

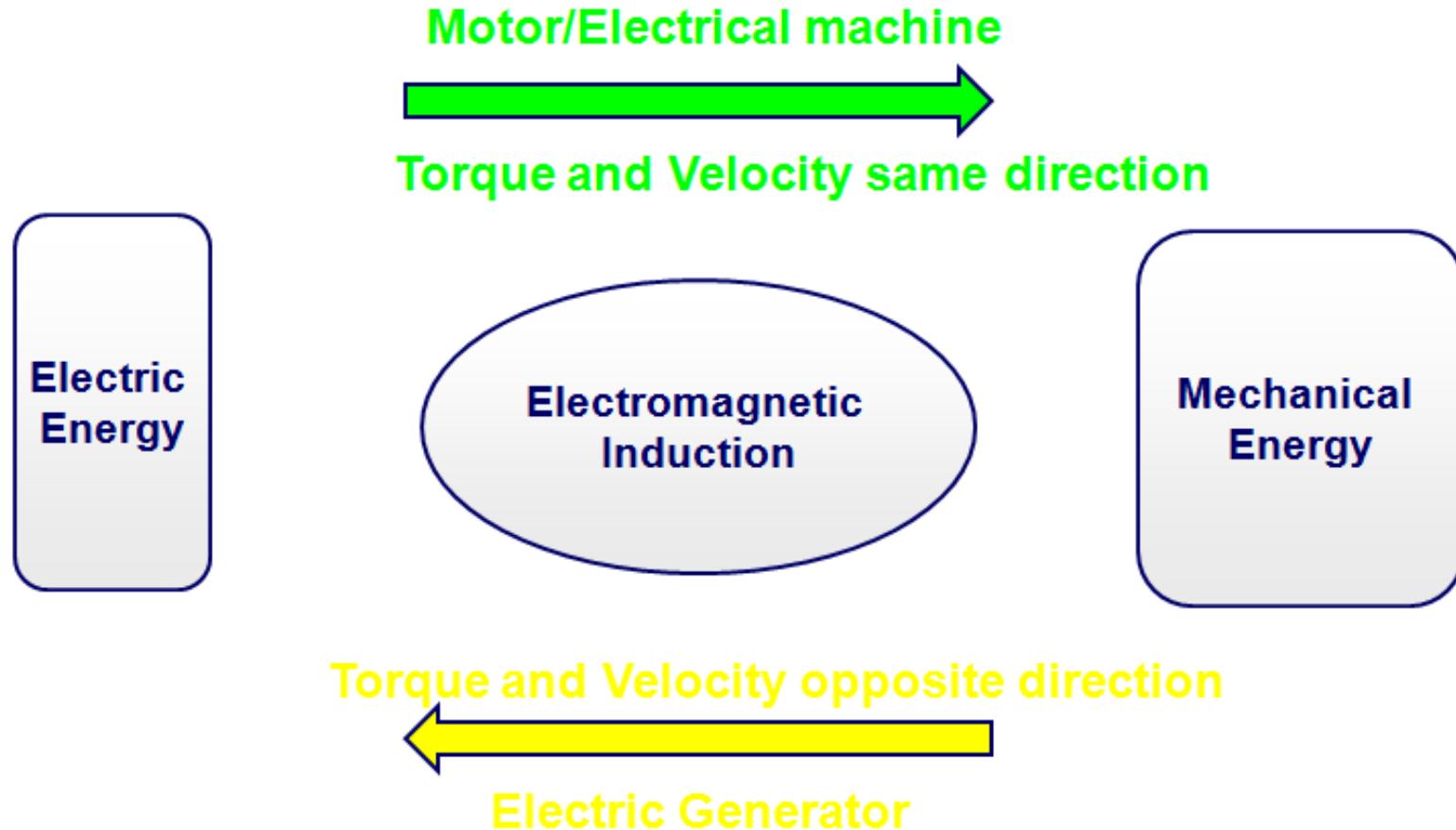
MPS超小型电机解决方案

Jun 2020 Jerry.W

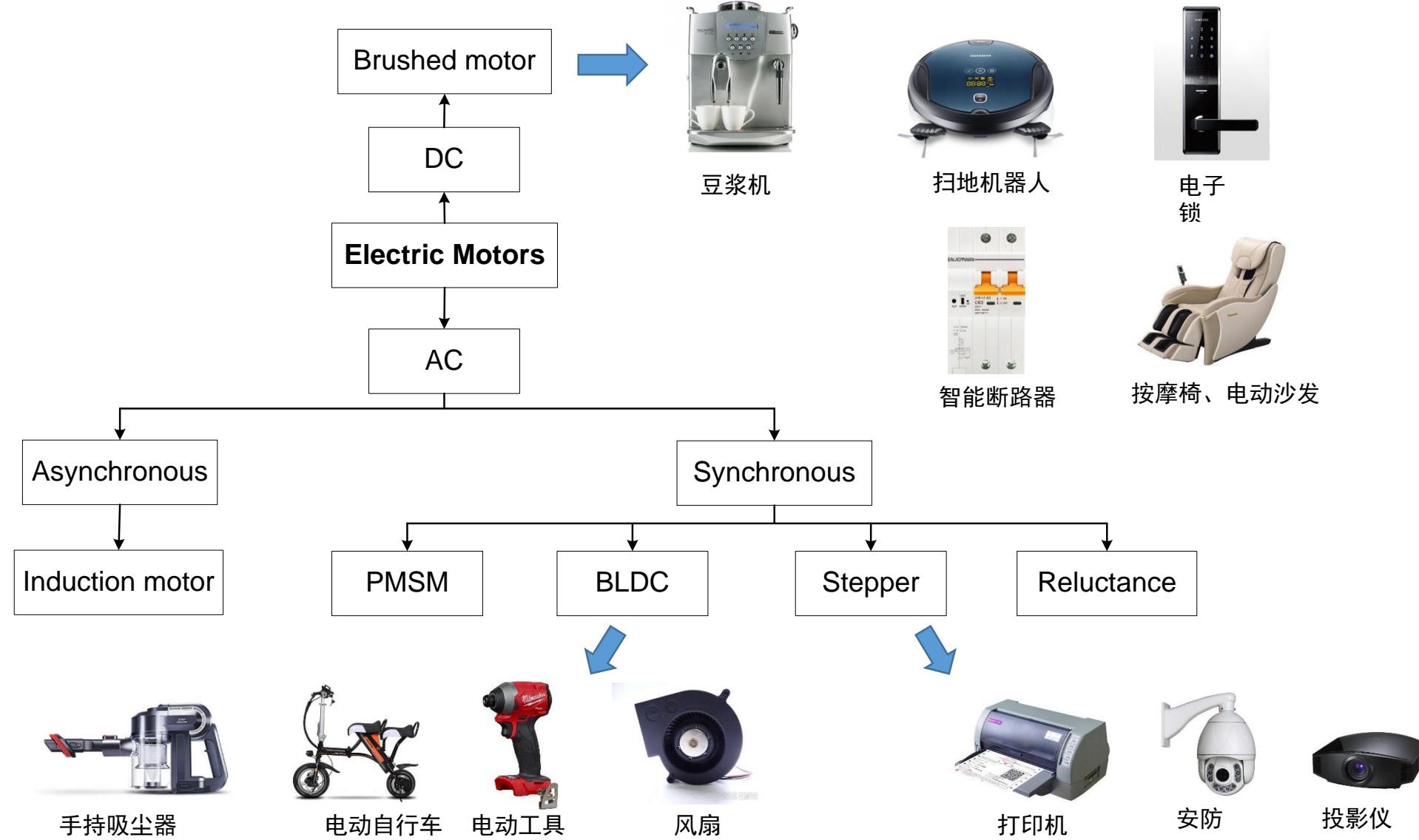
MPS

电机的定义和作用

A device which implement electro-mechanical energy conversion



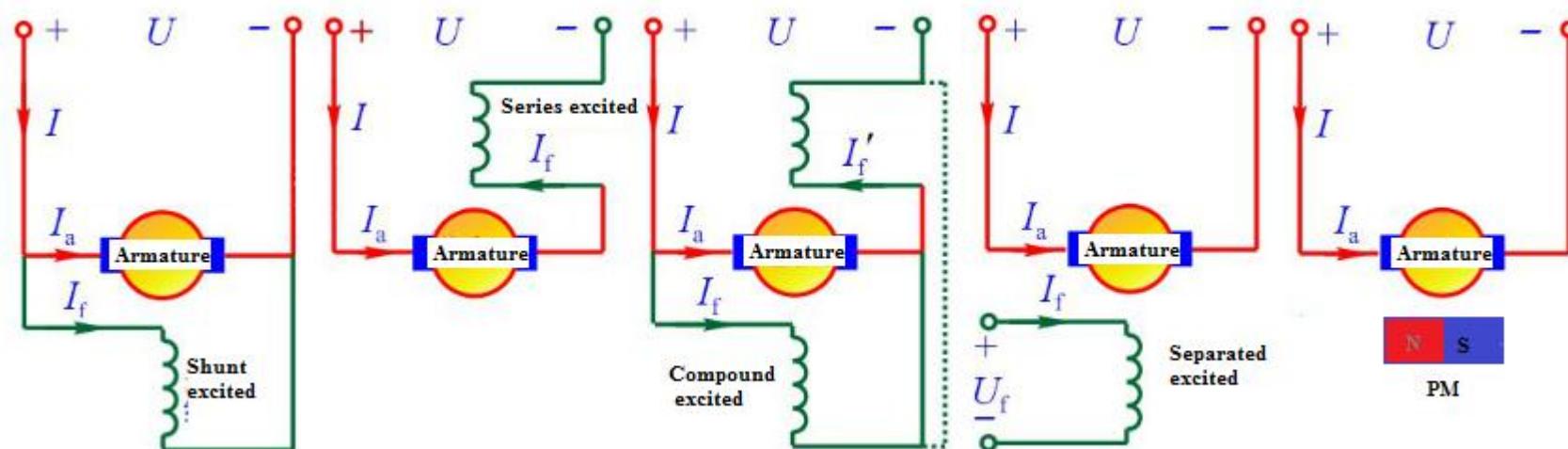
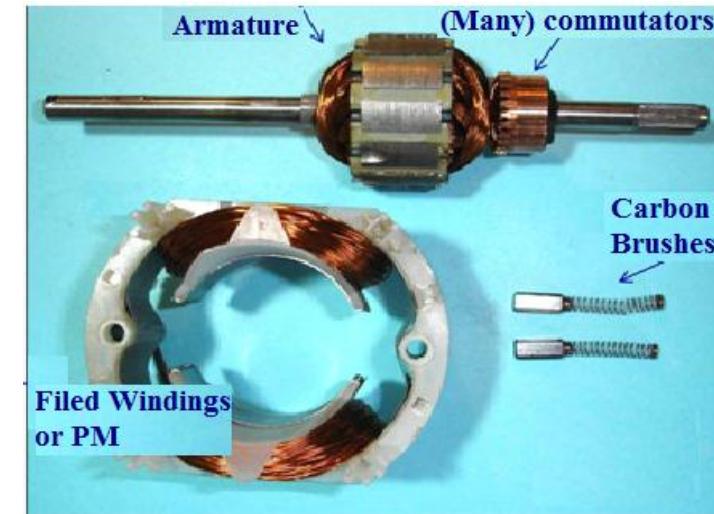
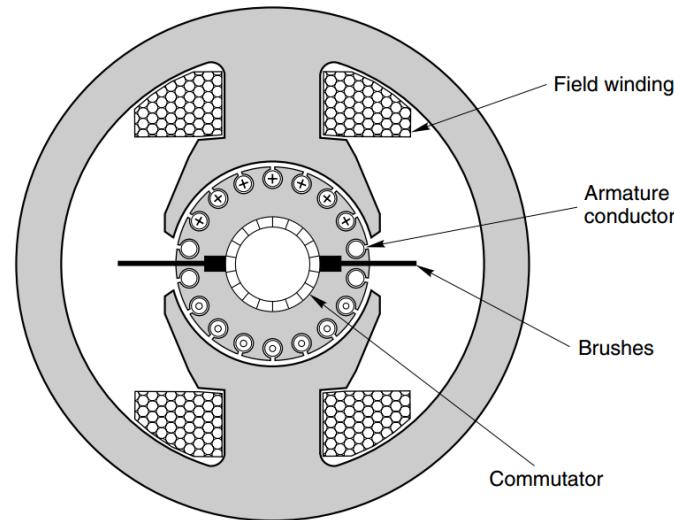
电机分类及主要应用



几种常用电机的对比

	优势	劣势
有刷电机	简单易控 高性价比 启动转矩高	机械换向引起的噪音 机械换向带来的寿命问题 换向电火花 电枢的热量散去
无刷电机	高效率 高功率密度 六步换向控制易实现 FOC控制可实现高精度控制	系统成本高 梯形波反电动势设计困难 正弦波控制算法实现复杂
步进电机	较好的位置精度和重复定位精度 电机旋转角度正比于脉冲数 不同电状态，转子也有锁定力矩 电机停转有最大的保持力矩	速度限制 难以获得较大转矩 输入频率不当引起系统震荡 功率密度低 负载过重的失步问题

有刷电机及分类

