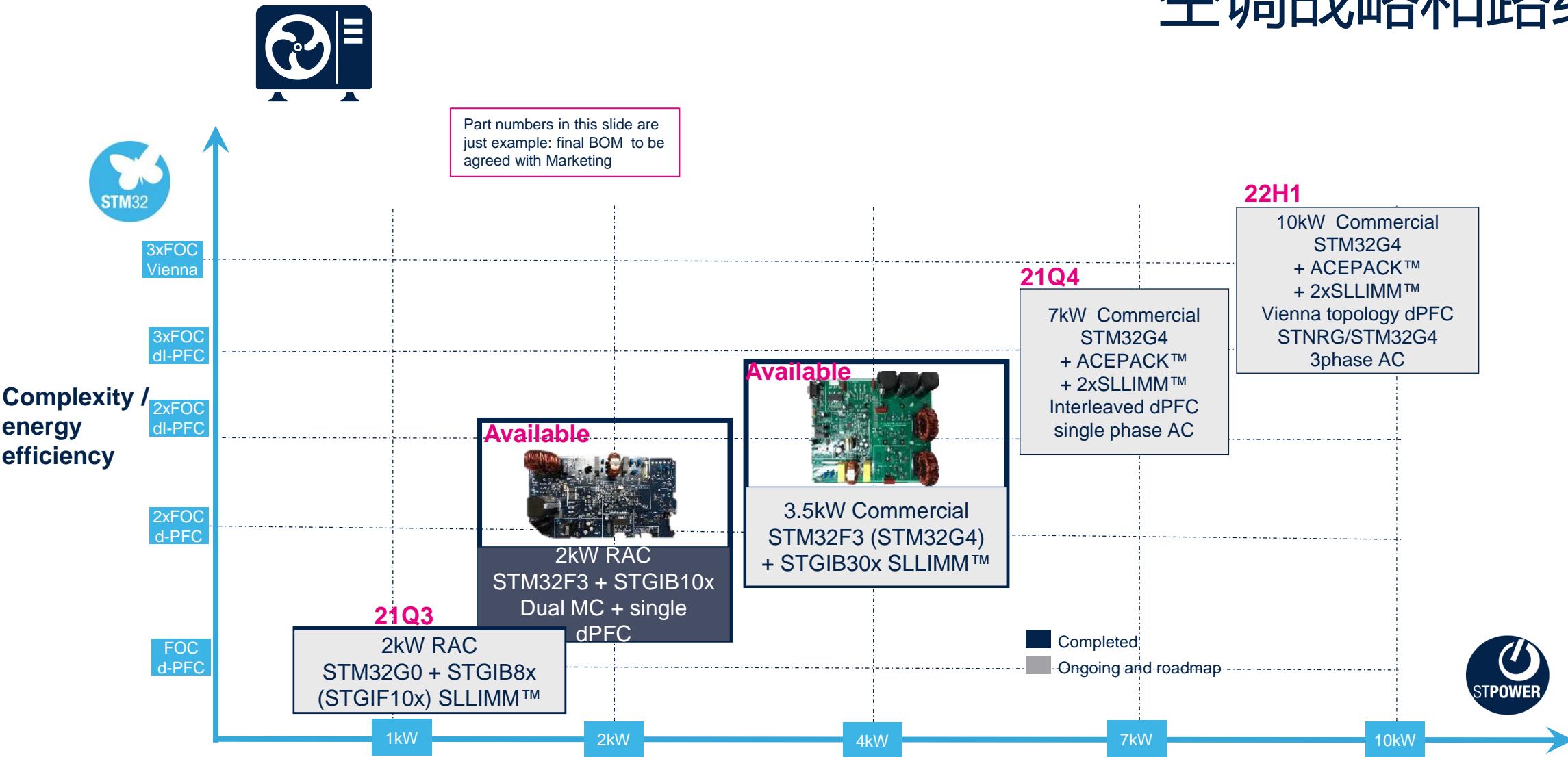
FW Examples / No configuration possible in MC Workbench tools:

STM32 series	F0 STSpinFO B	F1	F3	F4	F7	L4	G0	G4	H7
• 6 Step	✓			✓				✓	
• PFC		✓							
• DUAL CORE H7 example									✓

# 应用解决方案



# 空调战略和路线图



# 实用用用测试--1.5P 空调

ST's IPM has 0.15%~0.38% higher efficiency than competition

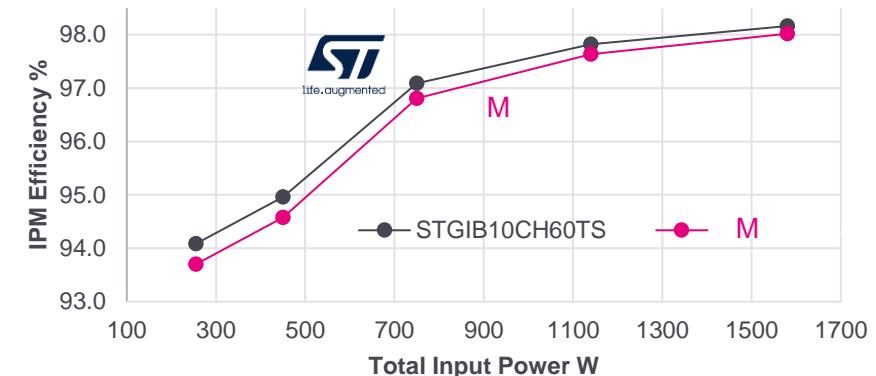


TEST CONDITION		IPM INPUT			IPM OUTPUT	RESULTS	
Frequency (Hz)	Aircon input power(W)	DC voltage(V) from PFC	Motor Current range (A)	5min Input Energy (Wh)	5min Output Energy (Wh)	Efficiency (%)	Tcase(Max) C
20	255	293.84	1.38-1.39	13.5768	12.7738	94.085	35.6
30	450	403.04	1.88-1.89	28.7335	27.285	94.959	41.6
50	750	402.97	2.55-2.58	54.2288	52.6492	97.087	47.1
70	1140	402.85	3.36-3.38	85.1568	83.3029	97.823	50.6
90	1580	402.74	4.16-4.18	119.265	117.076	98.165	60.8

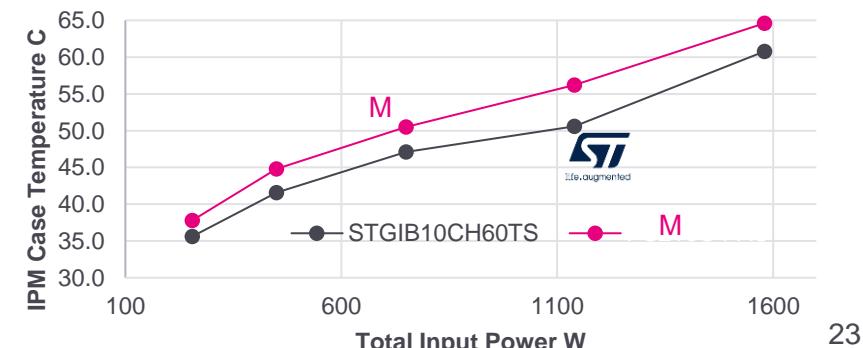
device "M"

TEST CONDITION		IPM INPUT			IPM OUTPUT	RESULTS	
Frequency (Hz)	Total A/C input power(W)	DC voltage (V) from PFC	Motor Current range (A)	5min Input Energy (Wh)	5min Output Energy (Wh)	Efficiency (%)	Tcase(Max) C
20	255	293.79	1.38-1.39	13.3522	12.5112	93.701	37.8
30	450	402.59	1.87-1.88	28.103	26.5781	94.574	44.8
50	750	402.49	2.55-2.58	53.4795	51.7705	96.804	50.5
70	1140	402.38	3.36-3.38	84.5334	82.536	97.637	56.2
90	1580	402.33	4.15-4.20	118.994	116.638	98.020	64.6

