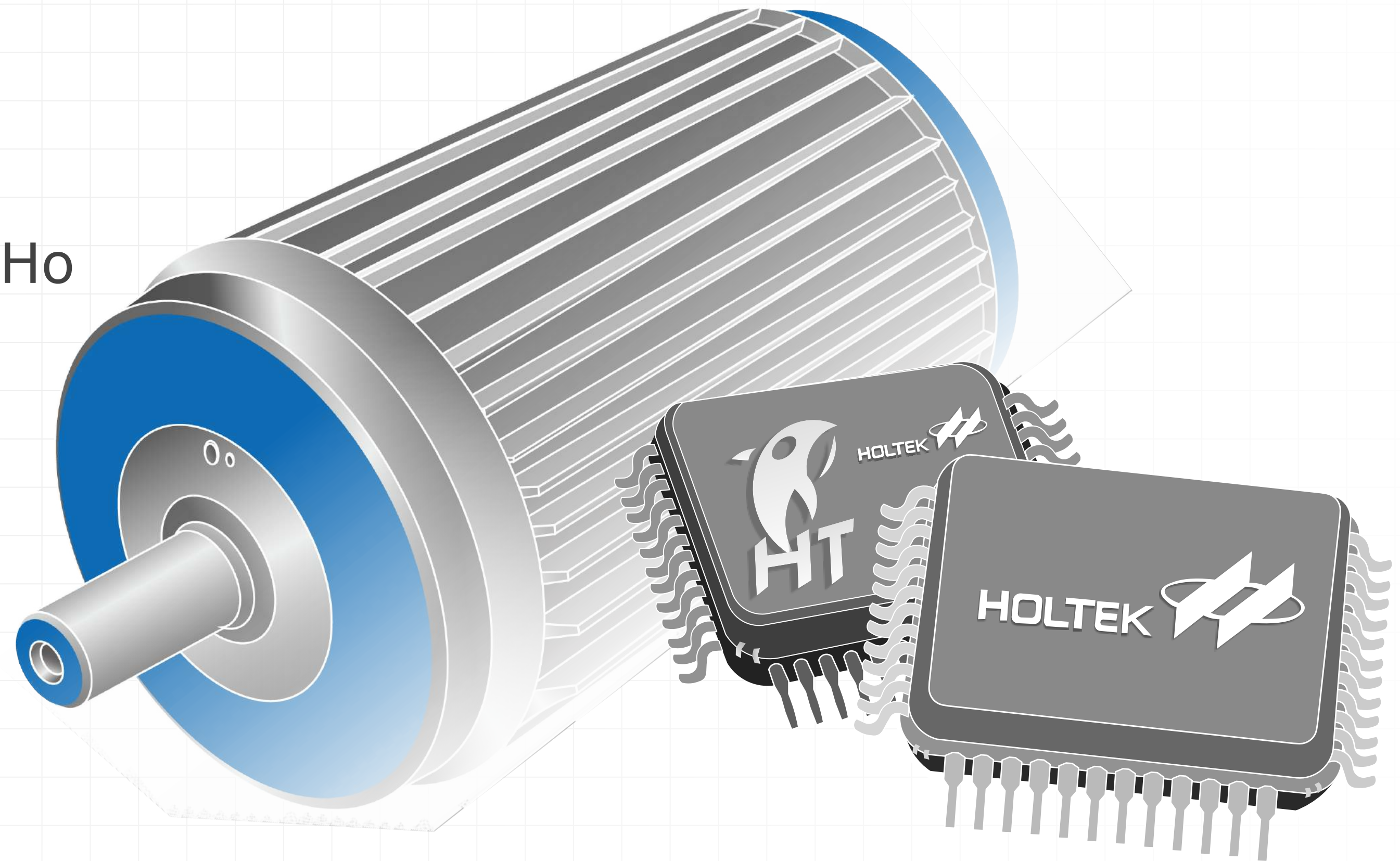


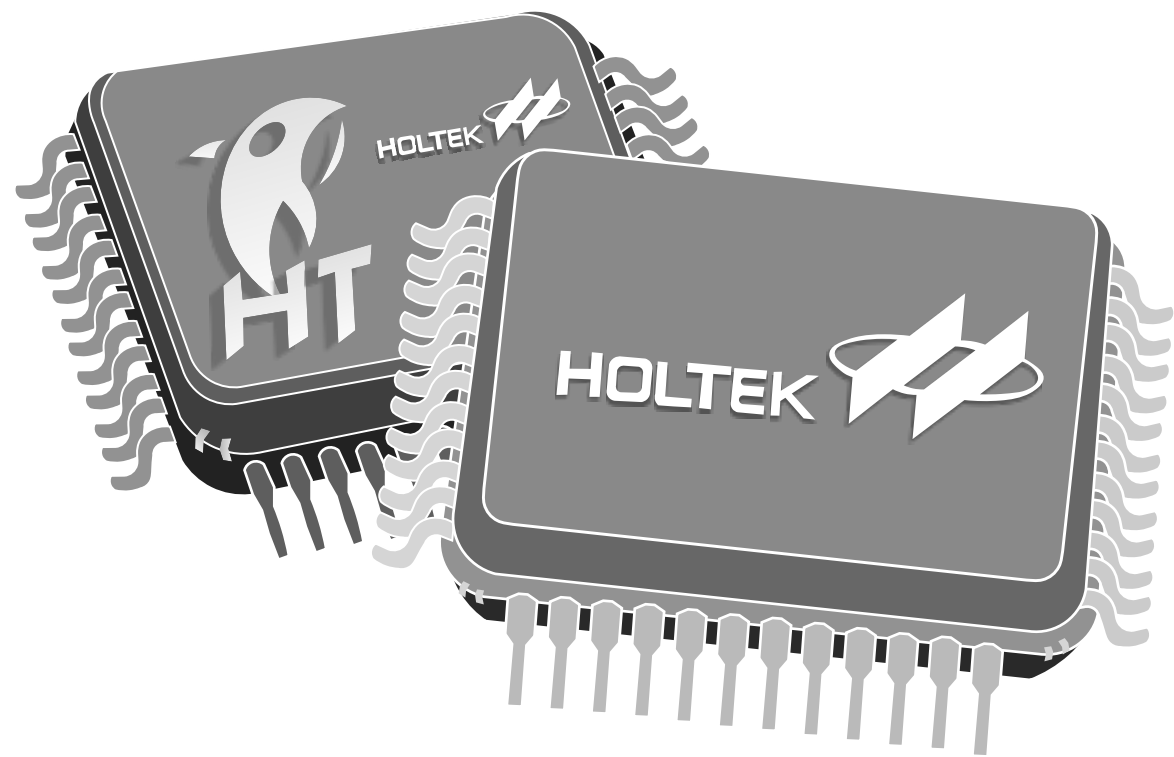


High-Efficiency BLDC Motor Control HT32 MCU Solutions

Speaker : Dr. Steven Ho
steven.ho@holtek.com.tw

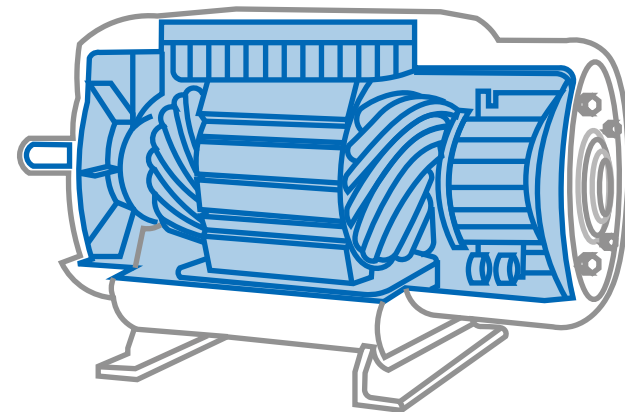


- 1. Motor Development and Market Overview
- 2. HT32 BLDC Motor MCU Introduction
- 3. HT32 BLDC Motor Workshop Introduction
- 4. Holtek Motor Control Advantageous Techniques
- 5. Holtek Motor Control Solution Features

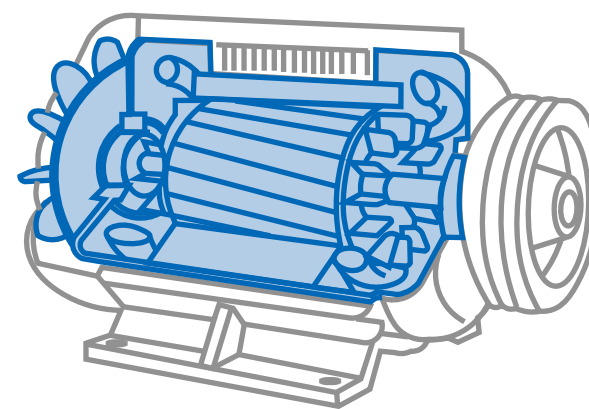




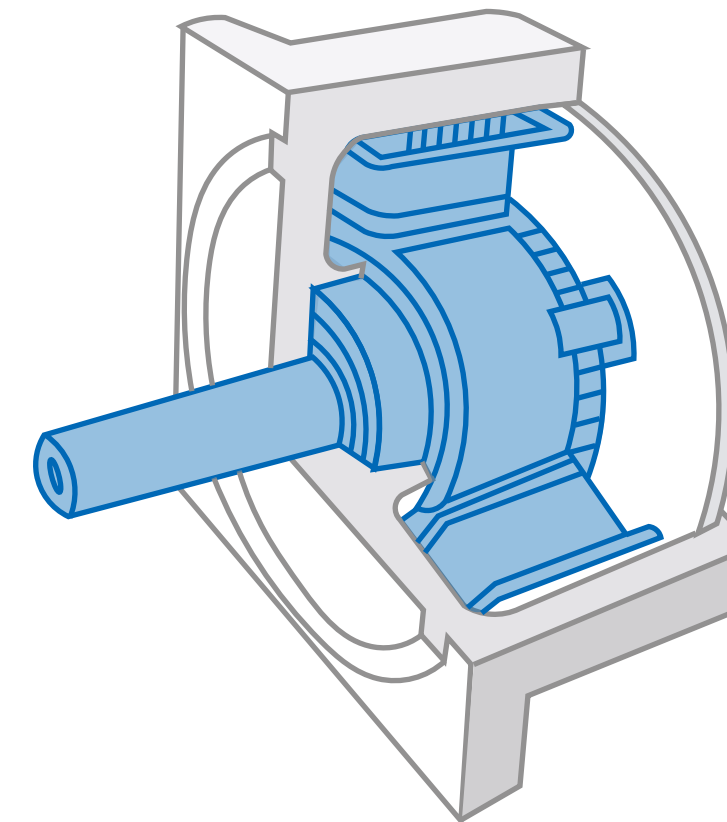
Motor Types and Development Trends



DC Motor
Brushed DC Motor



ACIM
AC Induction Motor



BLDC Motor
Brushless DC Motor



	Brushed DC Motor (DC Motor)	AC Induction Motor (ACIM)	Brushless DC Motor (BLDC Motor)
Advantages	A. Simple driving circuits B. Easy to control speed by adjusting voltage	A. AC induction driving (fixed speed) B. Simple instructure, low production costs, no maintenance issues	A. Higher power conversion efficiency B. Easy to meet high speed requirements C. Low speed & large torque, no noise D. Torque proportional to current, high linearity
Disadvantages	A. Friction between commutator and carbon brush can cause sparks and longevity problems B. Winding structure is less prone to heat dissipation C. Loud operation noise	A. Low power conversion efficiency & higher temp. rise @1KW or less B. Louder driving noise C. More types of driving algorithms but need to combine with MCU features	A. Complex motor structure, higher costs B. Complex driving circuits C. More types of driving algorithms but need to combine with MCU features

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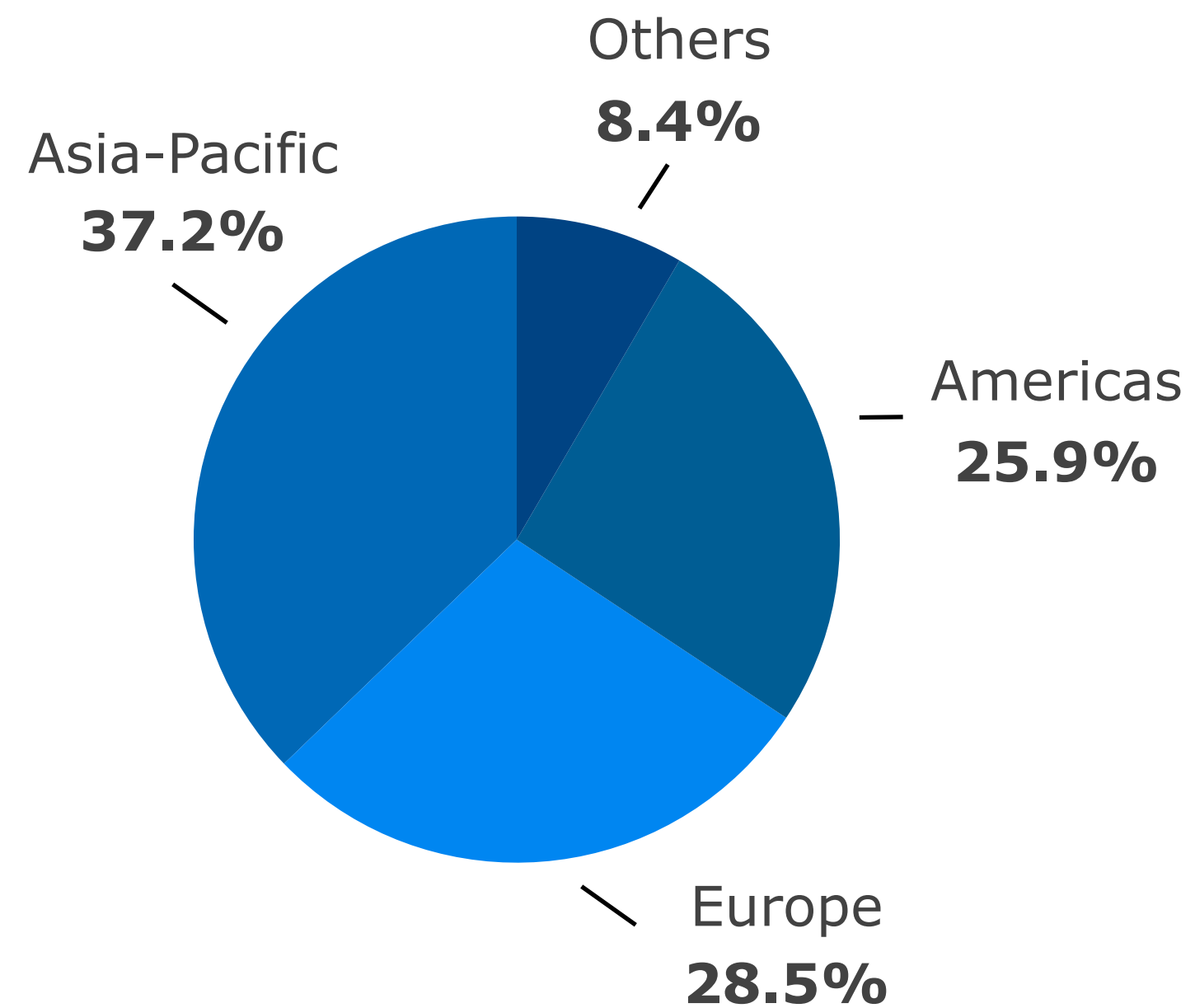
Global Motor Market Size Keeps Growing



■ BLDC market size from 2021 to 2025



Data source : Grand View Research



Data source : IndustryARC





Motor Modules

- Modular design, small PCB size
- MCU integrated gate-driver
- MCU integrated driver

FOC / Sensorless

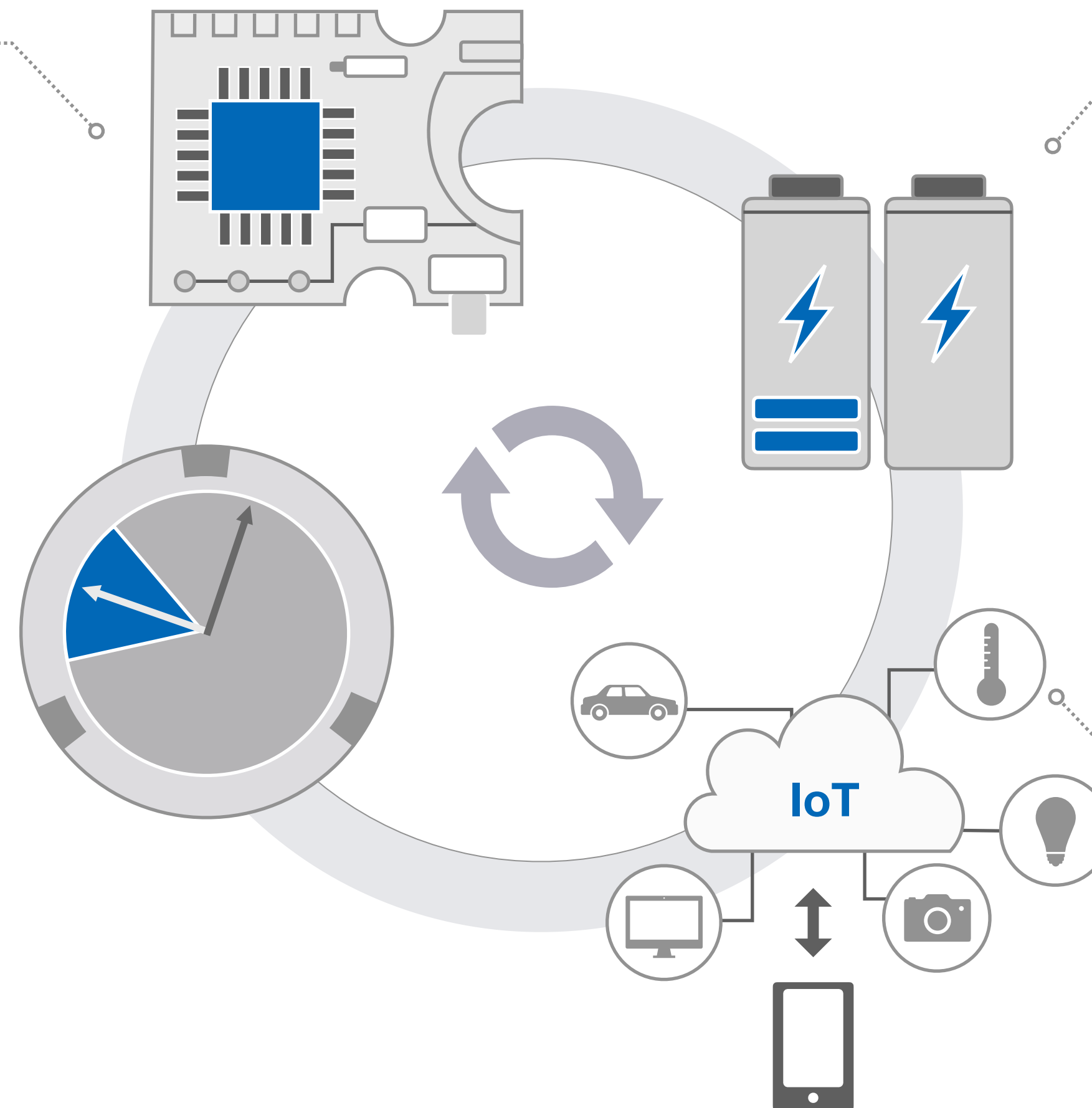
- Sensorless design, reduced costs
- FOC high efficiency

Li-batteries

- Handheld, more convenient
- Power / garden tools
- Vacuum cleaners
- Sweeping robots
- Personal care

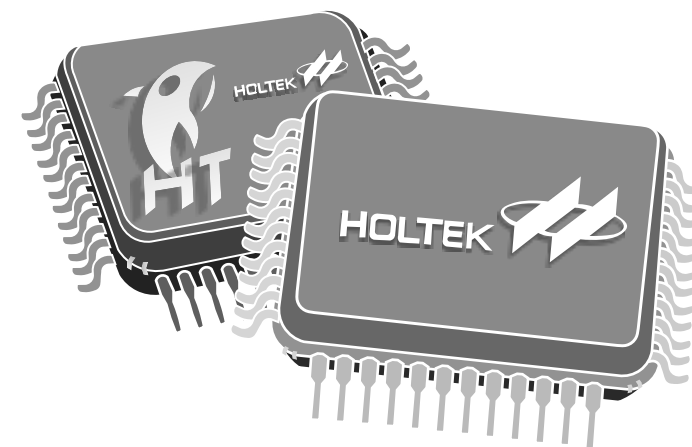
Internet of Things

- Automatic air conditioning, constant temp. and humidity
- Smart home
- Smart office

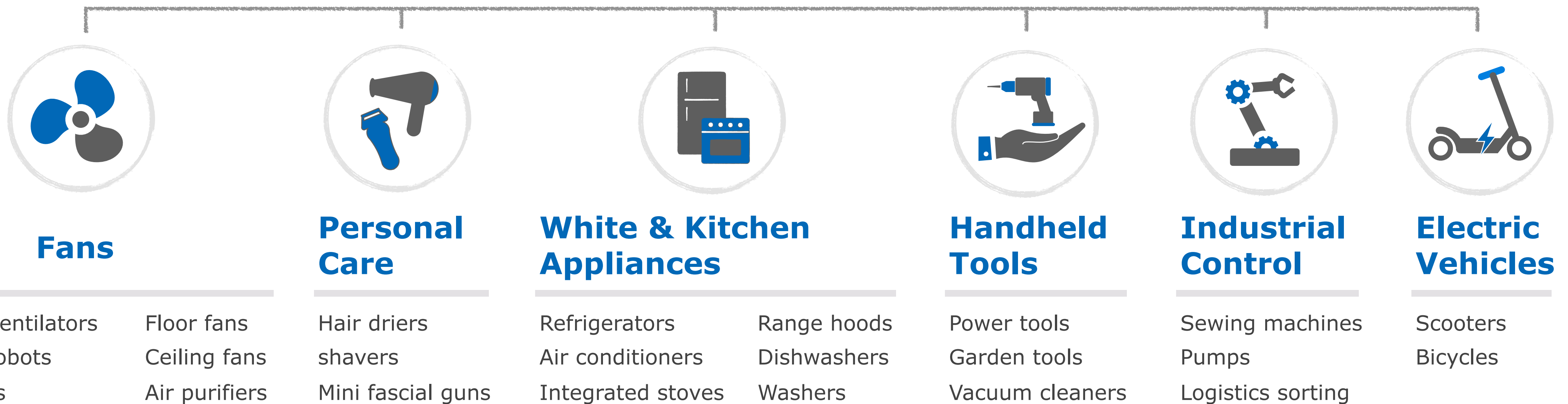


■ Holtek BLDC Motor MCU Vision :

- Committed to provide complete BLDC motor mixed-signal SoC chip solutions
- Focus on BLDC motor applications, providing superior algorithms and services



Holtek BLDC Motor MCU

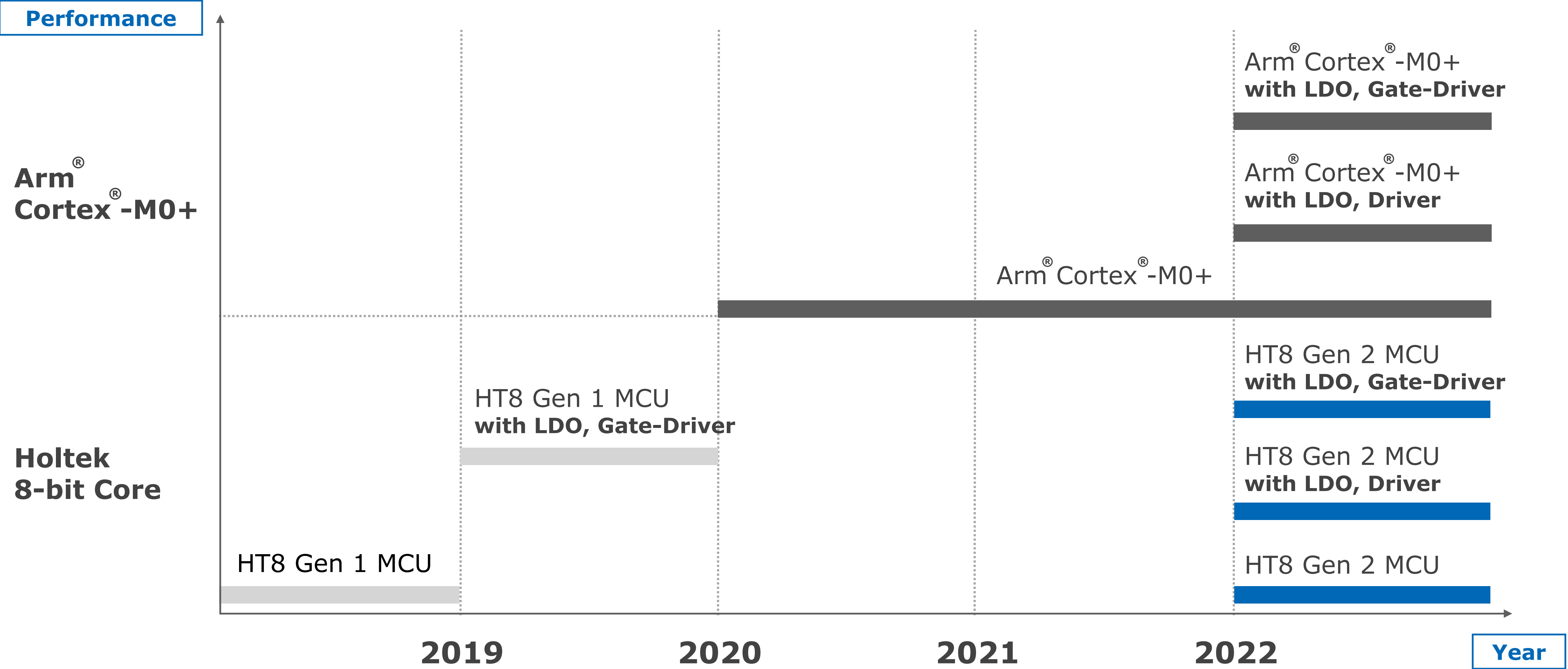


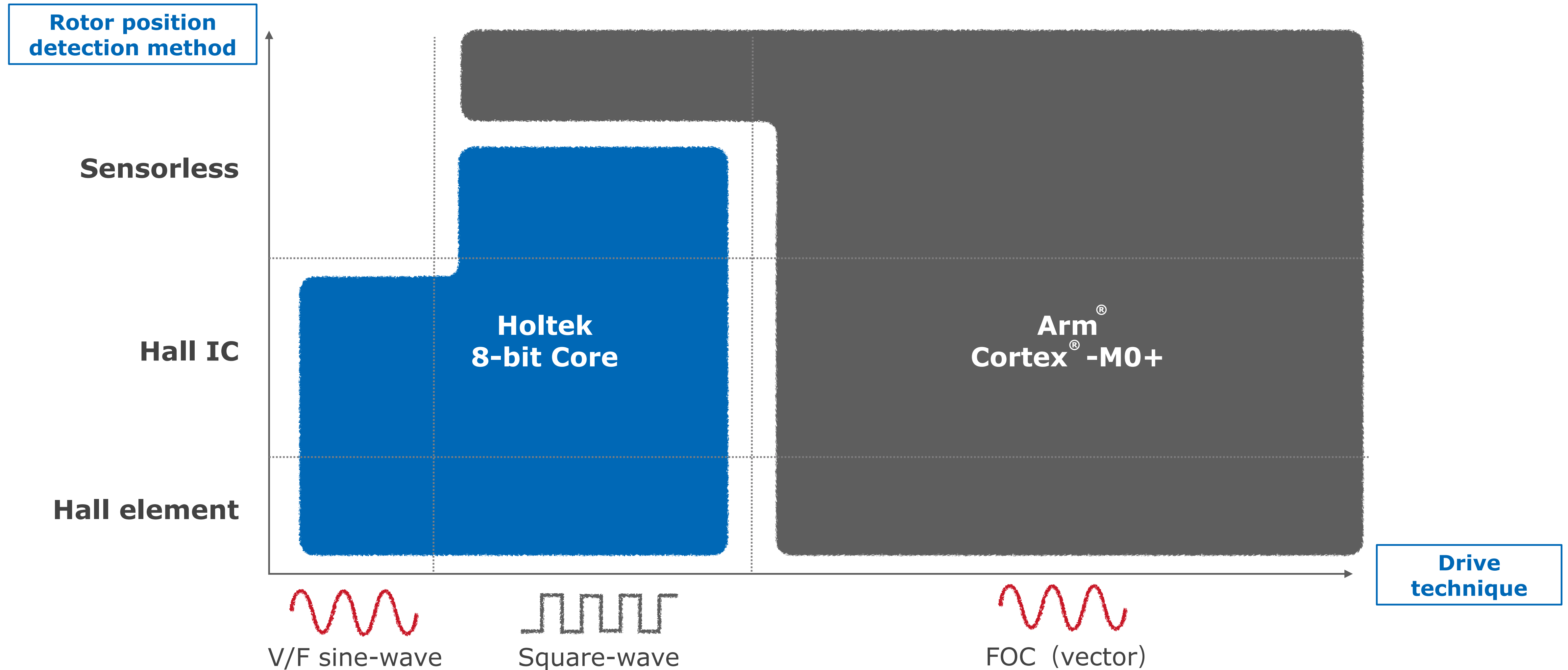


Holtek HT32 BLDC Motor MCU Introduction



Holtek BLDC Motor MCU Roadmap

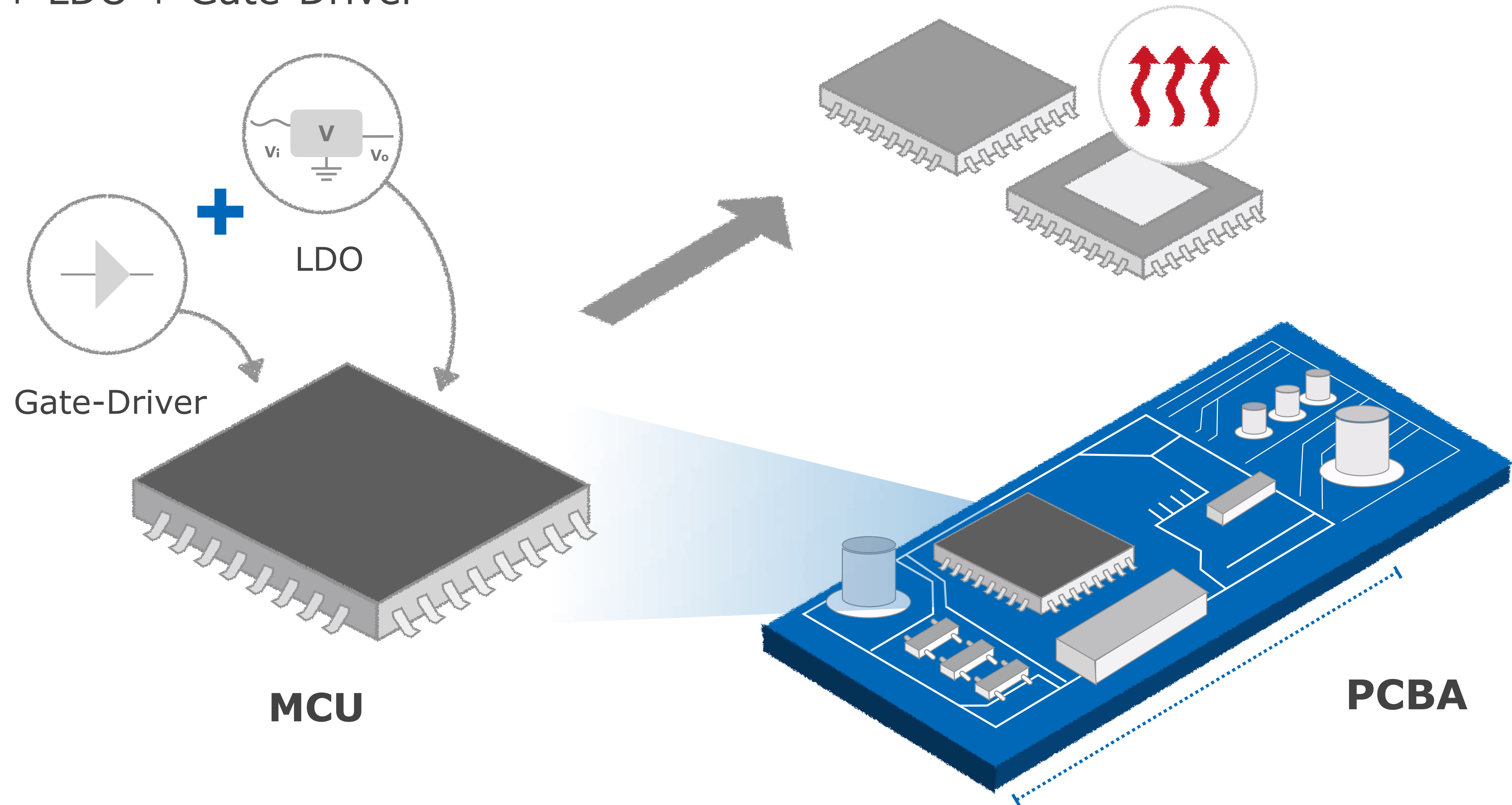




MCU Integrated Gate-Driver



■ MCU + LDO + Gate-Driver



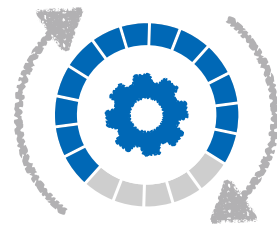
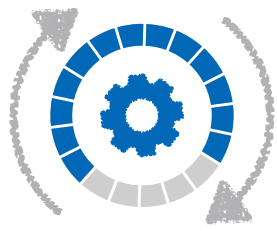


Integrated Gate-Driver Features



■ Gate-Driver features :