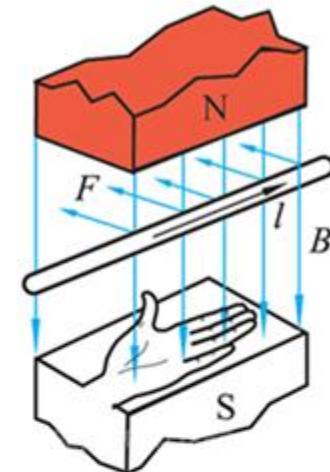


有刷电机- 左手定则和转矩系数

❖Left hand rule and Torque constant

One conductor

$$F = B * I * L$$



One coil

$$T_1 = 2rF = 2rBIL$$

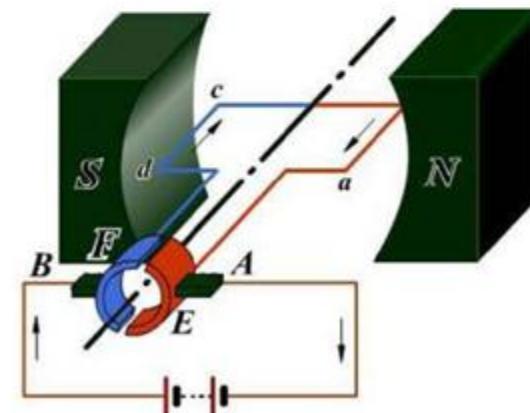
Many conductors (Z_d)

$$T_d = Z_d * T_1 = rZ_d B I L$$

Torque constant

$$K_t = r * Z_d * B * L \text{ (Nm/A)}$$

$$T_d \propto I$$

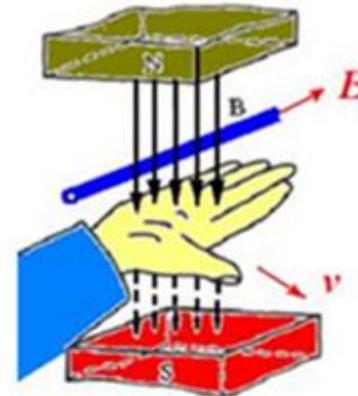


有刷电机- 右手定则和反电势系数

❖ Right hand rule and Back-EMF constant

One conductor

$$E = B \cdot L \cdot v$$



Linear and angular velocity

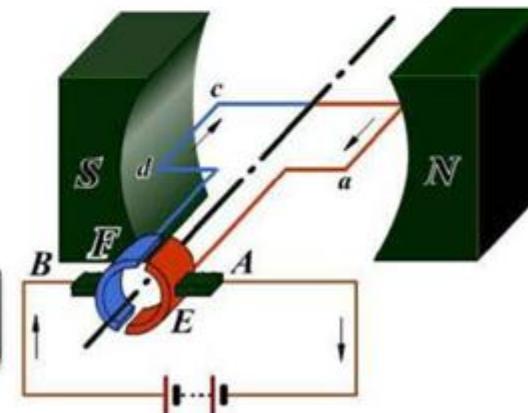
$$v = w \cdot r$$

Many conductors (Z_d)