Energy Efficiency



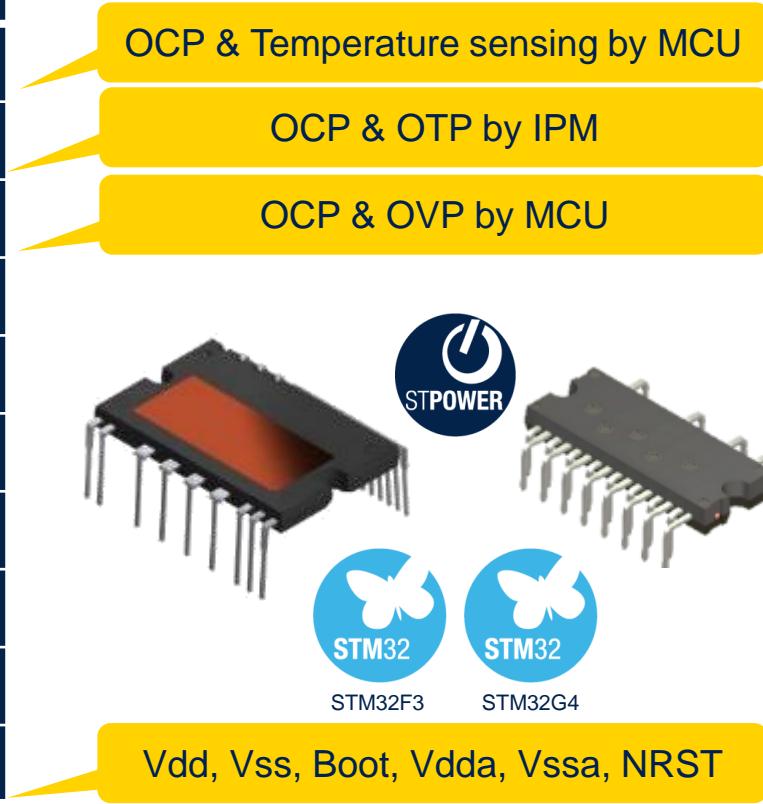
Case Temperature



# ST空调室外机Gen2

## 全部功能在一个64-Pin MCU + 2 IPMs

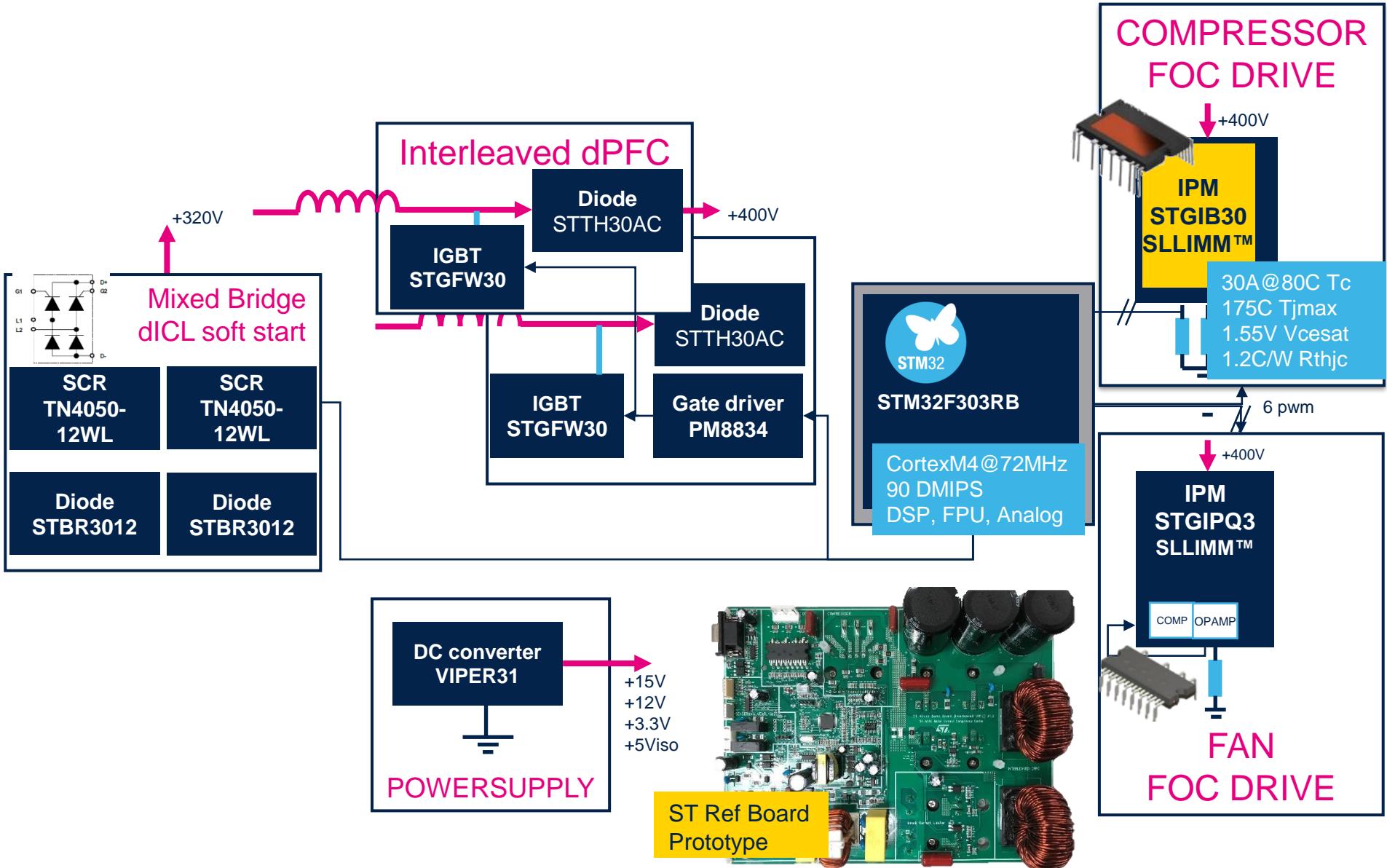
Function	Digital I/O	Analog I/O	Total
Compressor	6	9	15
Fan	7	1	8
PFC & ICL	4	6	10
USART comm	2		2
SWD debug	2		2
I2C EEPROM	2		2
Stepper valves	4		4
Other analogs		6	6
Other digitals	4		4
MCU functional			11
<b>GRAND TOTAL</b>			<b>64</b>



# 4kW空调、热泵解决方案 室外机---双电机和交错式数字PFC

## Key Features

- STM32F3 /G4 based full platform control
- Dual BLDC motor FOC, compressor & fan
- Digital Interleaved PFC, 2stages, CCM
- Digital Soft Start Inrush Current Limiter no relay, no NTC

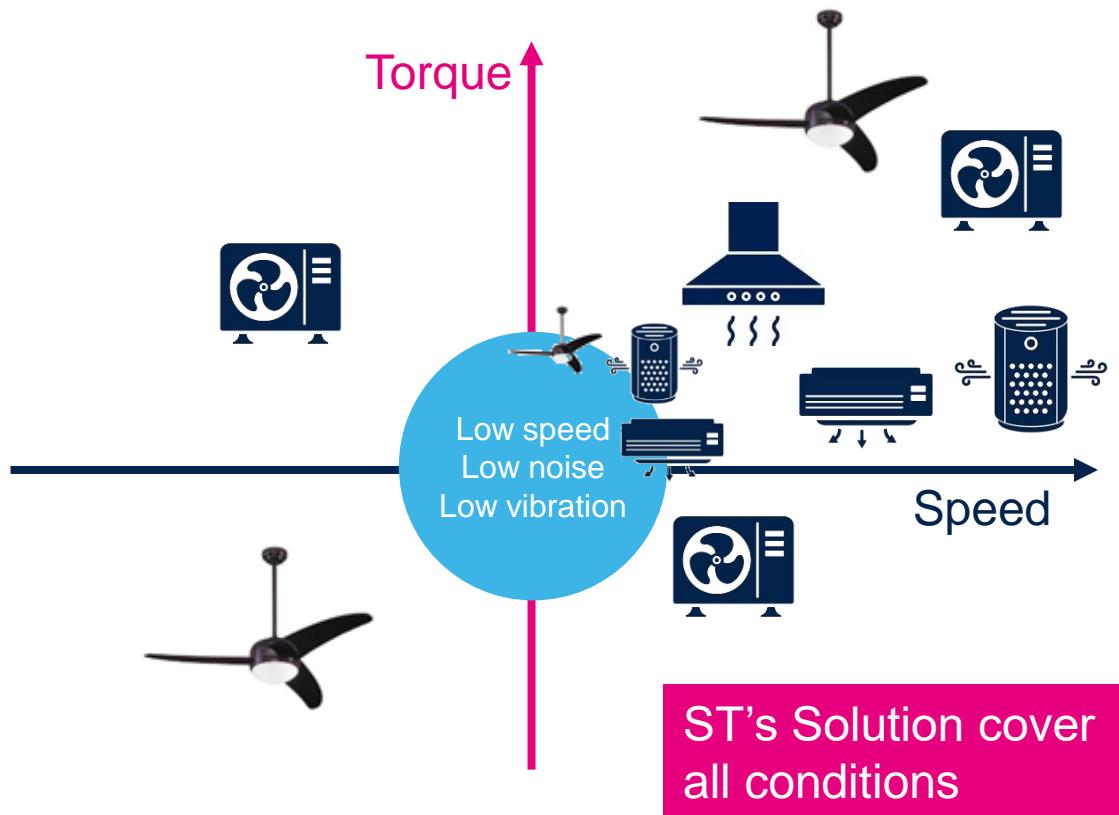


# 风机类参考解决方案

## 室内风机, 油烟机, 吊扇, 工业风机等

### 主要特性

- 全速度范围运行的风机驱动解决方案  
(空调室外风机、室内风机, 风扇, 吊扇, 工业风扇)
- 初始位置检测Initial Angle Detection (IAD)
- 带BEMF检测的顺风、逆风启动 (32ms)  
电频率可到1.6HZ
- 100% 成功率 - 50万次 顺风、逆风启动
- 反转刹车制动
- 降低听觉噪音