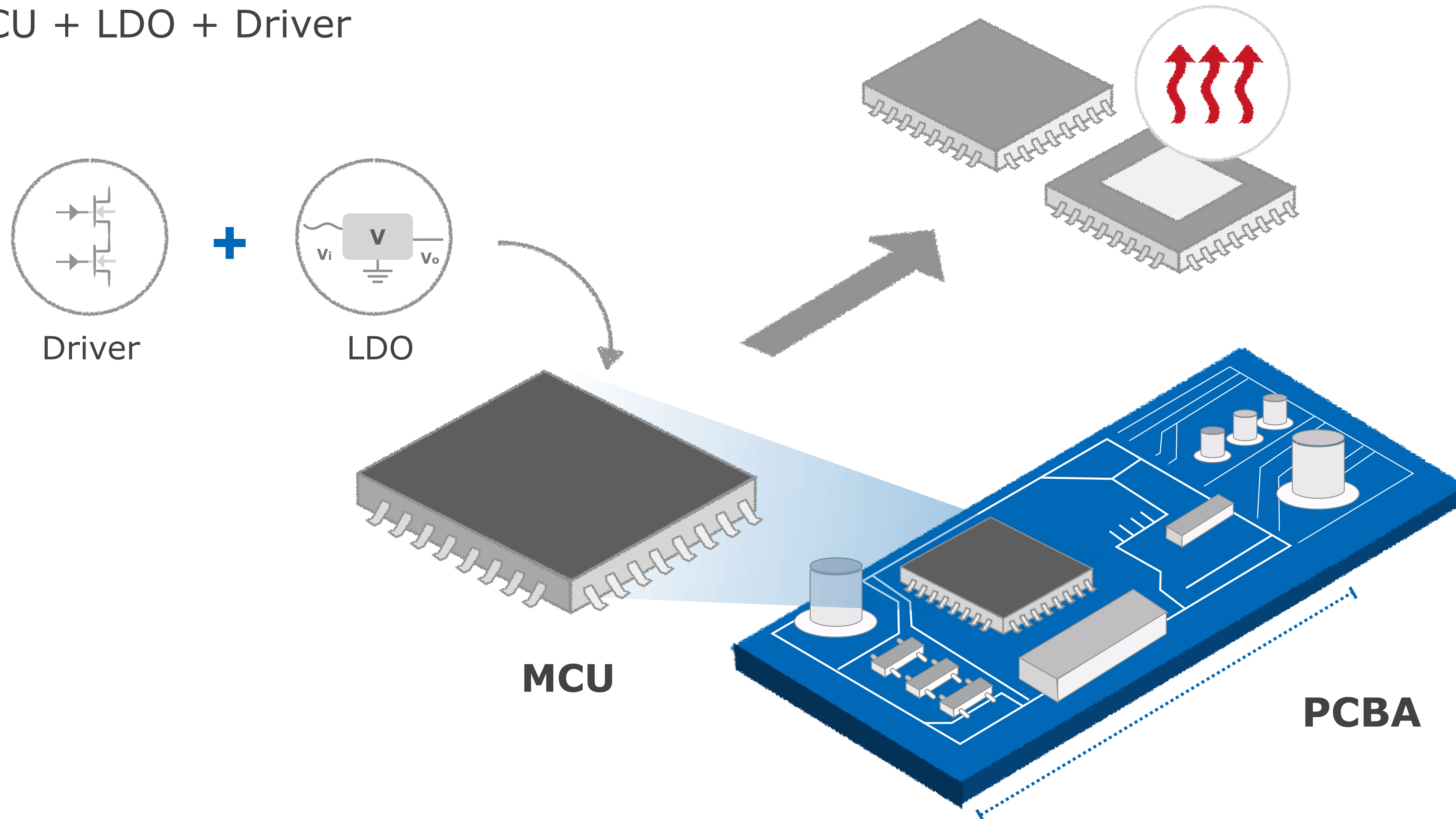
- 5V LDO
- Bootstrap diode (only N/N)
- Low sleep current
- Protect :
 - UVLO
 - Shoot-through
 - OTP
- -40°C~105°C

600V N/N		
200V N/N		
110V N/N	2023/3	2023/3
48V N/N		
36V P/N	2022/12	2022/12
18V P/N		
	Holtek 8-bit Core	Arm [®] Cortex [®] -M0+

MCU Integrated Driver



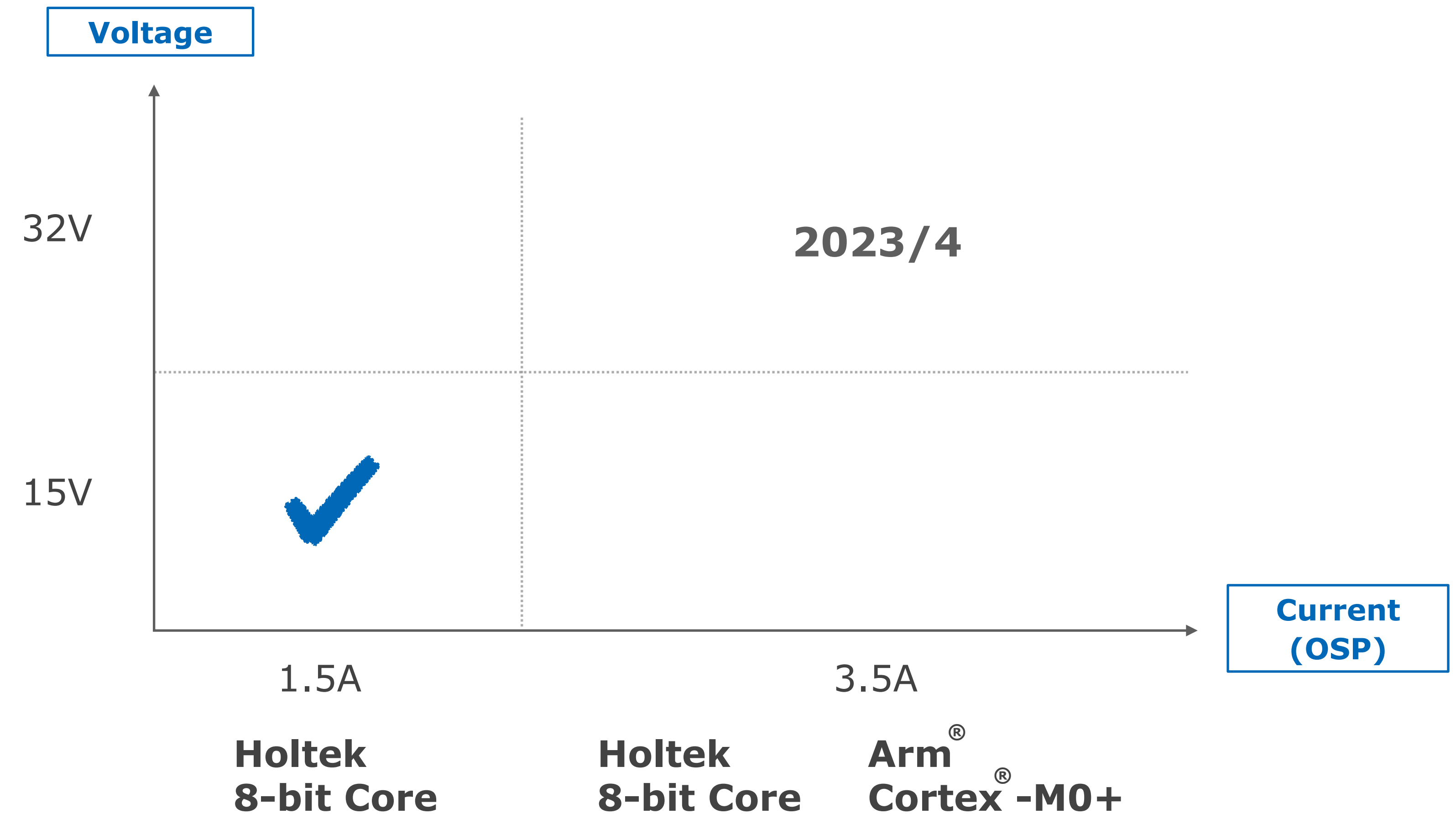
■ MCU + LDO + Driver





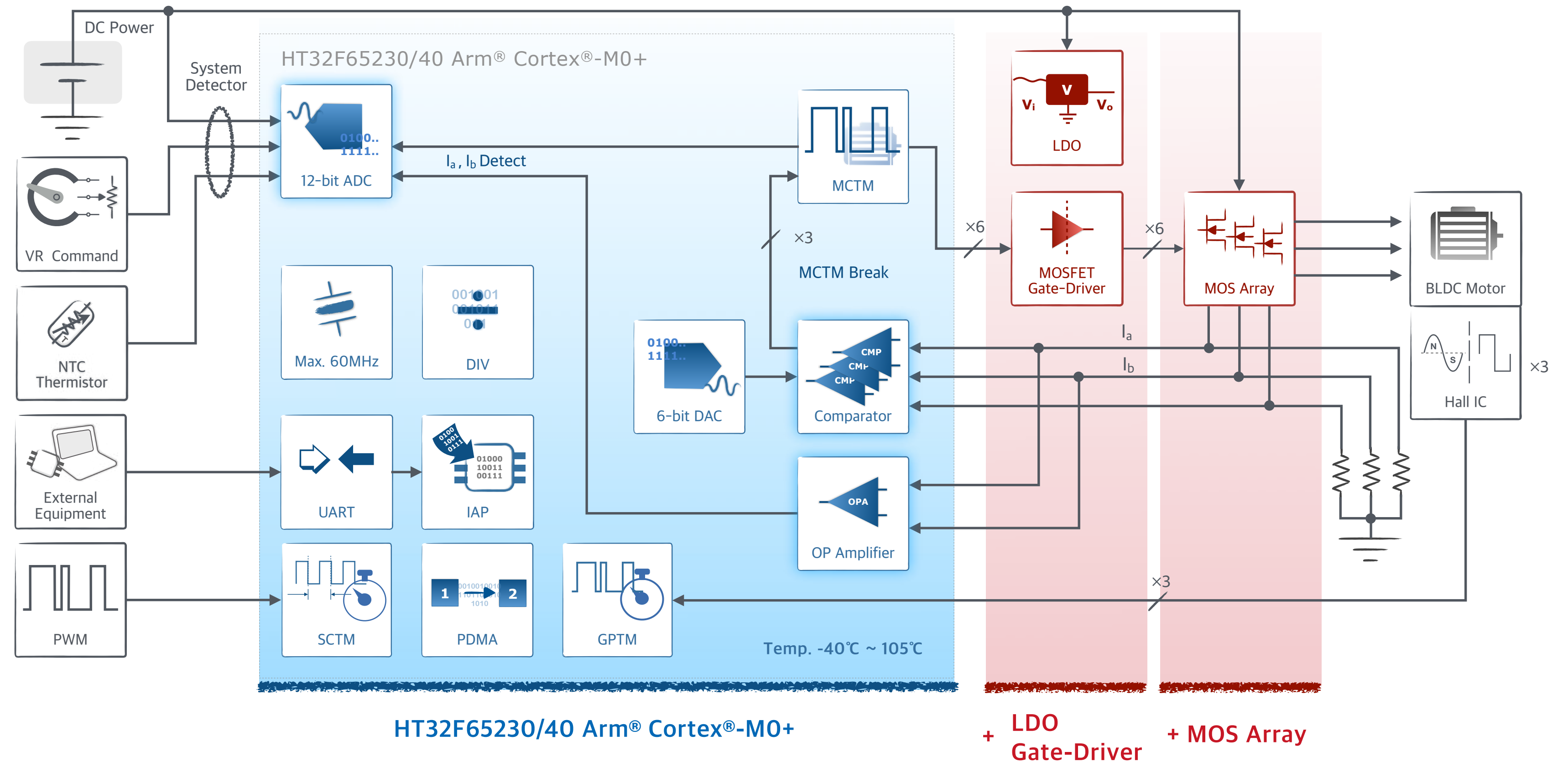
■ Driver features :

- 5V LDO
- Charge pump
- Low sleep current
- FG (OD)
- Protect :
 - UVLO
 - OSP
 - OTP
- -40°C~105°C



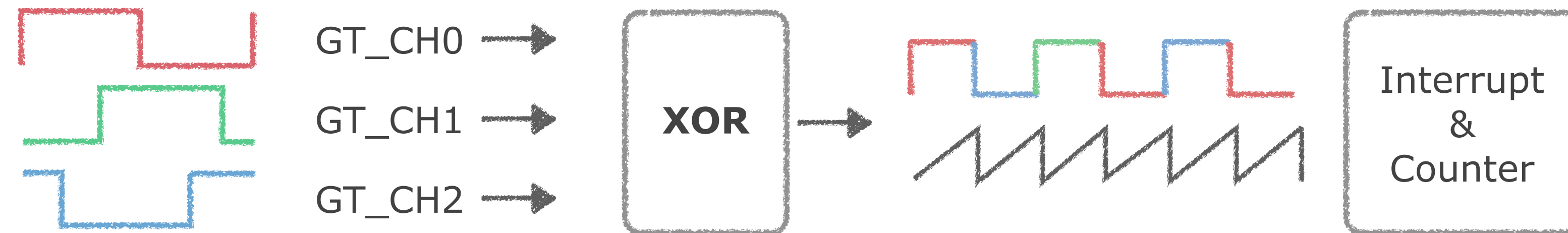
- 2-shunt FOC solution

- Phase current synchronous sampling : 1Msps ADC×2 + OPA×2
- ADC high priority trigger mechanism
- PWM arbitrary cycle trigger

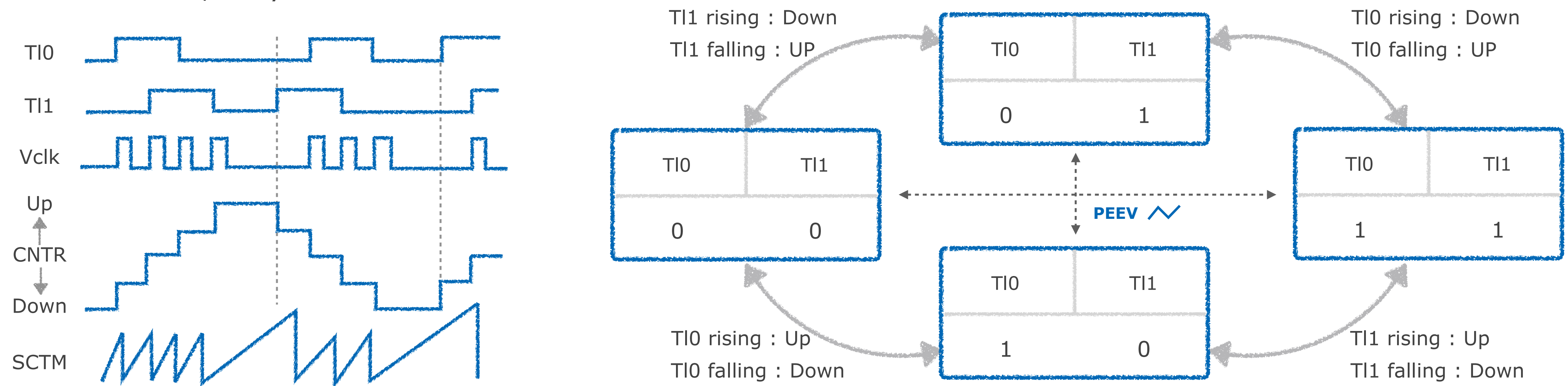


■ GPTM assisted rotor position sensor detection

- Hall XOR, reducing program complexity



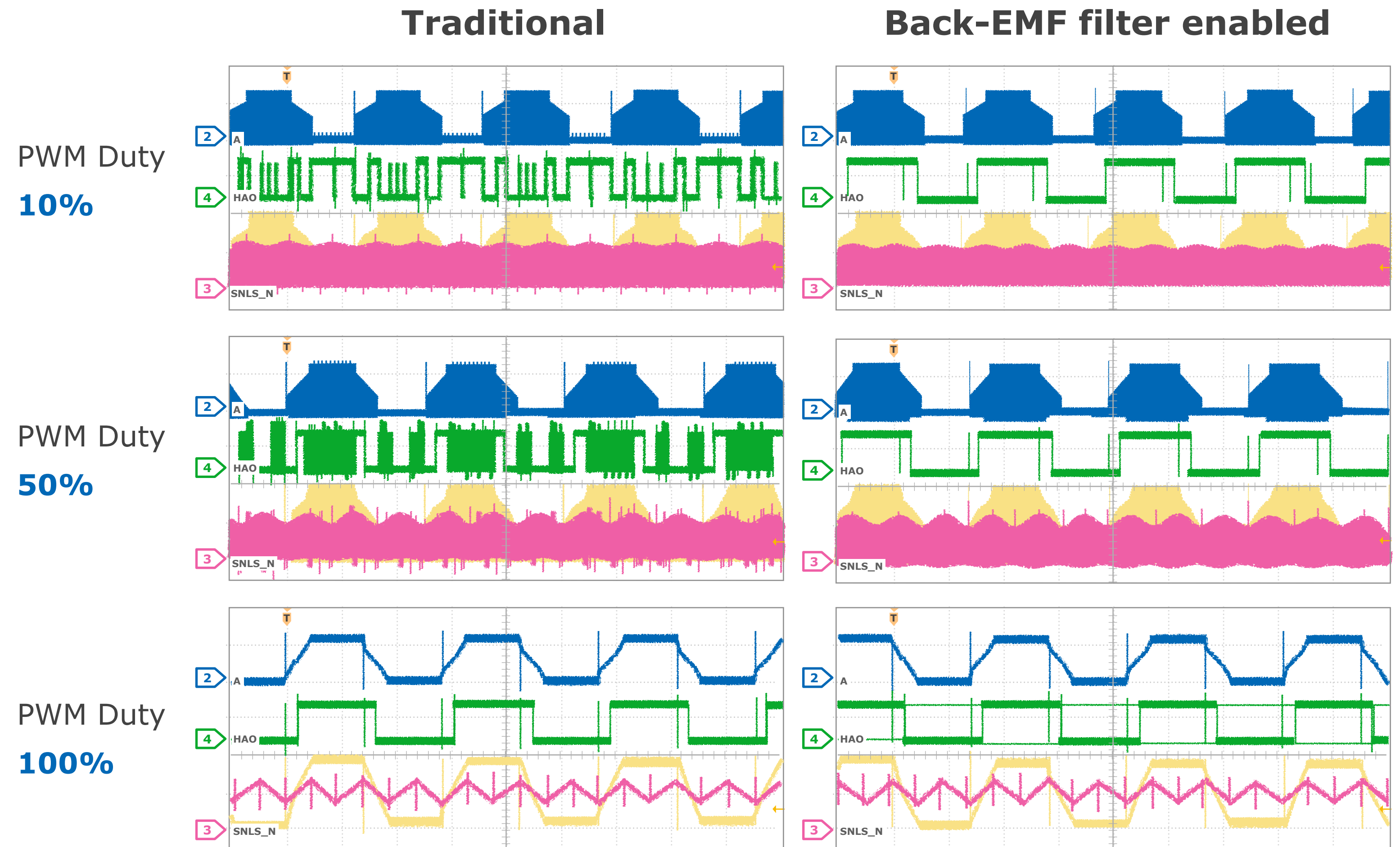
- Works with SCTM, easy to use the encoder





■ MCU integrated square-wave sensorless filter

- Improved start-up reliability and phase change accuracy
- Reduced phase delay of traditional digital filters
- Reduced PCB layout burden





■ HT32 Series MCU UL 60730-1 Class B Software Safety Certification

- UL60730 Certificate Number : E365564

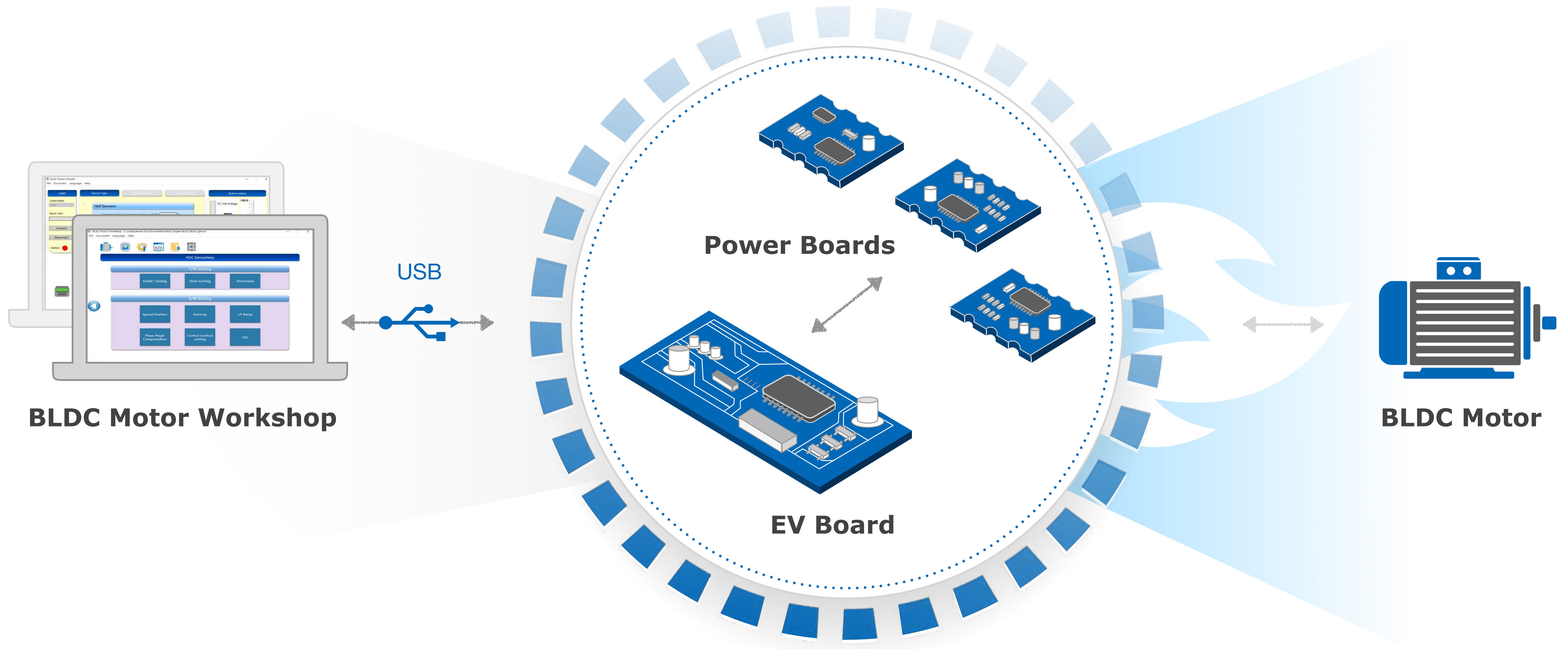


■ HT32F65x40 Series Motor UL Software Certification

- Motor control "UL / IEC 60730-1 Class B" software safety certification

- UL60730 Certificate Number : UL-US-2019981-0

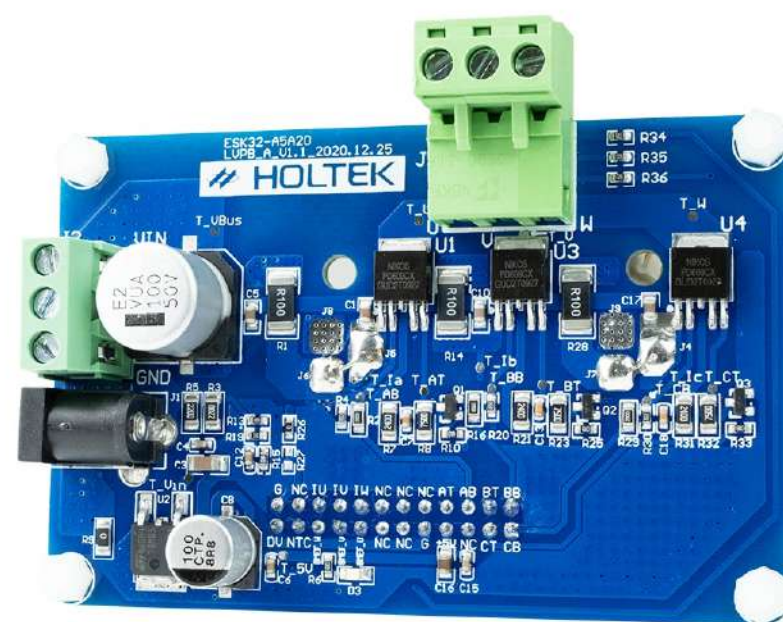




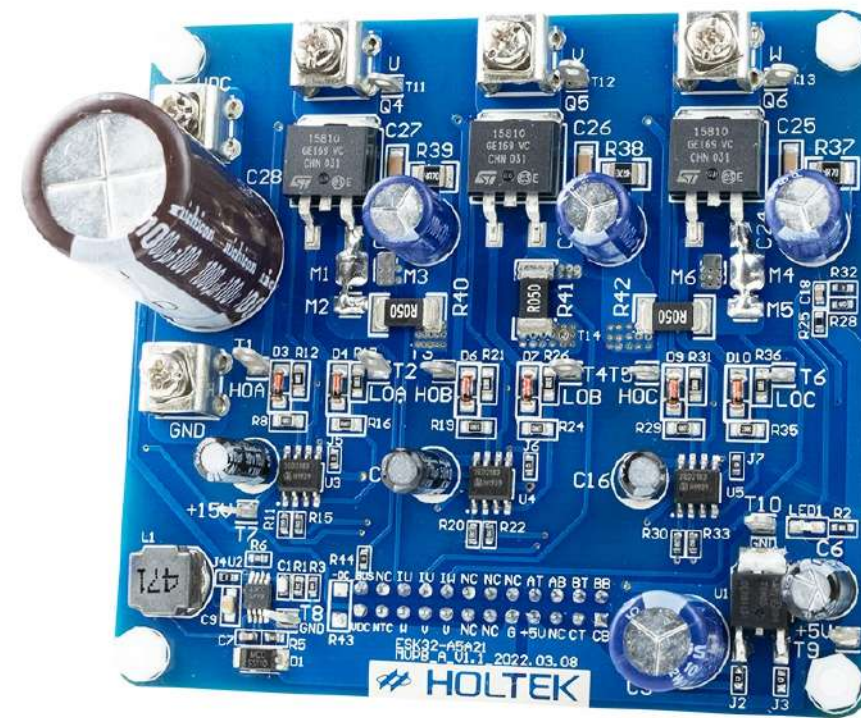
HT32 BLDC Motor Workshop Features



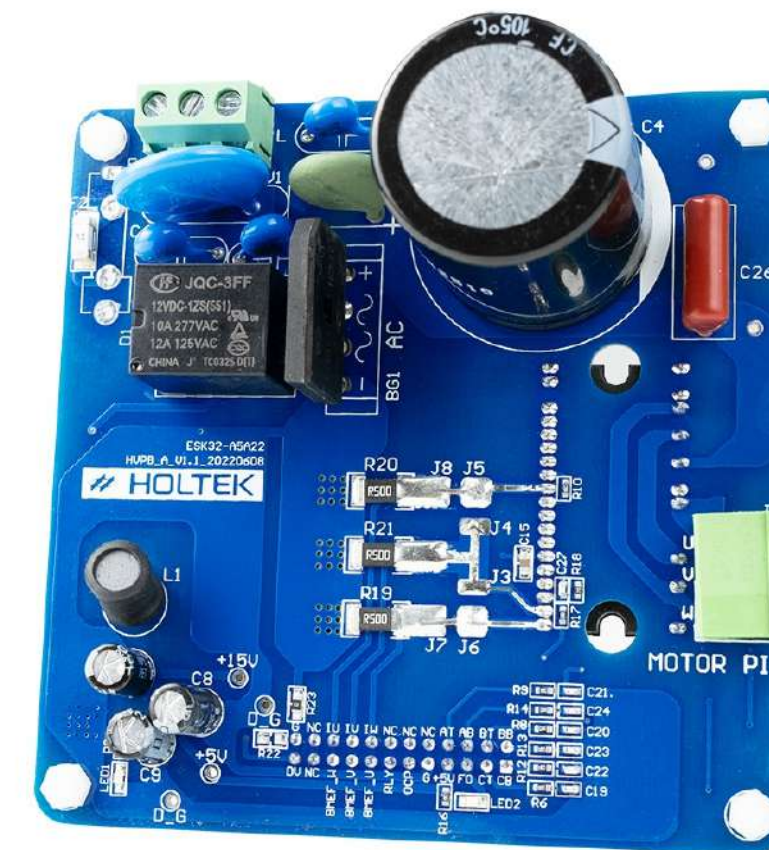
- Control algorithms : FOC Hall Sensor & FOC Sensorless
- Graphical interface :
 - Parameter adjustment
 - Real-time control
 - Virtual oscilloscope
- Project secondary development
- EVB + Power Boards :



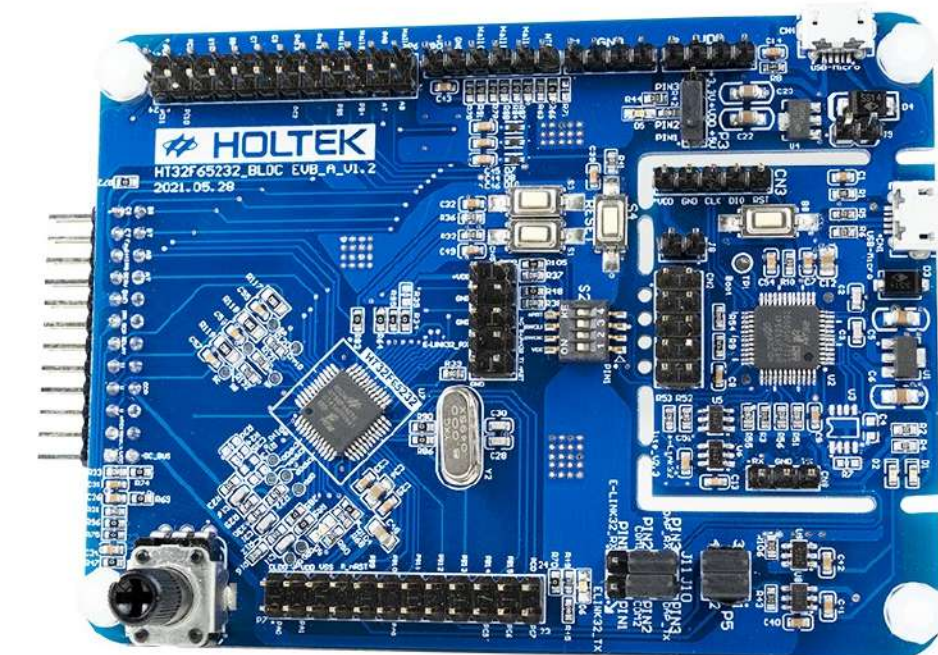
DC 8V~26V / 2.5A



DC 15V~60V / 20A



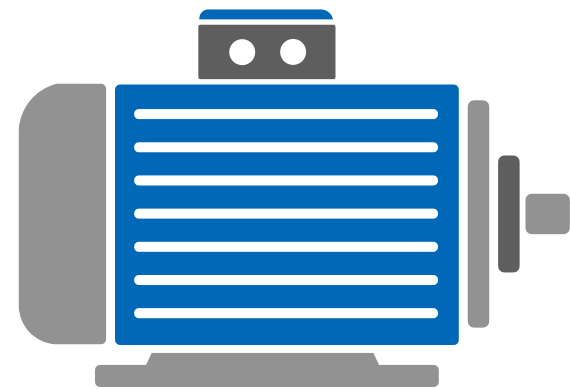
AC 85V~265V / 2.5A



EVB

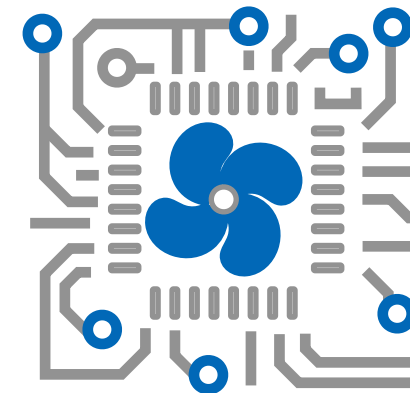


- Two sets of software required :



BLDC Motor Workshop

- Guide the user to fill in motor and system parameters step-by-step
- Generate FOC projects for secondary development



BLDC Motor Monitor

- Real-time parameter adjustment and control
- Virtual oscilloscope for monitoring operation features
- Exporting optimized parameters to project
- UL / IEC 60730-1 Class B motor control software safety certification compliant