$$E = w \cdot r \cdot B \cdot L \cdot Z_d$$

Back-EMF constant

$$K_e = r \cdot Z_d \cdot B \cdot L \text{ (V/rad/s)}$$



$$E \propto w$$

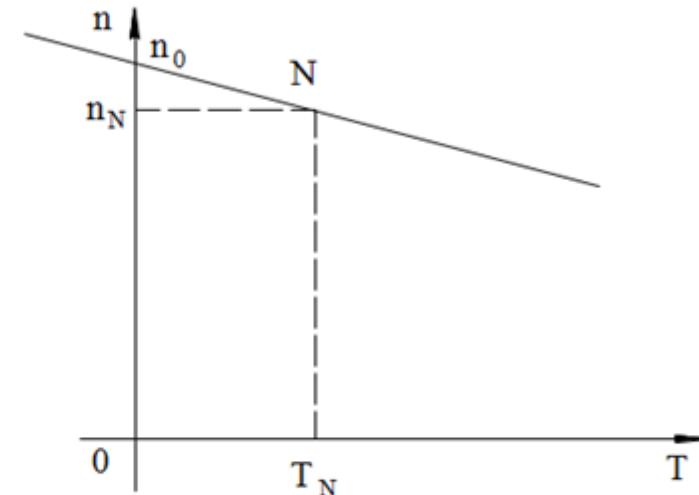
有刷电机 – 基本公式

❖ Basic formula and mechanical behavior

$$E_a = C_e \Phi n$$

$$U = E_a + I_a R_a$$

$$T = C_T \Phi I_a$$



$$n = \frac{U}{C_e \Phi} - \frac{R_a}{C_e C_T \Phi^2} T \quad \Rightarrow$$

Voltage/ resistor/ Field

有刷电机 – 运动方程

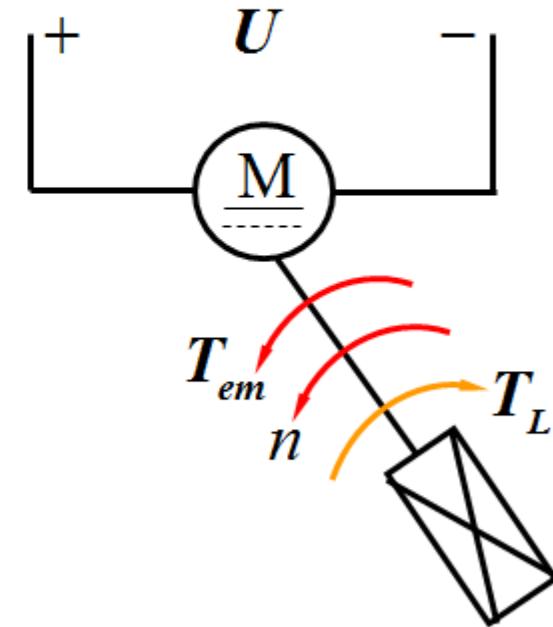
❖ Motion equation

$$T_{em} - T_L = J \frac{d\Omega}{dt}$$

J – Moment of inertia

T_{em} – Electromagnetic torque

T_L – load torque



有刷电机 – 启动和堵转

What is the armature voltage equation when the motor blocks?

$$\omega=0 \rightarrow E=0$$

$$U = RI + E + L \frac{di}{dt} \rightarrow I = \frac{U}{R}$$

If $U=12V$, $R=1\Omega$, $I=12A$

When the motor is blocked, the current is very large.

The motor and driver will break down.

What is the current curve and speed curve when the motor has been starting?

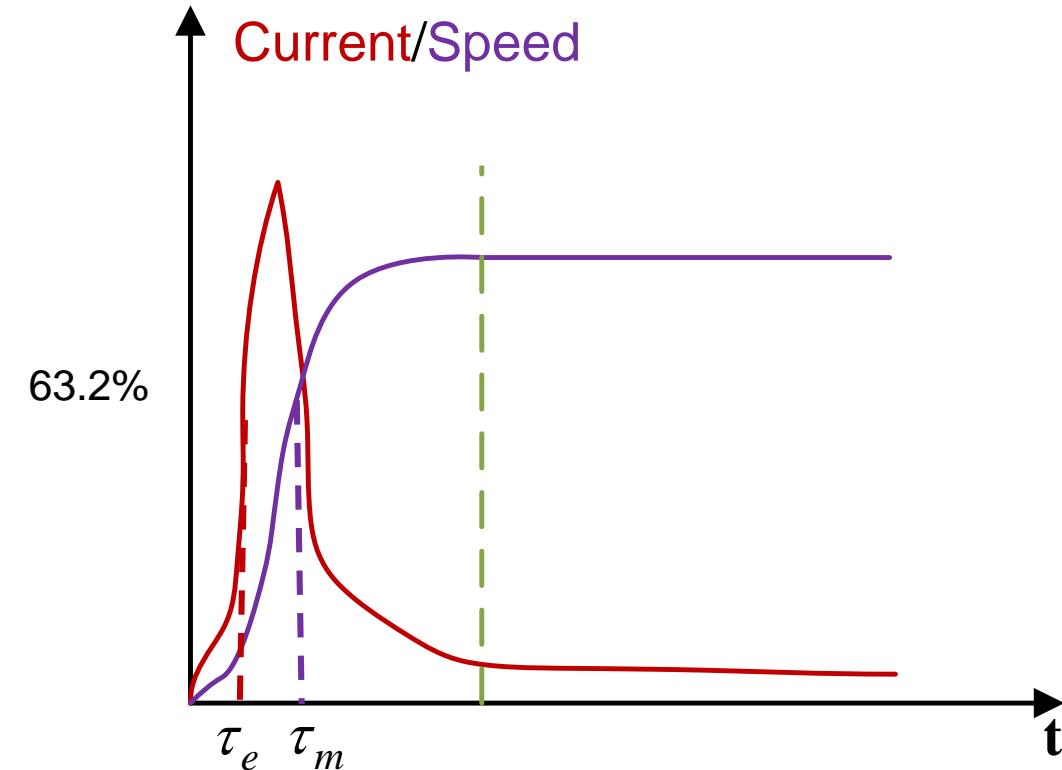
Mechanical equation:

$$T_e - T_L = J \frac{d\omega}{dt}$$

the electrical and electro-mechanical time-constant:

$$\tau_e = \frac{L}{R}$$

$$\tau_m = \frac{JR}{K_T K_E}$$



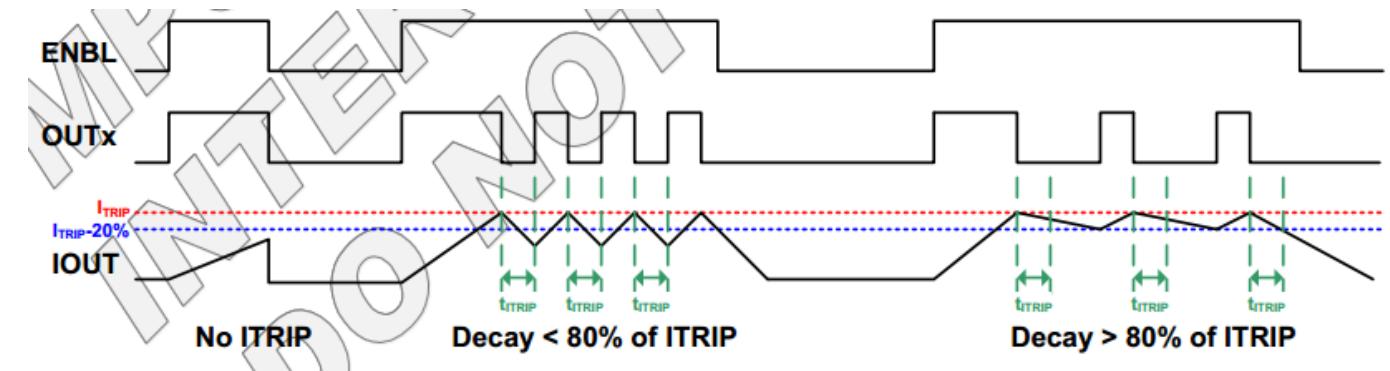
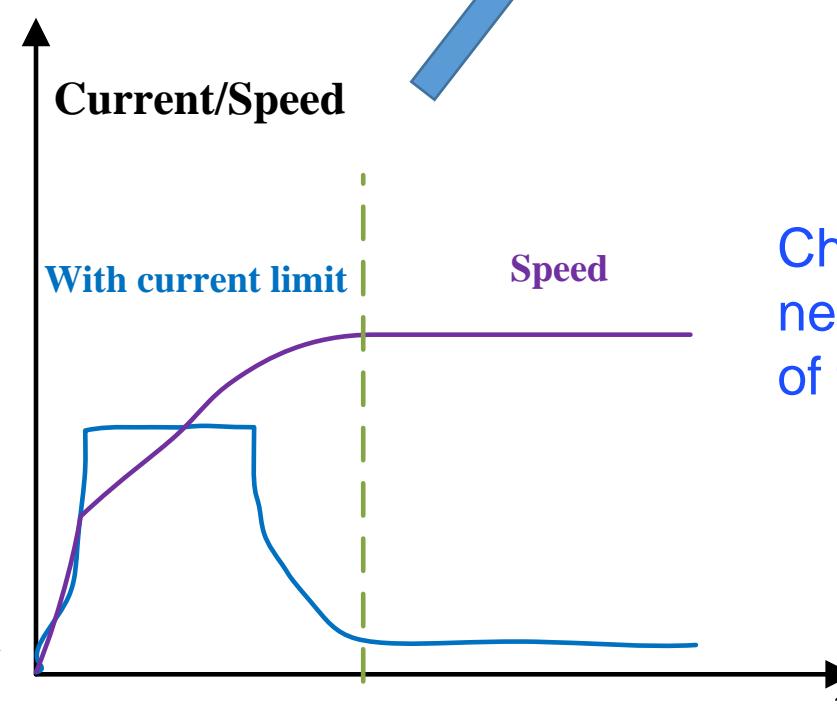
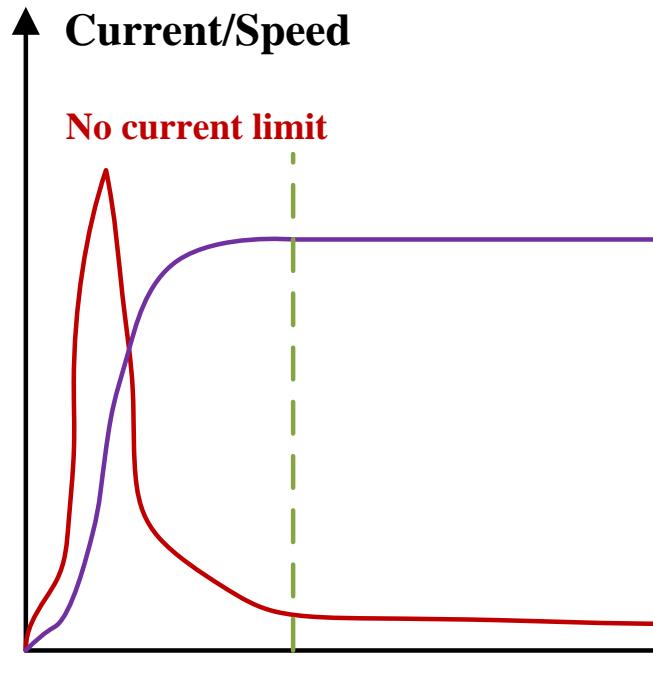
How to reduce the spike of current?