An ST sensorless algorithm to detect initial rotor angle

- Before the motor is started, the function is able to measure the initial rotor position
  - in few milliseconds,
  - with an angle accuracy of  $\pm 30$  electrical degrees, same resolution of Hall Sensors
- Then the startup procedure is automatically configured to set the best initial direction
  - avoiding a backward rotation and maximizing the torque generated
- The advantages of the IAD function are:
  - Successful startup rate
  - Quick acceleration
- The IAD function is implemented on both 1-shunt and 3-shunt topologies
- The IAD function doesn't need additional HW, and is compatible with STM32 and STSPIN32 series



# Fans, FW IPs

## 2.顺风、逆风启动

An ST sensorless algorithm to enable motor drive while the motor is already running

- Startup on Fly function is implemented on both 1shunt and 3shunt topologies
- The IAD functions in two versions with and without bemf sensing network, compatible with STM32 and STSPIN32 series



Expected speed range: 60rpm ~ 1500rpm



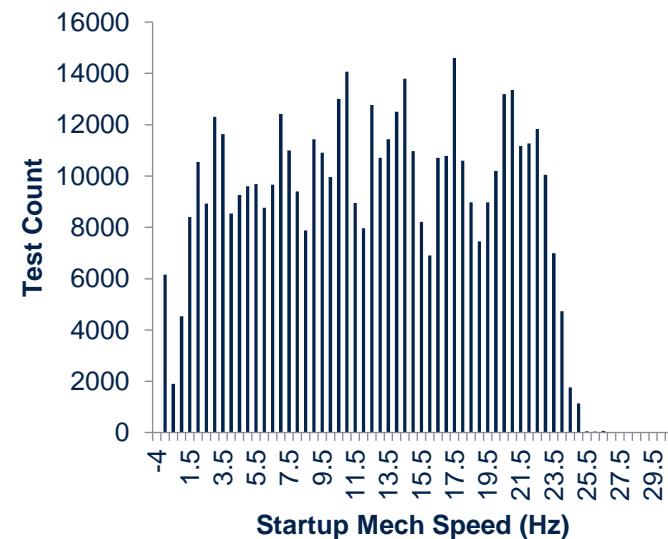
Total test count:  
492,241



Failed count: 0



Minimum speed catches a spin motor: 12rpm



VIDEO

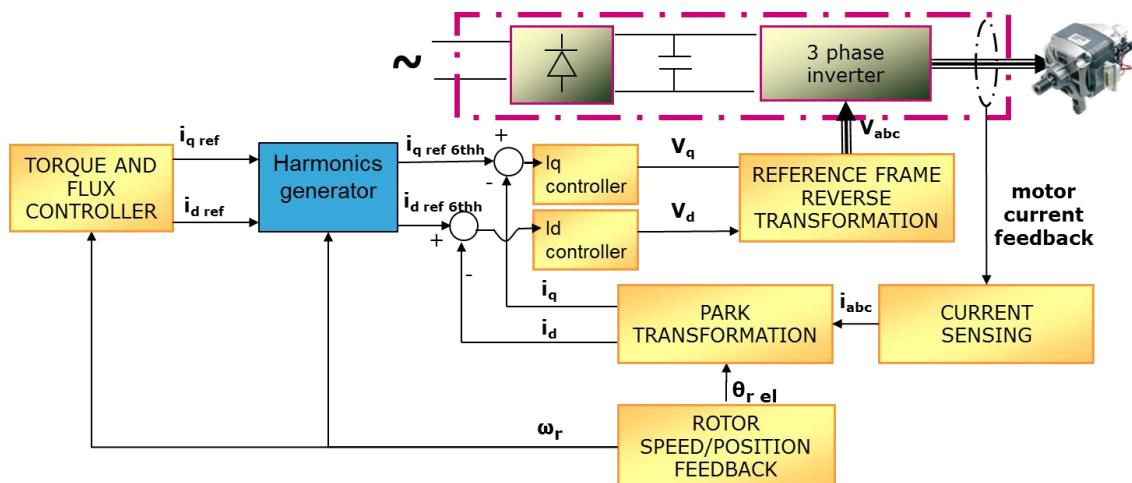


# Fans, FW IPs

## 3. 听觉噪声/ 抖动 的降低

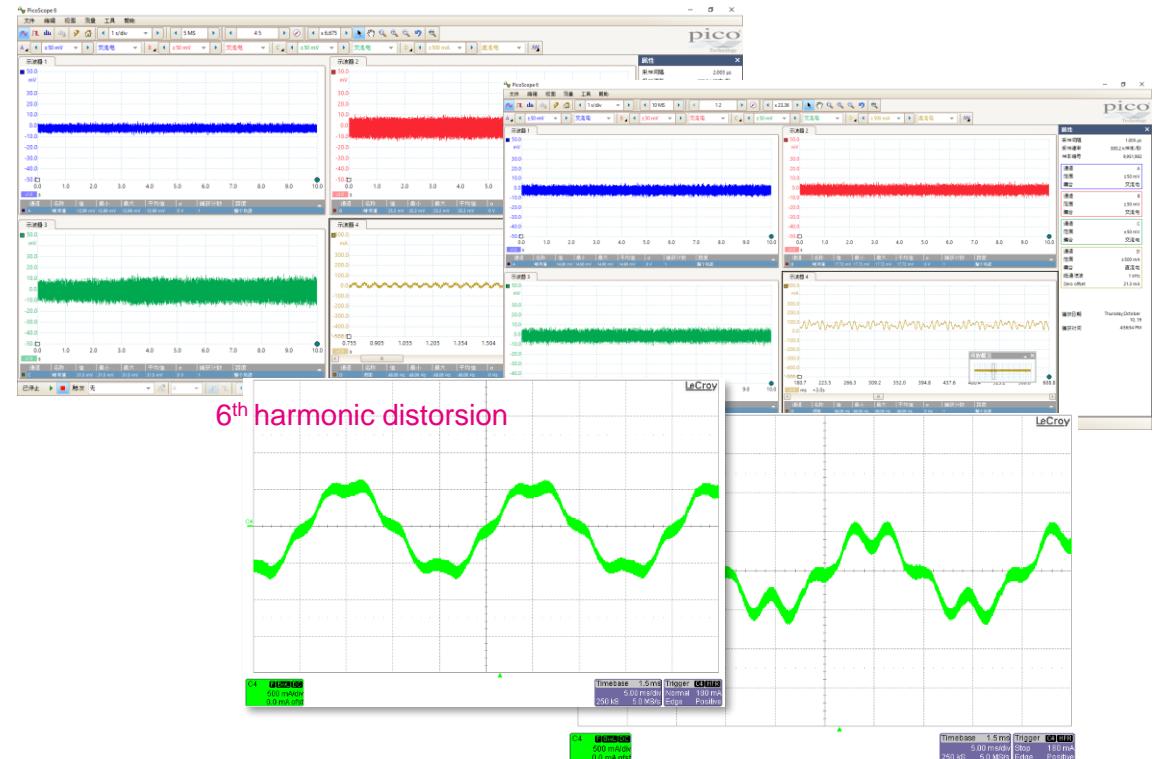
An ST FOC in module to reduce acoustic noise

- Working on the Park reference frame, it generates a 6<sup>th</sup> harmonic of the main motor electrical frequency, according to the diagram below (ST patent)
- 5<sup>th</sup> and 7<sup>th</sup> harmonics will be introduced in the motor phase currents to counteract the 6<sup>th</sup> harmonic torque ripple



(12) United States Patent  
Costanzo et al.