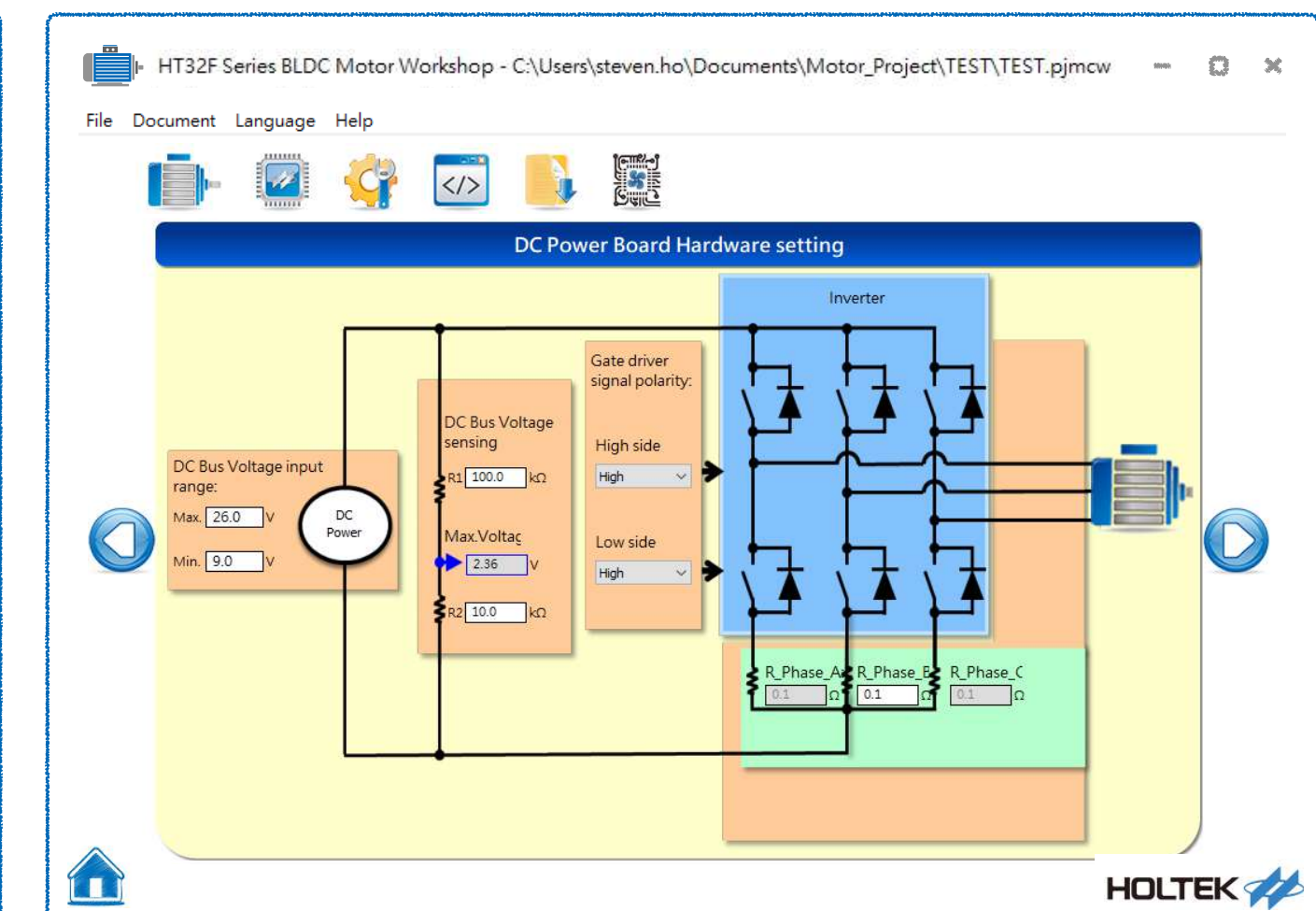
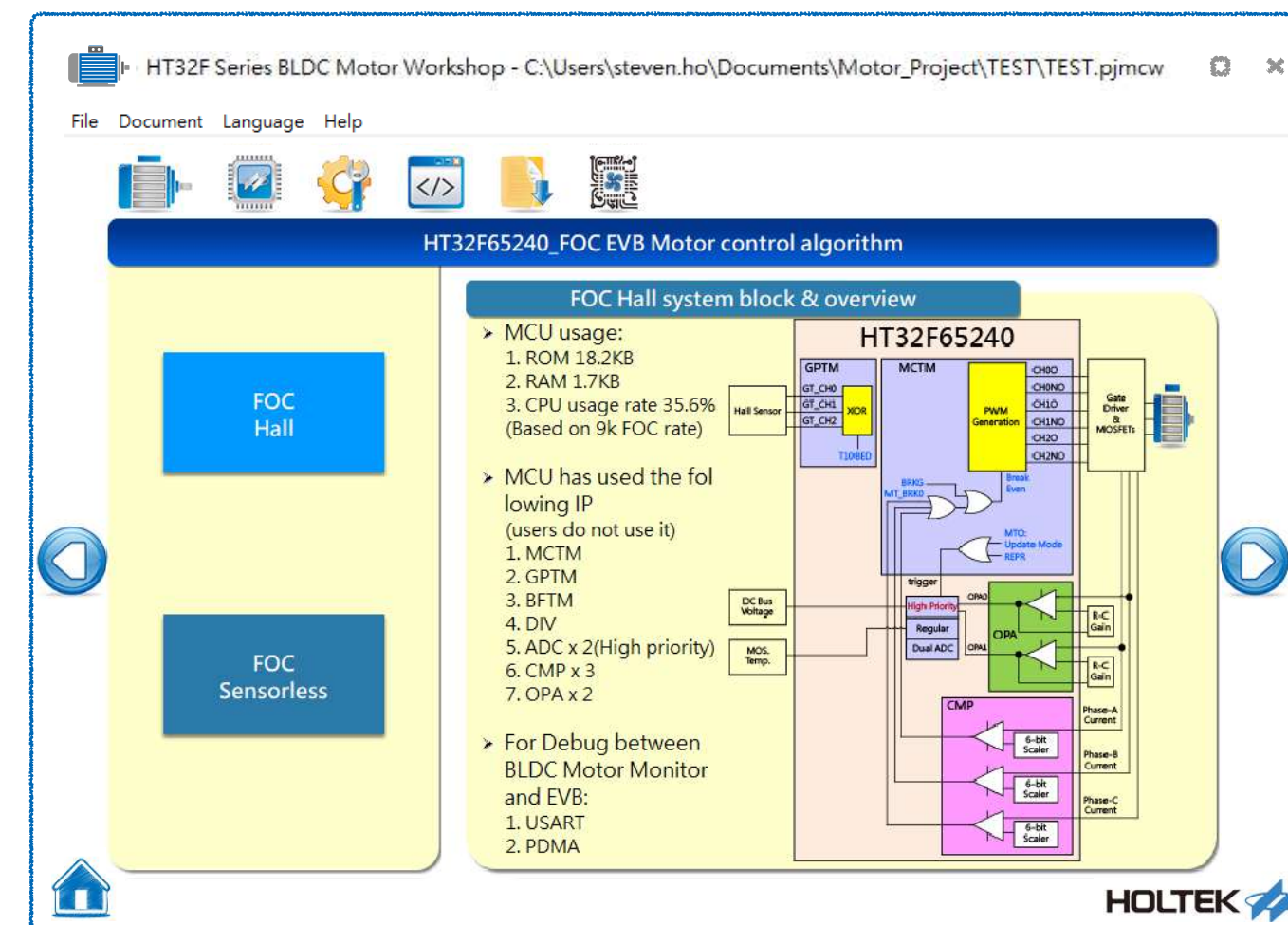
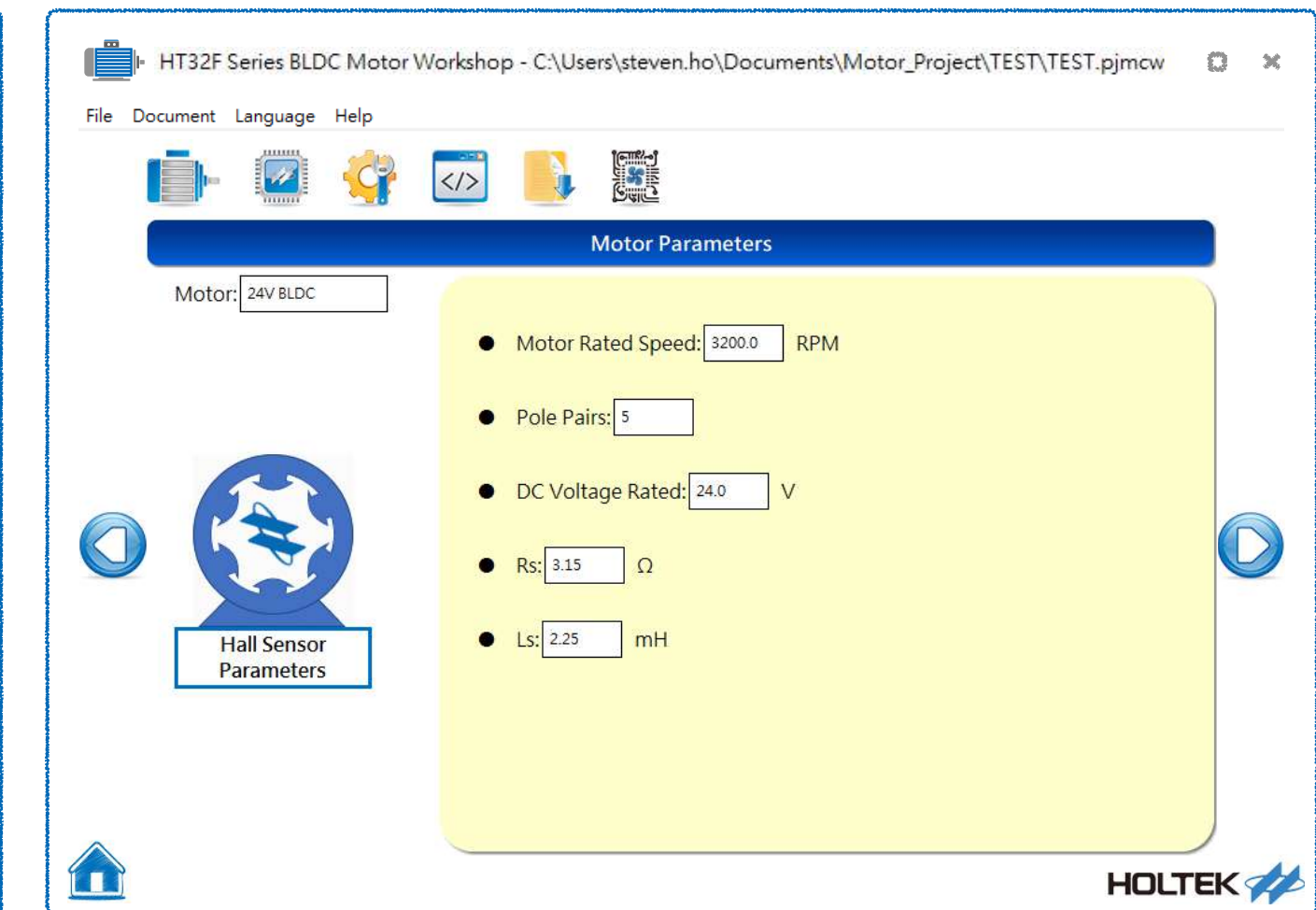
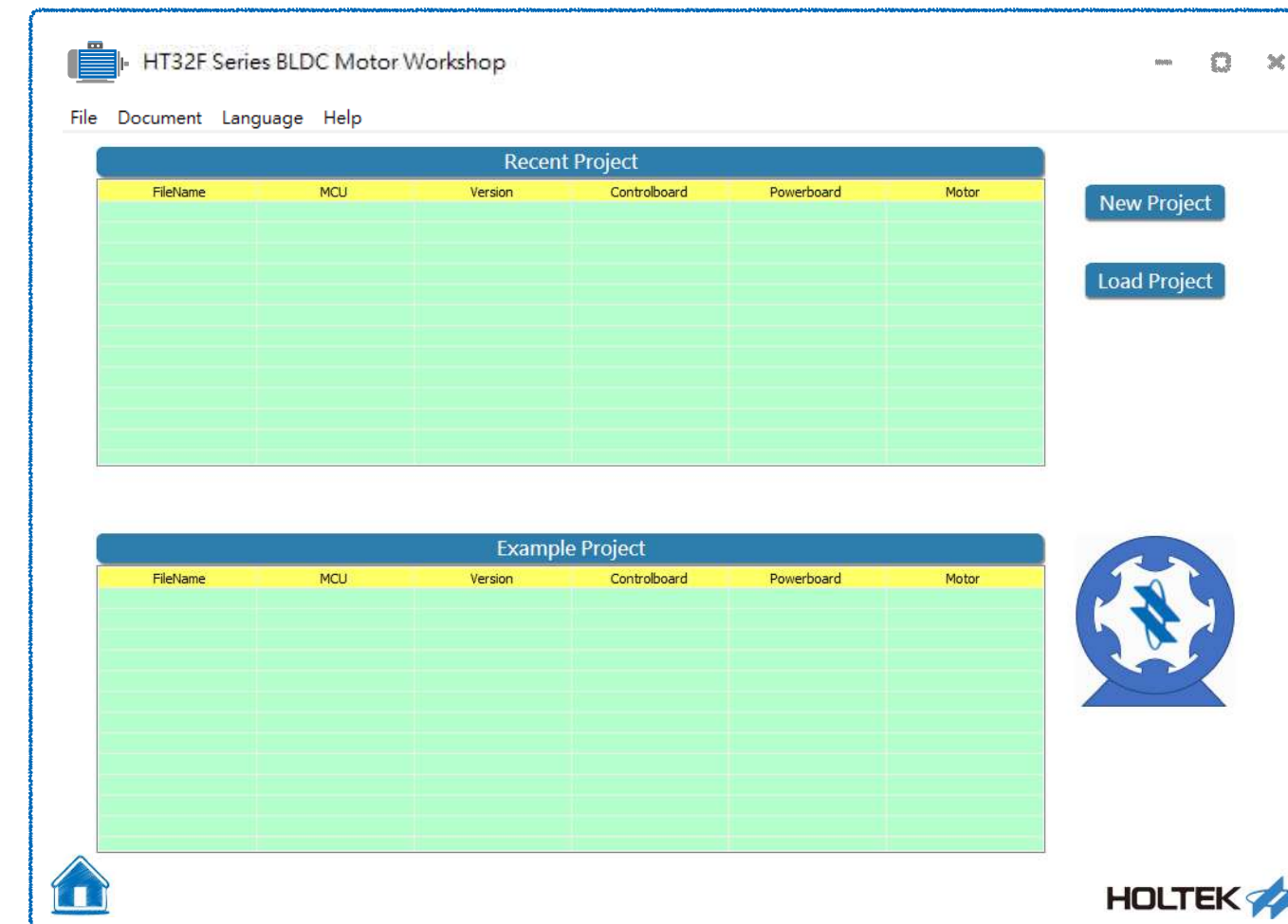
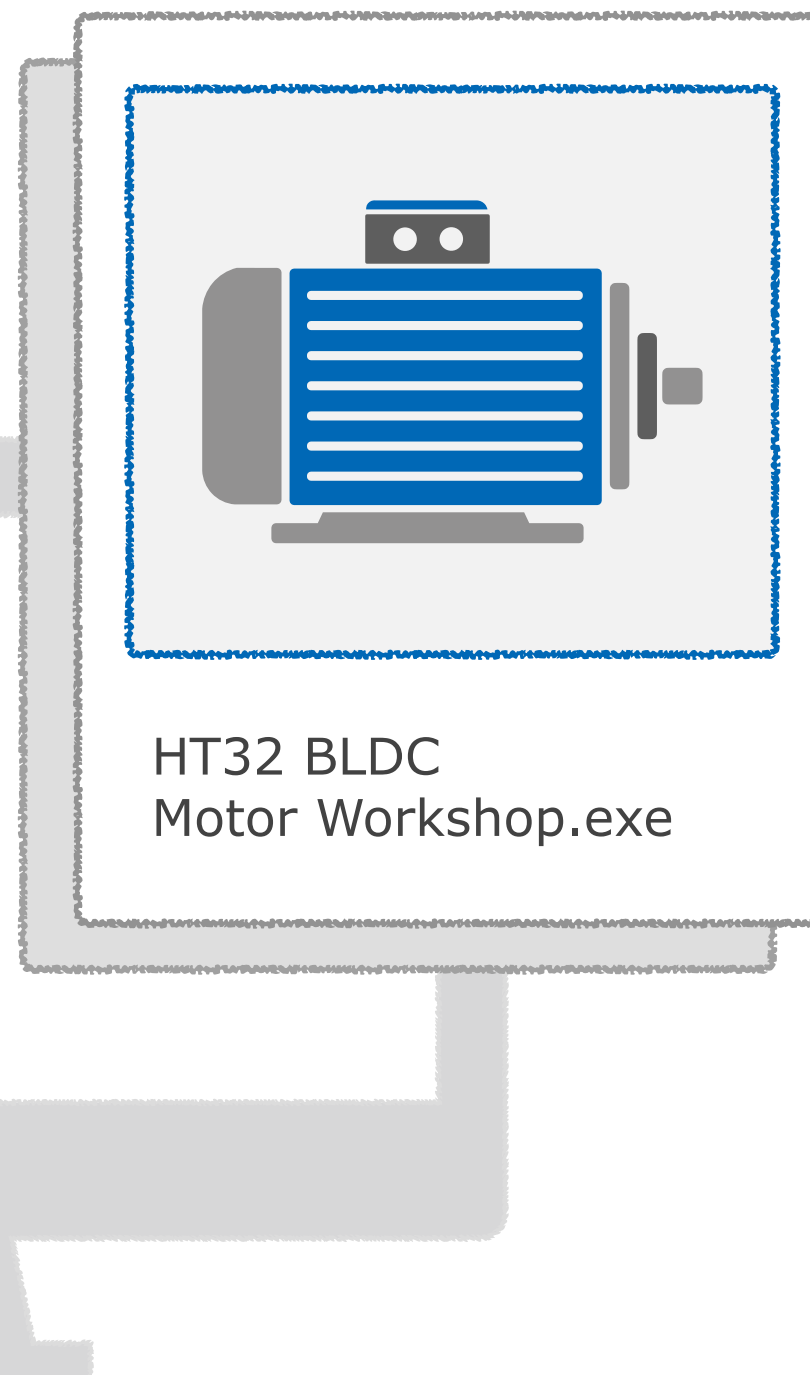
Keil

- Program compilation
- Online emulation
- Secondary development

HT32 BLDC Motor Workshop



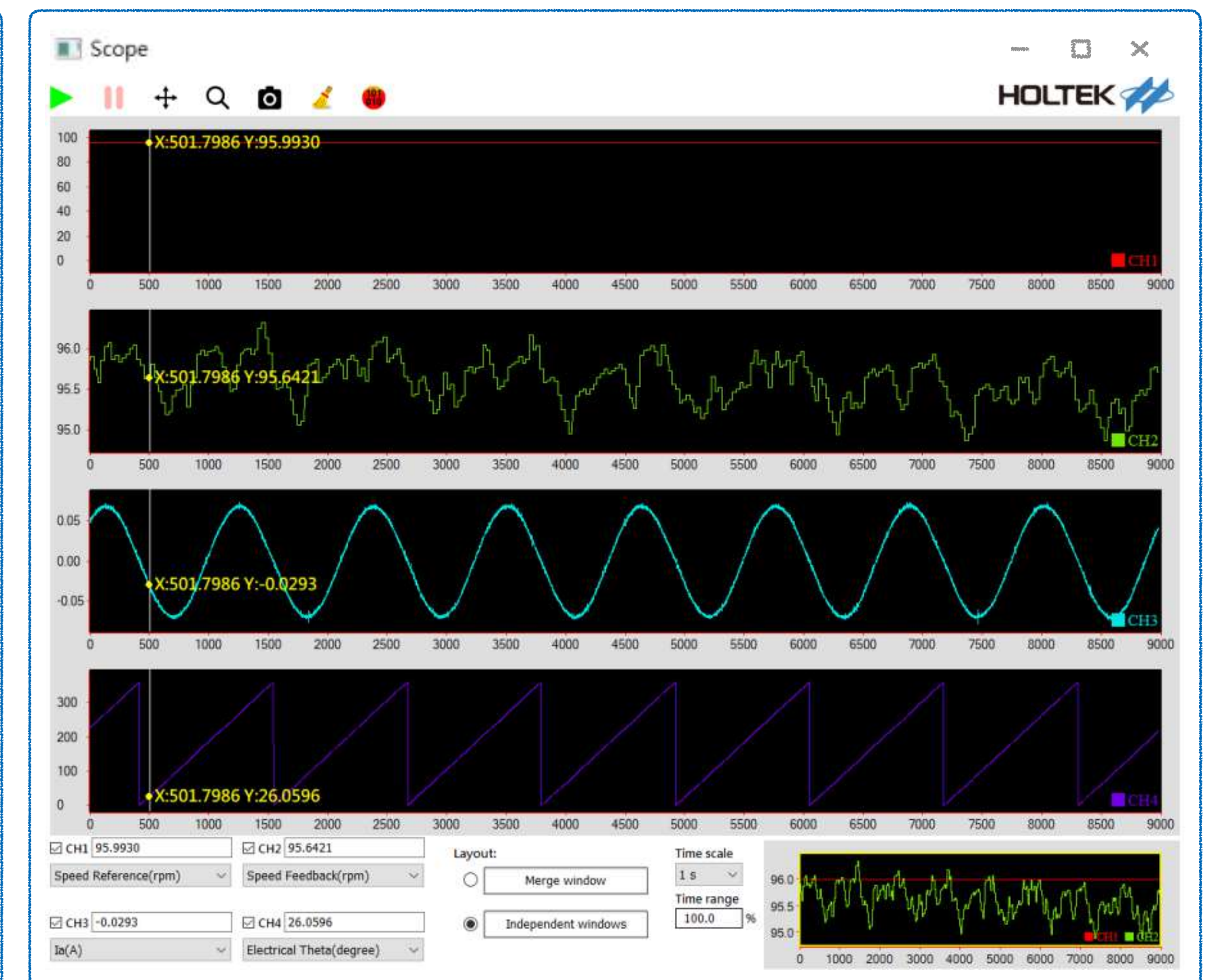
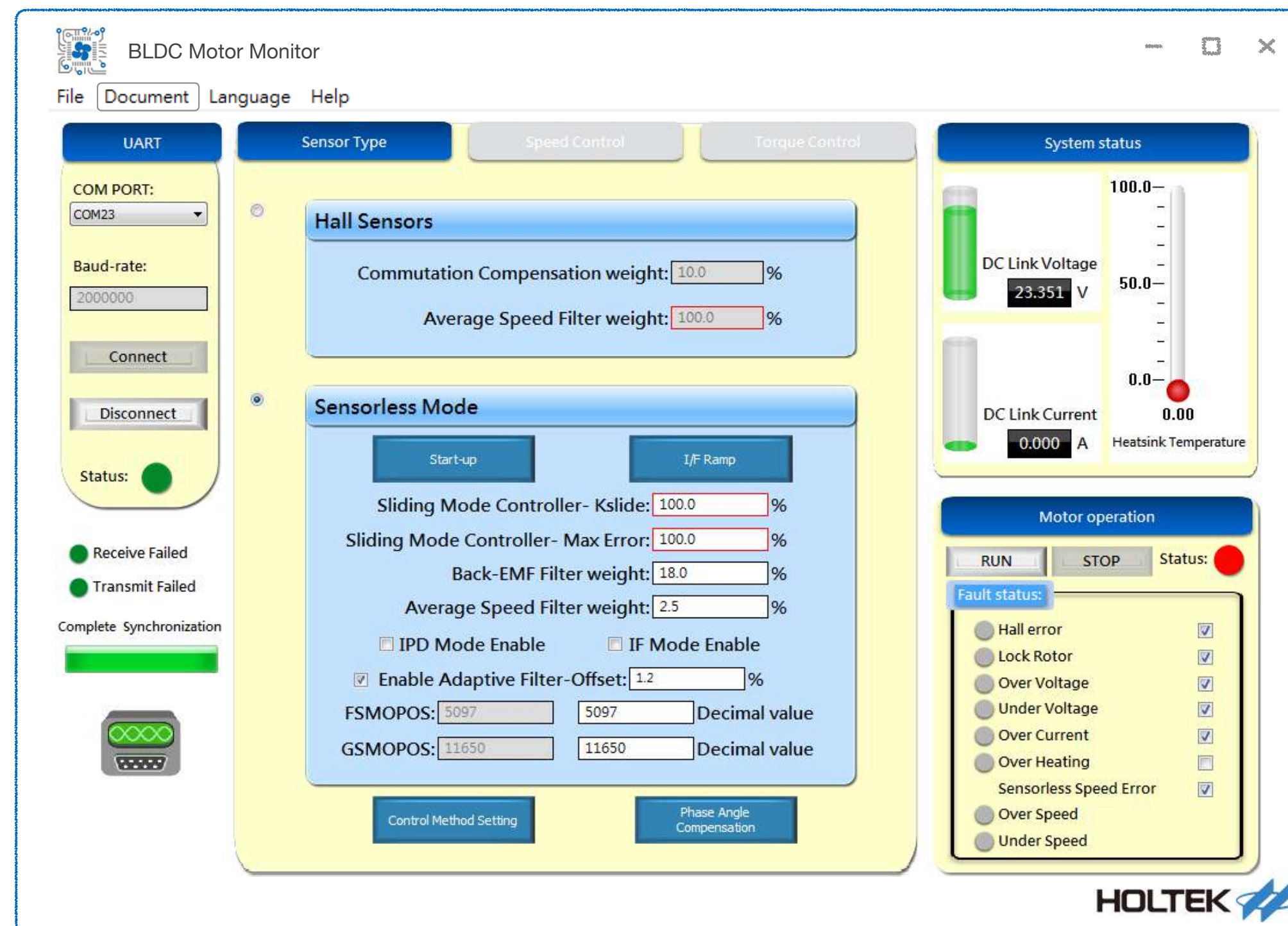
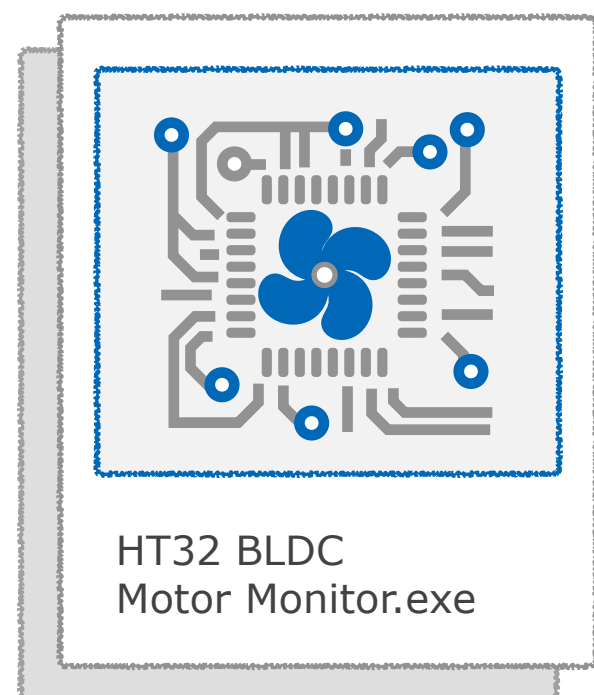
■ Parameter adjustment



HT32 BLDC Motor Monitor



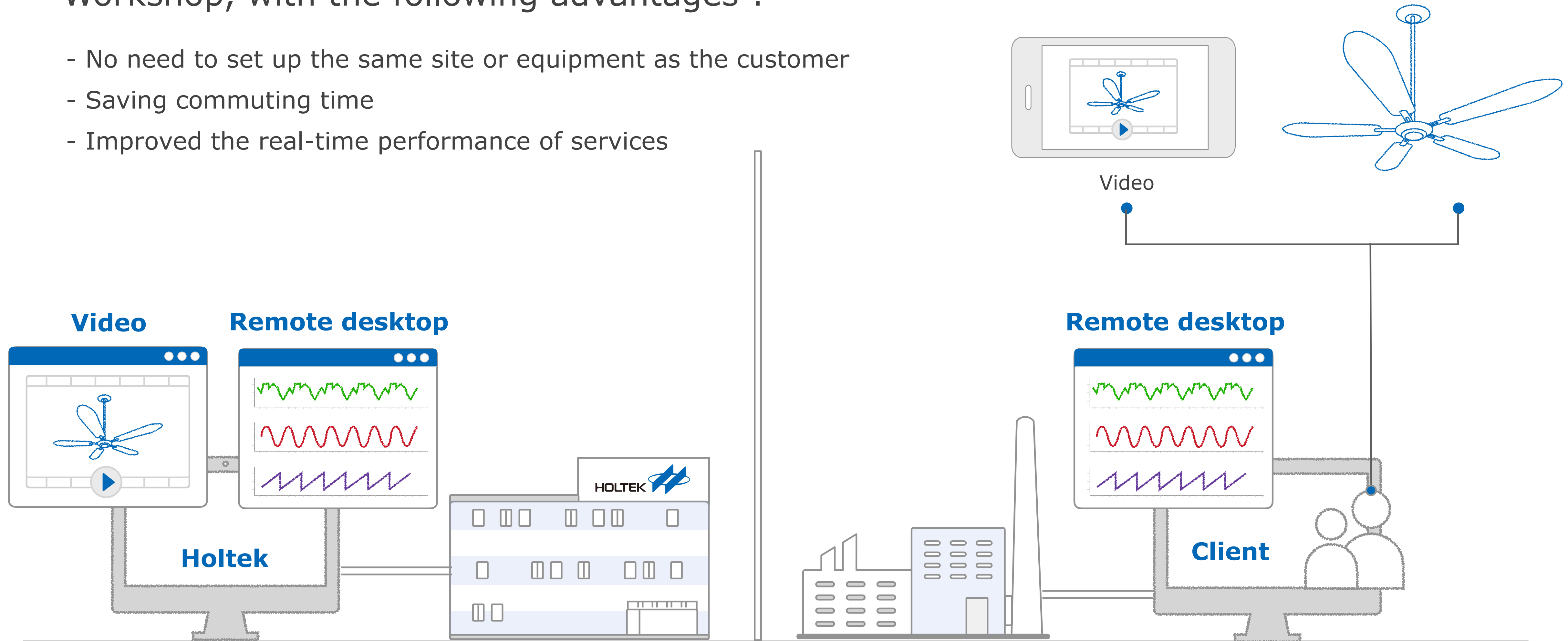
- Real-time control
- Real-time monitoring of motor operation features and system status :
 - Wired transmission (USB - UART), high resolution up to 2Mbps
 - Wireless transmission (Bluetooth - UART), speed reduced to 115Kbps



Remote Adjustment

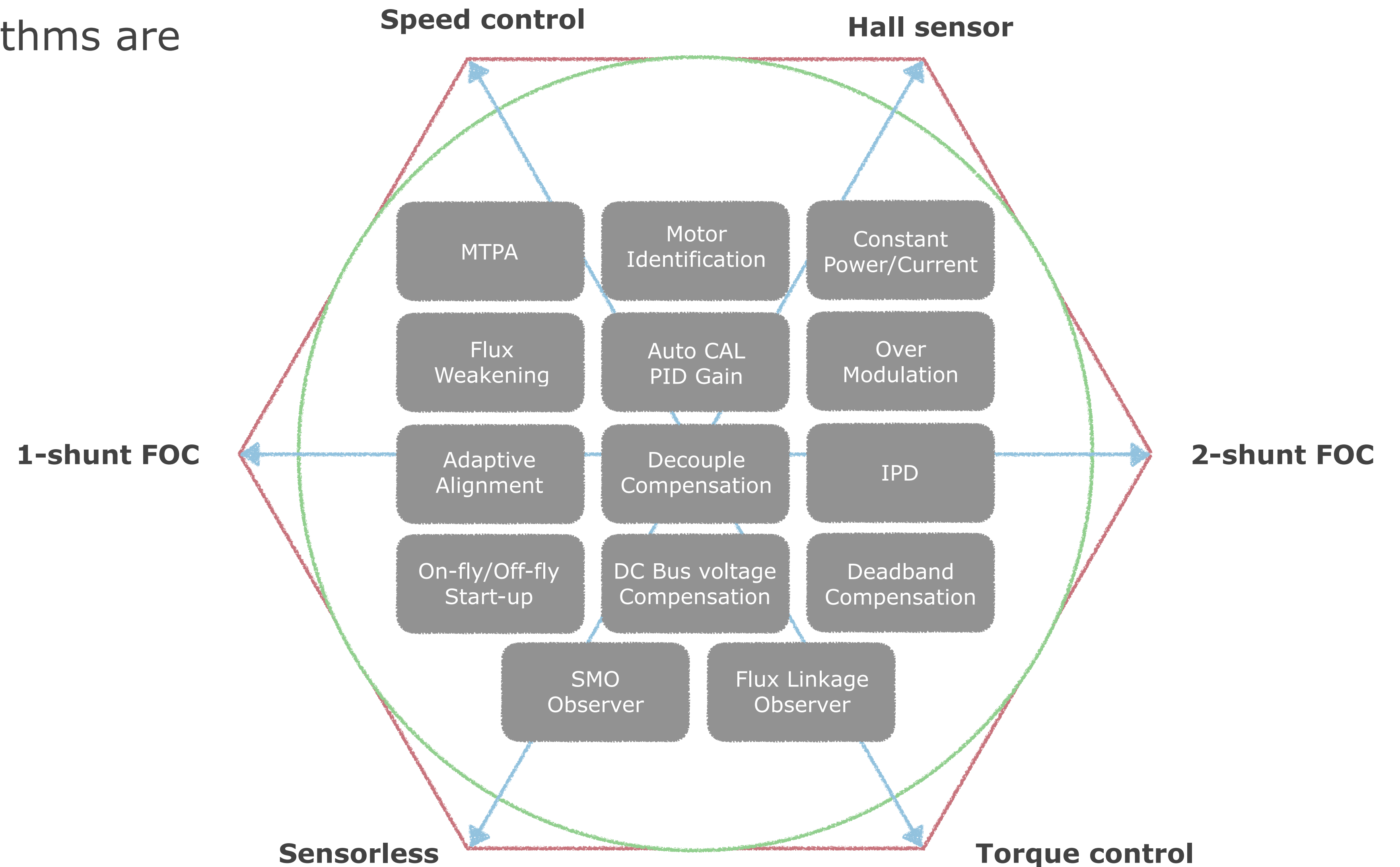


- Remote adjustment can be achieved basing on the real-time monitoring function of the Workshop, with the following advantages :
 - No need to set up the same site or equipment as the customer
 - Saving commuting time
 - Improved the real-time performance of services