有刷电机 – 软启和电流限制

Used for Blocking and starting.

$$U = RI + E + L \frac{di}{dt} \rightarrow I = \frac{U}{R}$$

$$T_e - T_L = J \frac{d\omega}{dt}$$

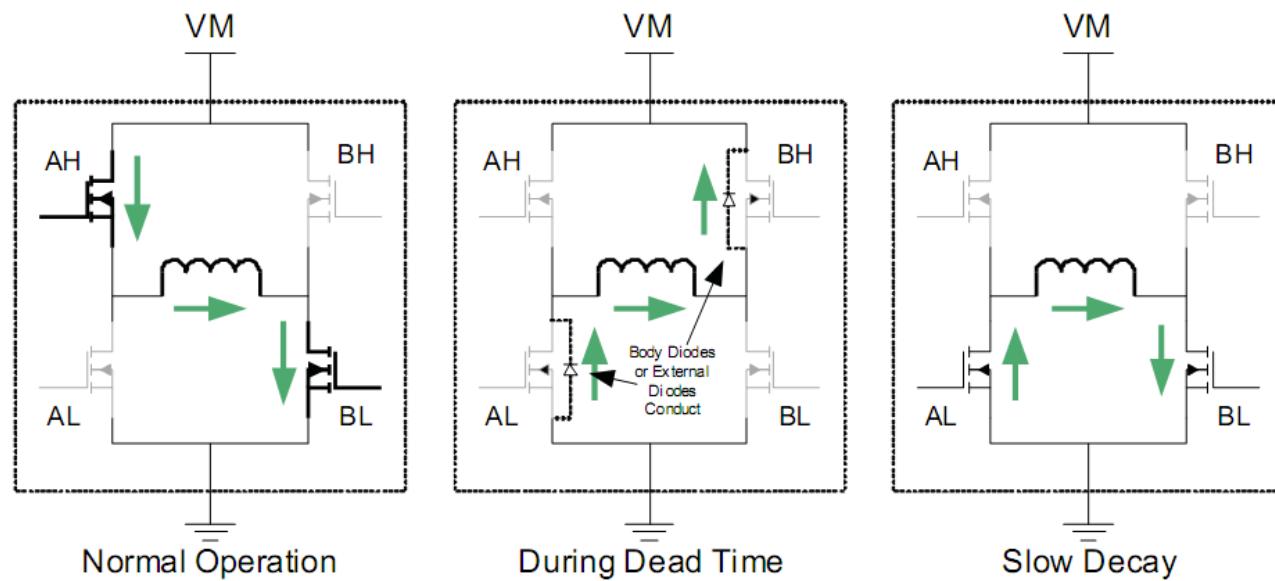
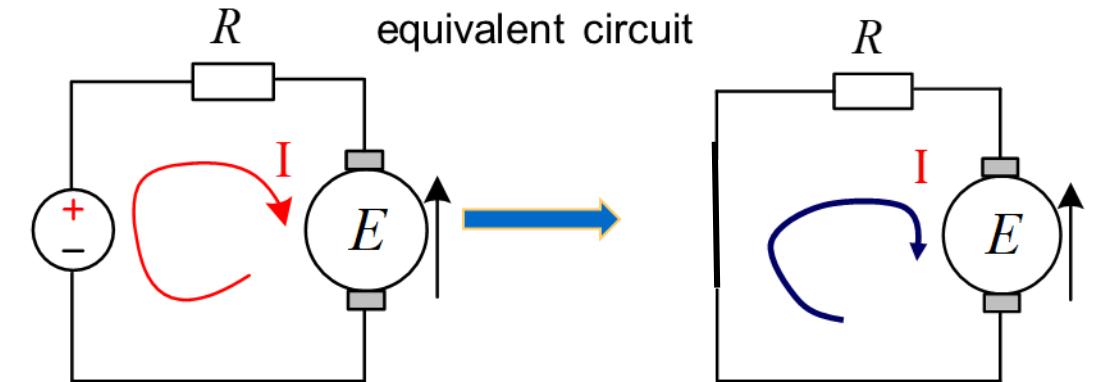


Choosing the value of limited current needs to weigh the response and life of the motor.

有刷电机 – 刹车模式

■ Energy consumption)

Methods: Disable the high side energizing FET
and then enable the opposite low side FET



$$I = -\frac{E}{R}$$

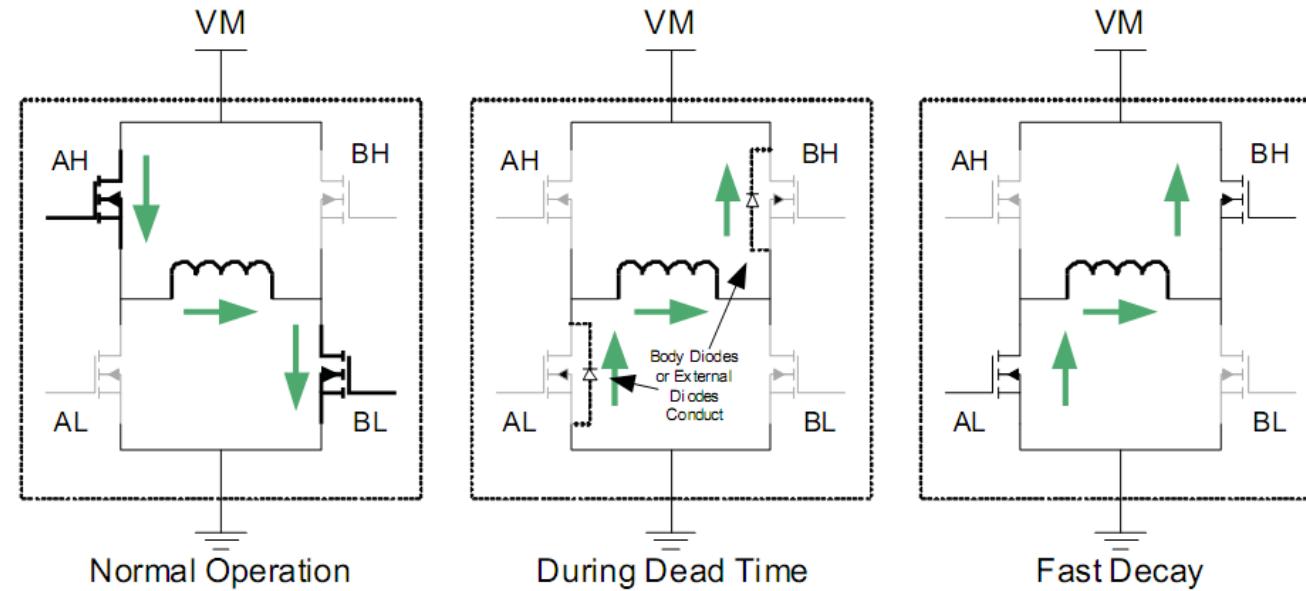
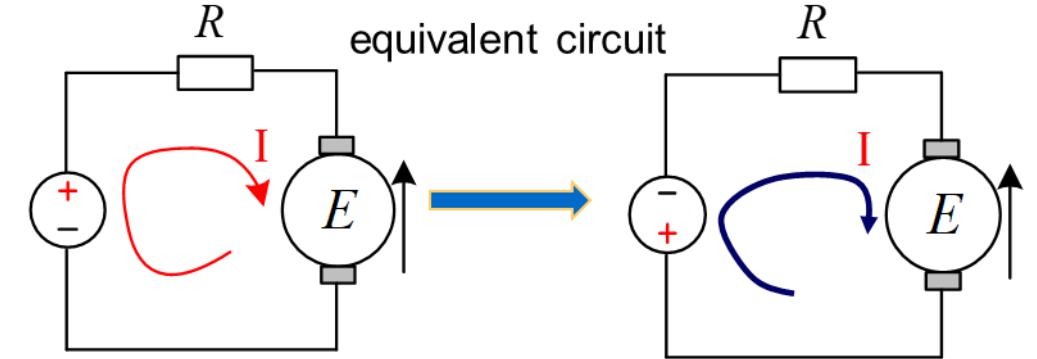
有刷电机 – 刹车模式