(10) Patent No.: US 8,816,616 B2  
(45) Date of Patent: Aug. 26, 2014



# Fans, architectures and products

Multiple combinations for different architectures and cost and space requirements



Application	Power	Discrete IGBT	Discrete MOS	IPM / SMD IPM
<b>AC Indoor Unit</b>	30W~100W	STGD3HF60HDT4	STD5N60DM2	STGIPQ3H60 STIPN2M50 STGIPN3H60
<b>AC Outdoor Unit</b>	100W~200W	STGD5H60DF	STD8N60DM2	STGIPQ3H60 STGIPQ5H60
<b>Kitchen Hood</b>	100W~250W	STGD5H60DF	STD8N60DM2	STGIPQ3H60 STGIPQ5H60
<b>Ceiling Fan</b>	30W~100W	STGD3HF60HDT4	STD5N60DM2	STGIPQ3H60 STIPN2M50 STGIPN3H60
<b>Air Purifier</b>	30W~100W	STGD3HF60HDT4	STD5N60DM2	STGIPQ3H60 STIPN2M50 STGIPN3H60
<b>Industrial FAN</b>	Anything up to many kW	Full current rating H and M series IGBT		SLLIMM G2 8A~35A

# Development boards for fan applications

STM32F030 +  
STGIPQ3H60  
100W Fan Reference solution



From APAC MC CC

STSPIN32F0601 +  
STGD5H60DF / DM2 SJ-MOS  
300W Fan Reference solution



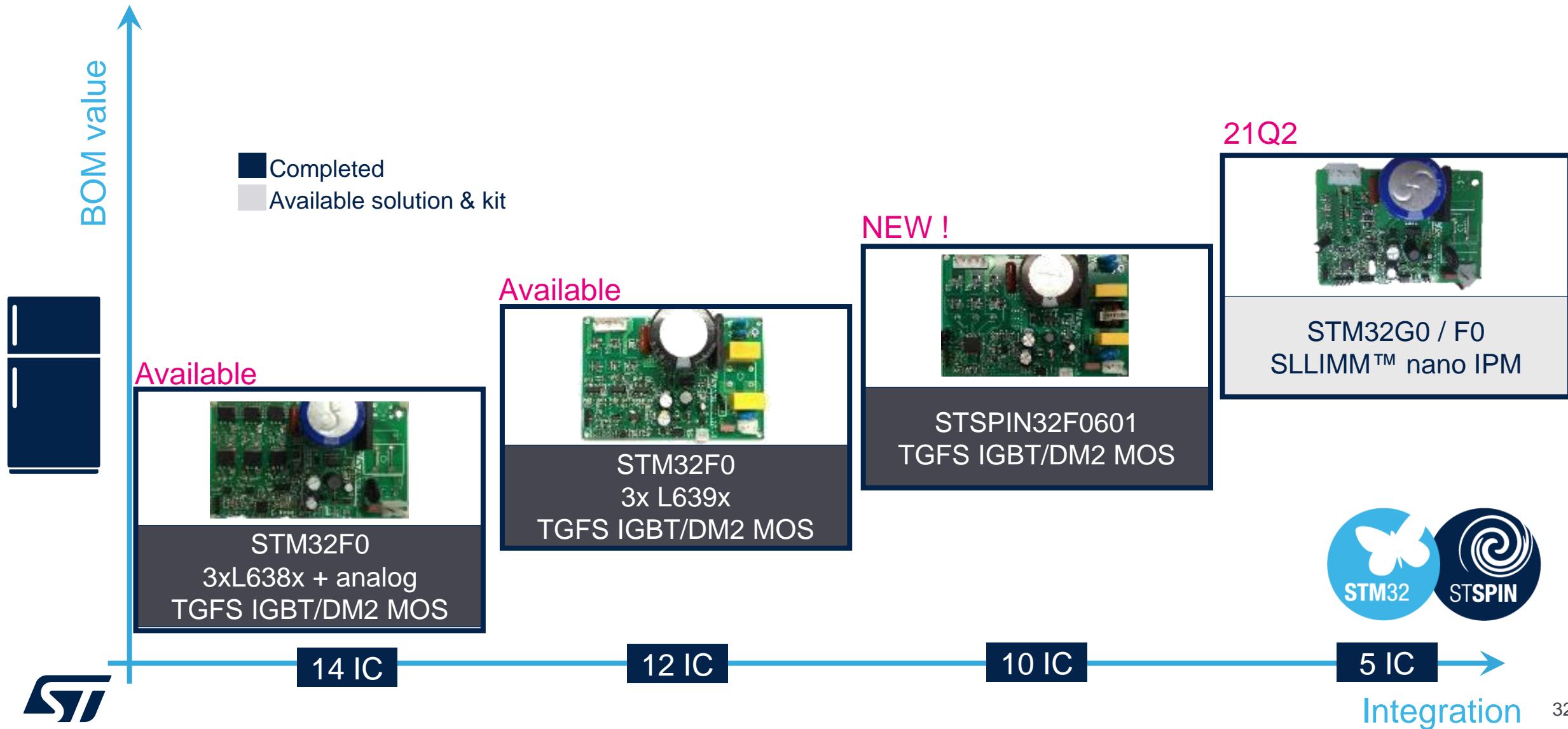
EVSPIN32F0601S1

STM32G0 +  
SLLIMM® IPM / nano IPM  
1A – 35A



NUCLEO-G0x + STEVAL-IPMx

# 250W冰箱 不同硬件架构, 电机驱动板



# ST冰箱解决方案 250W / 300W (650L)

- 与传统单相感应电机相比，具有逆变器解决方案的三相BLDC电机压缩机已成为新的市场趋势。
- 电机驱动电子部分可以与主控板分开或合并使用。
- 对于不同的MC部分没有区别，ST解决方案能满足一下三种情况

解决方案1：替代



解决方案2：替代  
冰箱温度优化



解决方案3：一体化



# 250W冰箱解决方案

## STSPIN32F0 – STM32G0 – discrete products

Leading manufacturers say that ST offers the best energy efficiency and COP on the market



Power and thermal measurements*	
Max power	240 W
Max temperature on IGBTs (steady state):	80.1 °C
Reliability Test	
15 seconds RUN 3 seconds STOP Continuous repetition, 500k cycles	

Compressor 1 Test				
Board	Speed	COP	Inverter efficiency (%)	Inverter Power Loss (W)
ST Solution	1600	2.08	96.336	1.546
	2000	2.079	96.62	1.79
Competitor 1	1600	2.072	96.302	1.549
	2000	2.076	96.579	1.807