- Other advanced algorithms are under development





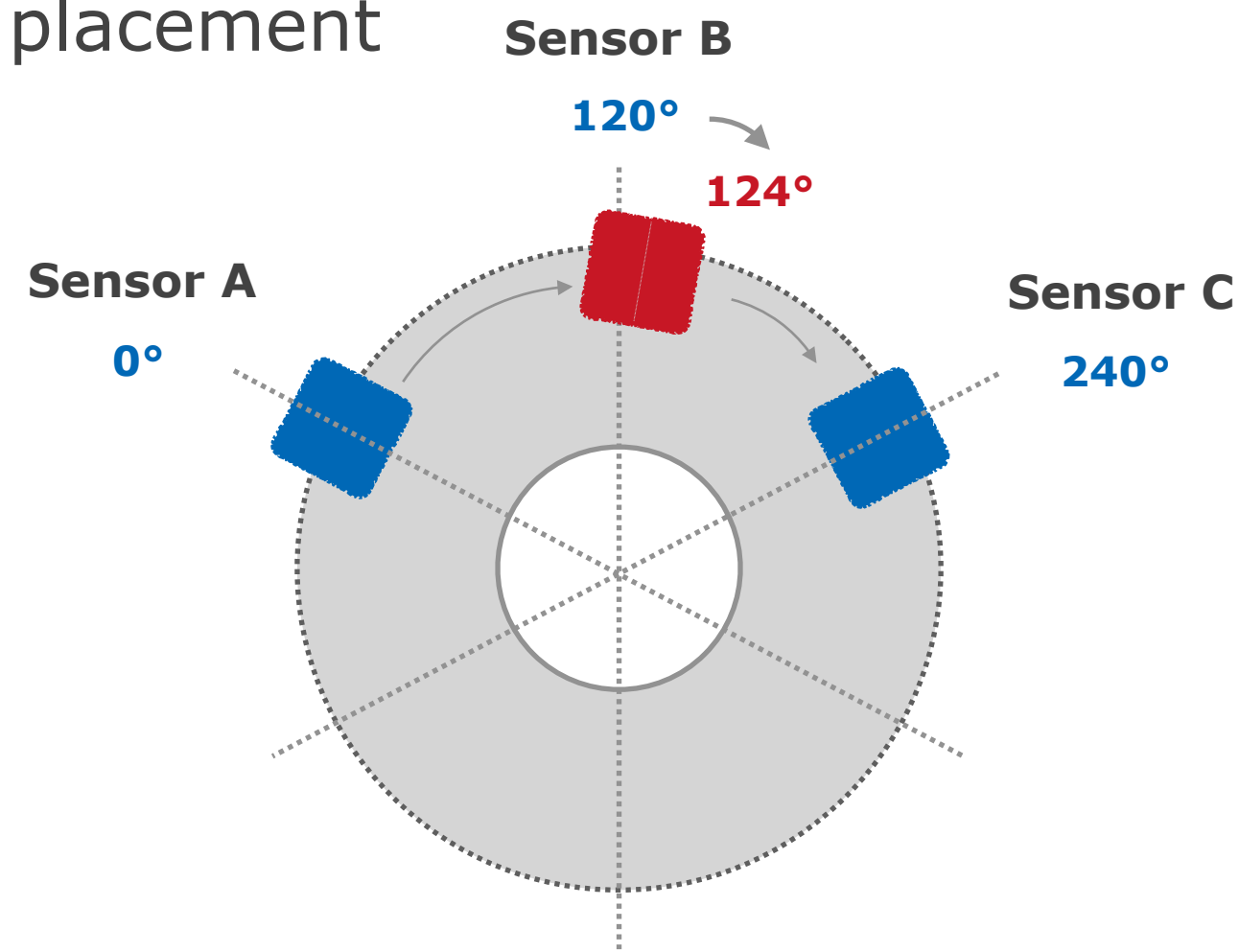
Holtek BLDC Motor Advantageous Techniques

Hall Sensor Compensation Strategy

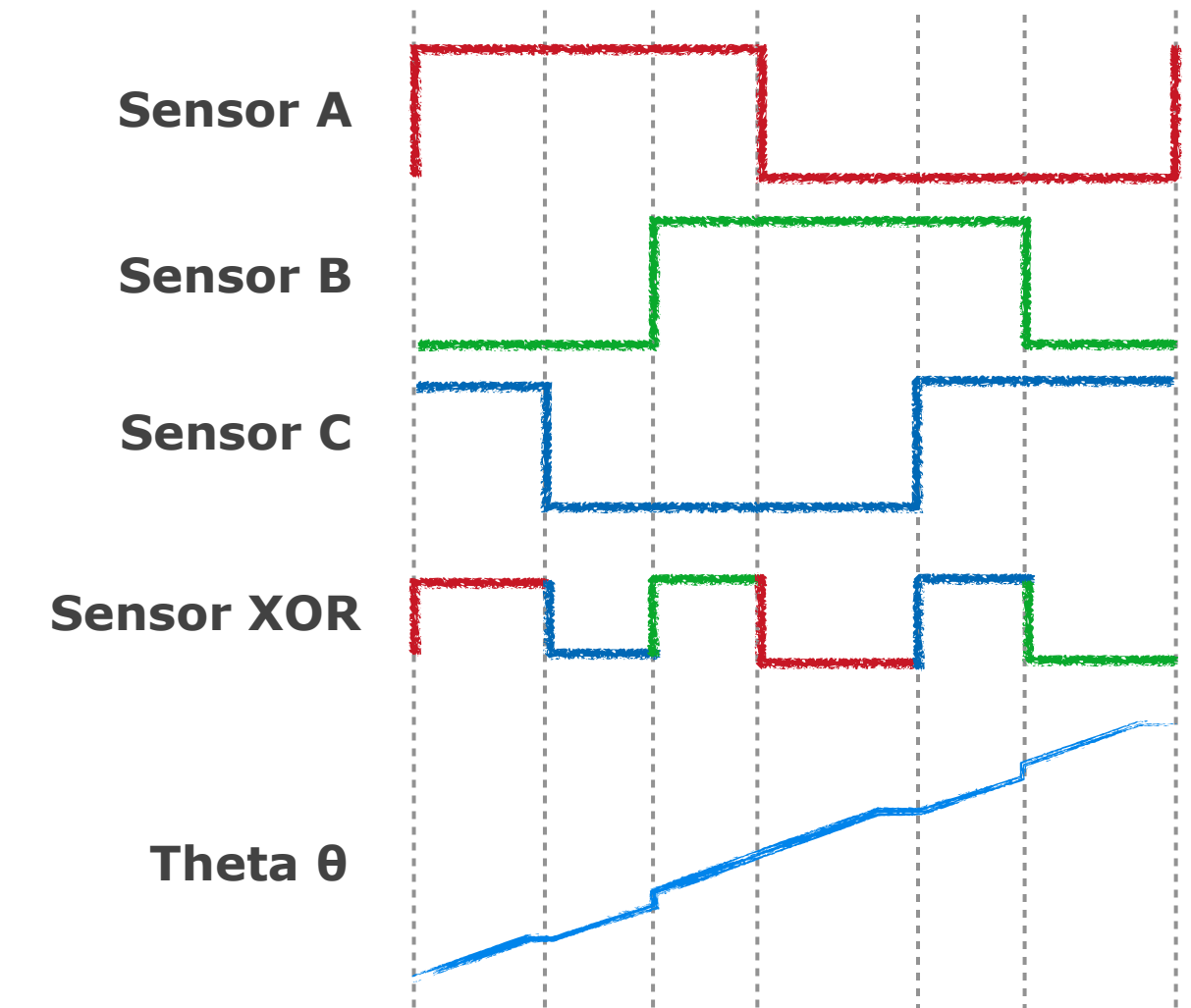
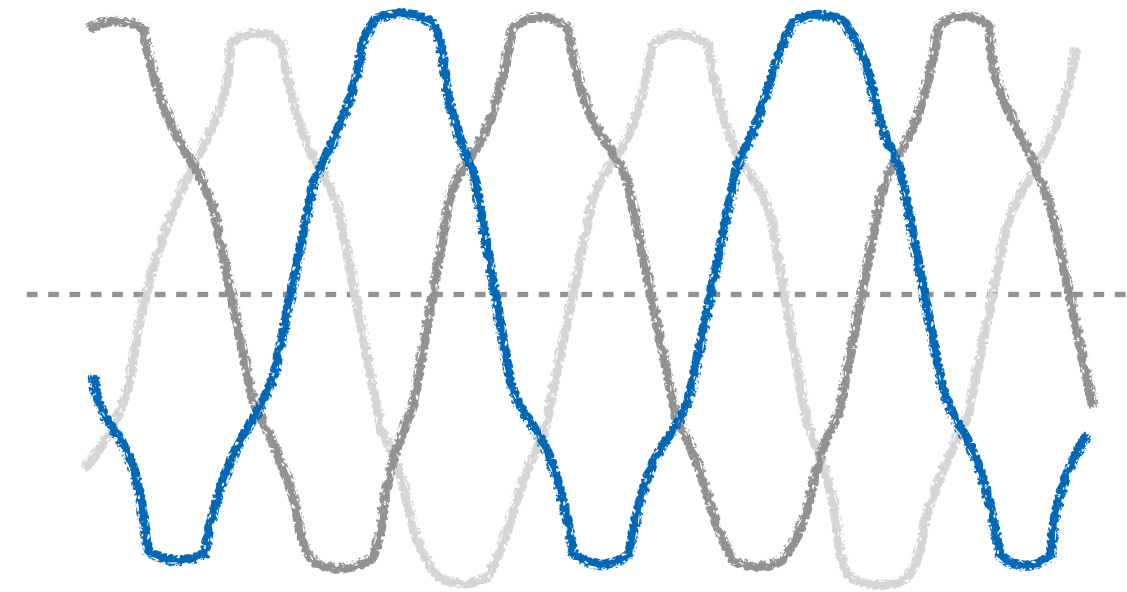


■ Uneven placement of hall sensors is prone to vibrations and noise

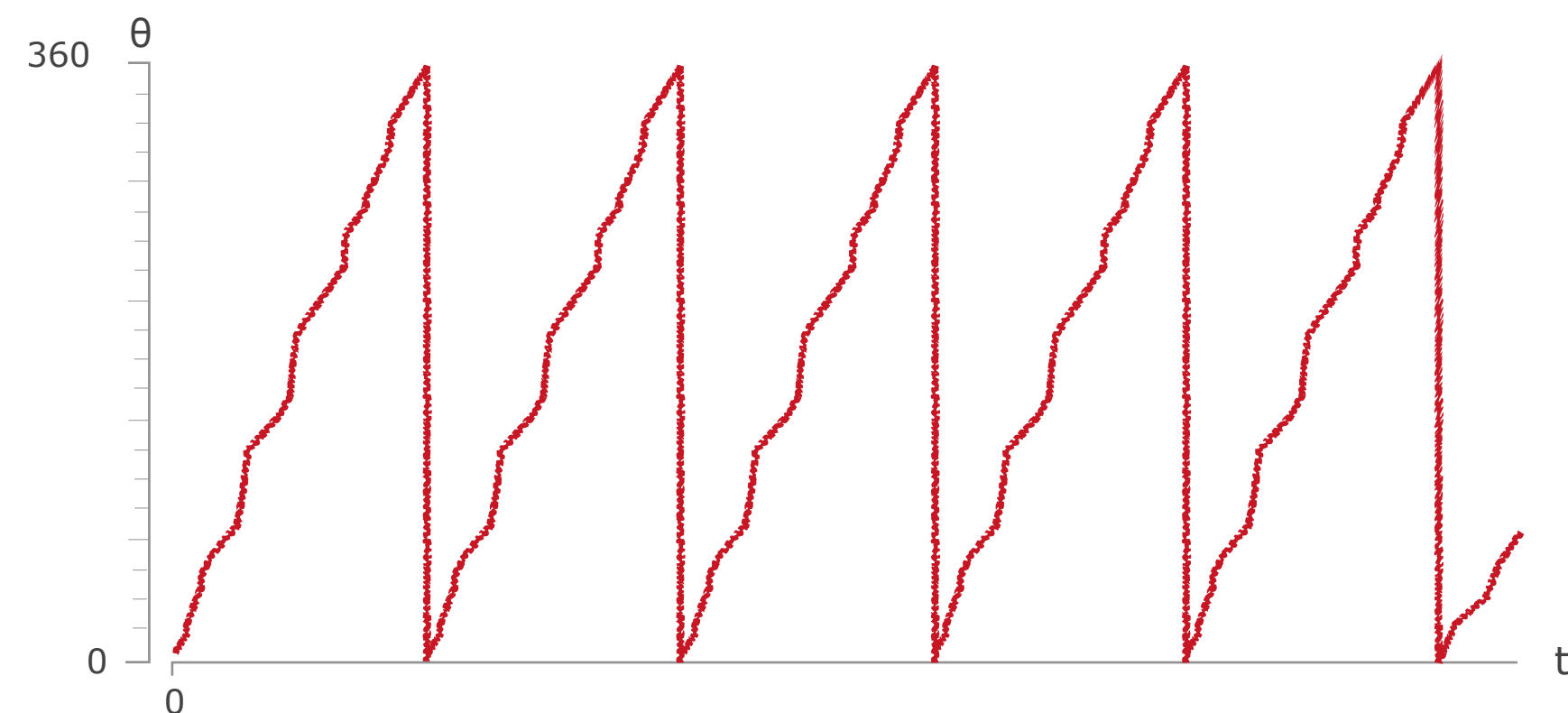
- Sensor placement



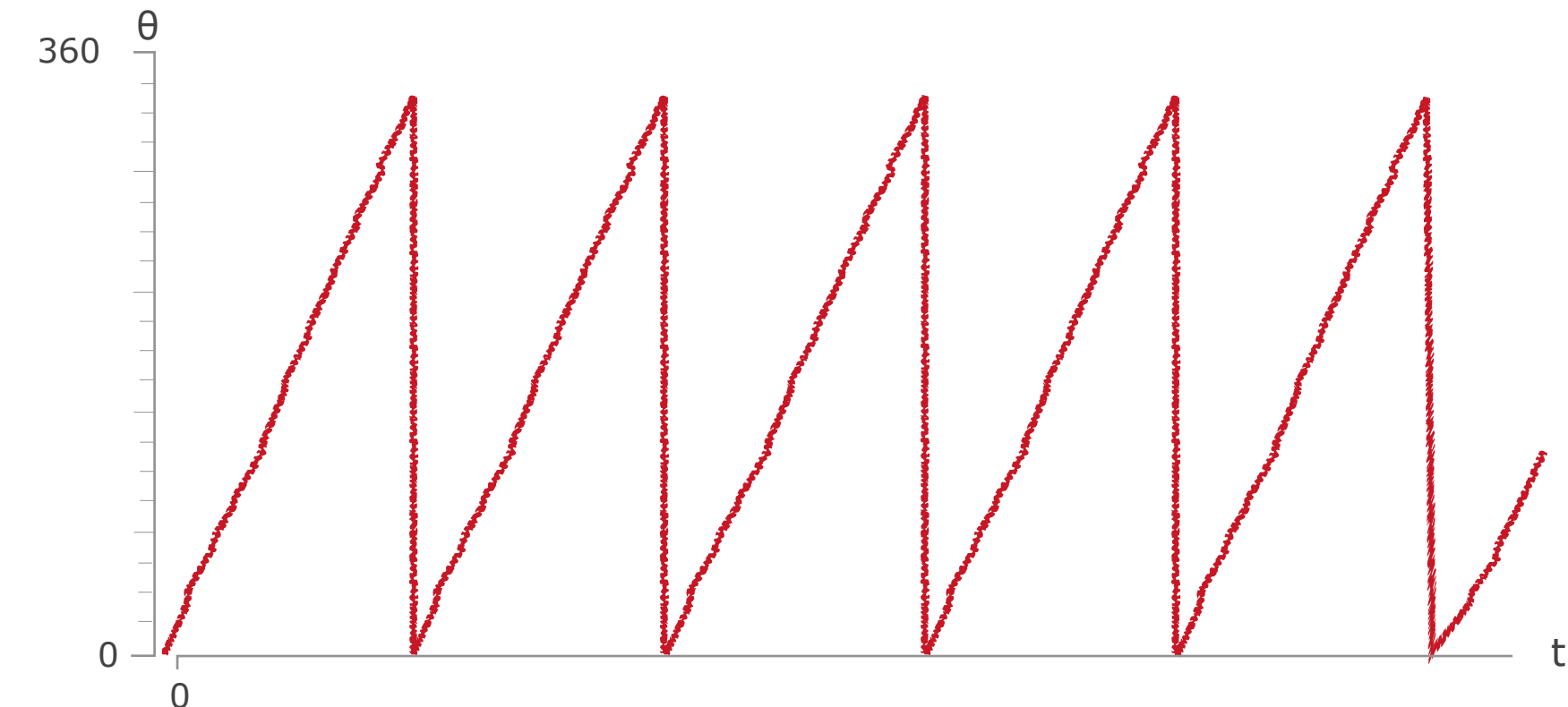
- Magnet charging



- Without hall sensor compensation



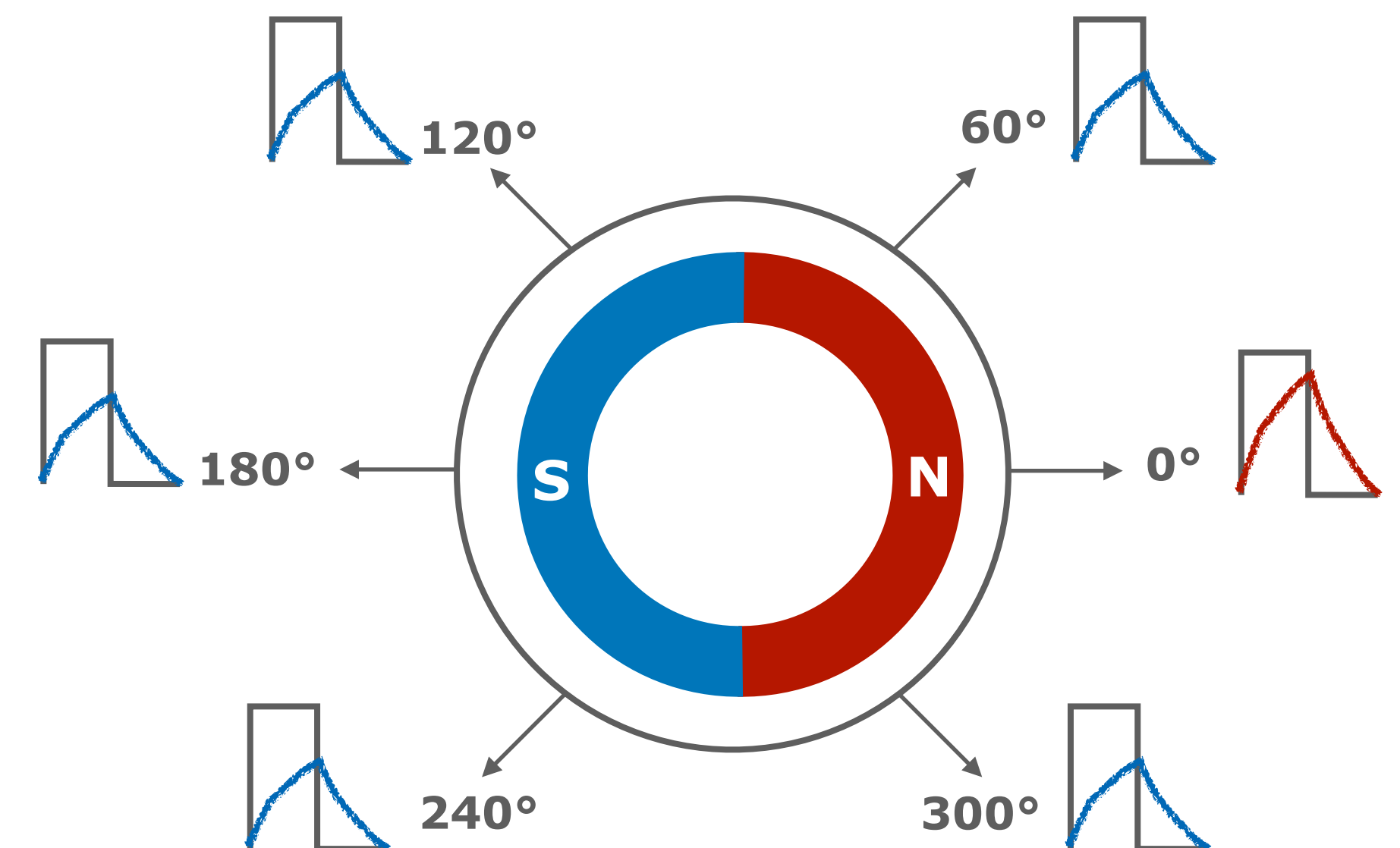
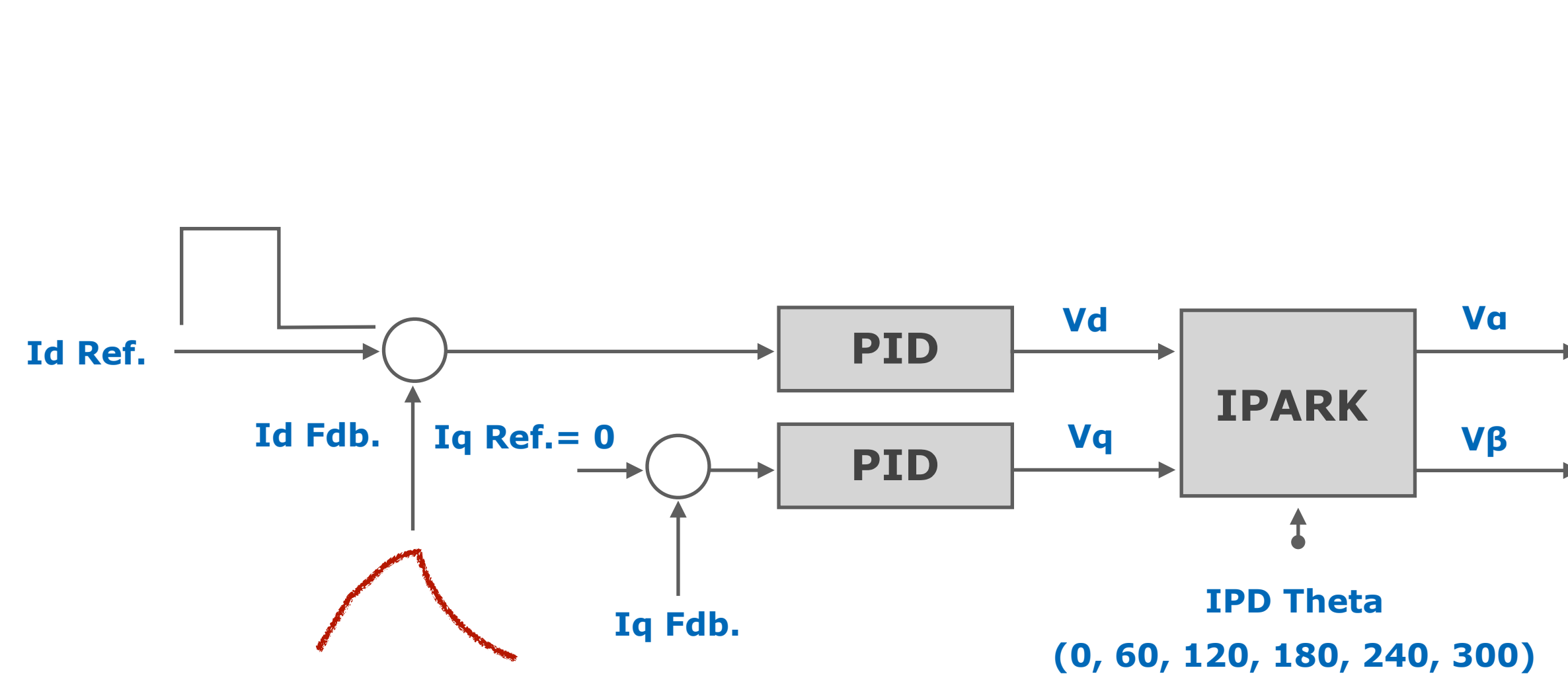
- With hall sensor compensation



■ Initial Position Detection (IPD) :

- Holtek patented technique

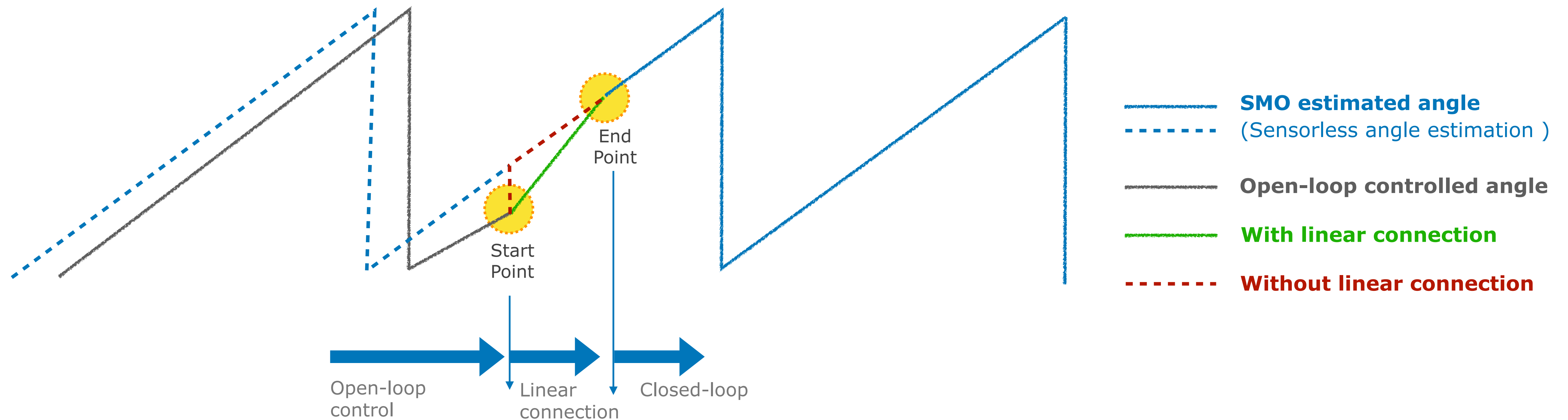
- Based on the FOC architecture, no additional programs are required
- No additional OPA-related circuits and current sampling resistors are required





■ Linear connection :

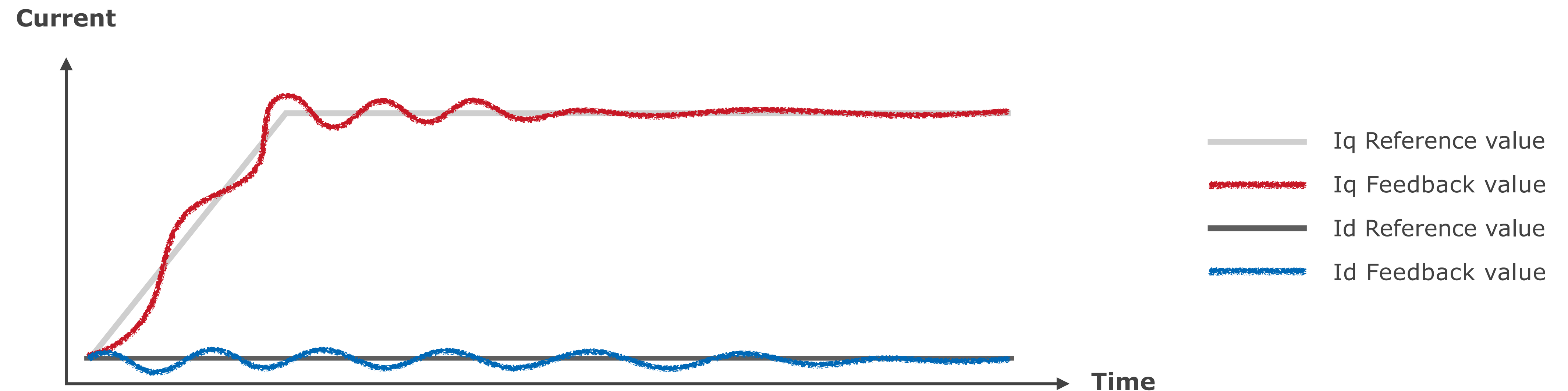
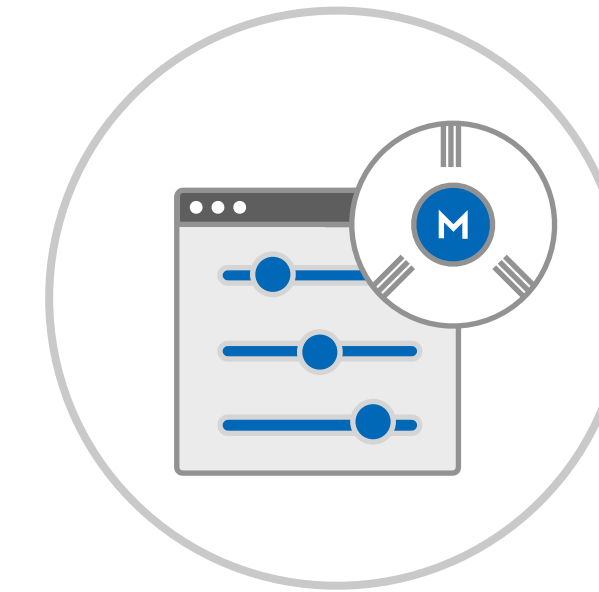
- FOC Sensorless operation is divided into three stages :
 - (1) Open-loop control; (2) connection; (3) closed-loop
 - When switching from open-loop to closed-loop, adding a linear connection can reduce the vibration and noise generated by the torque pulse caused by sudden angle changes





■ Current loop PID parameter optimization :

- The theoretical value of the PID parameter of the current loop is calculated from the motor and control parameters
- Greatly reduces the number of try-and-error times and improves efficiency
- The current loop operates stably reducing the torque ripples

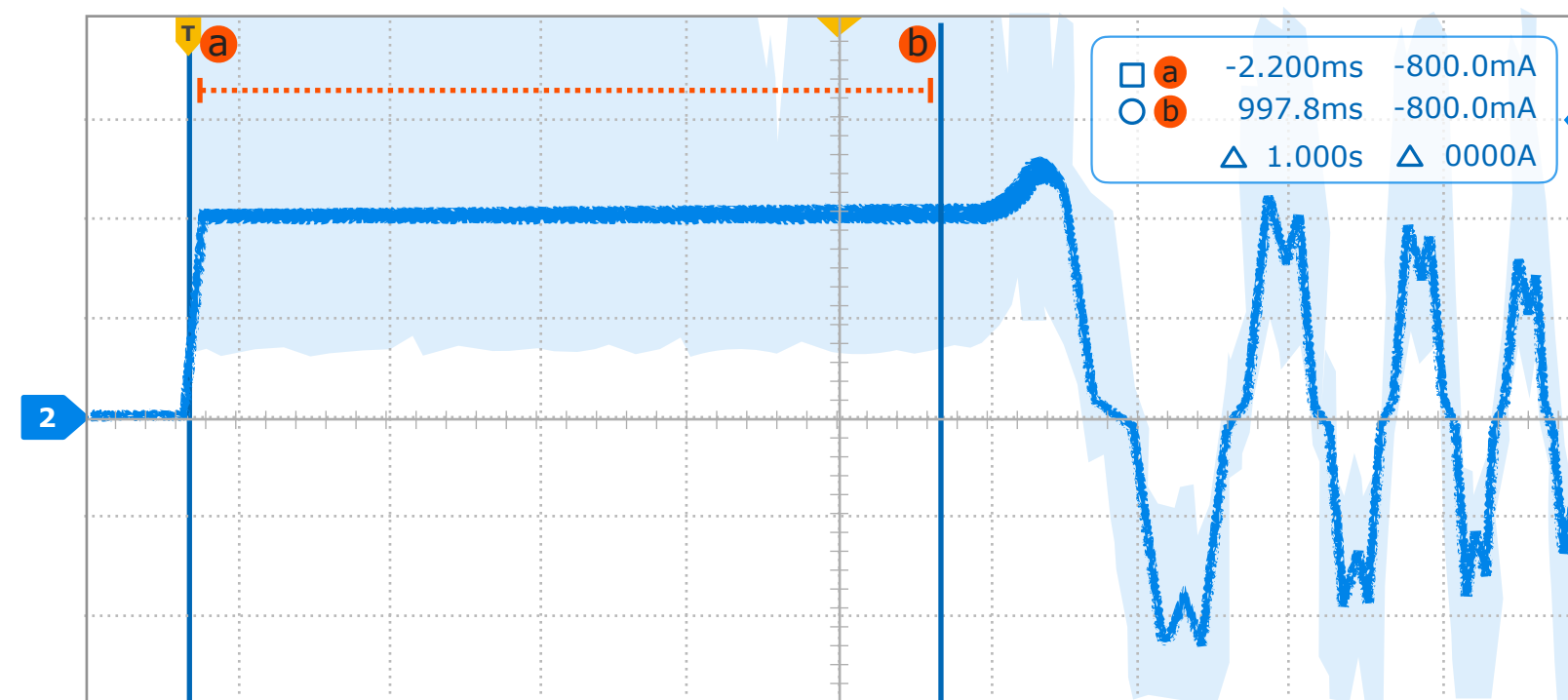




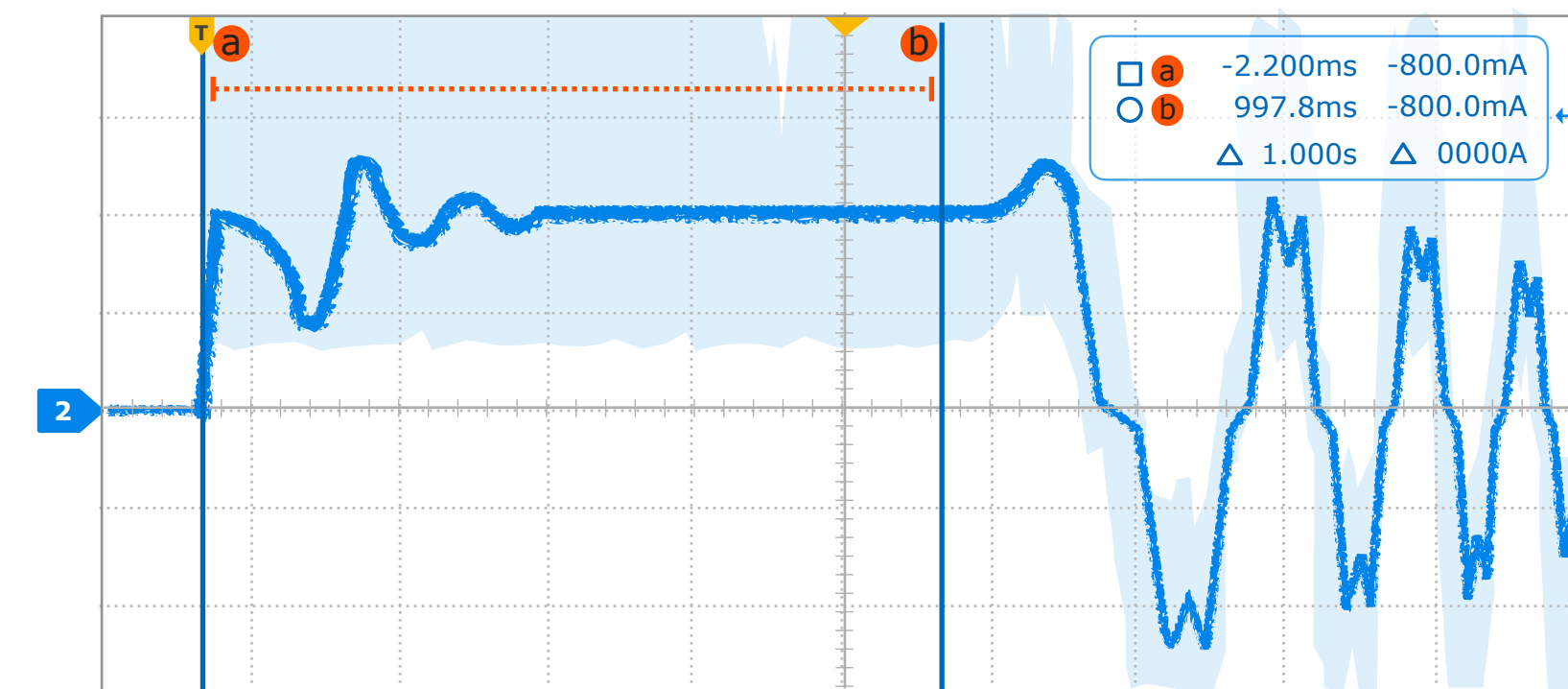
- Reduce the mechanism and blade vibrations
- Reduce start-up failure rate