■ Reverse braking

Methods: Disable the energizing FETs and then enable the opposite FETs

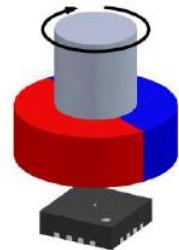
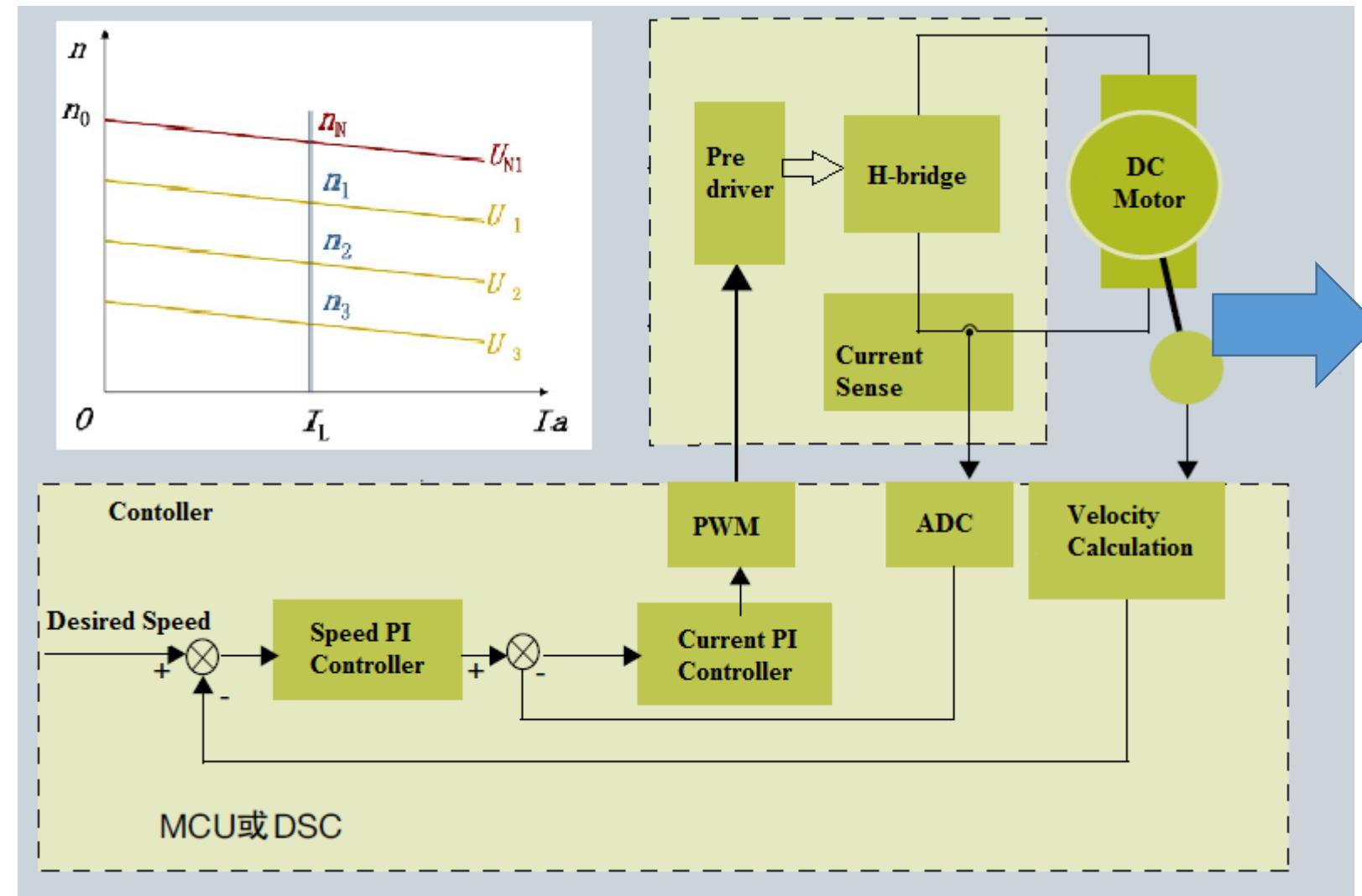
Benefit: Fast response