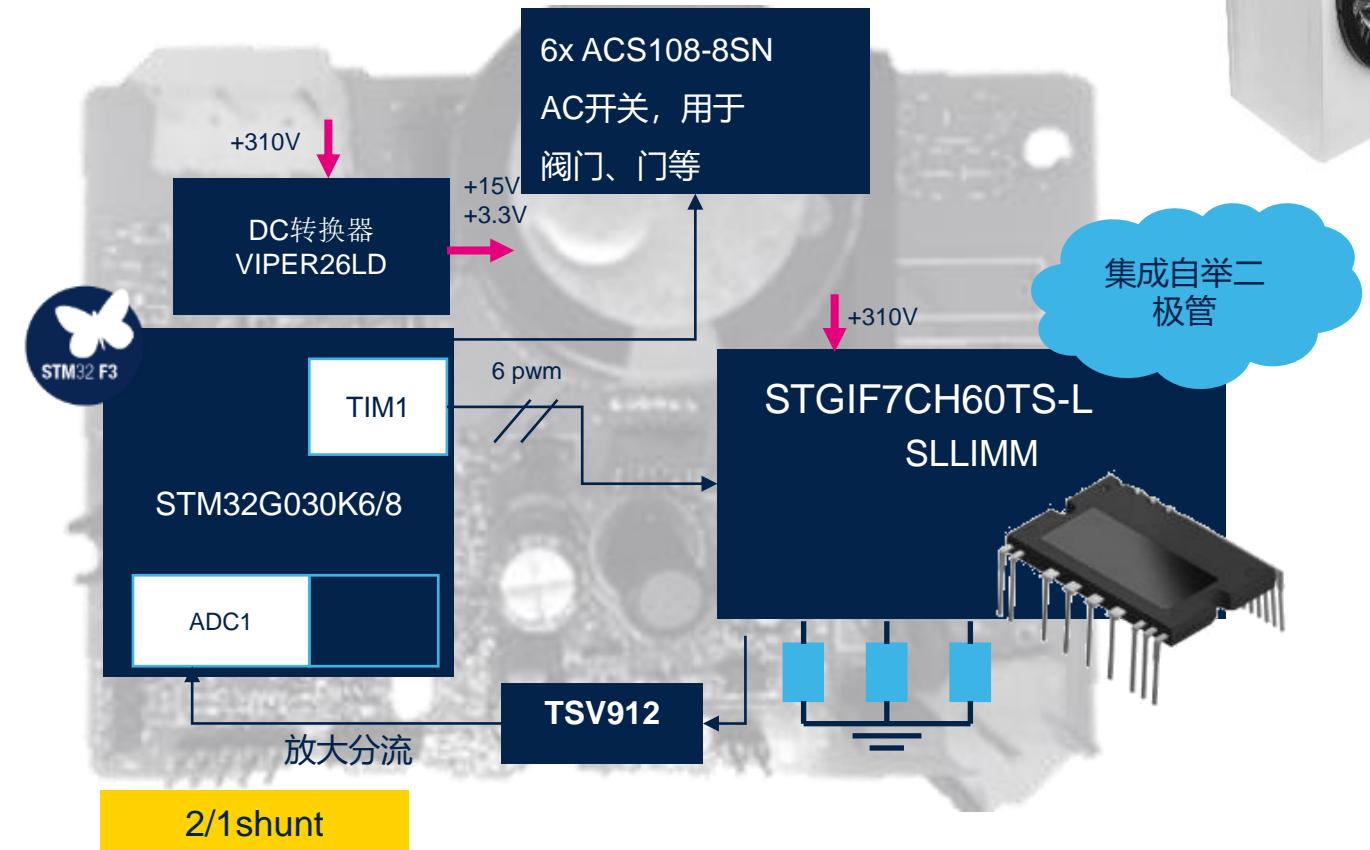
Compressor 2 Test				
Board	Speed	COP	Inverter efficiency (%)	Inverter Power Loss (W)
ST Solution	1600	1.979	95.89	1.774
	3000	1.945	96.74	2.702
Competitor 2	1600	1.91	93.31	2.94
	3000	1.919	95.24	4.01

# ST洗衣机硬件架构

## 500/700W IPM - ST的IGBT Trench Gate技术 – STM32G030K6/8

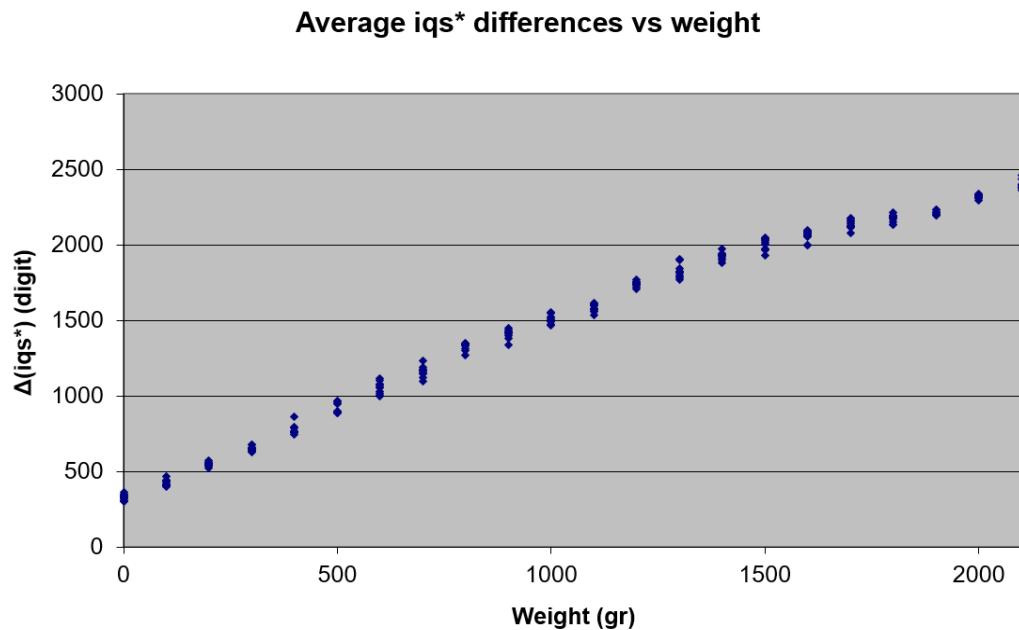
保护: OC, UVLO  
极大地减小了尺寸  
开发时间短  
高性能

ST产品:  
• STM32G030K6/8  
• STGIF5CH60TS-L  
• STGIF7CH60TS-L  
• STGIPQ8C60T-HZ  
• TSV912/TSV914  
• VIPER26LD  
• ACS108-8SN



# 重量及不平衡重量测量

Average  $\Delta(i_{qs}^*)$  obtained in the ten sets of measurements

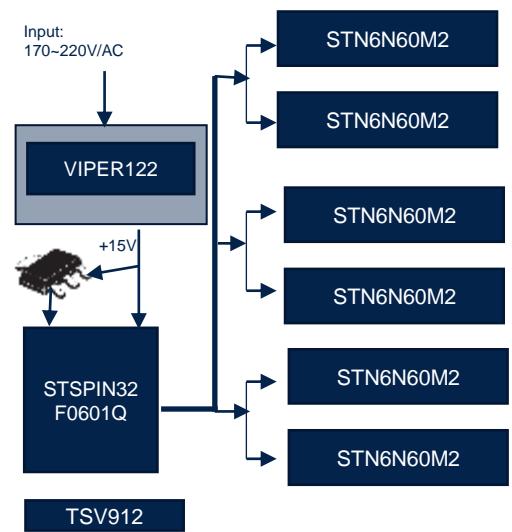
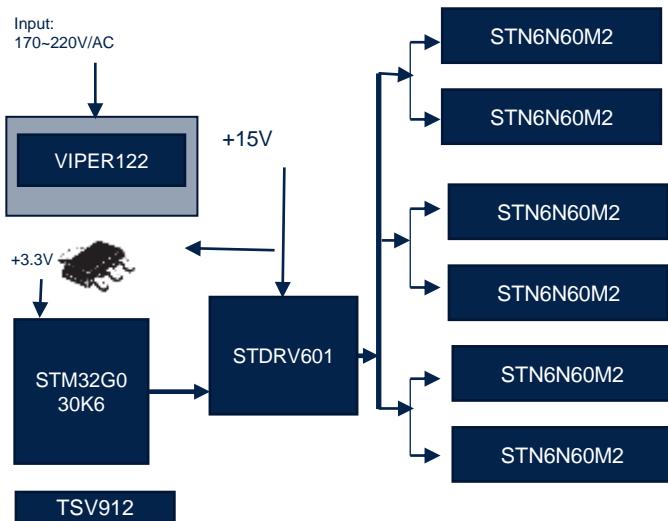


- Imbalance weight resolution can reach to 200g
- Total weight resolution can reach to 500g(unbalance weight < 500g)
- Due to non-standard counterweights (considering contact surface size), as total weight increases, resolution decreases, so total weight of this test only reach to 8000 grams

# 高速风筒解决方案

## 主要特点：

1. Maximum speed 110000RPM
  2. 800ms reach 100000RPM
  3. 1s motor after power off



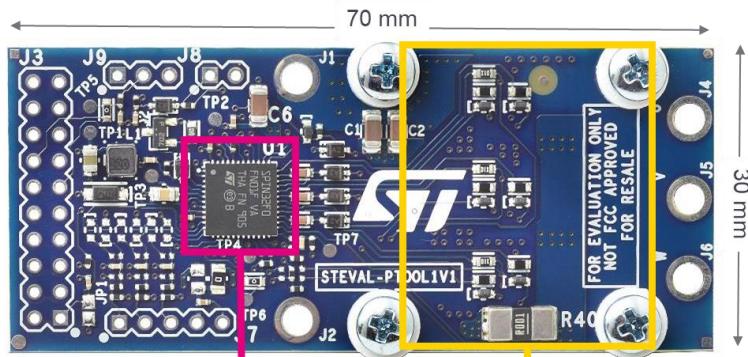


# 电动和园林工具(使用电池) 基于STSPIN32F0家族

Extreme integration & robustness, high torque / high speed  
Foc / 6-step; sensorless / hall / bemf detection

## Low-voltage design – STEVAL-PTOOL1V1

for battery packs up to 36V (2S – 6S)  
(STSPIN32F0B + 60V MOS STL180/220N6F7)