- Traditional fixed-time positioning

- Close to start-up angle (positioning time : 1 second)

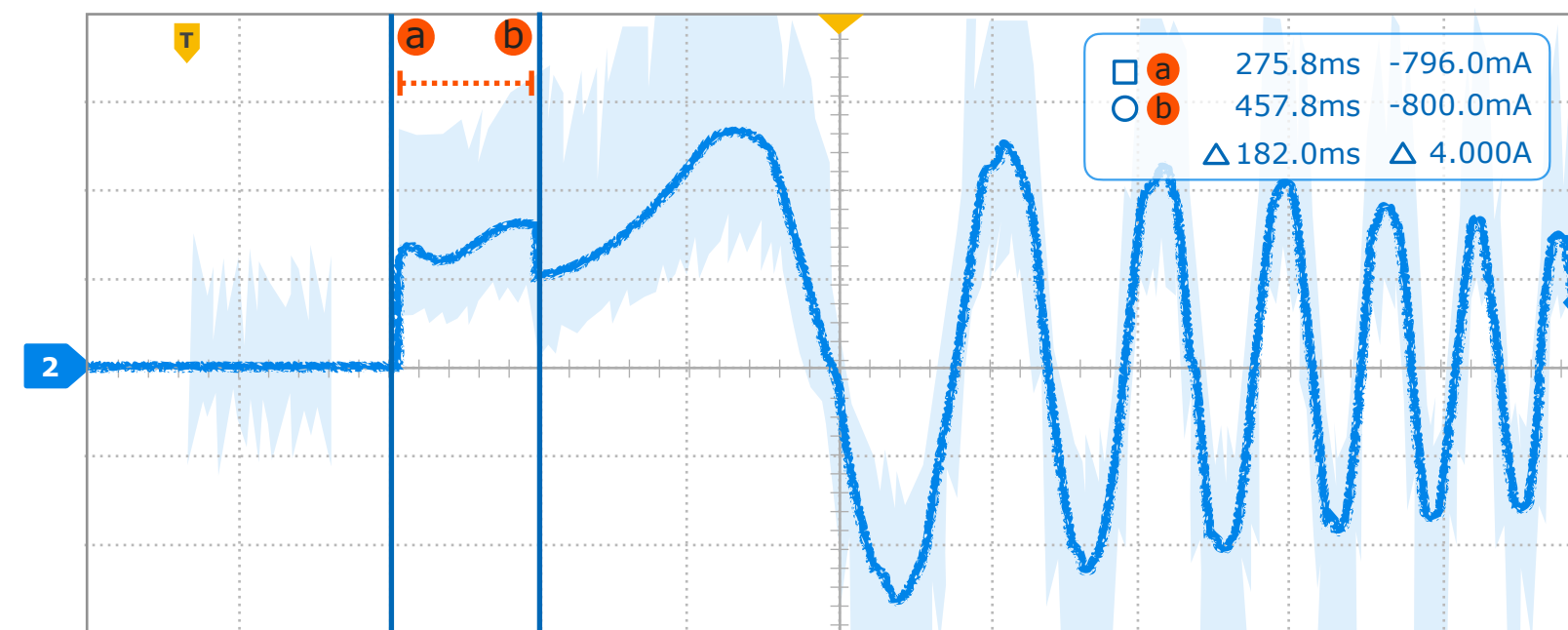


- Large offset from start-up angle (positioning time : 1 second)

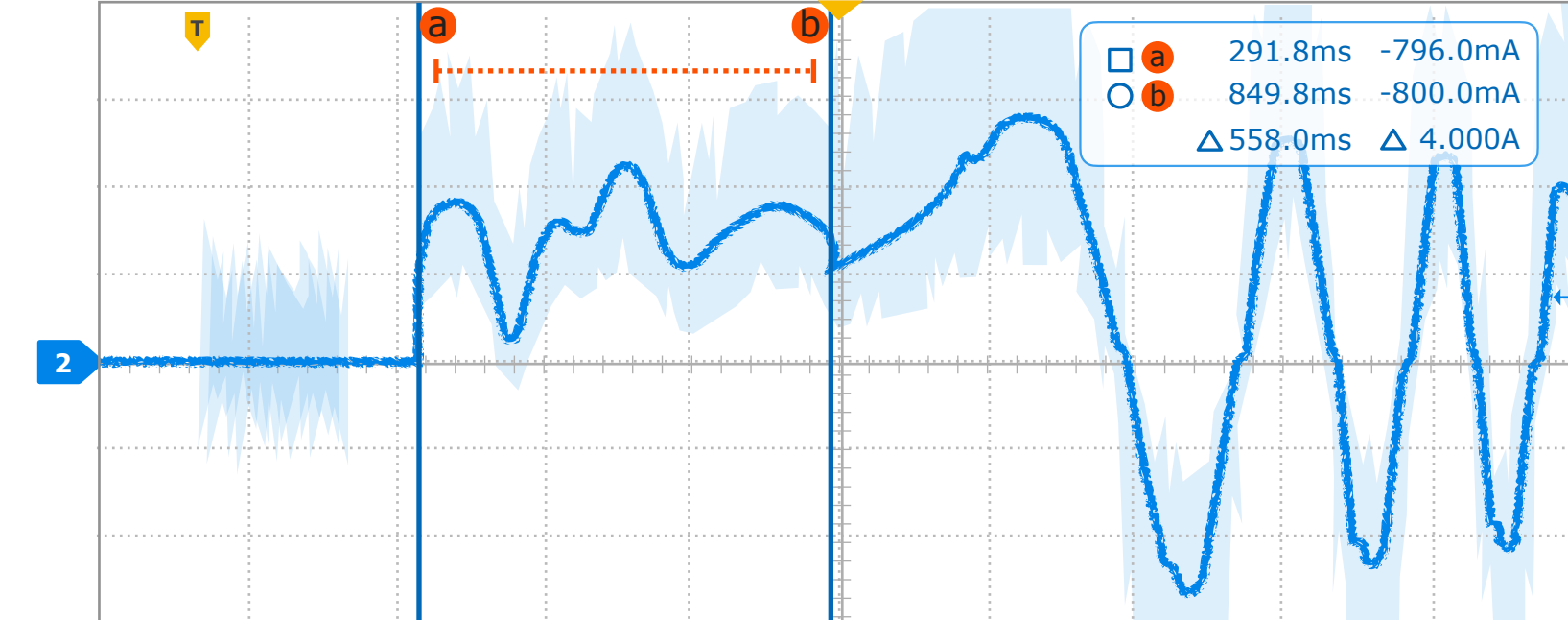


- Adaptive positioning

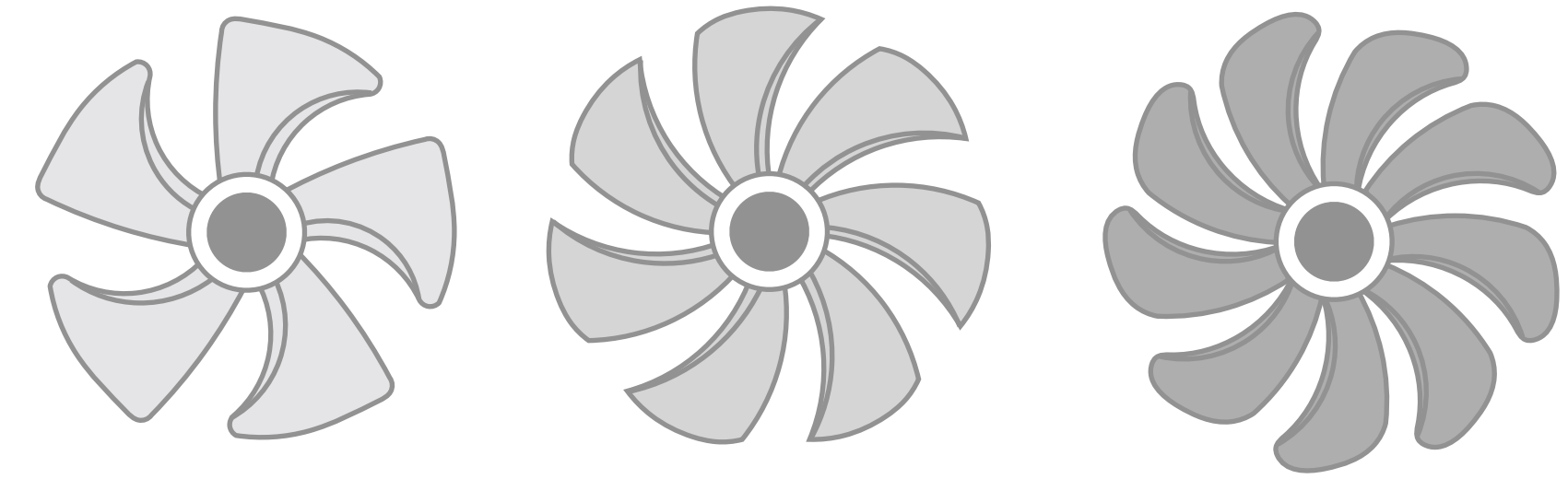
- Close to start-up angle (positioning time : 0.18 second)



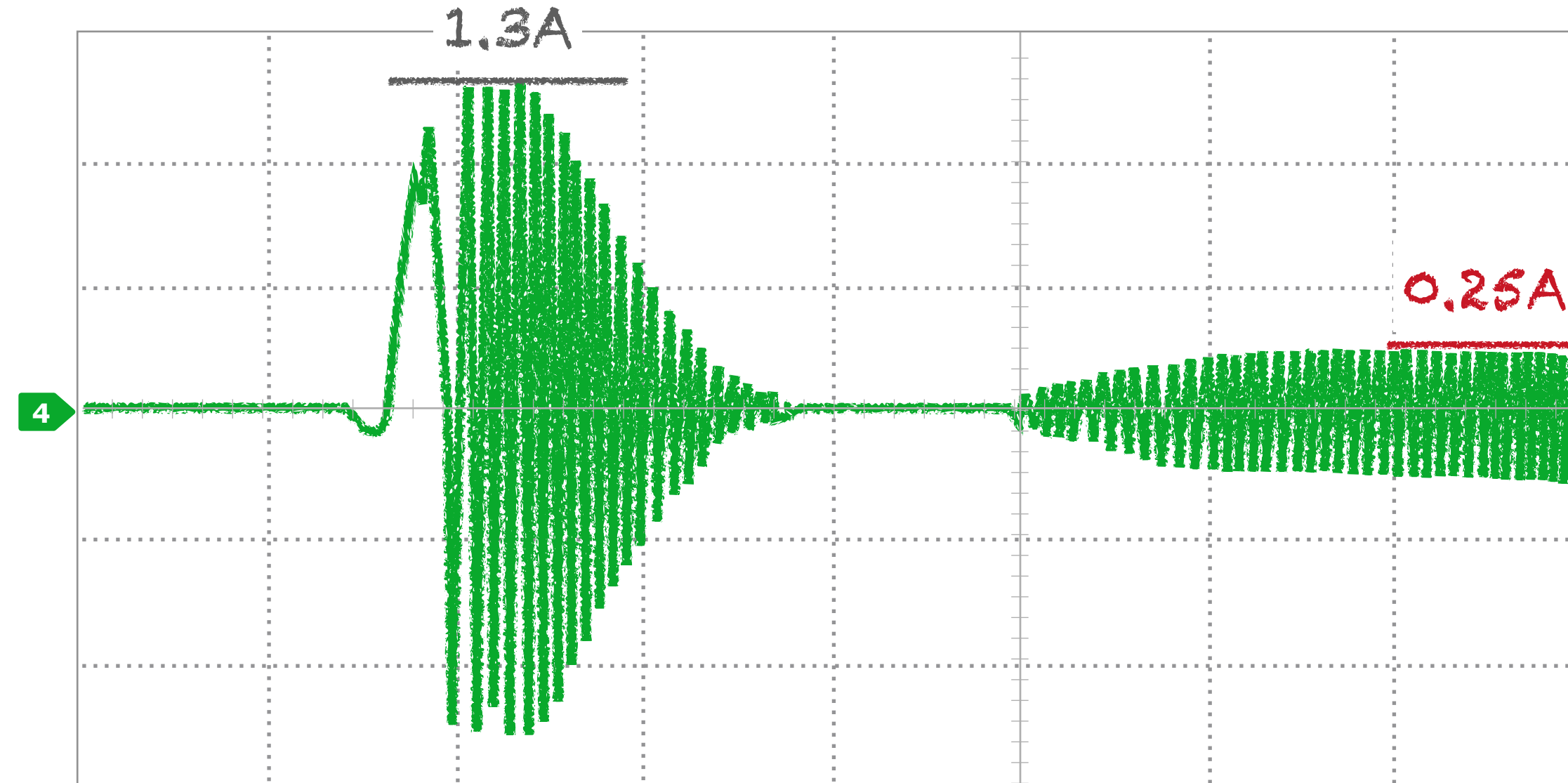
- Large offset from start-up angle (positioning time : 0.56 second)



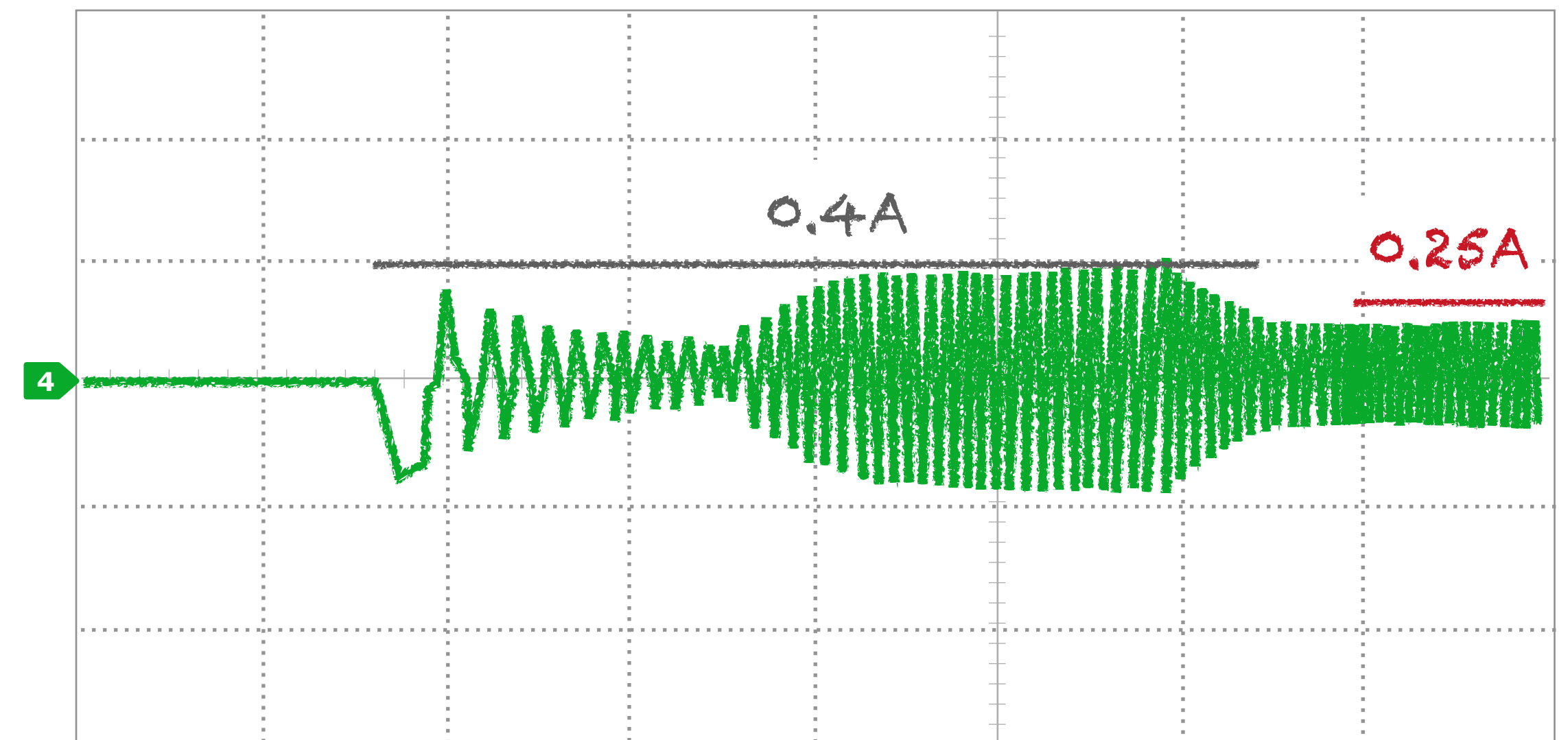
- Optimized load adaptivity
- 100% success rate of start-up
- The starting force can be flexibly adjusted to implement smooth start-up



Traditional : high current start-up to avoid failure



Adaptive start-up

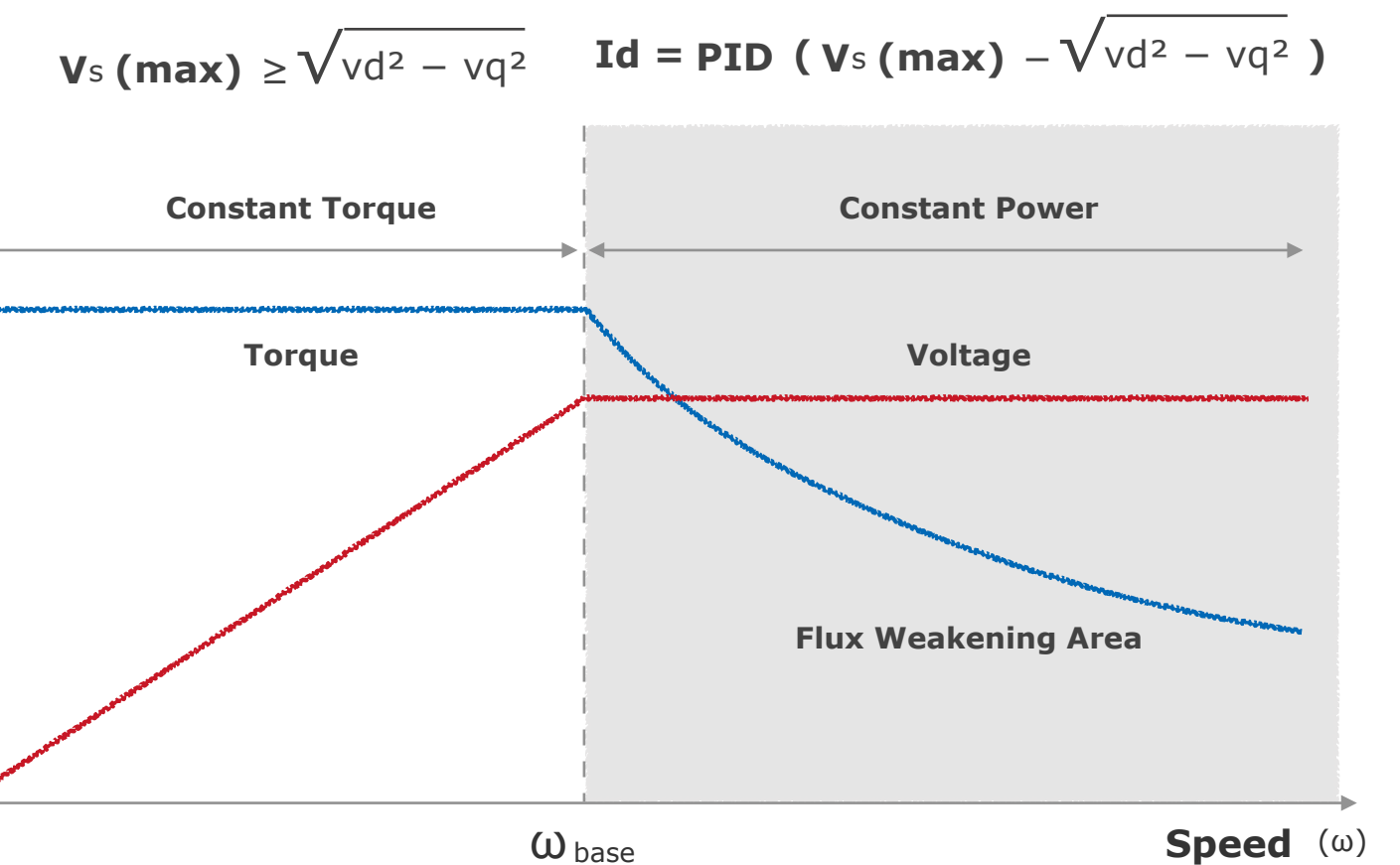




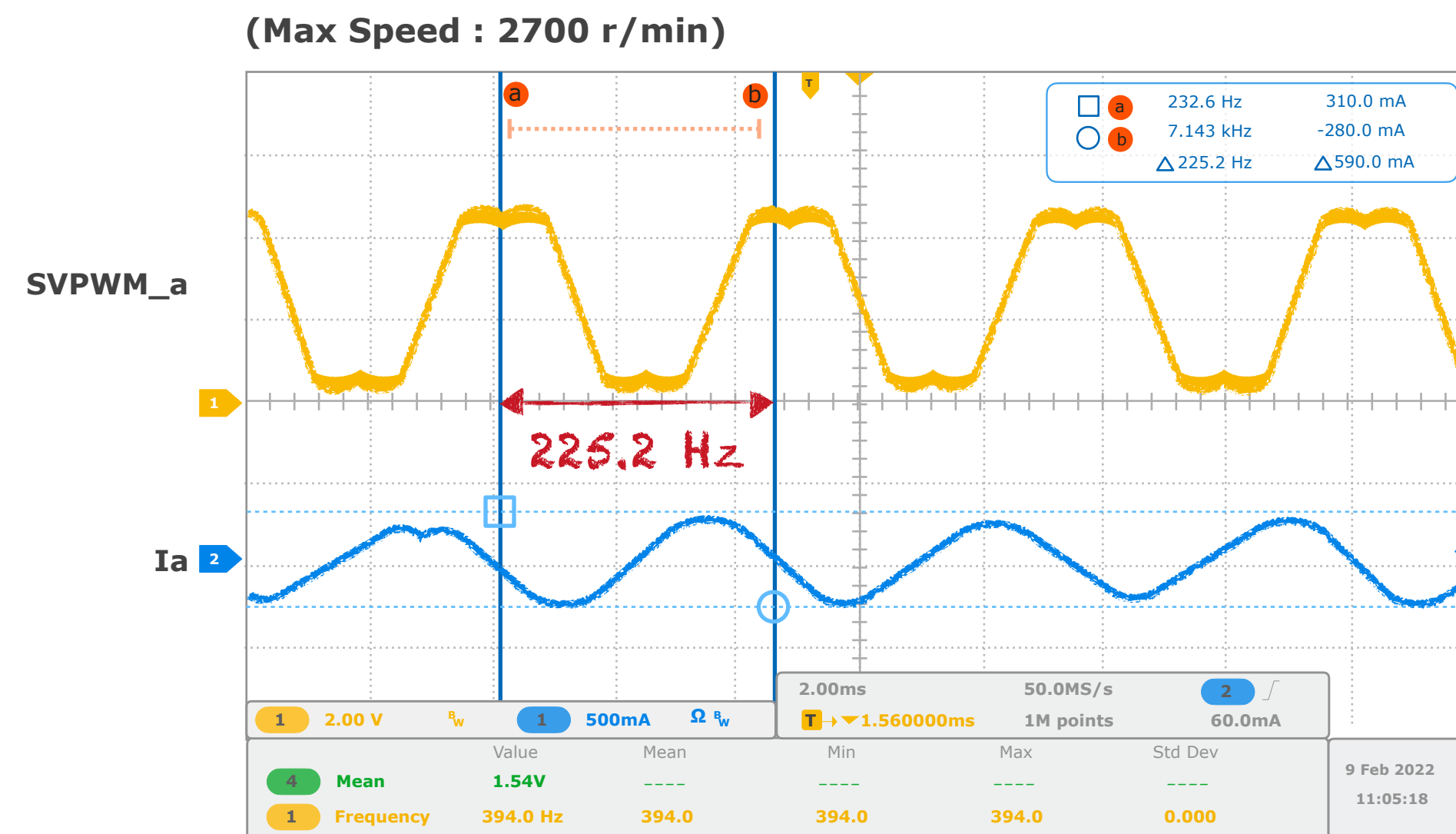
Flux Weakening Control



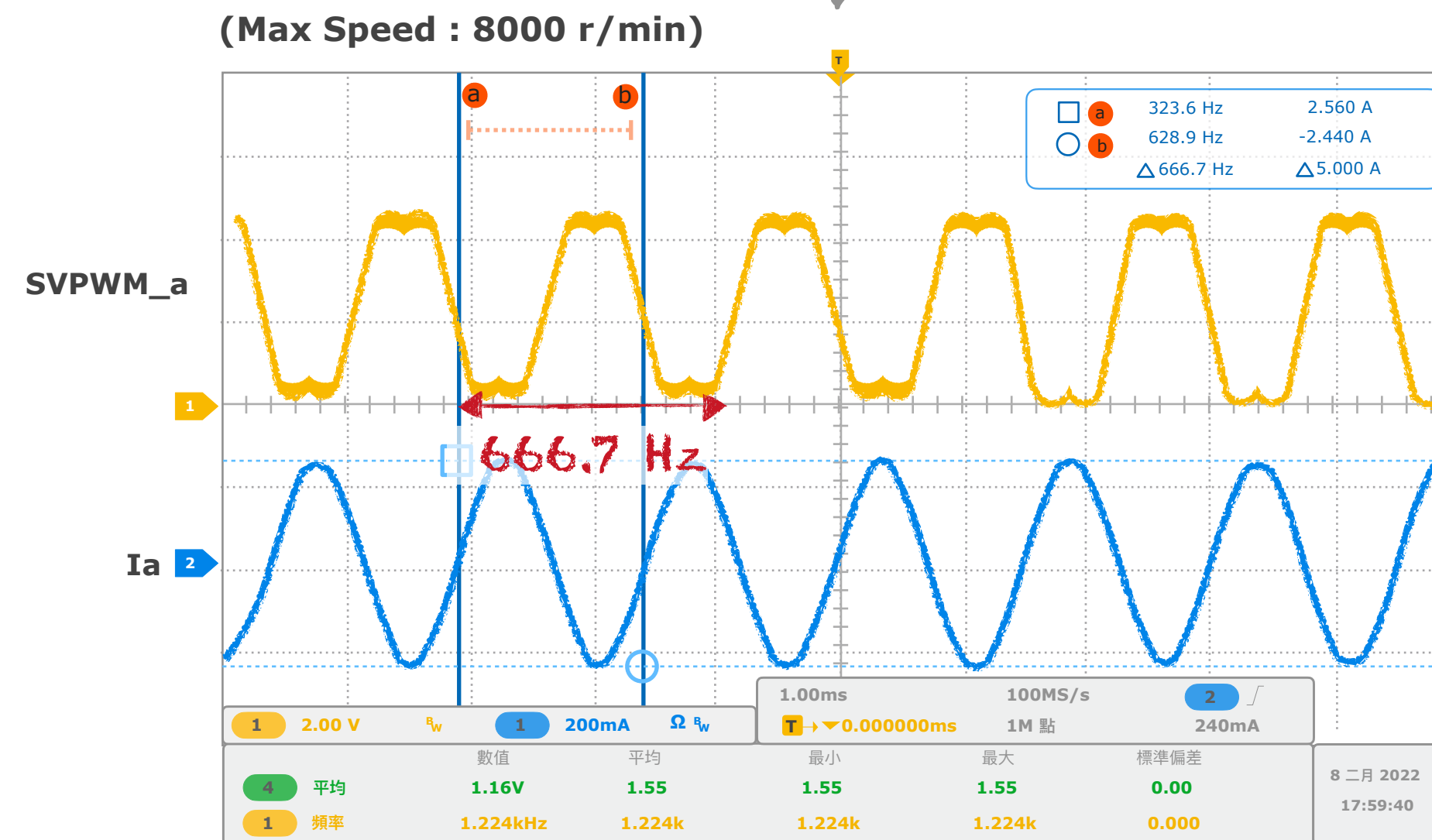
- Use flux weakening to increase the rated motor speed, achieving a wider speed adjustment range
- Pay attention to high temperature to avoid demagnetization during short-time operations
- Products : electric vehicles, compressors, washers, etc.