Drawback: Big energy shocks



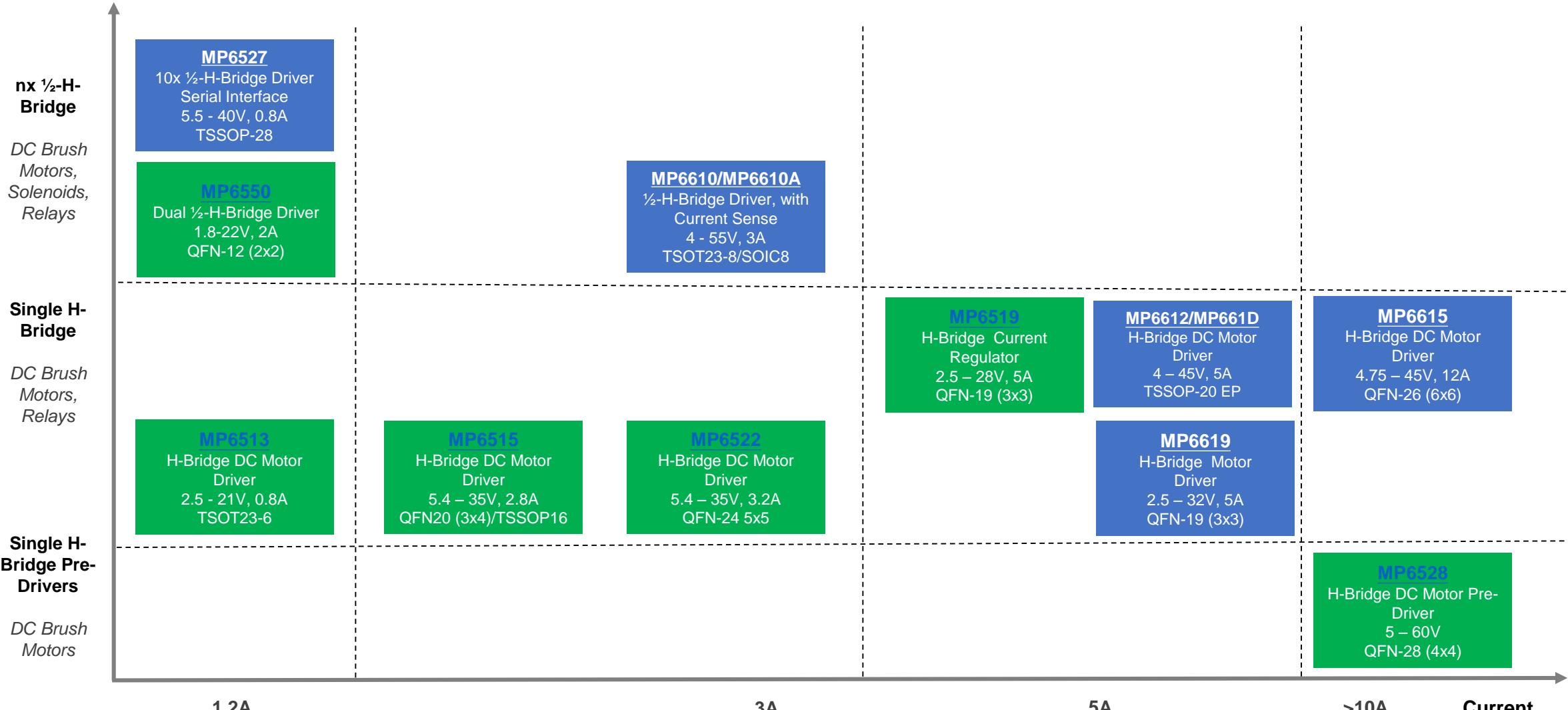
$$I = -\frac{U + E}{R}$$

有刷电机 – 速度控制



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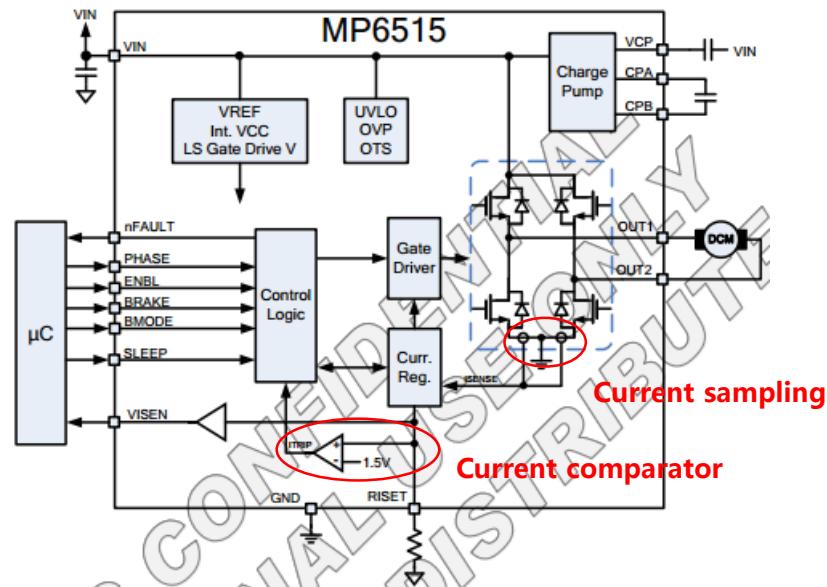
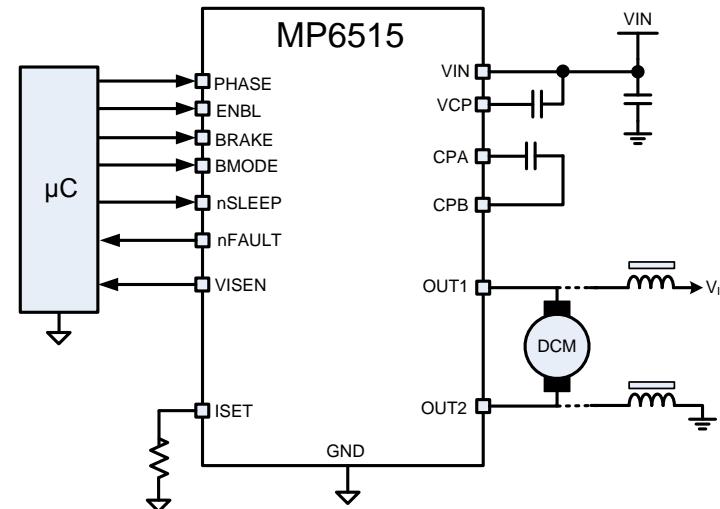
MPS 有刷电机产品



MP6515/16/22 – 24V/50W 解决方案

FEATURES

- Wide 8V to 35V Input Voltage Range
- 2.8A Maximum Output Current
- Internal Full H-Bridge Driver
- Cycle-by-cycle **Current Limit**
- No Control Power Supply Required
- Simple, Versatile Logic Interfaces
- 3.3 and 5 V Compatible Logic Supply
- Overcurrent Protection
- Overvoltage Protection
- Shutdown
- Undervoltage Lockout
- Fault Indication Output
- Thermally Enhanced TSSOP Package



Applications

- Coffee Machines
- Printers
- Currency Handling Equipment
- Solenoid Drivers

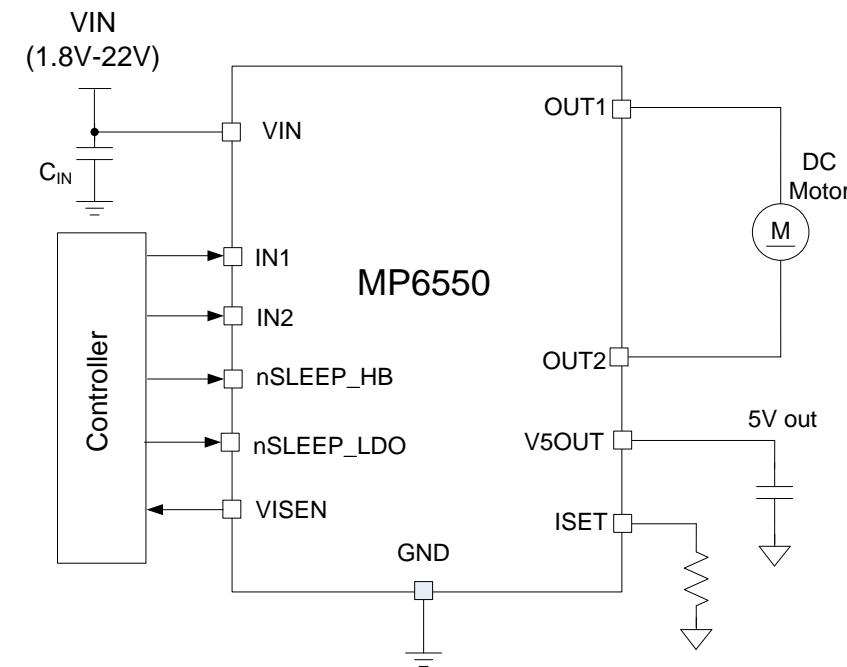
MP6513/13L/6550 12V/20W解决方案

FEATURES

- Internal Dual $\frac{1}{2}$ -H-Bridge Driver
- 1.8V – **22V** Supply Voltage Range
- **2A** Continuous Output Current (**3A Peak**)
- Integrated LDO Voltage Regulator(50mA)
- MOSFET On-Resistance: 100mohm / FET

Applications

- Robotics
- Toys
- Cameras
- Medical Devices



	V5OUT	nSLEEP_LDO	IN1	12	11	10	IN2
VIN							OUT2
OUT1							GND
ISET							nSLEEP_HB
nFAULT							VISEN

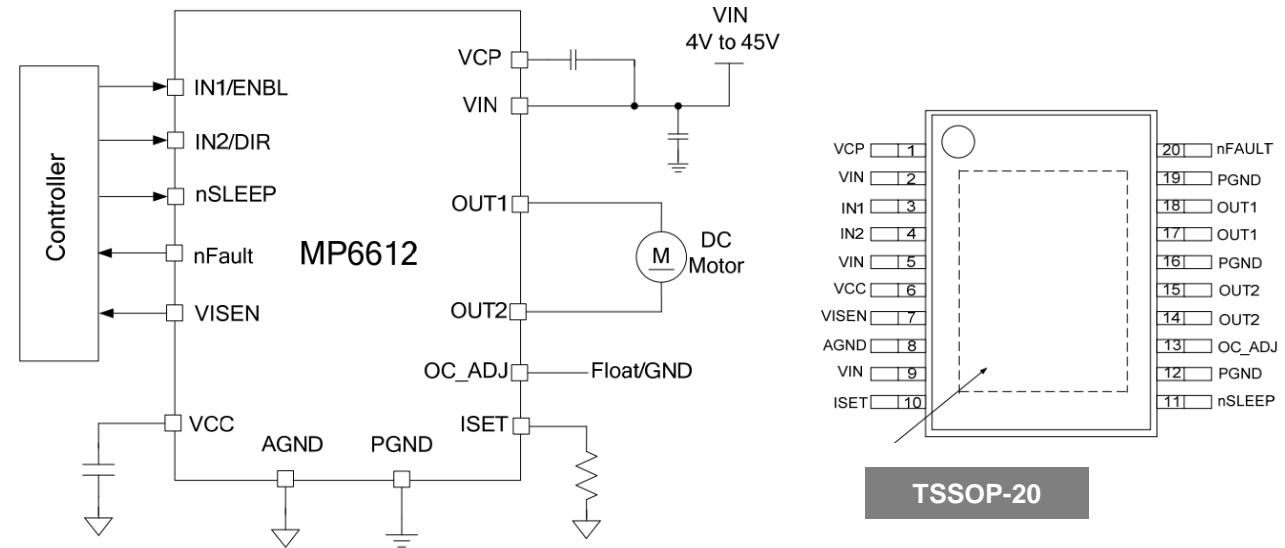
QFN12 2x2

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MP6612/MP6612D –24V/120W 解决方案

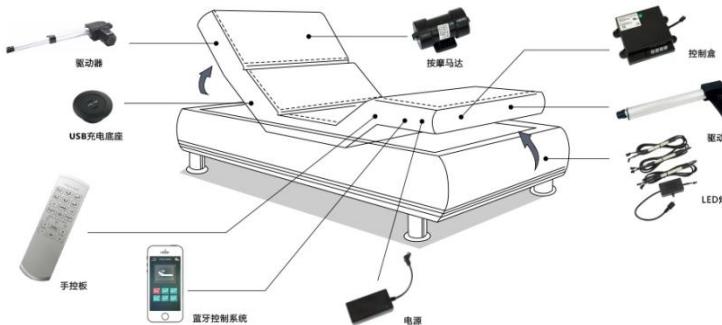
FEATURES

- Constant-current H-bridge Driver
- MP6612: Wide 4V to 45V**
- MP6612: 5A continuous (12A peak)**
- Cycle-by-cycle Current Regulation / Limit
- 65mΩ Rdson for Each FET of H-Bridge
- 1µA Shutdown Mode



Applications

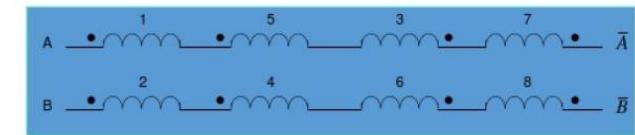
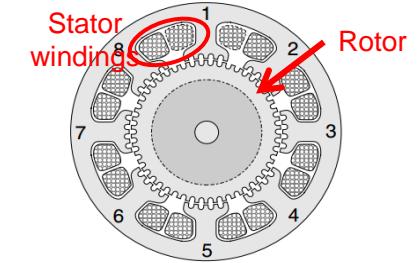
- DC Motors
- Solenoid/Valve Drivers