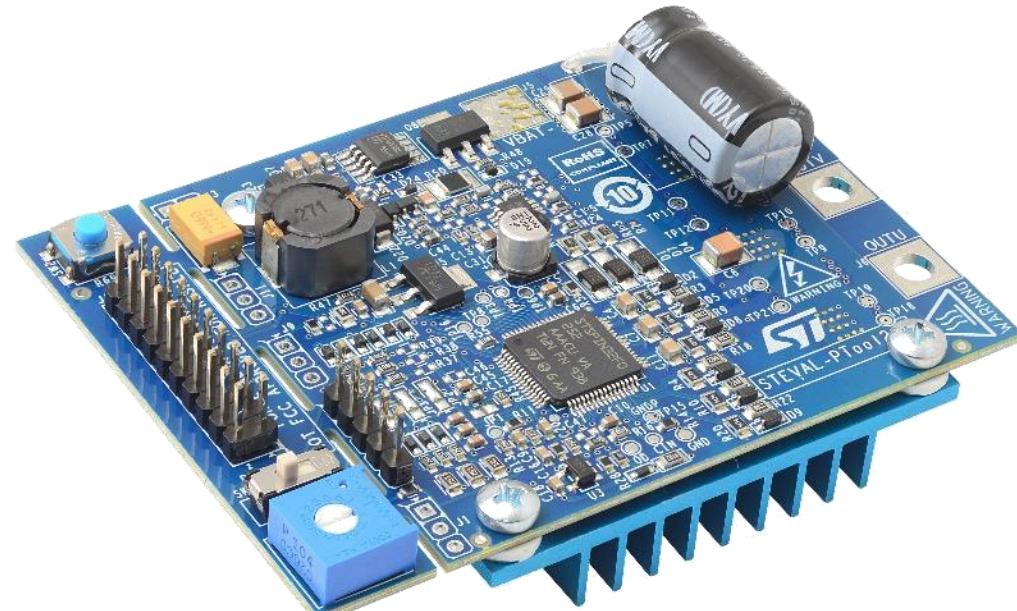


**STSPIN32F0B**  
45V fully integrated  
3phase BLDC driver (600mA)

**STL180N6F7**  
60V, 1.9mΩ MOSFET  
(Bottom side)

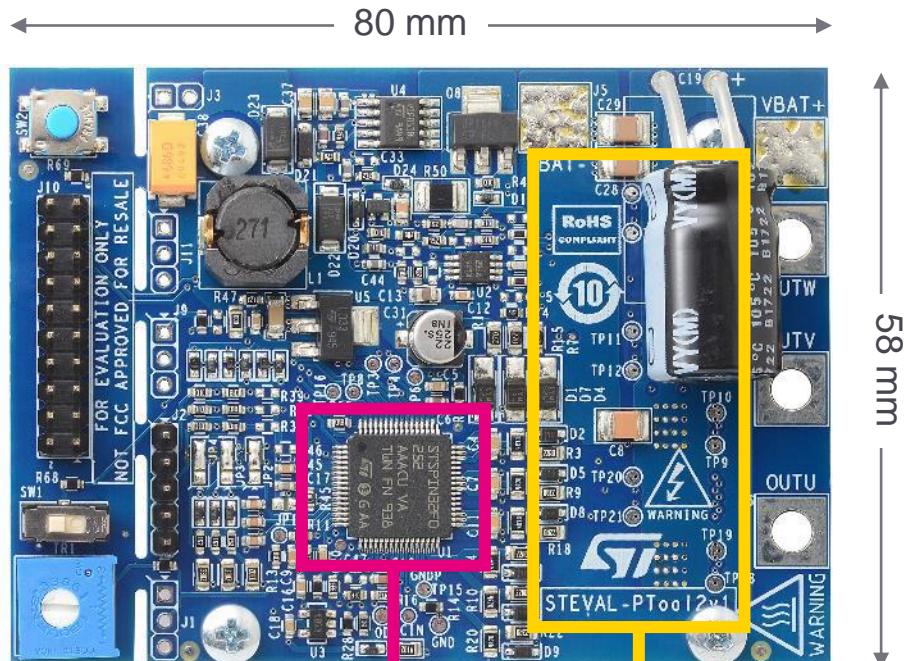
## High Voltage Design – STEVAL-PTOOL2V1

for battery packs up to 60V (8S – 15S)  
(STSPIN32F0252 + 80V MOS STL130N8F7 / STL135N8F7AG)



# STEVAL-PTOOL2V1

## High voltage power tools reference design (8S – 15S)



**STSPIN32F0252**  
250V integrated  
3phase BLDC driver (1A)

**STL130N8F7**  
80V, 3 mΩ MOSFET  
(Bottom side)

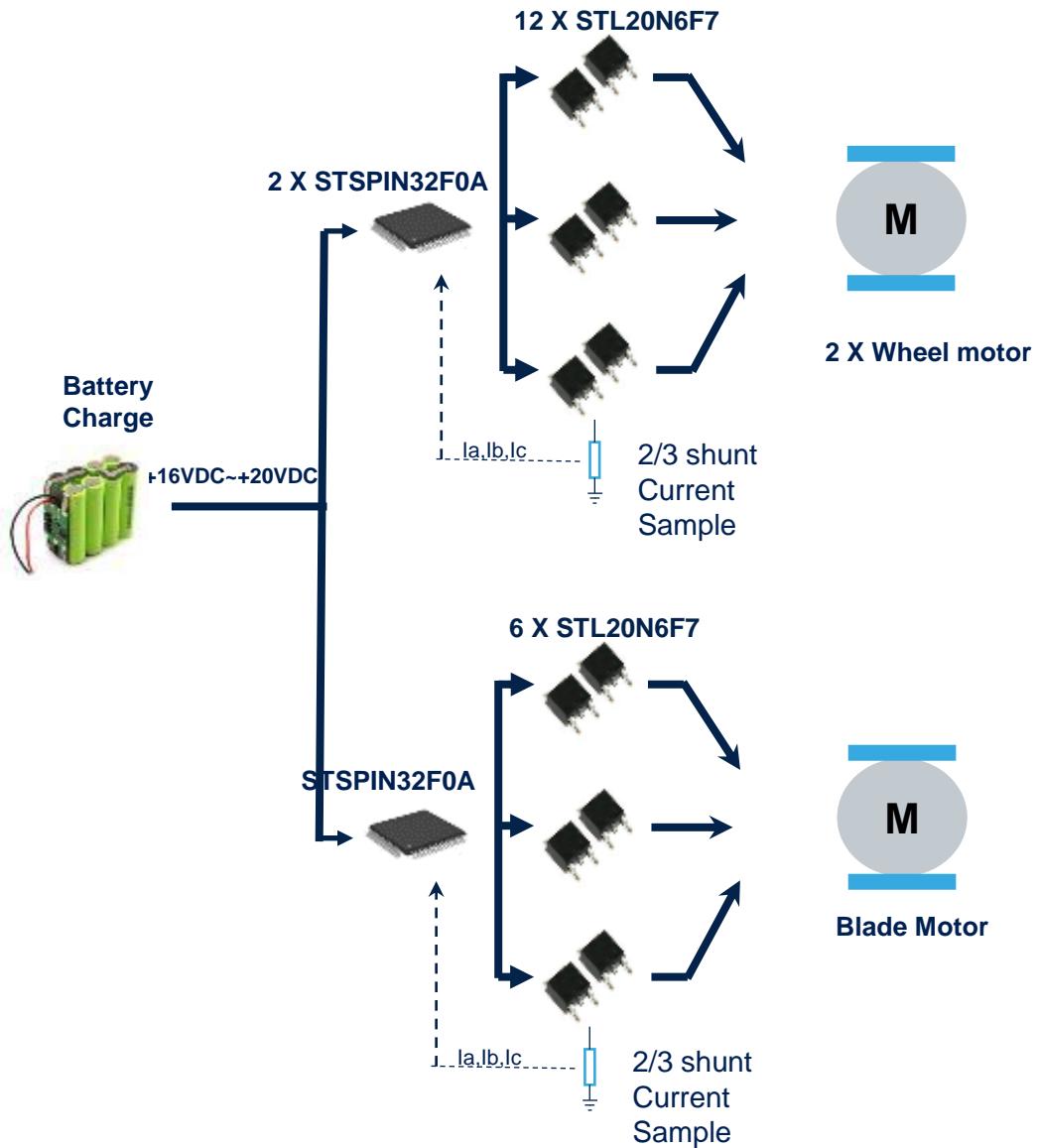
- Max operating ratings: 80V, 15A<sub>RMS</sub>
- Very low stand-by power consumption
- 6-Step single shunt with Hall sensors inputs
- Mounting options for:
  - Field Oriented Control, sensorless/sensored
  - BEMF detection circuitry
- Over Current Protection
- Trigger, direction and speed inputs available
- Speed control potentiometer available
- Heatsink (54x54x20 mm)
- Ready to use dedicated 6step FW