Increase the maximum speed of motor by **196.3 %**



Without flux weakening control



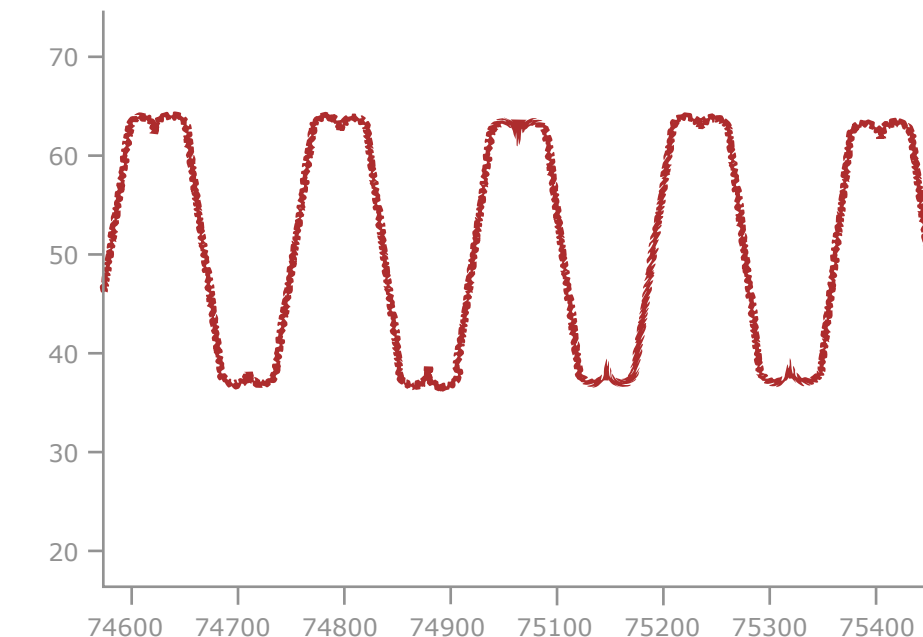
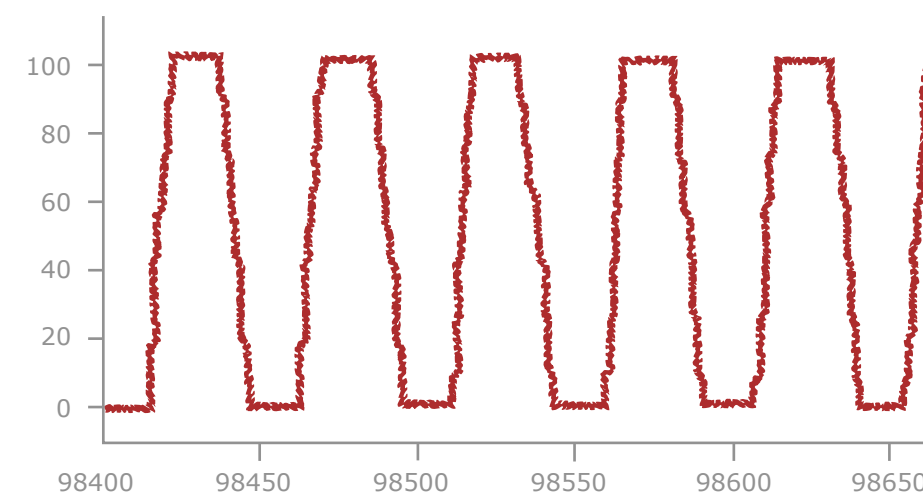
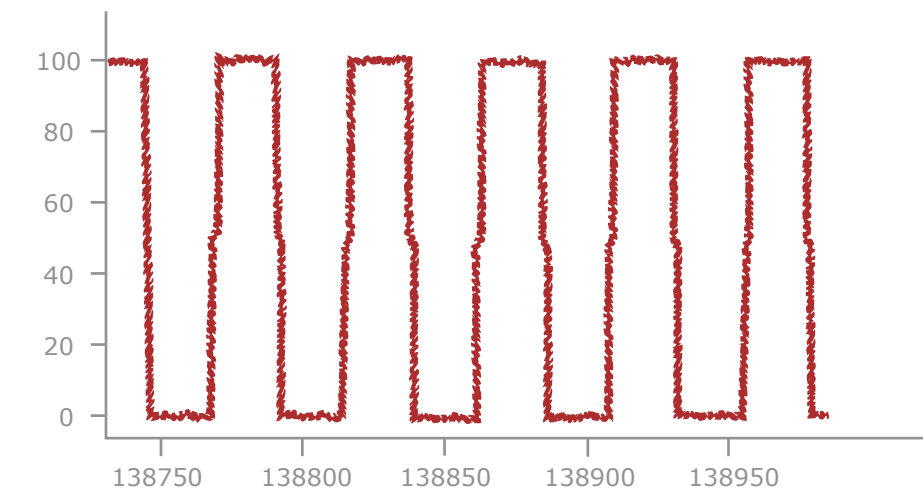
With flux weakening control



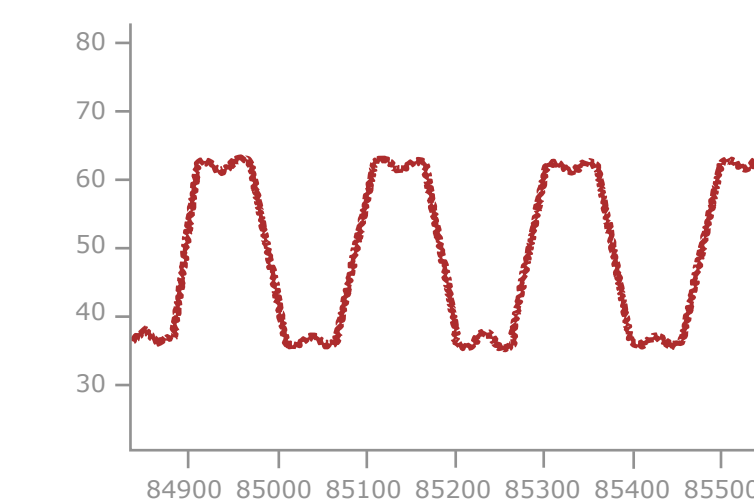
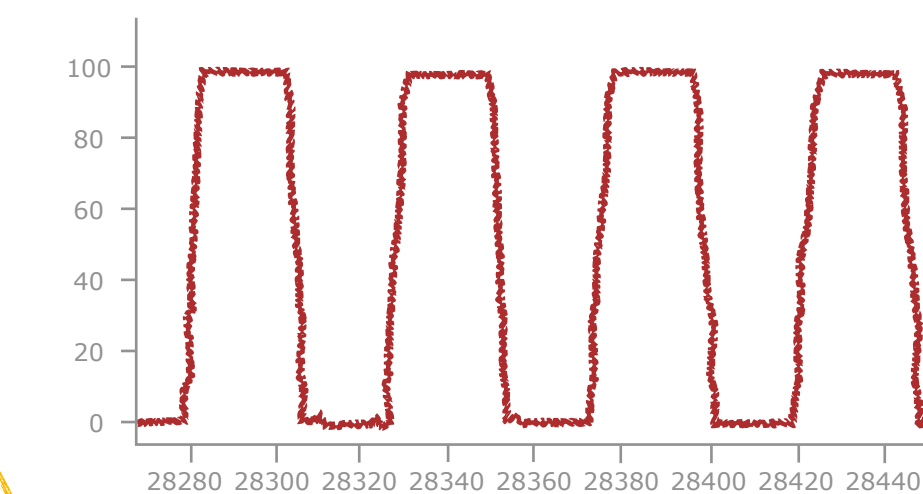
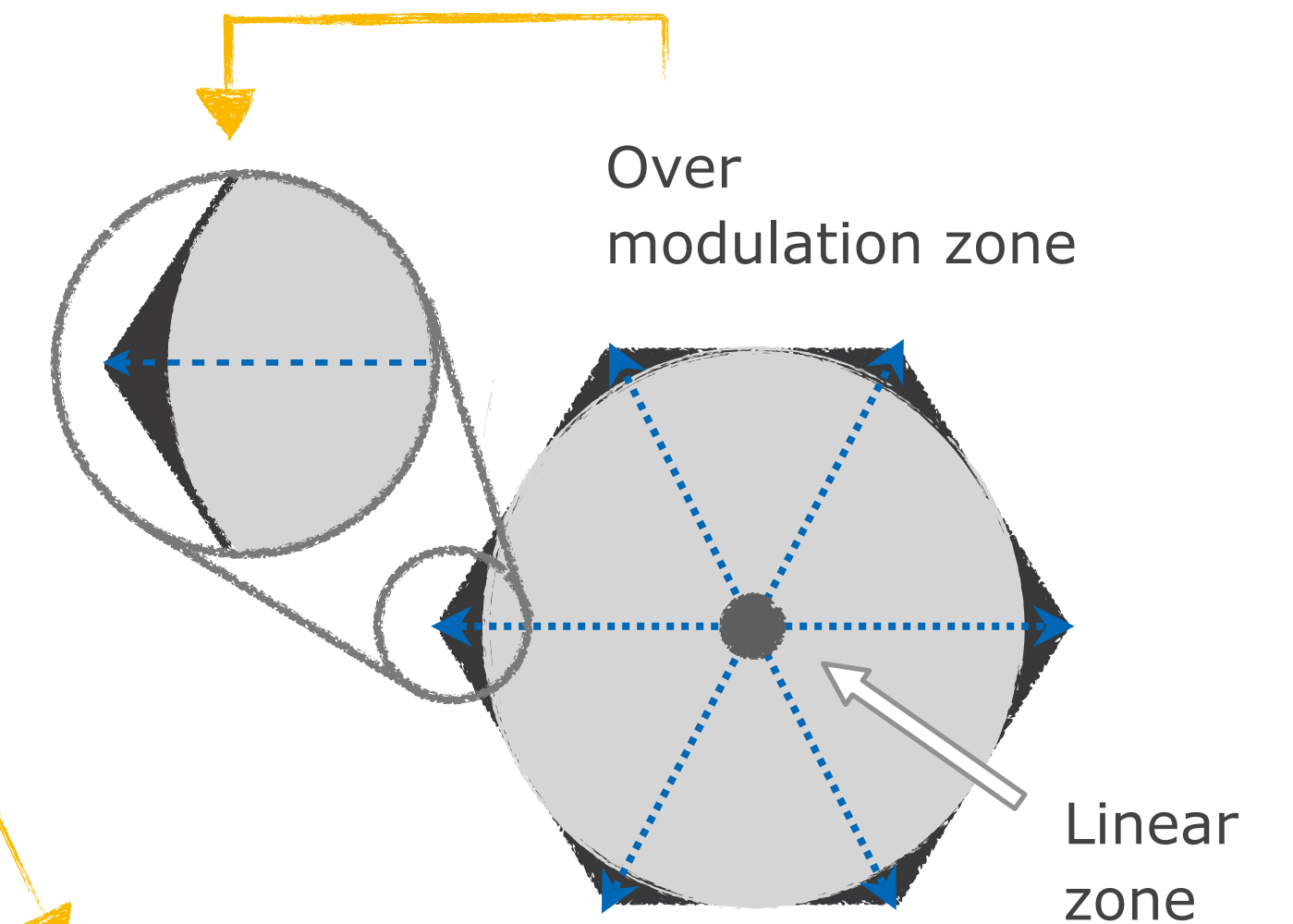
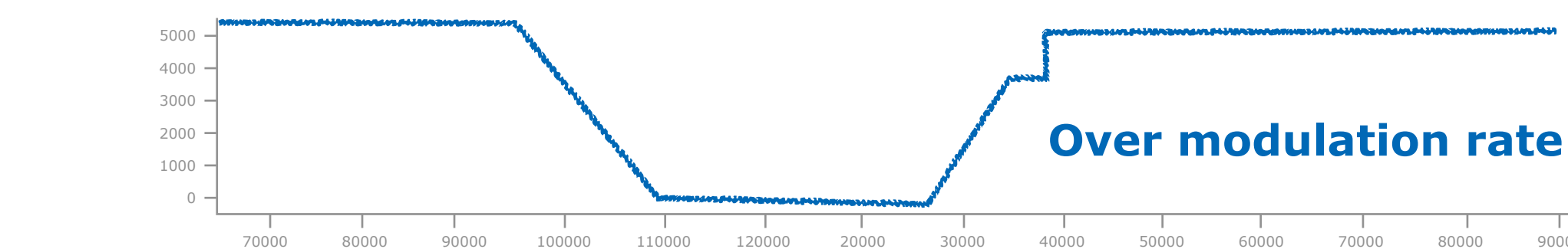
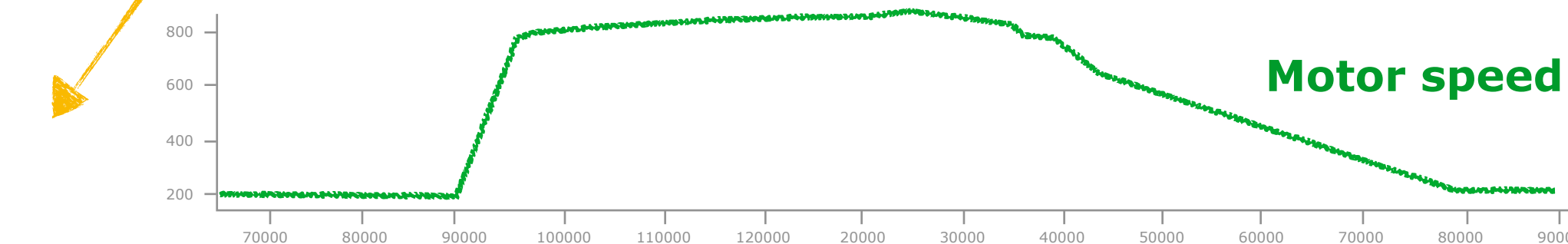
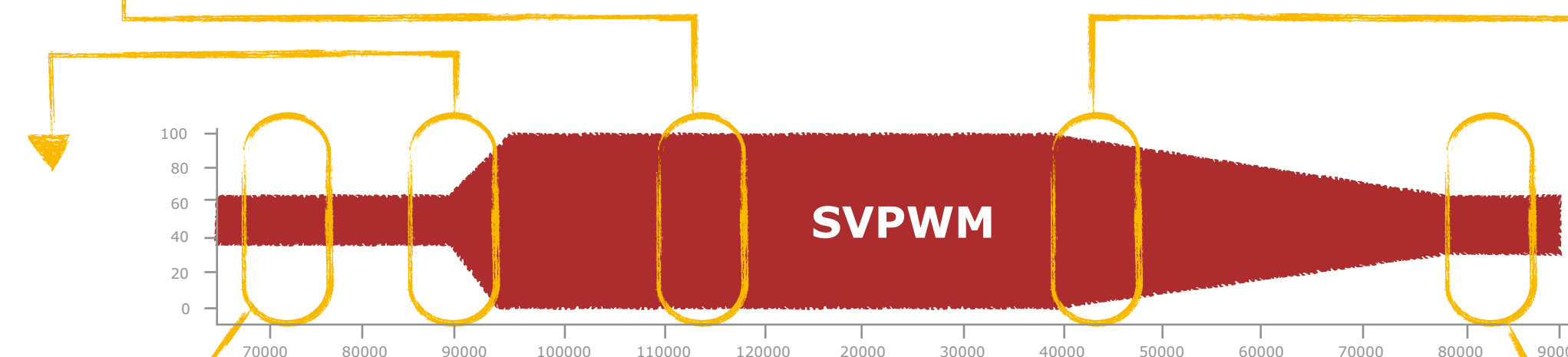
Over Modulation Technique



- Increase DC voltage utilization to increase motor speed
- Smooth over modulation zone entry / exit mechanisms



Linear zone → Over modulation zone → Linear zone

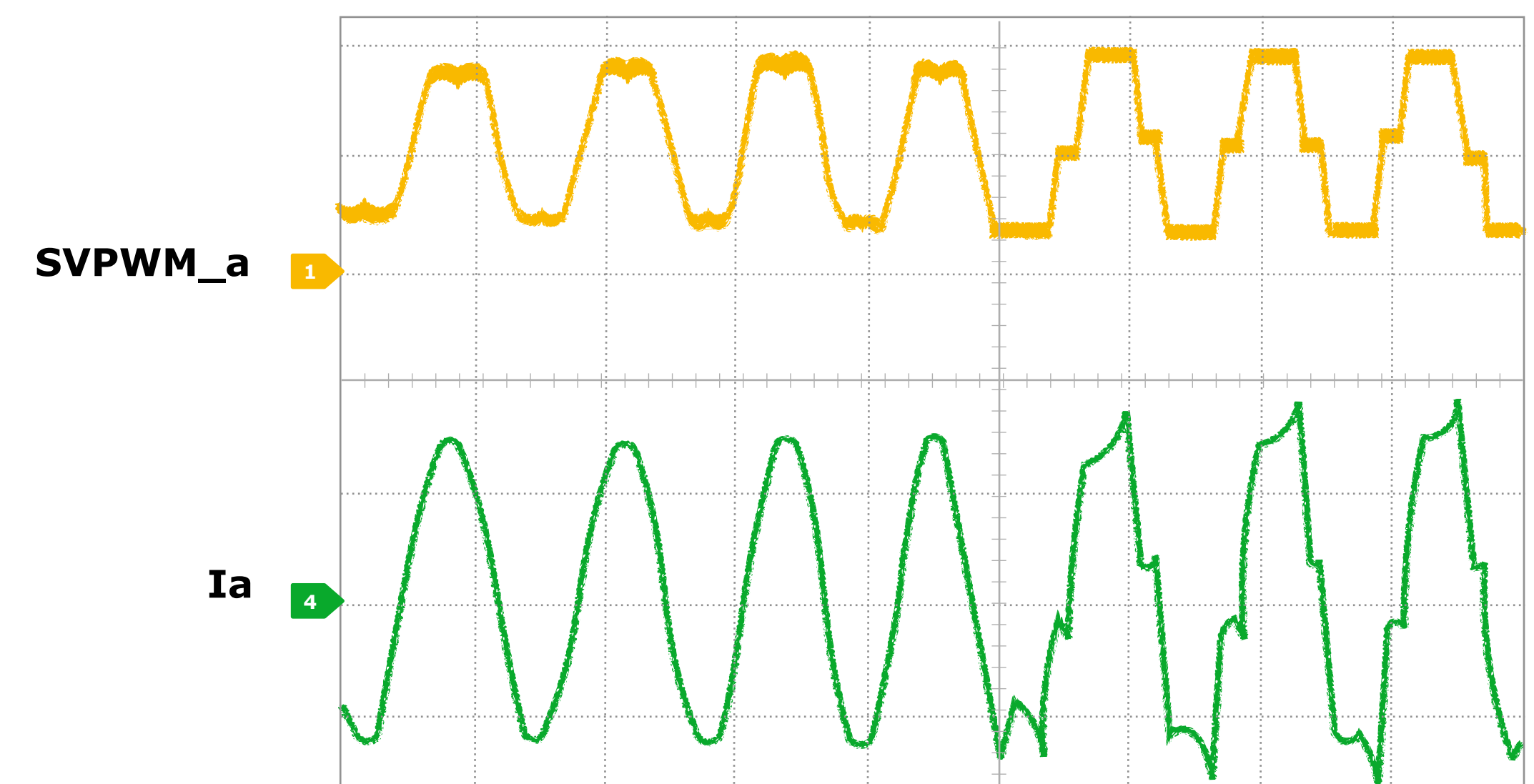
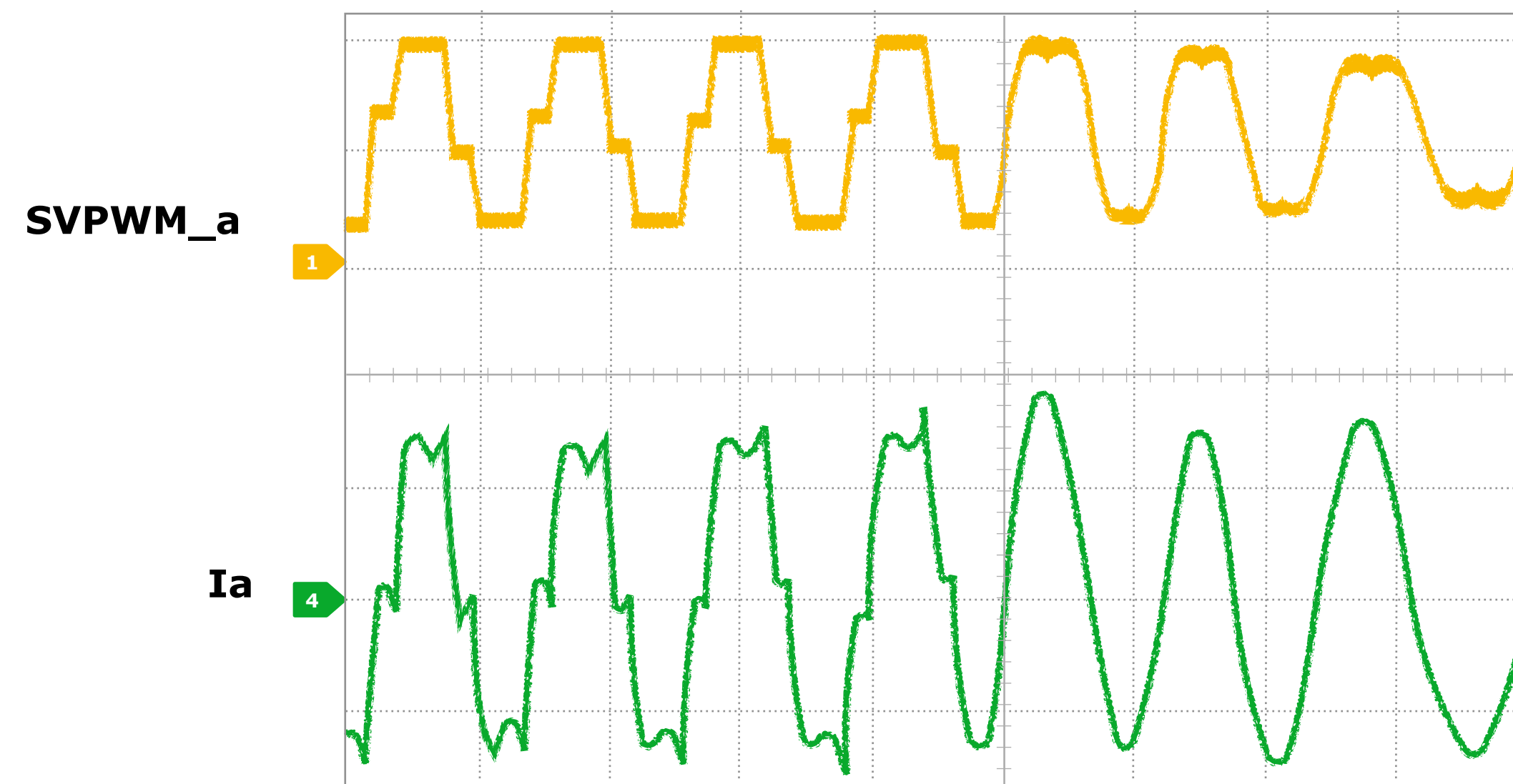
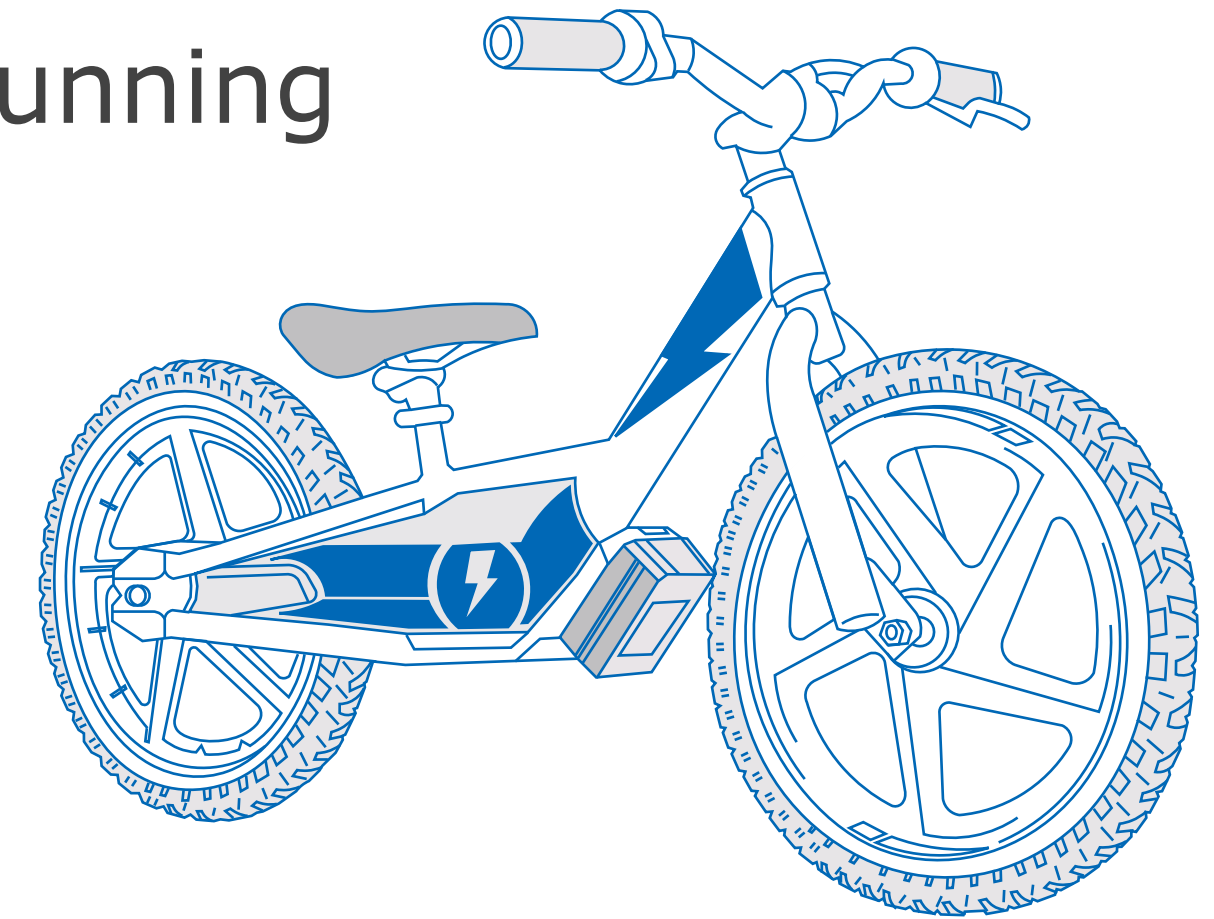




Square-Wave / Sine-Wave Switching



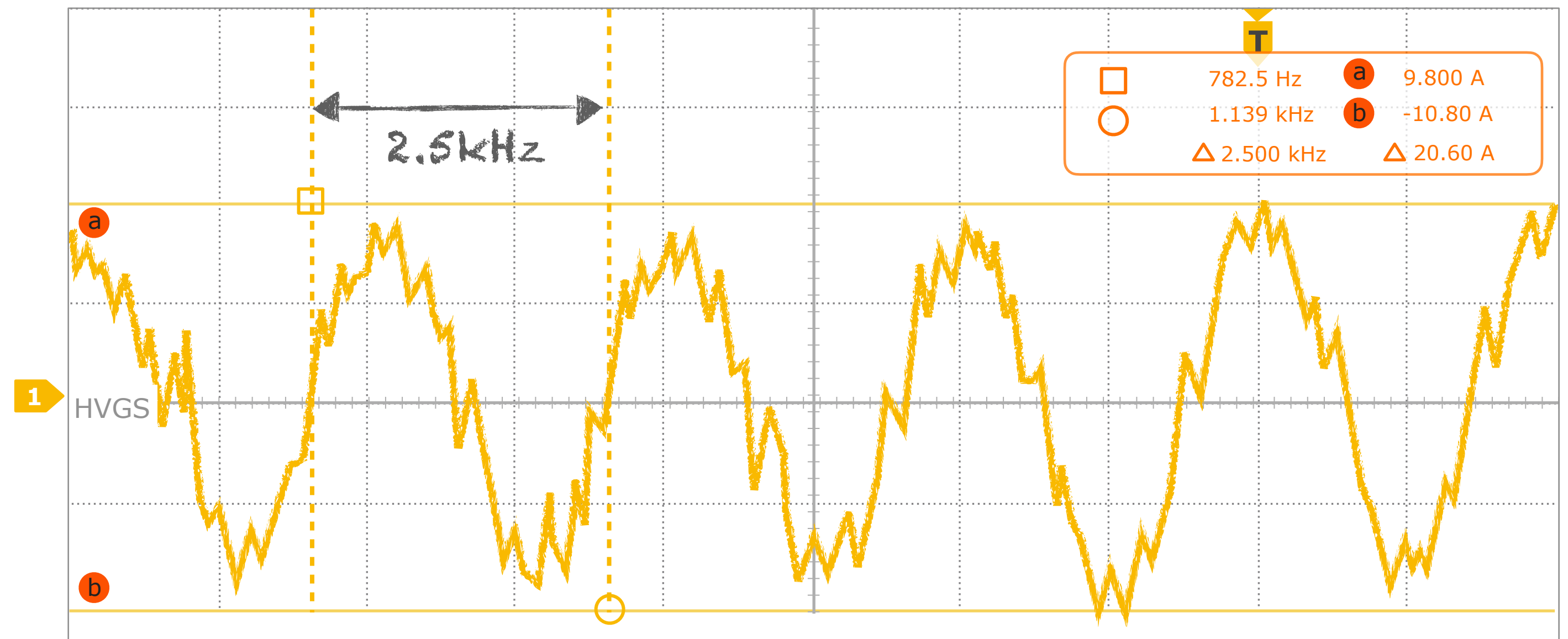
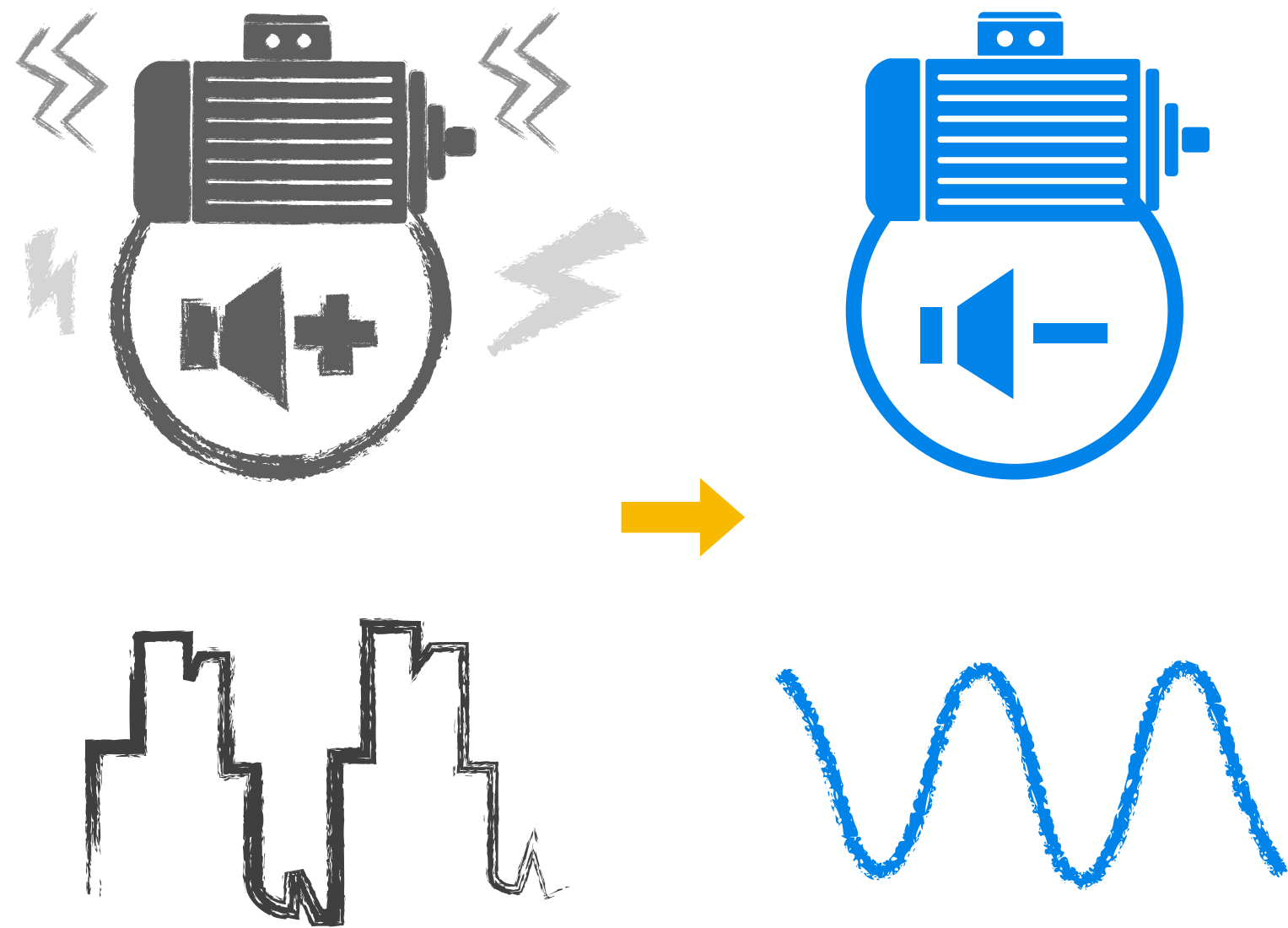
- Based on FOC loop, square-wave for start-up, sine-wave for running
- Smooth switching between square-wave and sine-wave
- Instantaneous large torque for start-up
- Products : electric vehicles



High-Speed FOC



- Max. 150,000RPM @2poles
- Products : hair dryers / vacuum cleaners / blowers

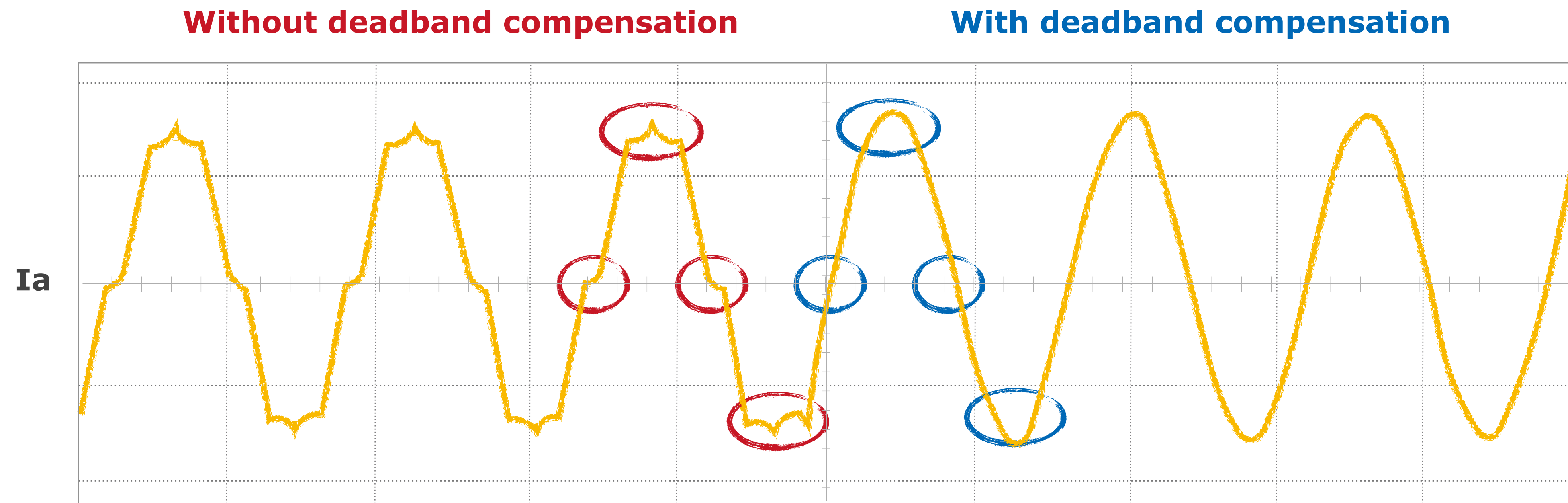




Deadband Compensation Strategy



- Deadband effect results in serious current distortion in low-speed conditions
 - Low-voltage P/N gate-driver has a small driving force
 - high-voltage IGBT element has a longer close time period
- Improve current waveform distortion and harmonic wave problems

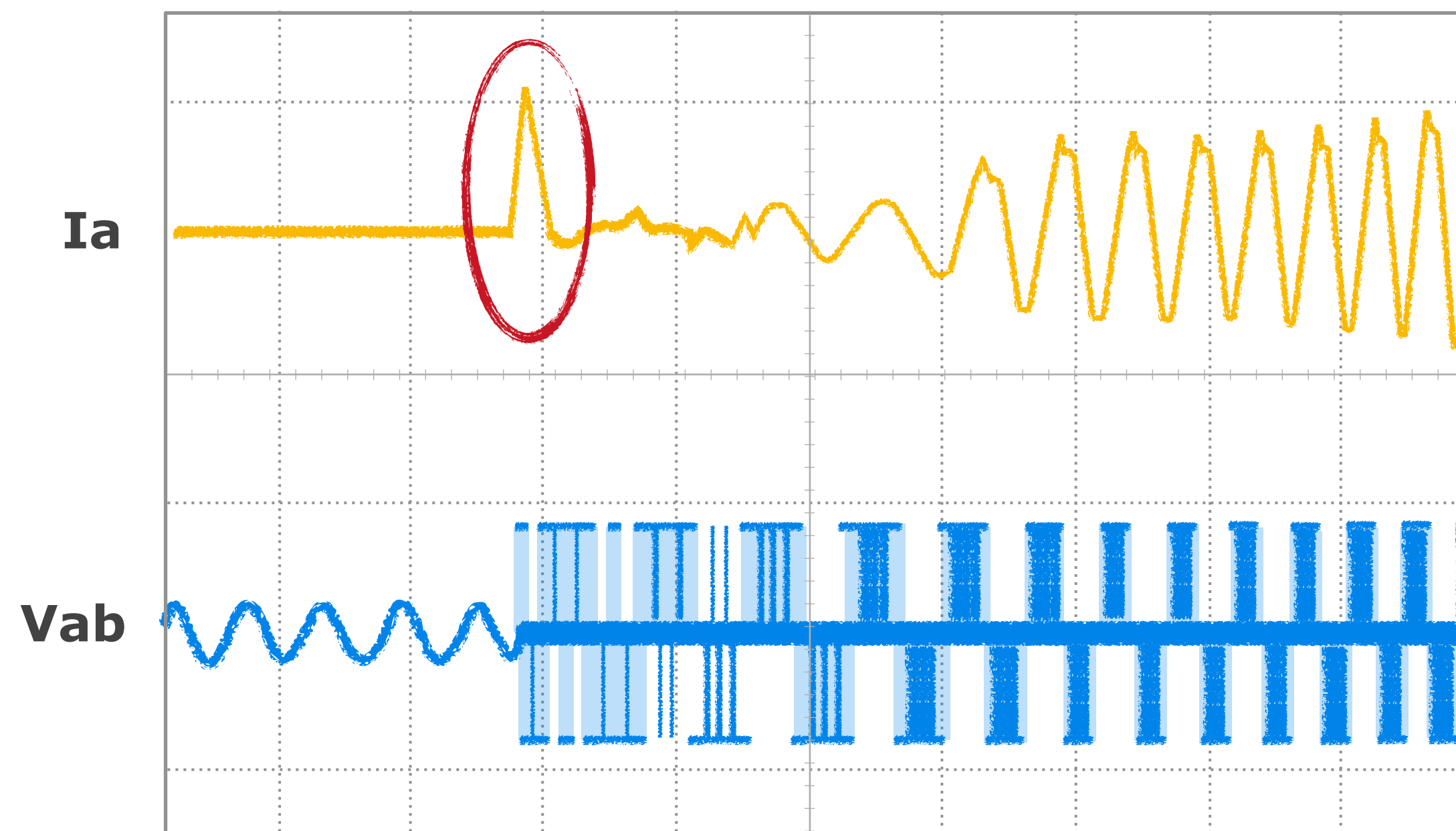


Voltage Compensation Strategy

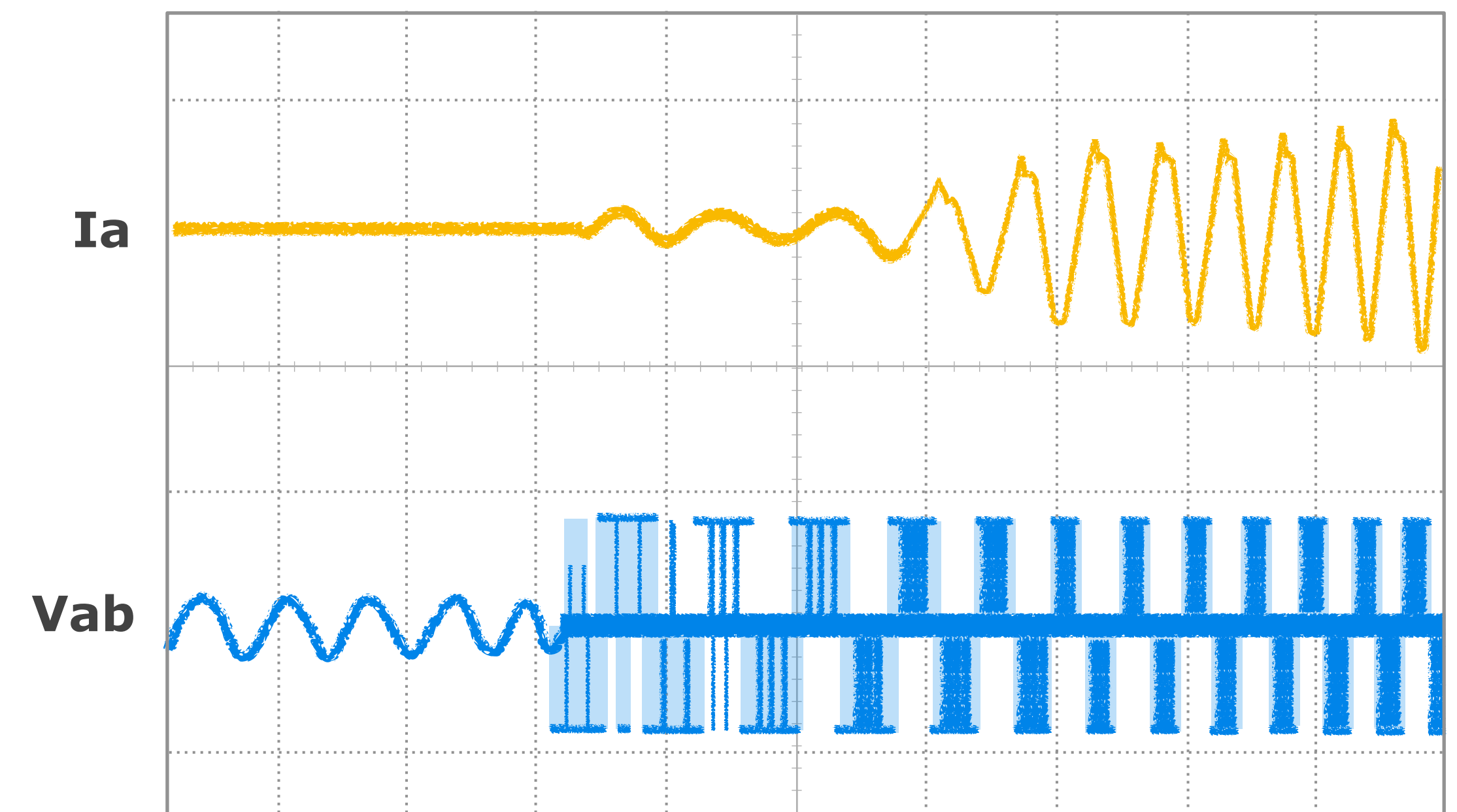


- Drive control intervention in the on-fly / off-fly processes will generate current surges
- Increase current control response, improve the high start-up current problems during operations
- Products : large load inertia, high-speed start / stop

Without voltage compensation



With voltage compensation



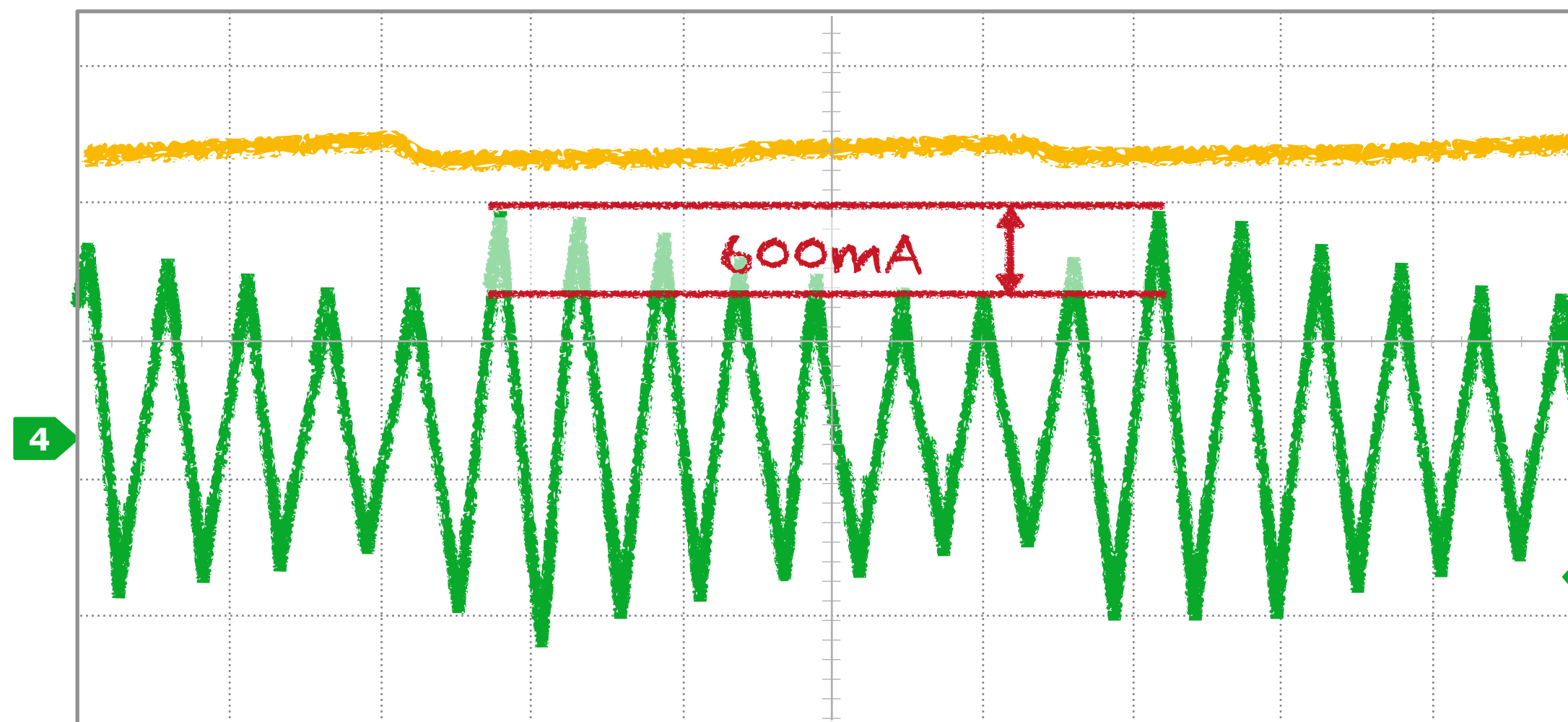
DC Bus Voltage Ripple Compensation



- PCBA space limitation allows for small capacitance value, resulting in vibrations and noise due to torque ripple
- Reduce current ripple according to DC bus voltage fluctuation, improve vibration and noise problems, reduce the maximum current value

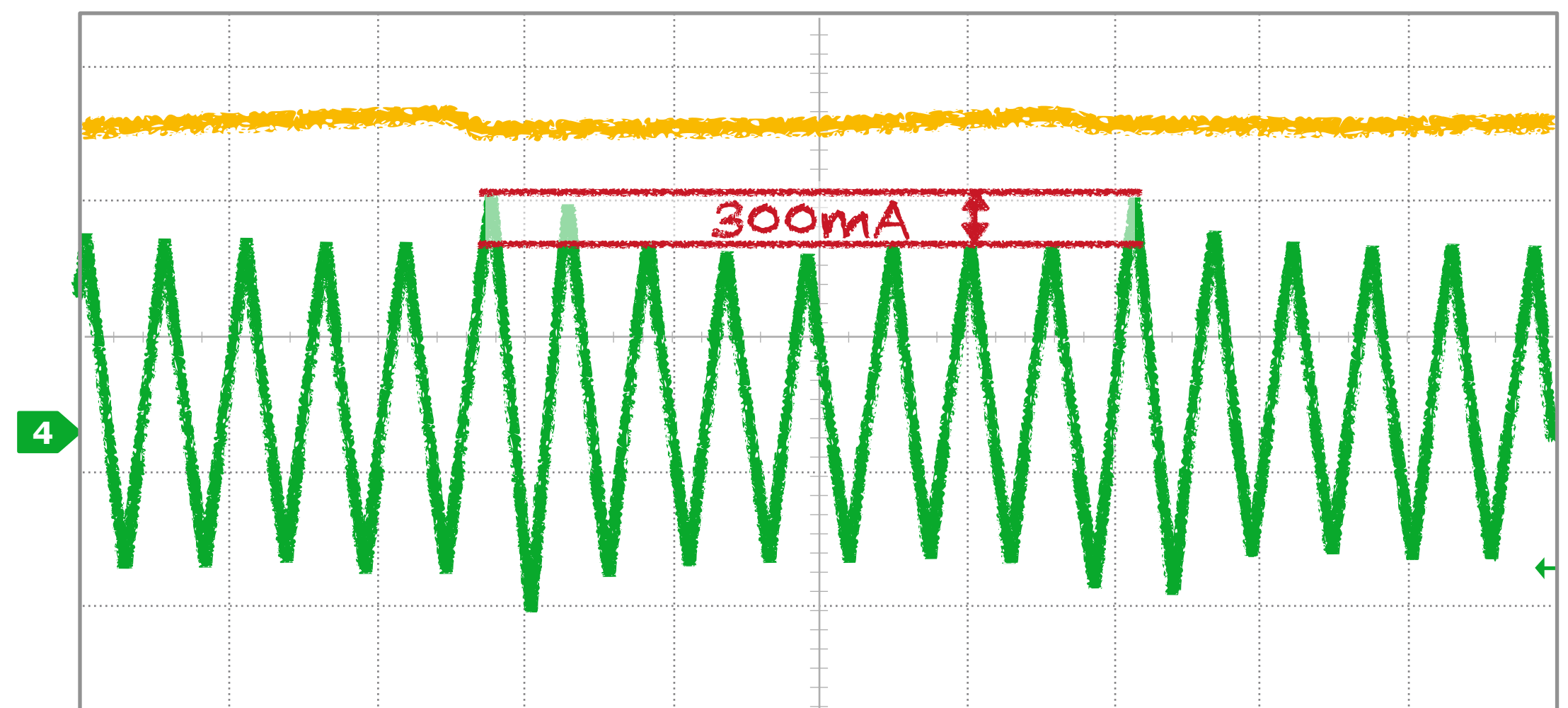
Without DC Bus Voltage Ripple Compensation

Motor phase current ripple : 600mA



With DC Bus Voltage Ripple Compensation

Motor phase current ripple : 300mA





Motor Controller UL Software Certification



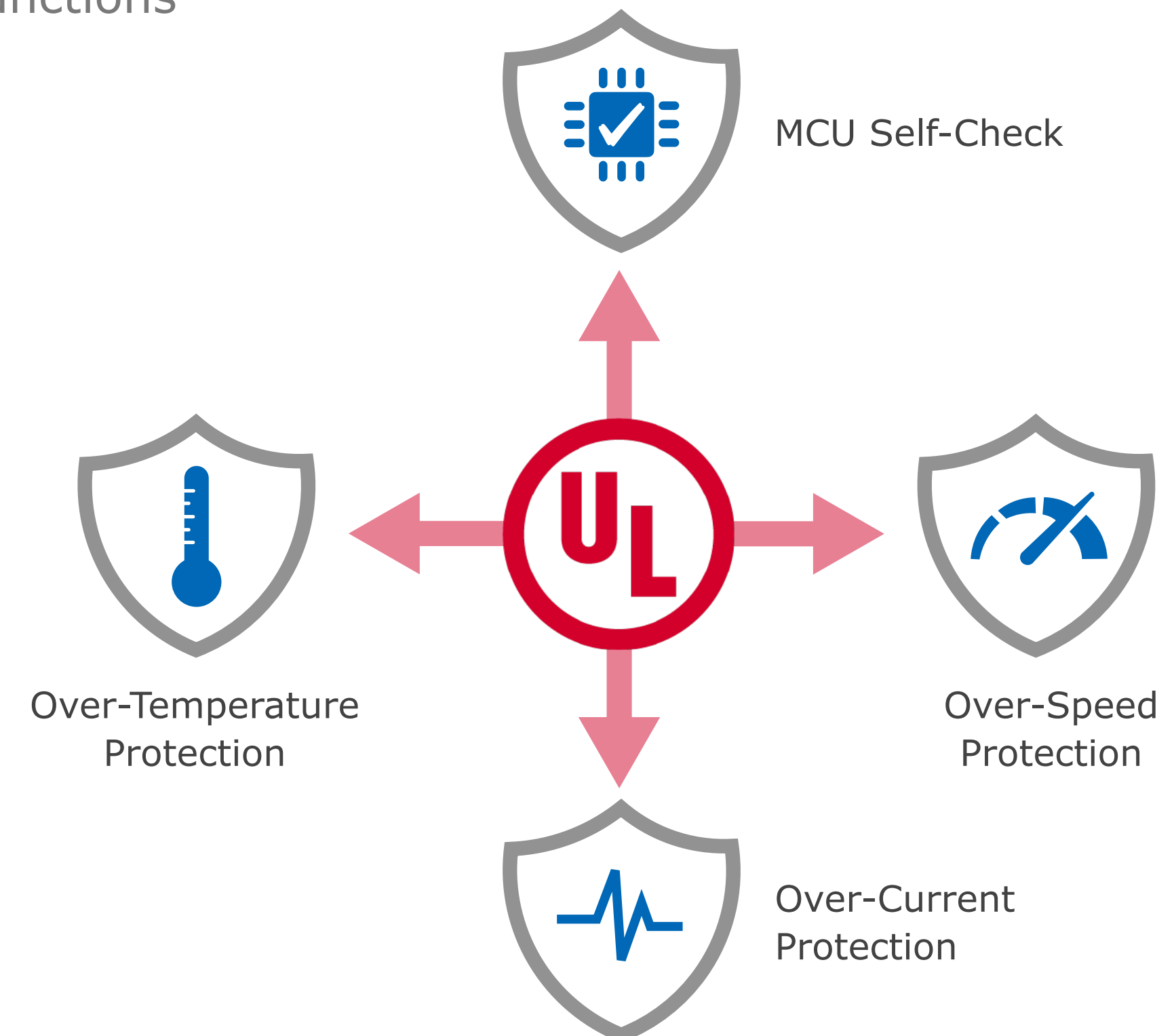
■ Holtek Motor Controller UL / IEC 60730-1 Class B Software Safety Certification :

- Holtek will provide the UL60730 factory inspection platform to customers to perform UL60730 information verification on the BLDC controller mass production

- UL60730 Certificate Number : UL-US-2019981-0



- MCU Self-Check
 - Over-Temperature Protection
 - Over-Current Protection
 - Over-Speed Protection
- Ceiling fan products need to meet the above four protection functions



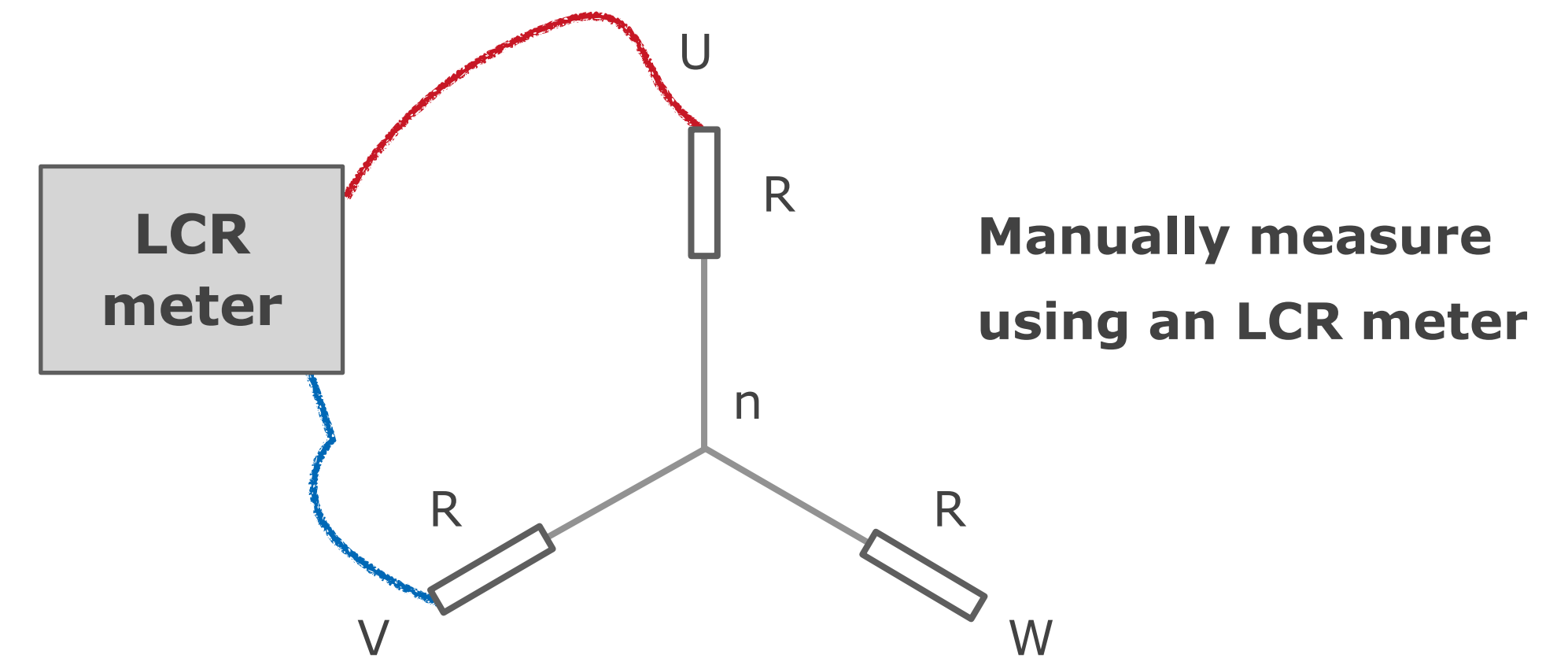


Motor Parameter Automatic Identification



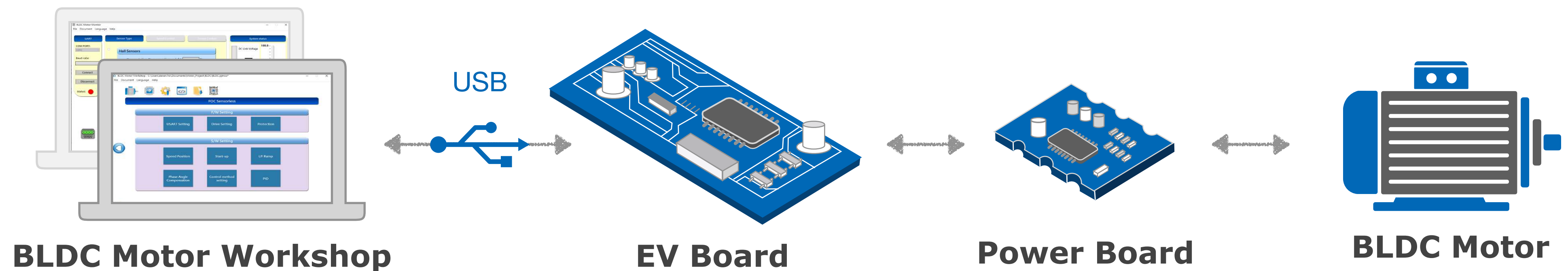
■ FOC operation-required motor parameters

- SMO F and G parameters
- Current loop PID gain
- Voltage compensation
- MTPA



■ Obtain motor parameters within several seconds, saving the time period of manual measurement

- Automatic measurement environment





Holtek BLDC Motor Solution Features

BLDC Ceiling Fan

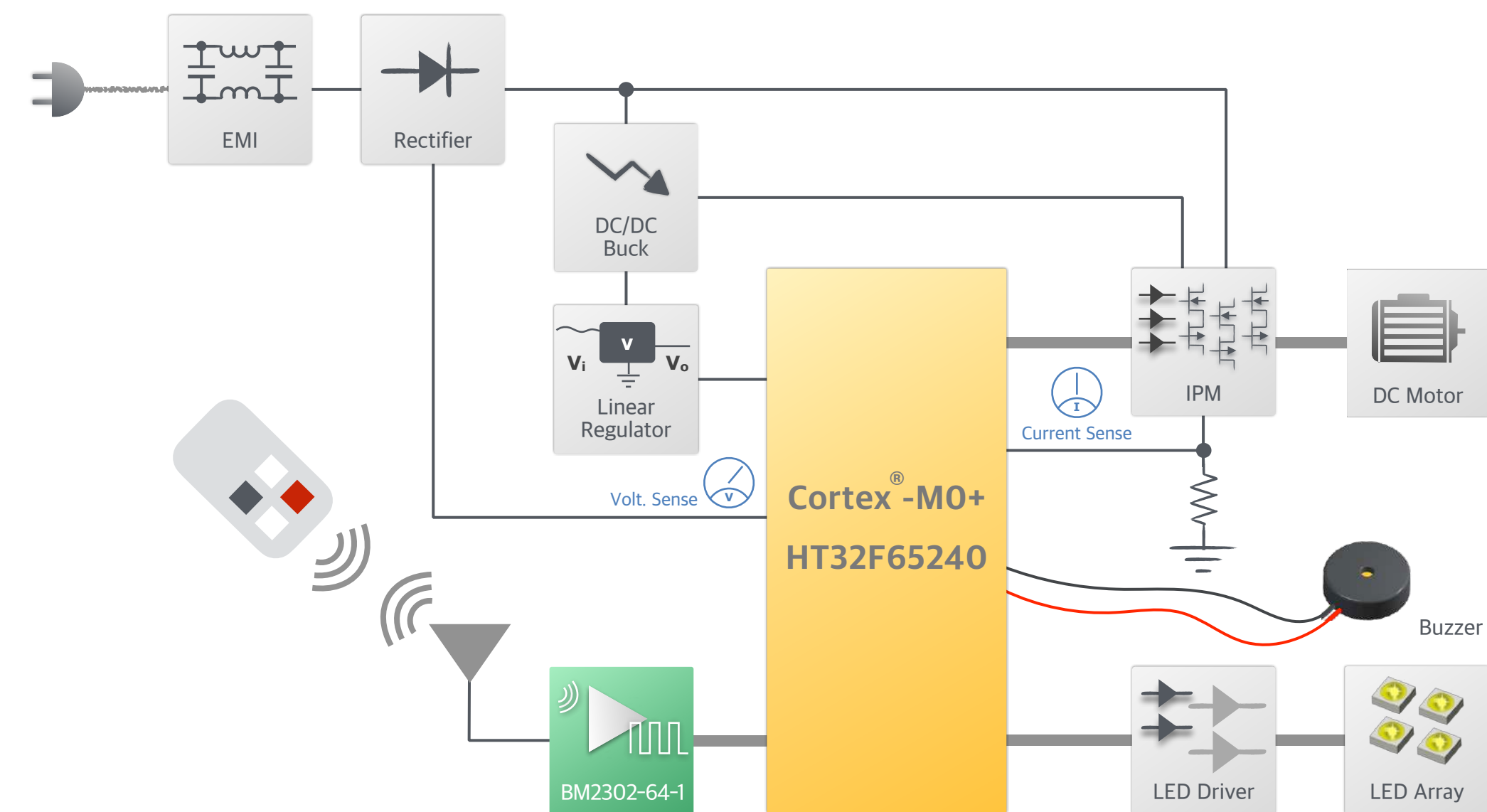
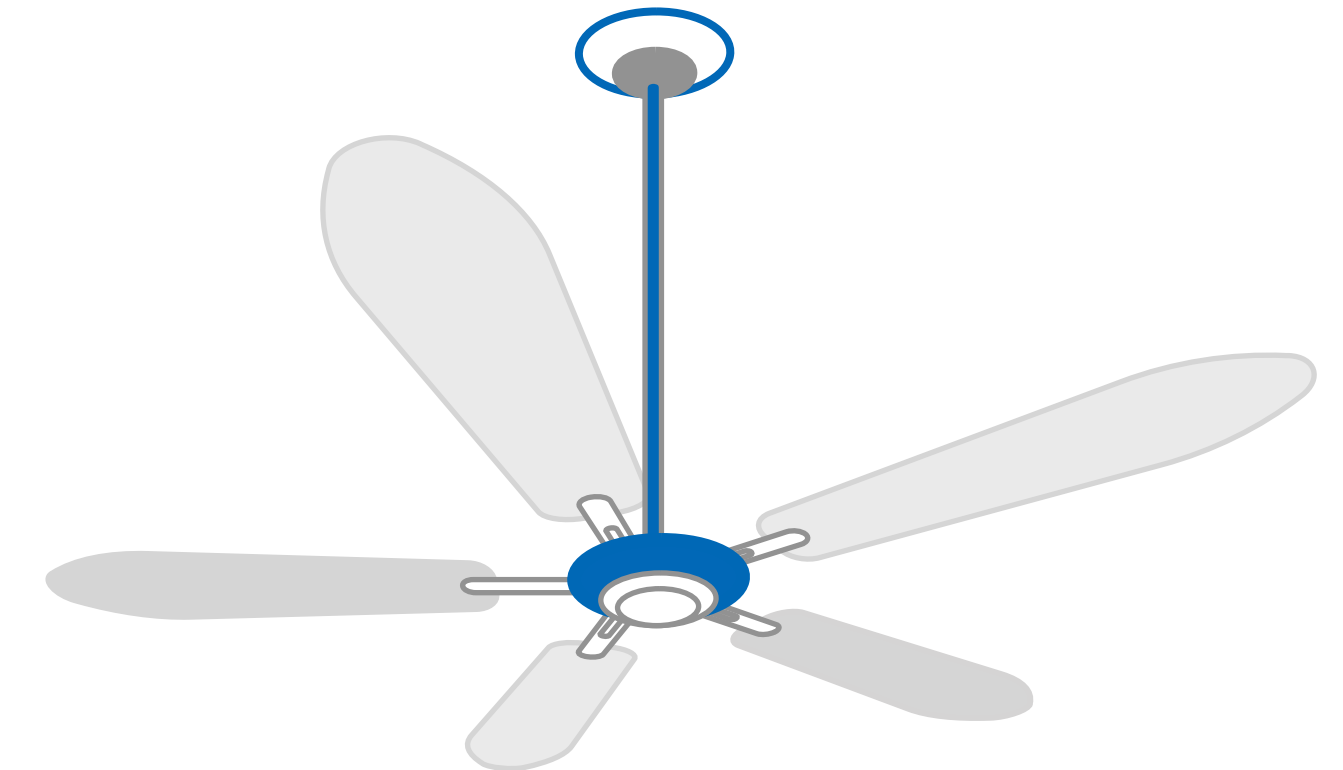
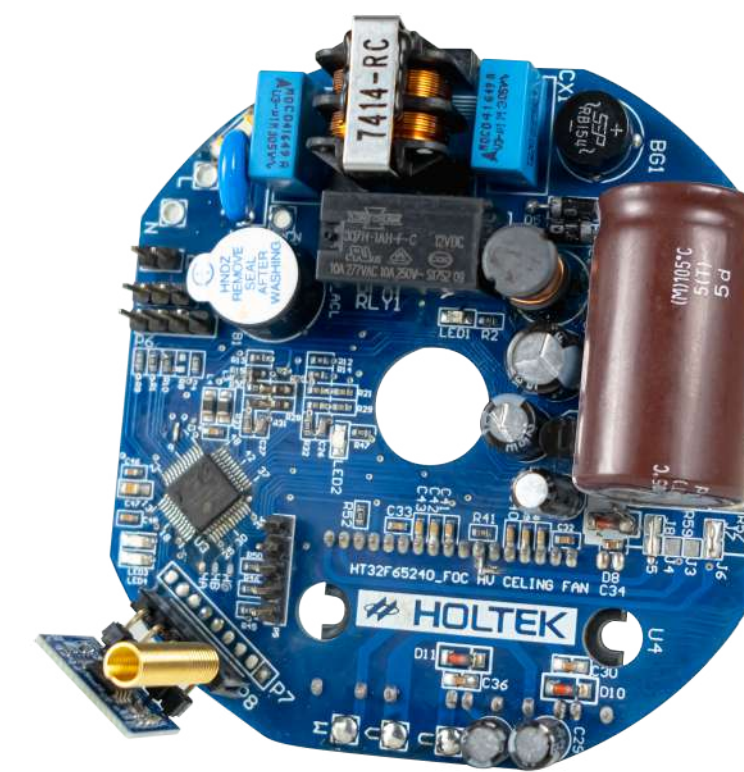


■ MCU type : HT32F65240

- Household use : 30W~40W @70 inches or less
- Industrial use : 100W @100 inches or more

■ Solution features :

- FOC Sensorless speed control
- Forward / backward rotation switching
- On-fly / off-fly start-up
- IPD (motor initial position detection)
- Protection : over-voltage, low-voltage, over-current, locked-motor, over-speed, under-speed
- Software UL60730 (optional)
- RF remote decoding
- Buzzer
- LED lighting / color temperature adjustment (TRIAC or PWM) (household use)



BLDC Hair Dryer

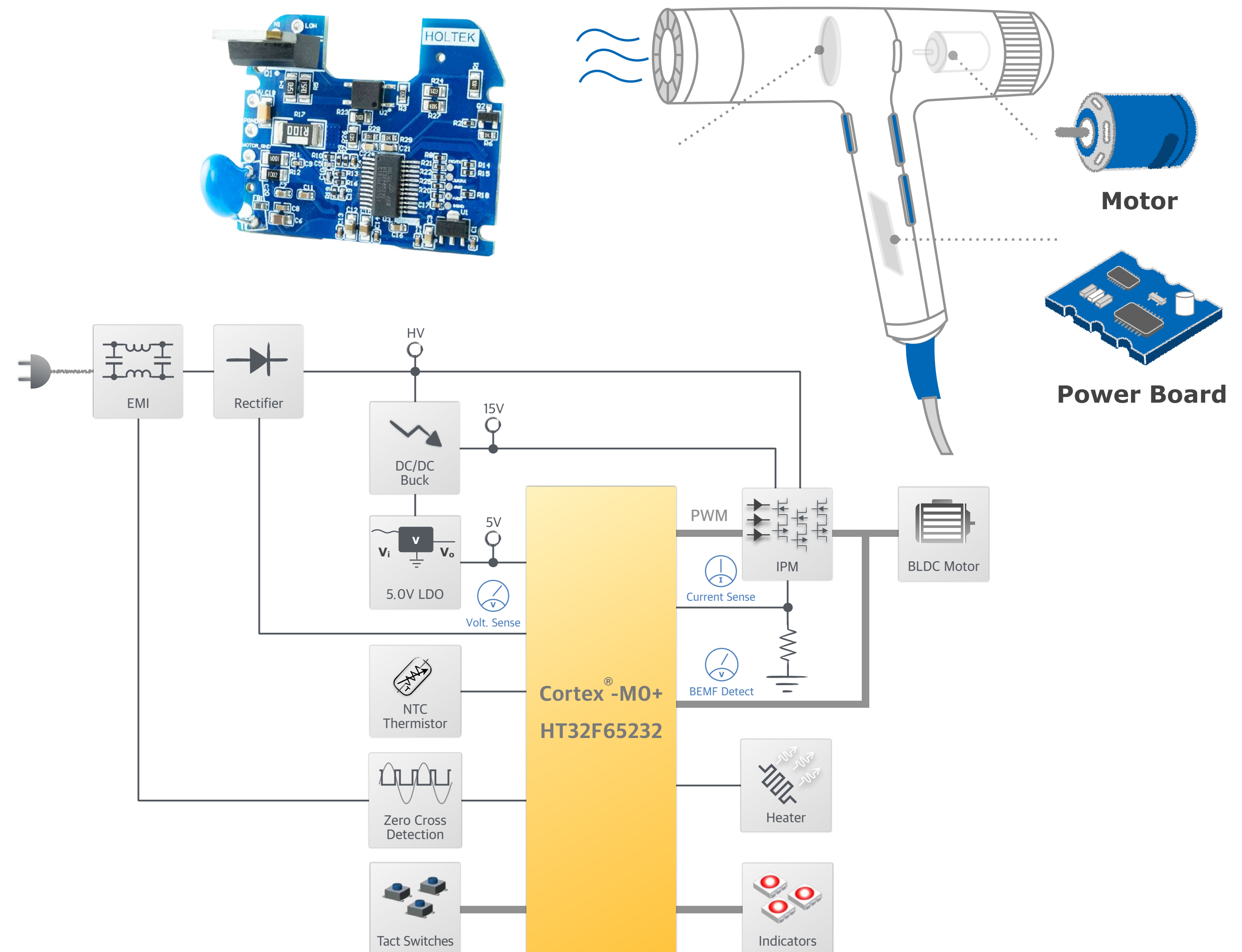


■ MCU type : HT32F65232

- AC 110V or 220V @100W

■ Solution features :