# 机器人割草机



## ST Solution Feature

STSPIN32F0A (SOC)	高集成度, PCB尺寸紧凑, 低系统成本
车轮电机控制	无感矢量控制低成本解决方案, 大启动转矩, 满足在全负荷中爬升的需求
刀片电机控制	无感矢量控制低成本解决方案, 新刹车算法, 可控母线电压的升幅
宽范围电池输入	6.7~45VDC



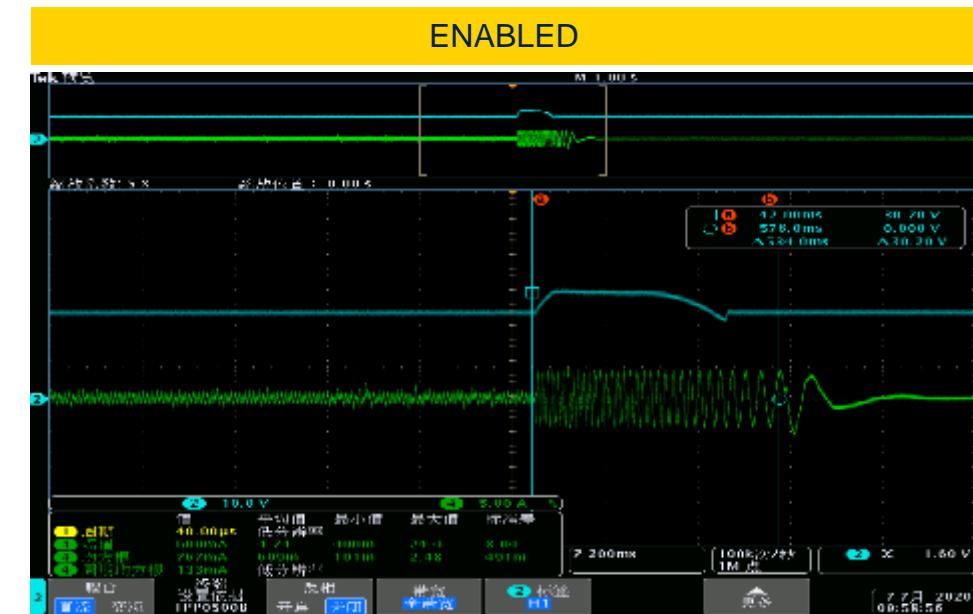
# 车轮电机控制

- 在无传感器FOC模式下,车轮电机的不同方向快速切换
- 启动时间小于300ms
- 不同方向切换的间隔时间小于330ms
- 额定负载下, 车轮电机的最低转速可以达到300RPM
- 在空载和额定负载下, 平稳启动, 快速的速度指令, 无过冲
- 大启动扭矩, 重载快速启动, 最大启动扭矩可达7N.m



# 刀片电机控制

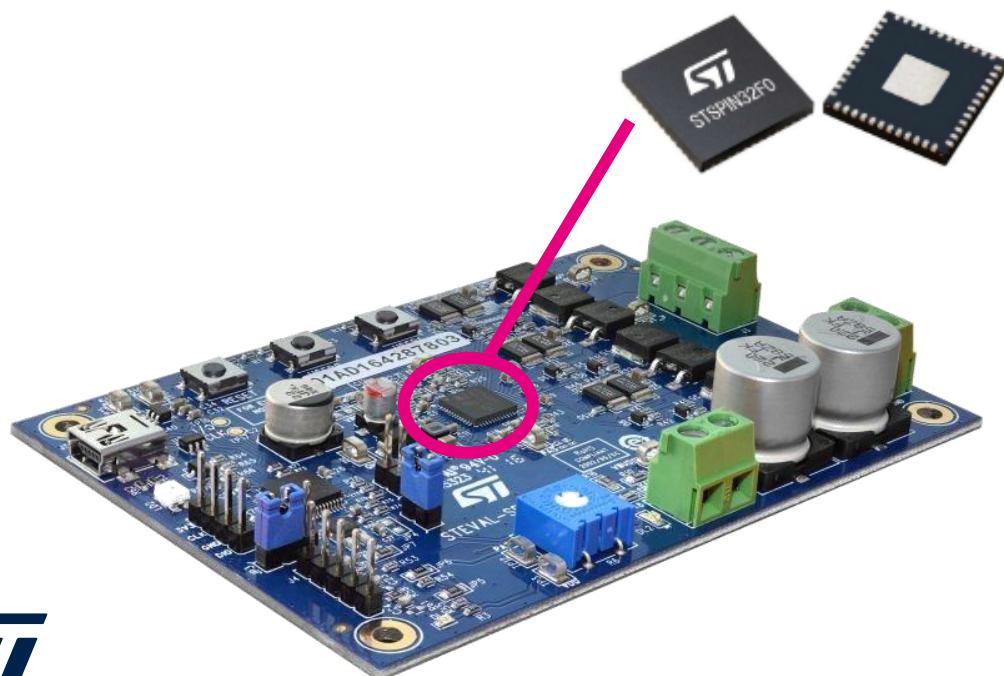
- 快速响应 : Quick Startup to full speed based on Sensorless FOC control;
- 传统主动制动策略: Voltage surge of Vbus is out of Control, the max voltage surge will reach 35Volts when motor braking from full speed; the braking time period from full speed to 300RPM is 440ms
- 电压跳变可控制动策略: the braking time period from full speed to 0RPM is 530ms, Controlled Voltage surge of Vbus reaches 30Volts (it could be set by FW freely)



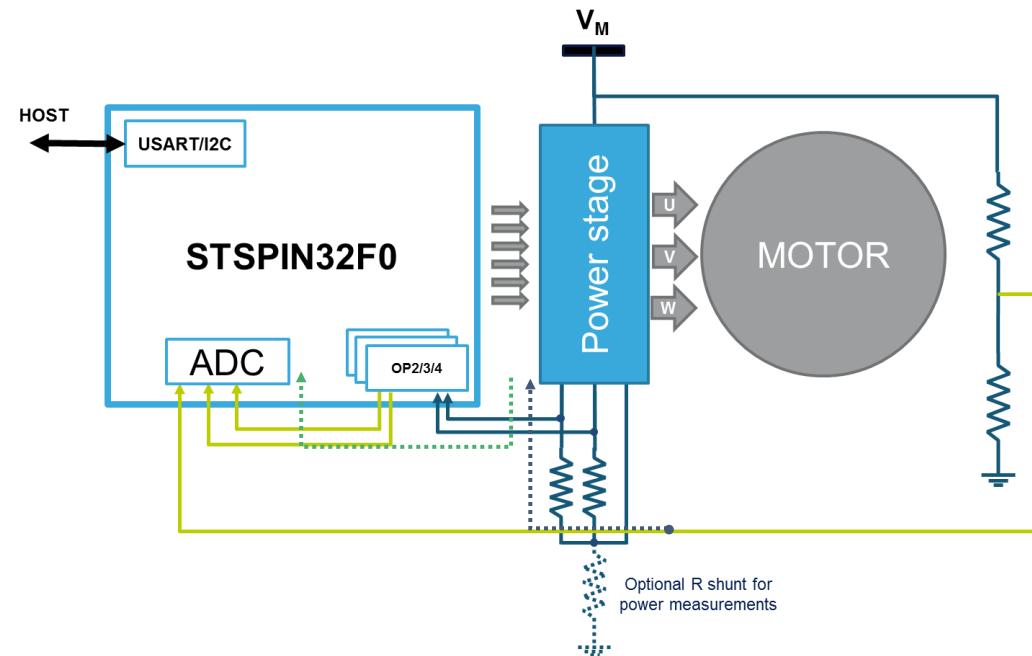
# 吸尘器参考设计

Complete HW + FW package tailored for suction motors in vacuum cleaners

- HW is based on STSPIN32F0/A + 6x STD140N6F7 MOSFETs
  - STEVAL-SPIN3201 is a good starting point; V supply = 8-45 V, I out = 15 Arms )
- FW is FOC sensorless in 2 -shunt configuration; 1 extra optional shunt can be used for power measurement