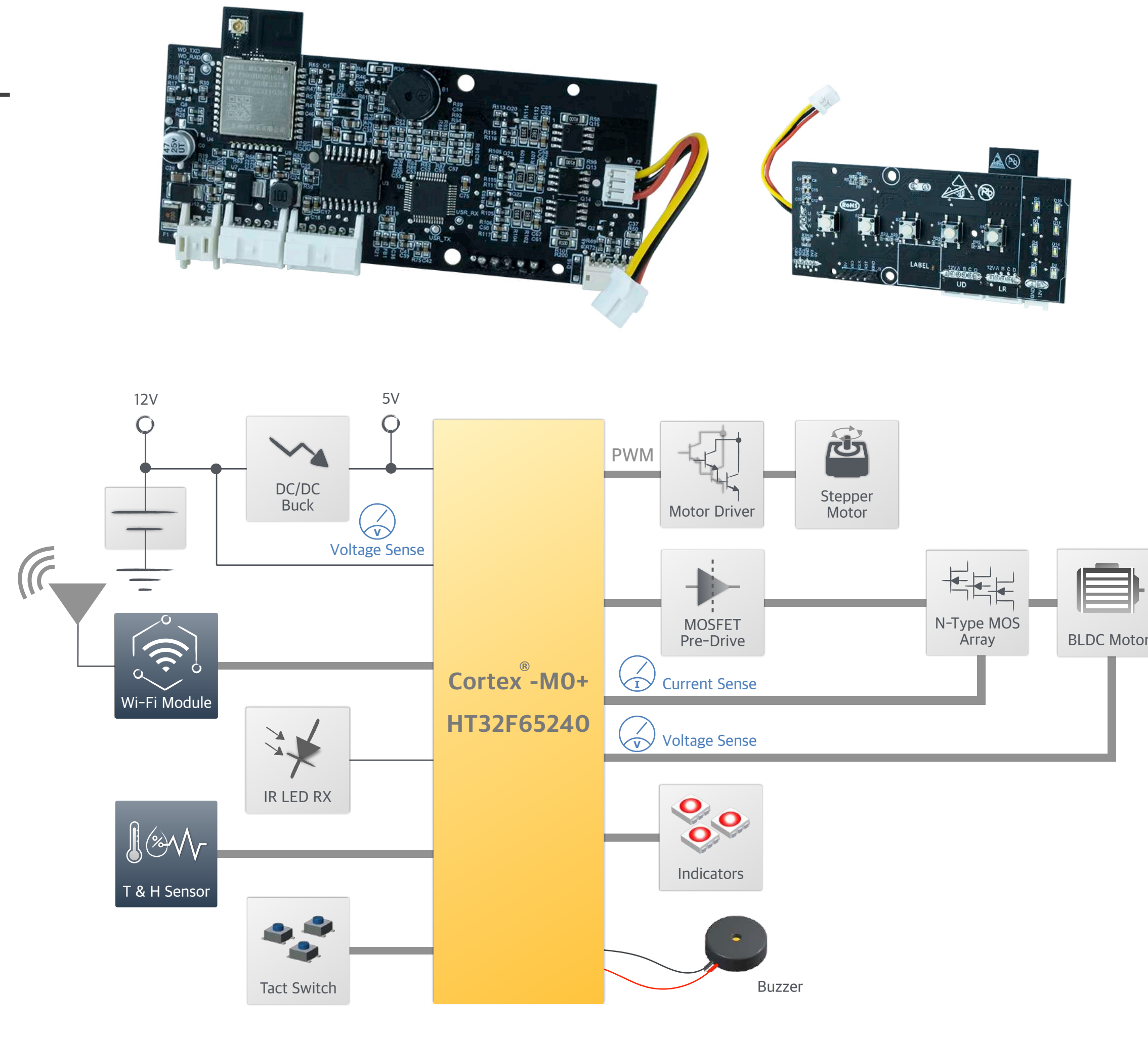
- 1-shunt FOC Sensorless torque / speed control
- Speed : 130,000RPM @2poles
- Advanced start-up : quick and smooth start-up at full voltage range without noise
- DC bus voltage ripple compensation
- Constant power control
- Cleaning filter during backward rotation
- Air outlet blocked protection avoids motor and drive board over-temperature
- Protection : over-voltage, low-voltage, over-current, over-speed, under-speed
- Heating coil temperature control



BLDC Floor Fan



- MCU type : HT32F65240
- Solution feature : master control + motor driving, two-in-one
 - 2-shunt FOC Sensorless, good silence effect
 - Flux linkage observer
 - Deadband compensation strategy
 - On-fly / off-fly start-up
 - Advanced start-up : quick, smooth and no noise
 - Protection : over-voltage, low-voltage, over-current, over-speed, under-speed
 - WiFi control (UART interface)
 - Oscillating control
 - Human machine interface (keys)



BLDC Handheld Vacuum Cleaner

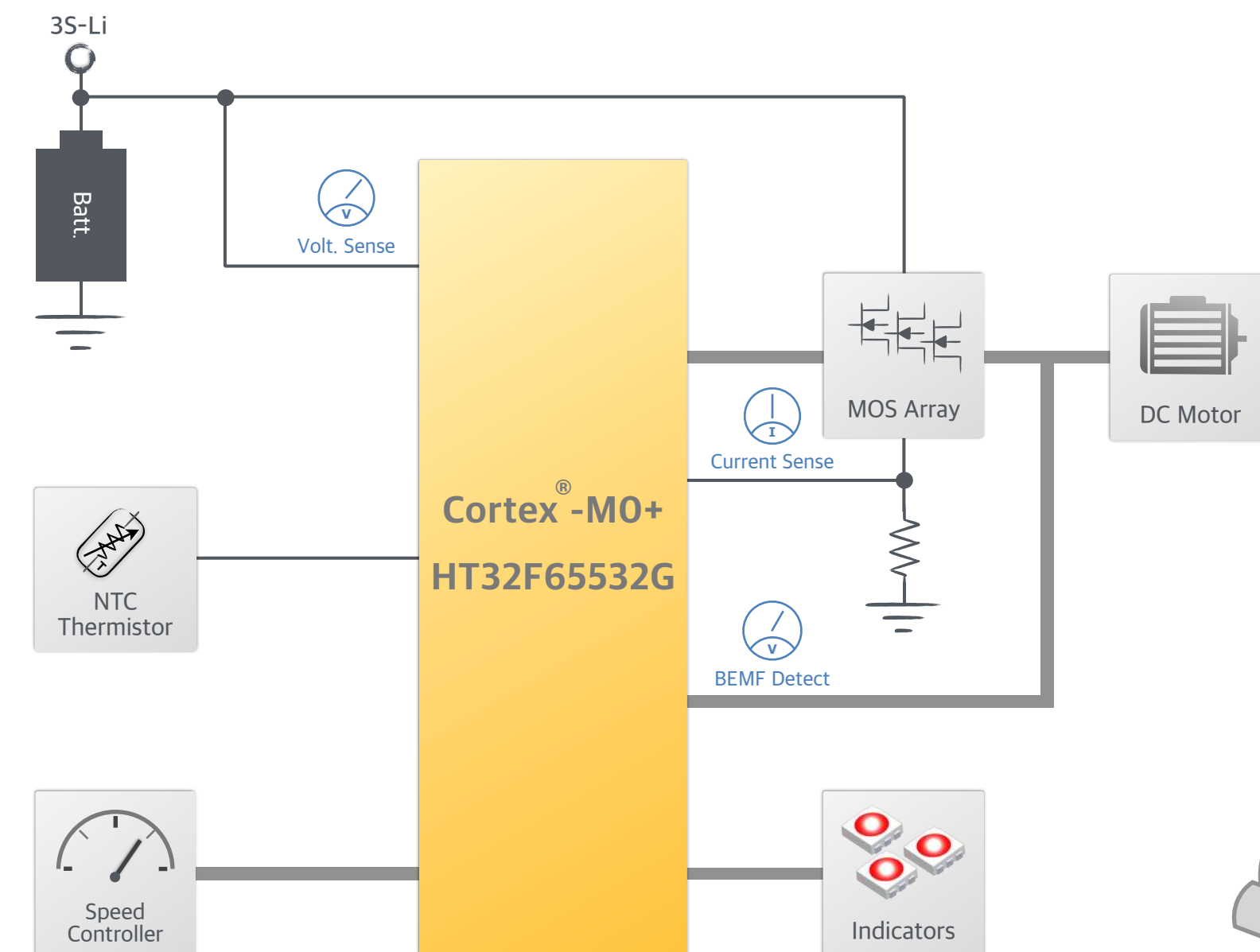


■ MCU type : HT32F65532G

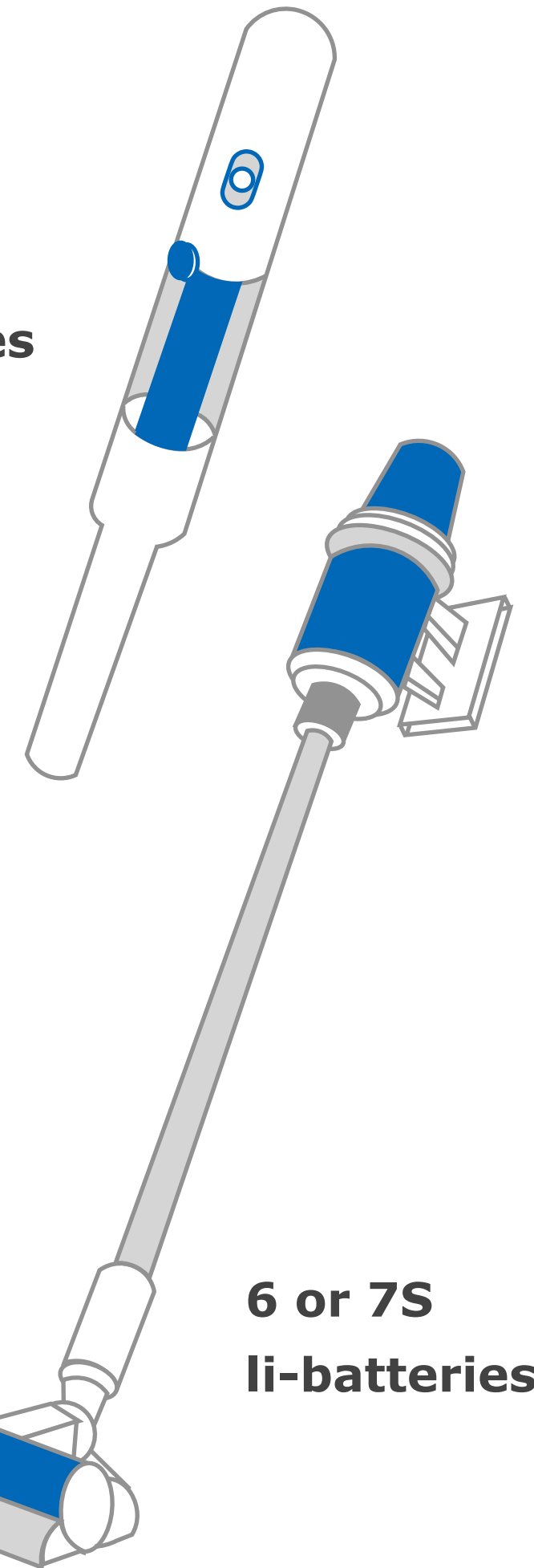
- Integrated 48V N/N Gate-Driver + LDO

■ Solution features :

- 1-shunt FOC Sensorless torque control
- PWM frequency up to 25kHz, reducing torque ripple
- Speed : 100,000RPM @2poles
- Advanced start-up : quick, smooth and no noise
- Air outlet blocked protection avoids motor and drive board over-temperature
- Protection : over-voltage, low-voltage, over-current, over-speed, under-speed



3S li-batteries



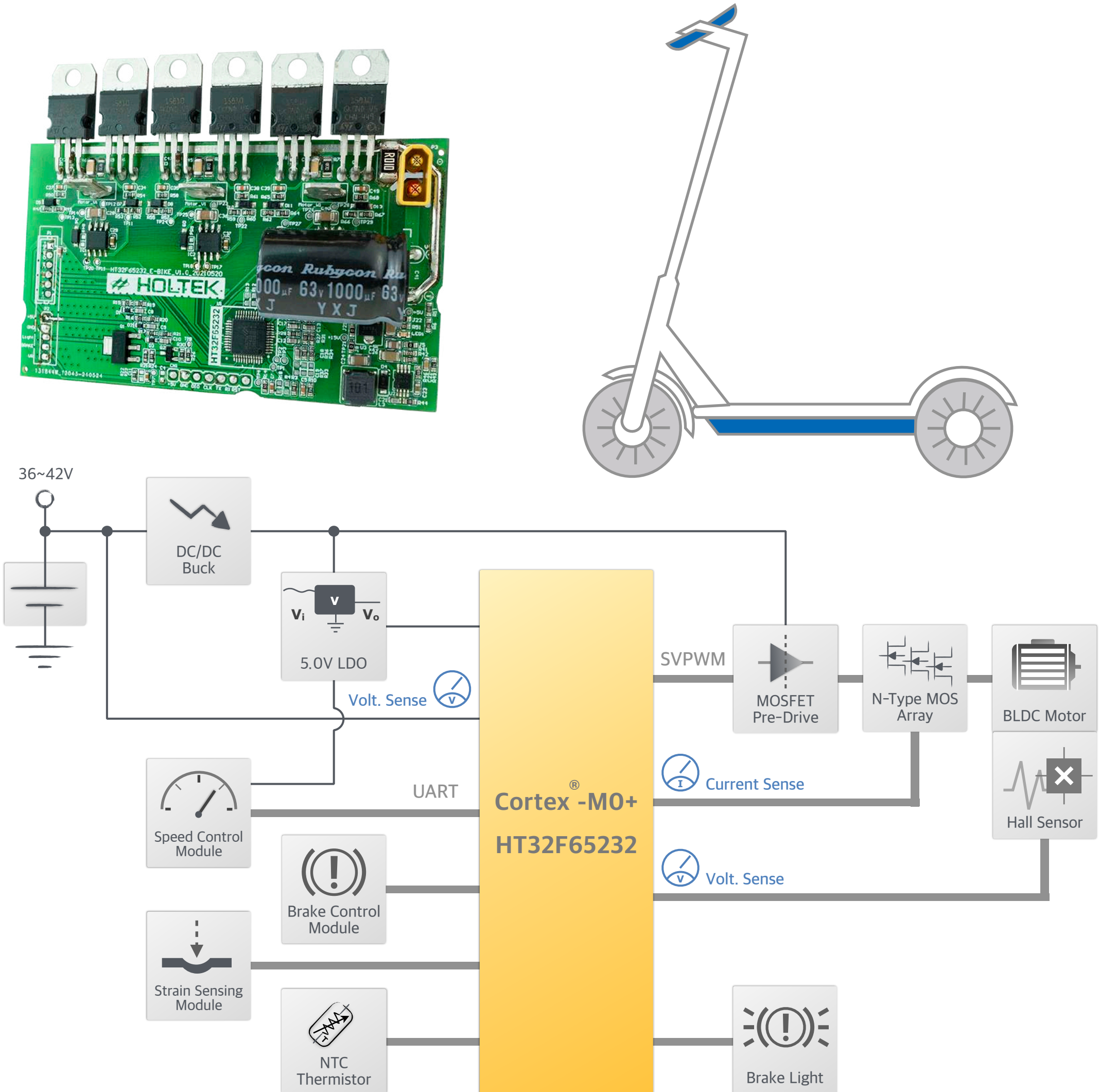
6 or 7S
li-batteries

■ MCU type : HT32F65232

- DC 36V / 350W

■ Solution features :

- 1-shunt FOC Hall torque control
- Hall even compensation
- Voltage compensation
- Hall lose detection
- Electric brake
- Over modulation technique
- Protection : over-voltage, low-voltage, over-current, over-speed, under-speed, locked-rotor
- Meter display – UART
- Throttle control – UART or AD
- Light signal control, brake signal and pedal (strain) sensing detection



BLDC Range Hood

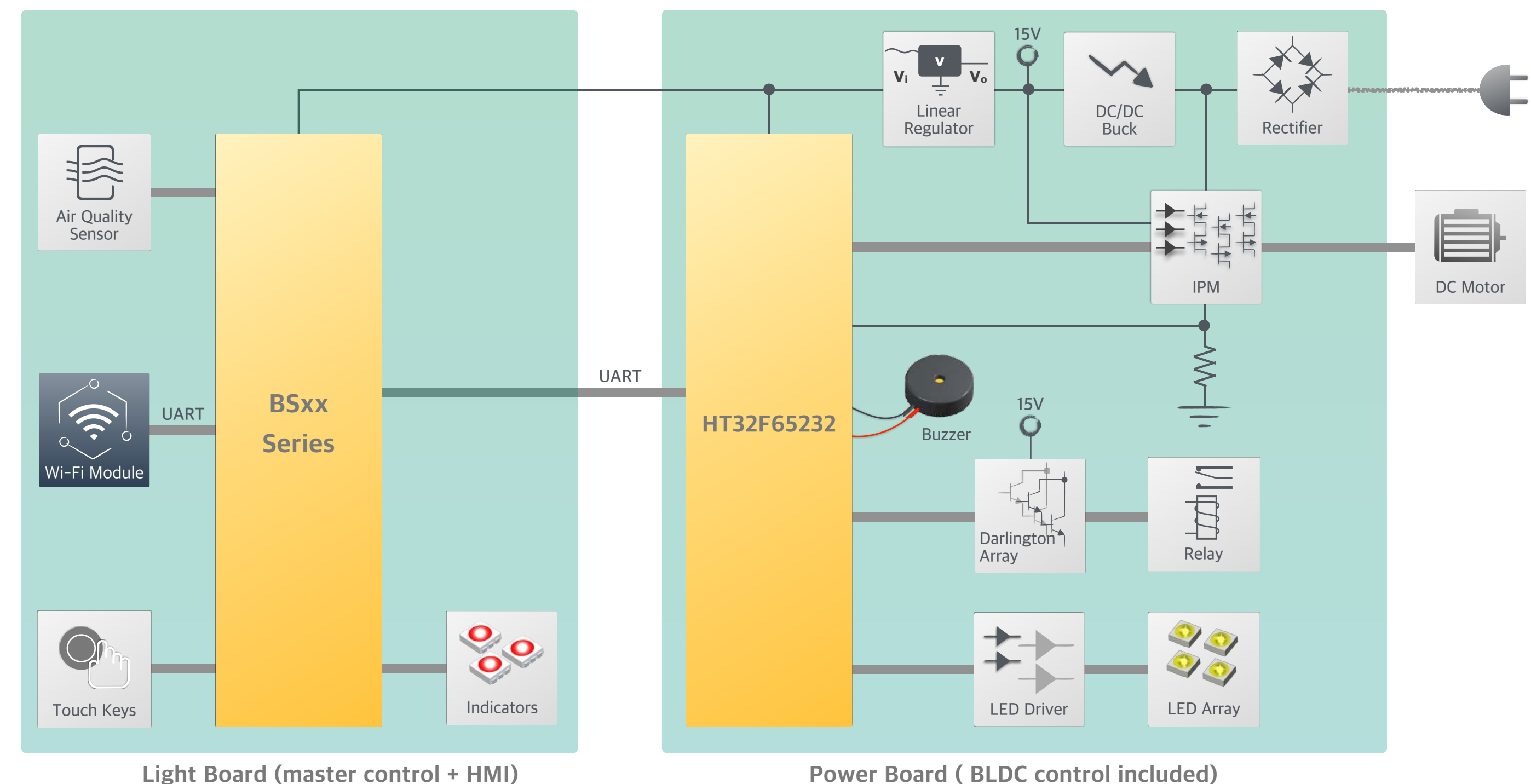
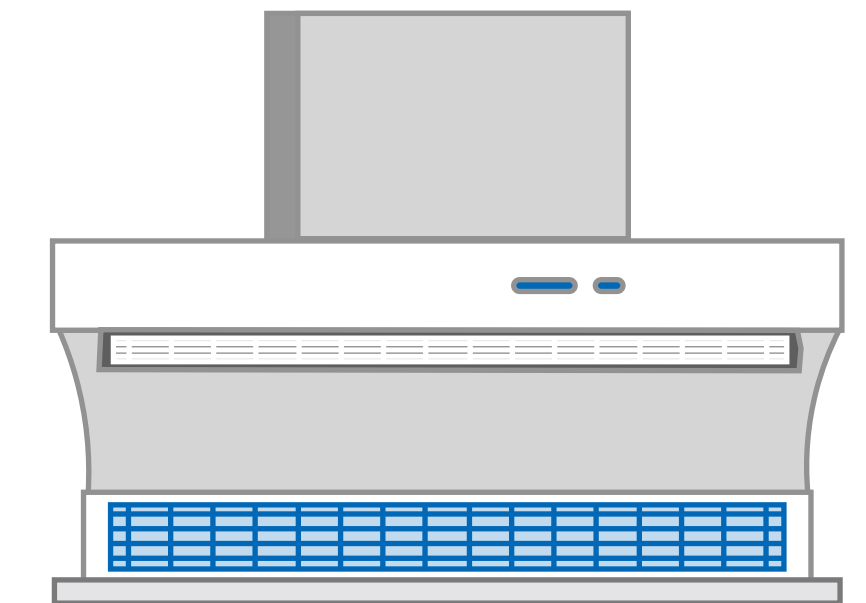
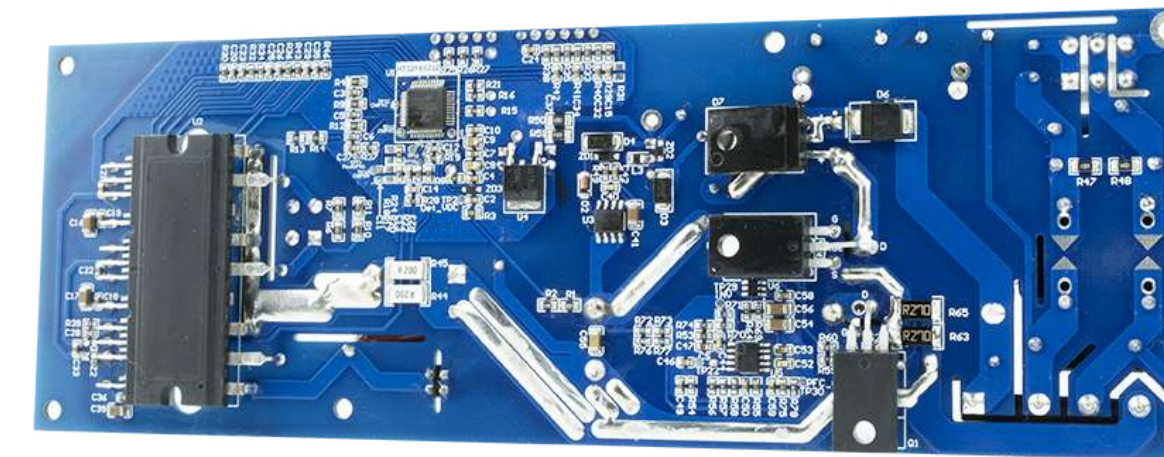


■ MCU type : HT32F65232

- AC 85~265V (PFC increases voltage to DC 400V) / 300W

■ Solution features :

- 1-shunt FOC Sensorless speed control
- Voltage compensation
- Constant power control
- Constant air flow control
- Adaptive positioning
- Protect : over-voltage, low-voltage, over-current, over-speed, under-speed, locked-rotor
- Master control communication : UART





BLDC Electric Impact Wrench

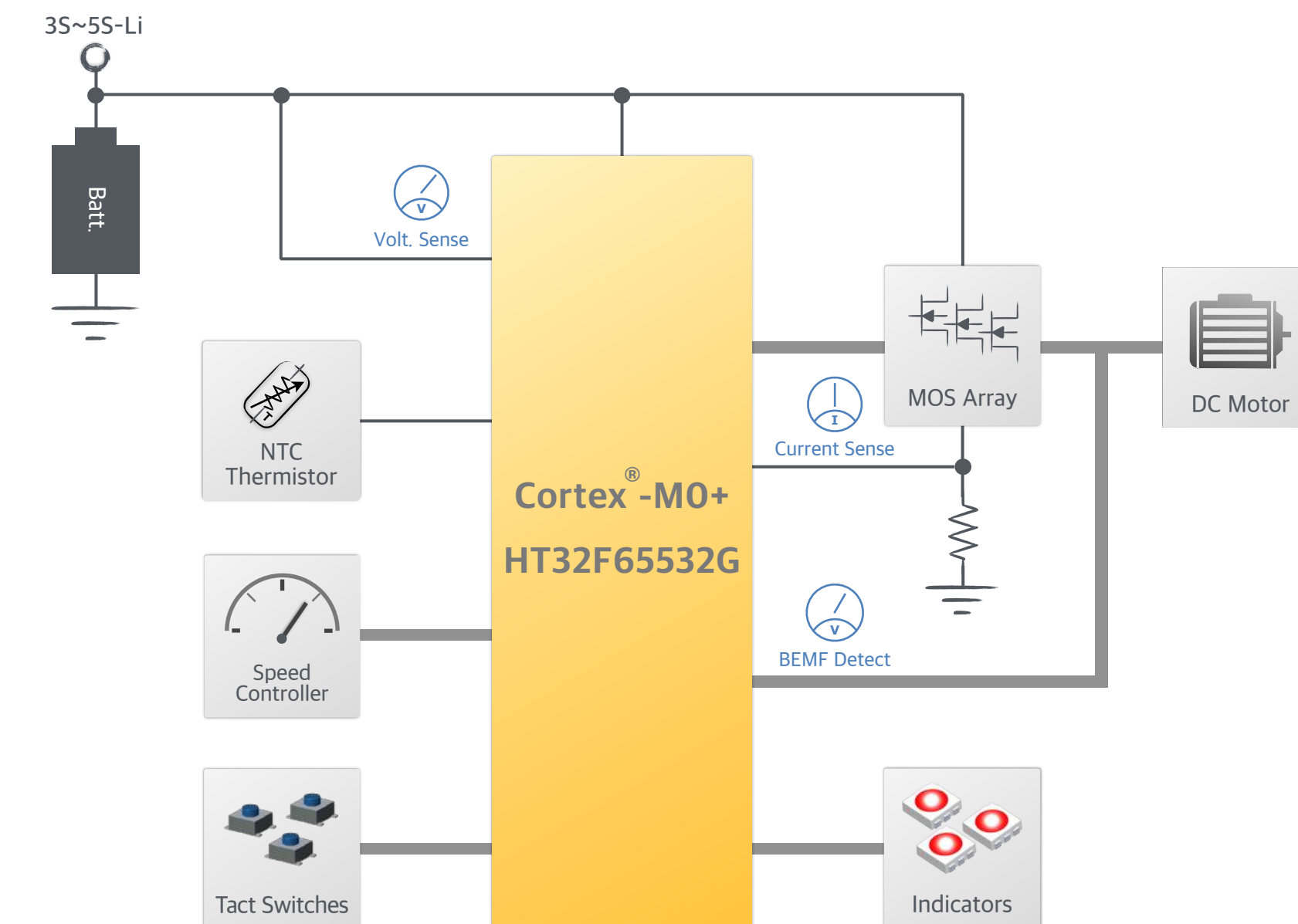
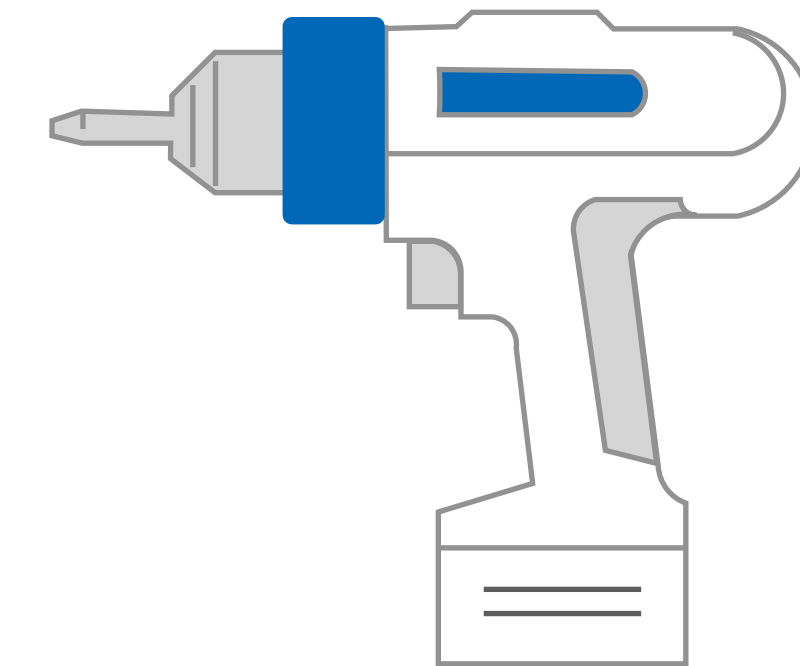
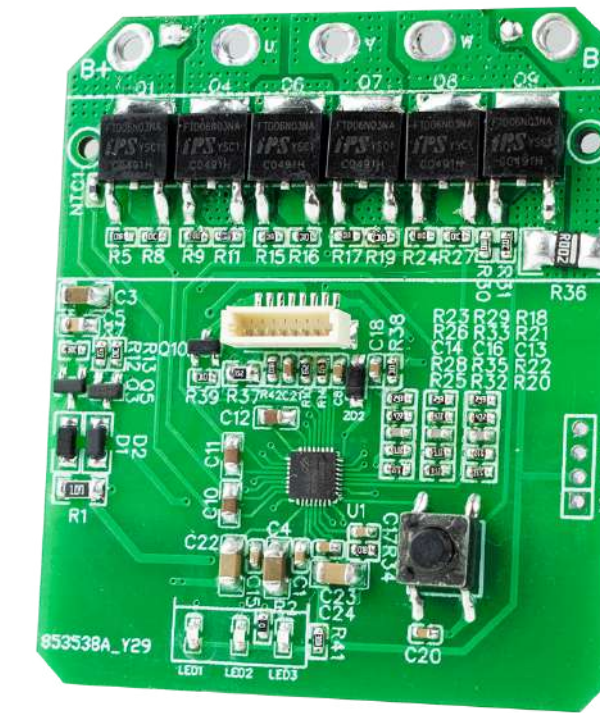


■ MCU type : HT32F65532G

- Integrated 48V N/N Gate-Driver + LDO
- 3S to 5S li-battery voltage

■ Solution features :

- Square-wave Sensorless control
- Specific back-EMF filter
- Backward self-stop
- Constant power control
- IPD (motor initial position detection)
- Battery module communication
- Protect : over-voltage, low-voltage, over-current, over-speed, under-speed, locked-rotor





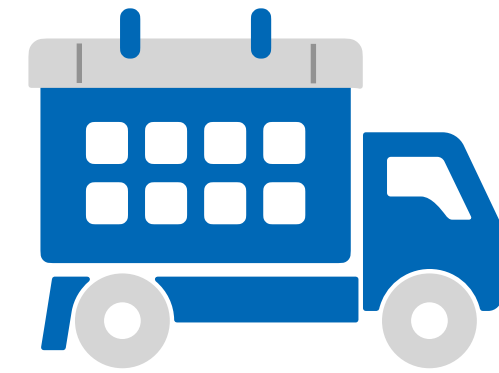
Holtek BLDC Motor MCU Advantages



Complete Product Specifications



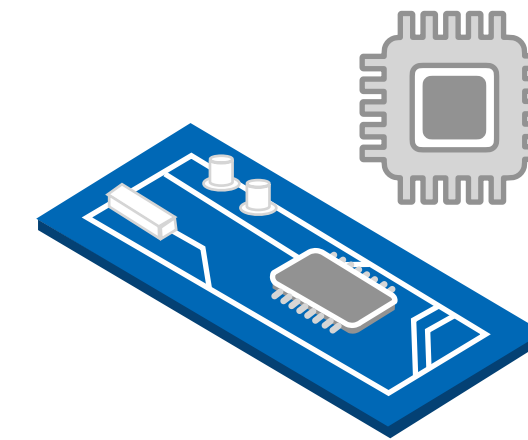
Low Cost



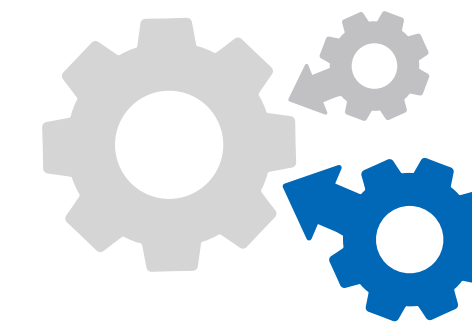
Stable Delivery Time



Local Technical Support Services



Development Tools



High Integration



HT32 / HT8

Motor Workshop



HOLTEK



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Sharing Success Through Excellence

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