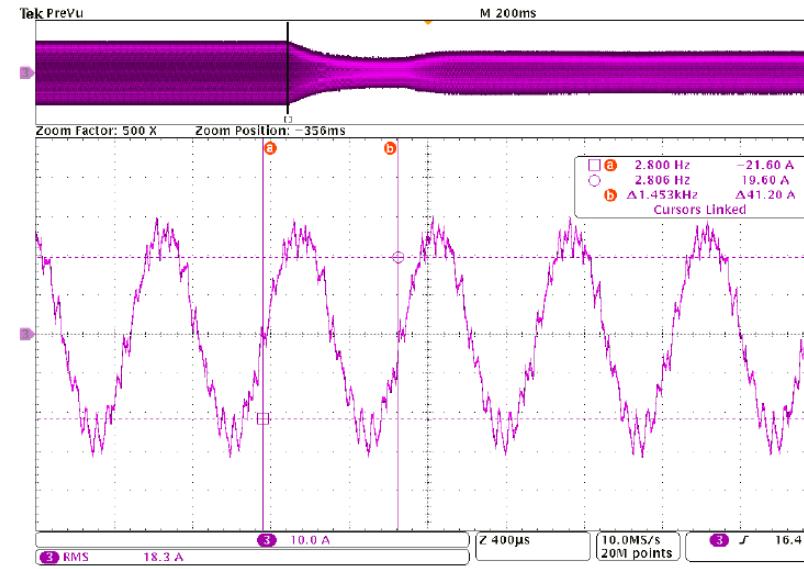
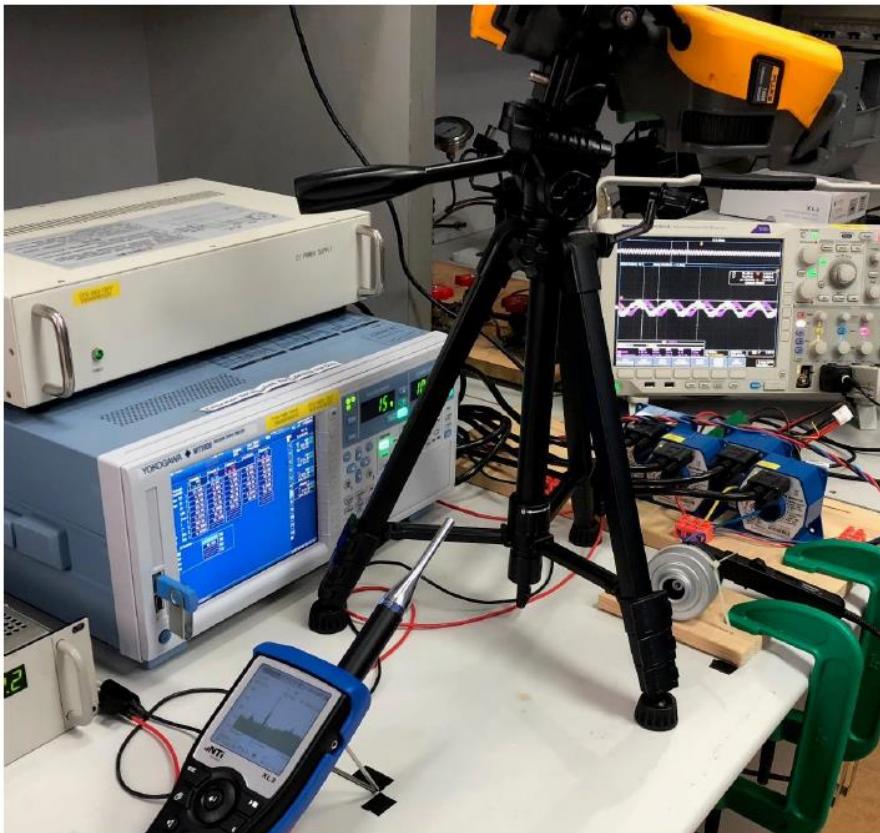


HW configuration example

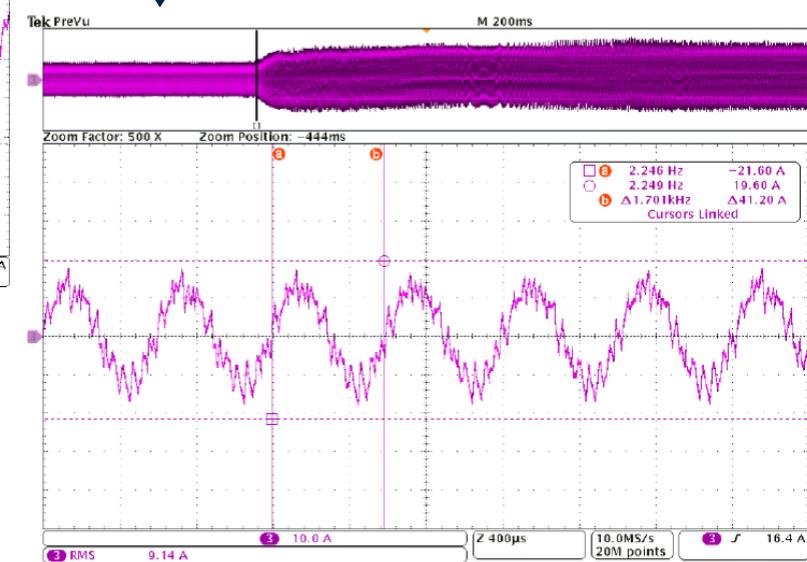


# 吸尘器参考设计

Up to 100k-130k rpm on single pole pair motors (proven on real cases),  
constant power mode to handle different working conditions of air inlet



Motor running at **87K rpm**  
motor accelerates with closed air inlet  
(decreased load)



**100K rpm reached**  
when the load changes (air inlet is reopened), the motor keeps under control

# 低压应用



**B-G431B-ESC1**

- STM32G4 MCU
- L6387ED gate driver
- STL180N6F7  
STripFET F7
- L7986TR,  
LD39050PU33R,

Discovery kit for ESC



**EVALKIT-ROBOT-1**

- STSPIN32F0A  
sip
- STL7DN6LF3  
Dual STripFET F7
- ST1S14PHR
- Modbus;  
Position Control

BLDC servo kit LV



**STEVAL-SPIN3201**

- STSPIN32F0A  
sip
- STD140N6F7  
STripFET F7
- 100k RPM motors

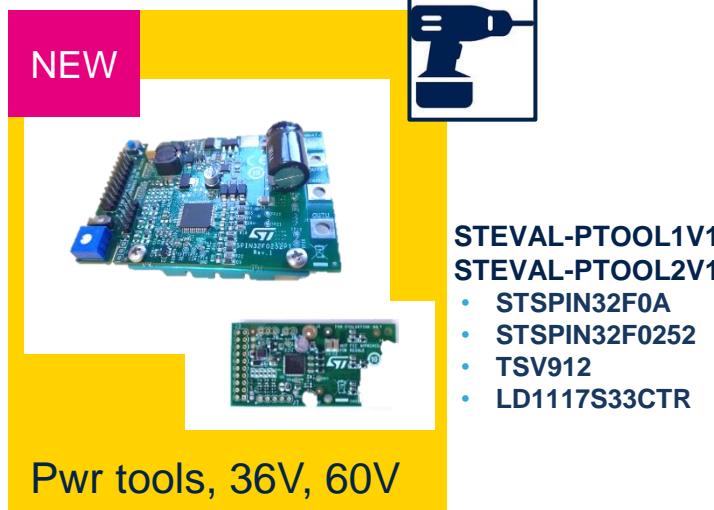
Vacuum cleaner



**STEVAL-CTM009V1**

- STM32 Nucleo Board
- STH310N10F7-6:  
STripFET™ F7 (36x)
- L6491 gate driver
- STTH102AY;  
STPS5L60SY;  
STPS3L40SY: rectifiers
- A7986: Buck boost  
regulator

5kW high current LV



**NEW**

**STEVAL-PTOOL1V1**  
**STEVAL-PTOOL2V1**

- STSPIN32F0A
- STSPIN32F0252
- TSV912
- LD1117S33CTR

Pwr tools, 36V, 60V



**STEVAL-ESC002V1**

- STSPIN32F0A  
sip
- STL140N6F7  
STripFET F7
- LMV321LILT signal  
cond.

Garden tools, 6-step

\*Part numbers just examples; parts to be agreed with ST Marketing

\*\*Architectures just examples in the ST-EVAL; architecture to be defined with customer



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