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步进电机（两相）-结构及分类

➤ Motor Structure



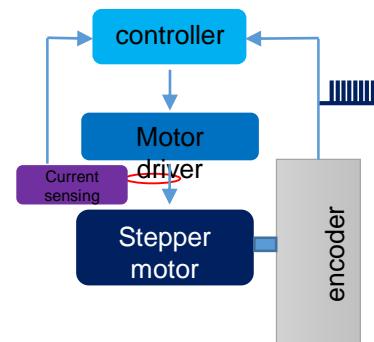
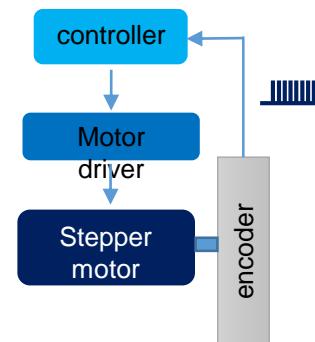
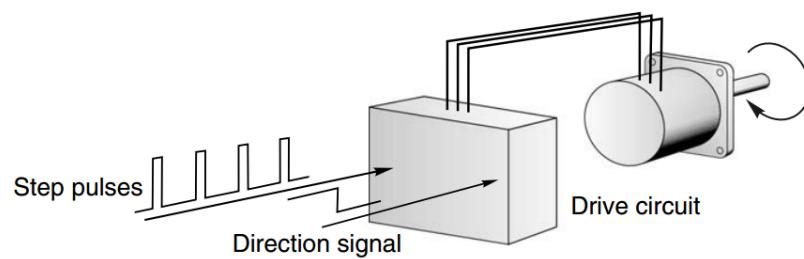
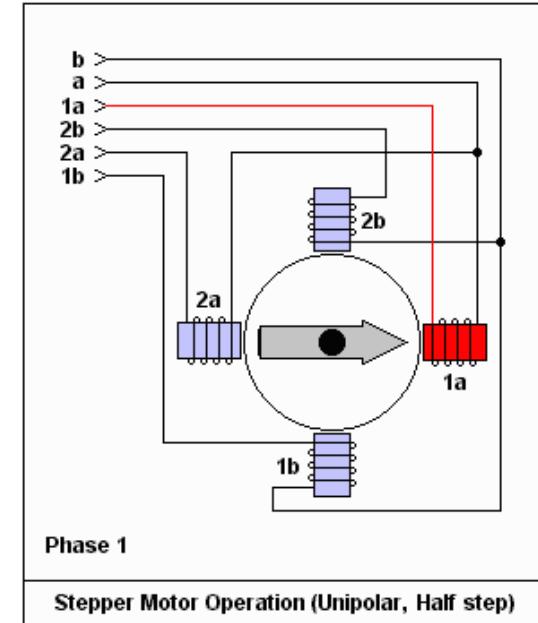
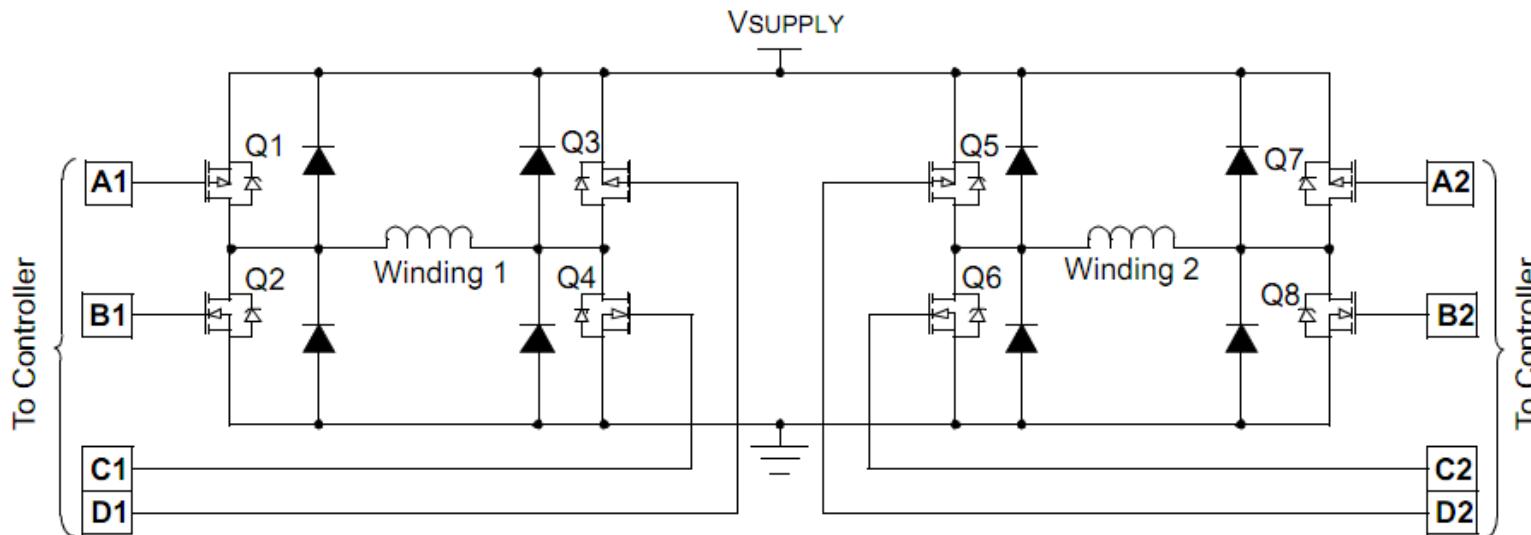
➤ Classification

VR

PM

Hybrid

步进电机（两相） - 驱动及控制



步进电机（两相） - 细分控制

The following are the most common drive modes:

◆ *Wave Drive(1 phase on)*

Only one winding is energized at any given time

◆ *Full Step Drive(2 phases on)*

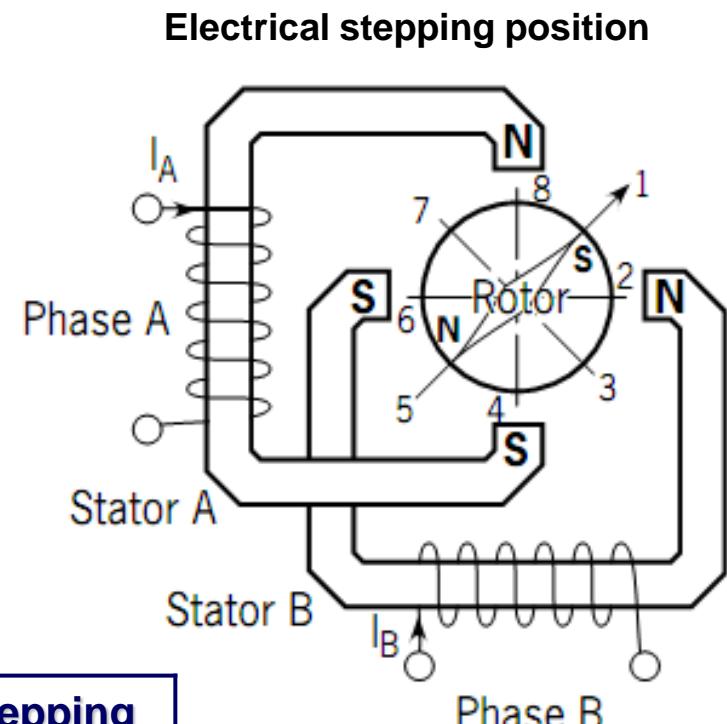
Energizing two phases at any given time

◆ *Half Step Drive(1 & 2 phases on)*

Combines both wave and full step modes

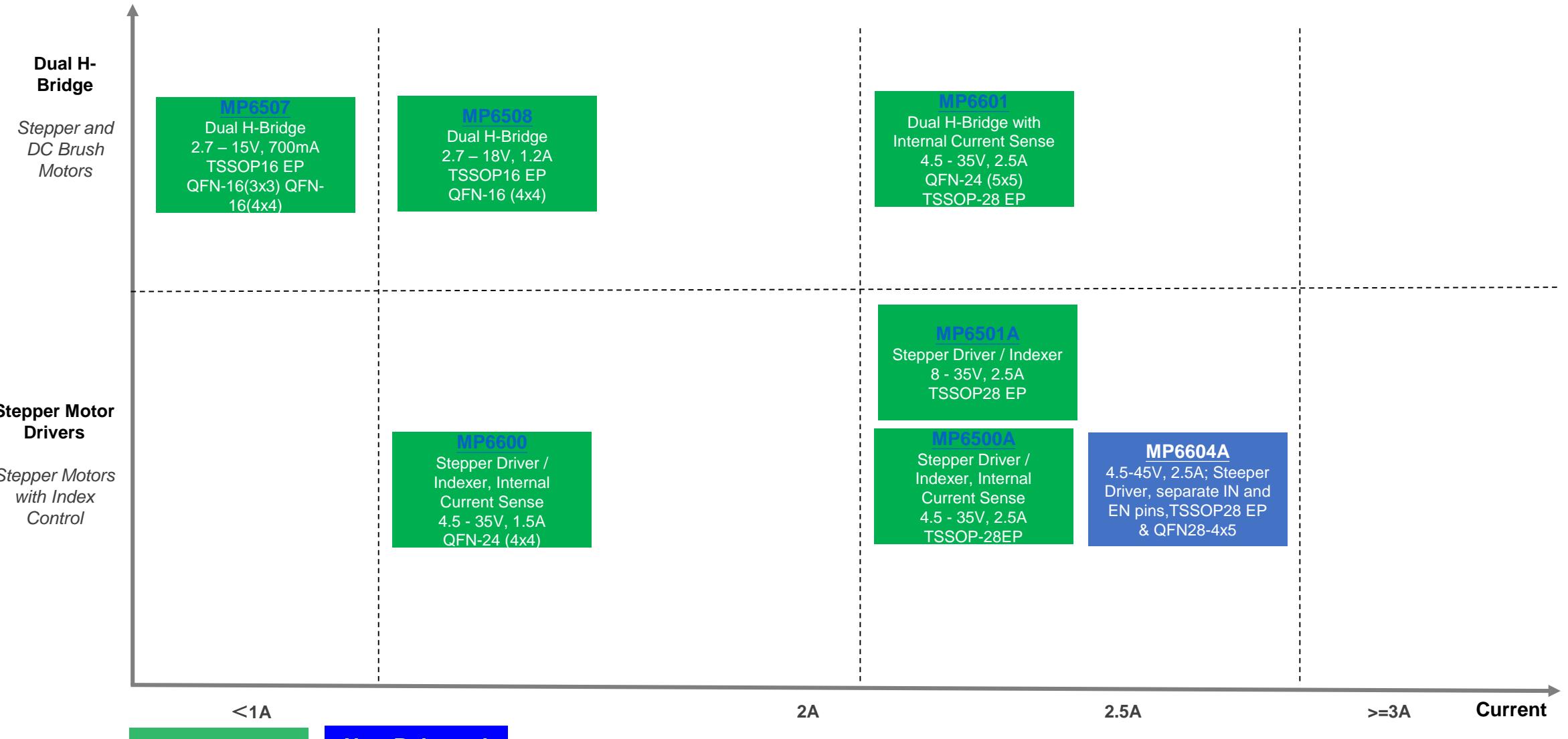
◆ *Microstepping(Continuously varying motor currents)*

Winding current continuously varies to be able to break up one full step into many smaller discrete steps



Stepping Mode	Sequence	Electrical Stepping Position
Wave Drive	A → B → <u>A</u> → <u>B</u>	8 → 2 → 4 → 6
Full Step Drive	AB → <u>AB</u> → <u>AB</u> → <u>AB</u>	1 → 3 → 5 → 7
Half Step Drive	AB → B → <u>AB</u> → <u>A</u> → <u>AB</u> → <u>B</u> → <u>AB</u> → <u>A</u>	1 → 2 → 3 → 4 → 5 → 6 → 7 → 8

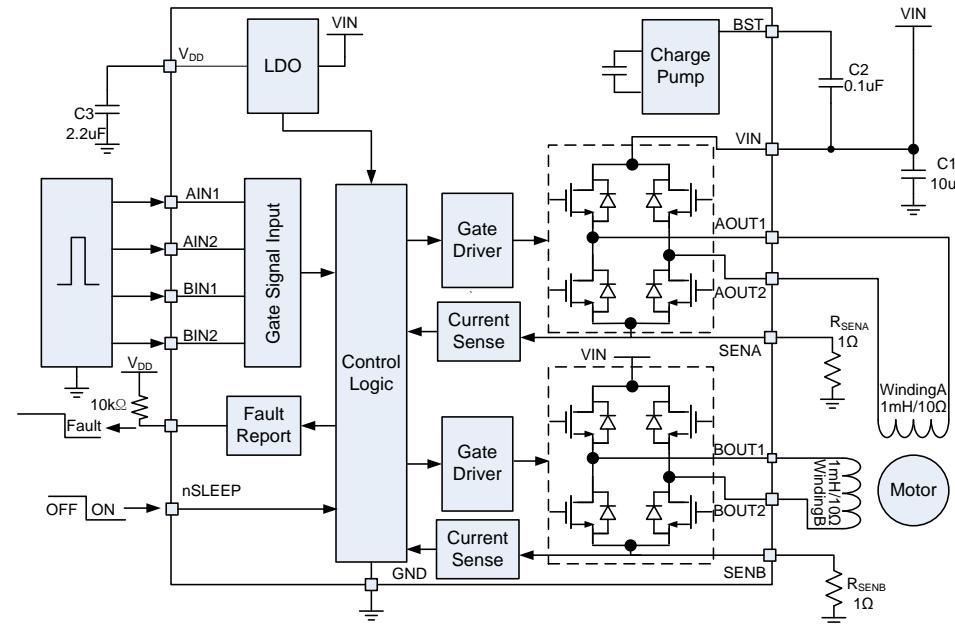
MPS 两相步进电机产品



MP6507双H桥产品及应用

FEATURES

- Two Internal Full-Bridge Drivers
- 2.7V - 15V Supply Voltage Range
- Output Current:
 - MP6506 – 500mA
 - MP6507 – 700mA
 - MP6508 – 1.5A
- Internal Gate Drive Charge Pump
- Low Quiescent Current: 1mA
- Low Sleep Current: 1µA
- Sink and Source Over-Current Protection
- Thermal Shutdown and Under-Voltage Lockout Protection
- Over-Temperature Output Flag
- Thermally-Enhanced QFN & TSSOP Packages



Applications

- Bipolar Stepper Motors
- DC Brush Motors
- Thermal Printers
- POS Terminals
- Cameras

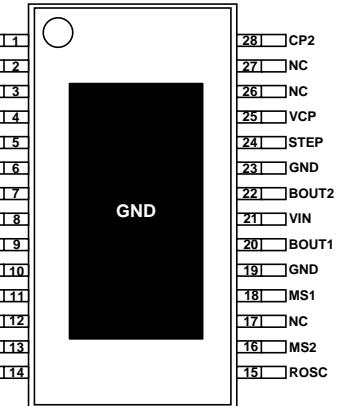
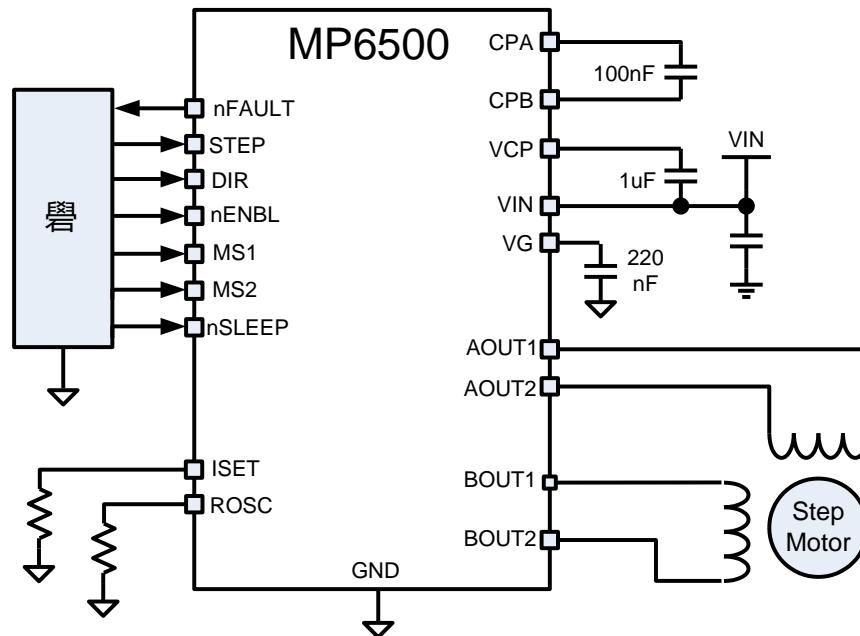


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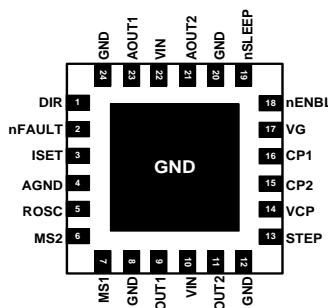
MP6500A步进开环及半闭环应用

FEATURES

- Dual Internal Full Bridge Driver
- 4.5V - 35V Supply Voltage Range
- 2.5A Output Current (MP6500, TSSOP & 5mm x 5mm QFN) (MP6500A TSSOP)
- 1.5A Output Current (MP6600, 4mm x 4mm QFN)
- Internal Current Sensing and Regulation
- Indexer supports up to 1/8-step
- Low On Resistance (HS:170mΩ;LS:150mΩ)
- Automatic Current Decay
- Low Power sleep mode



TSSOP28-EP



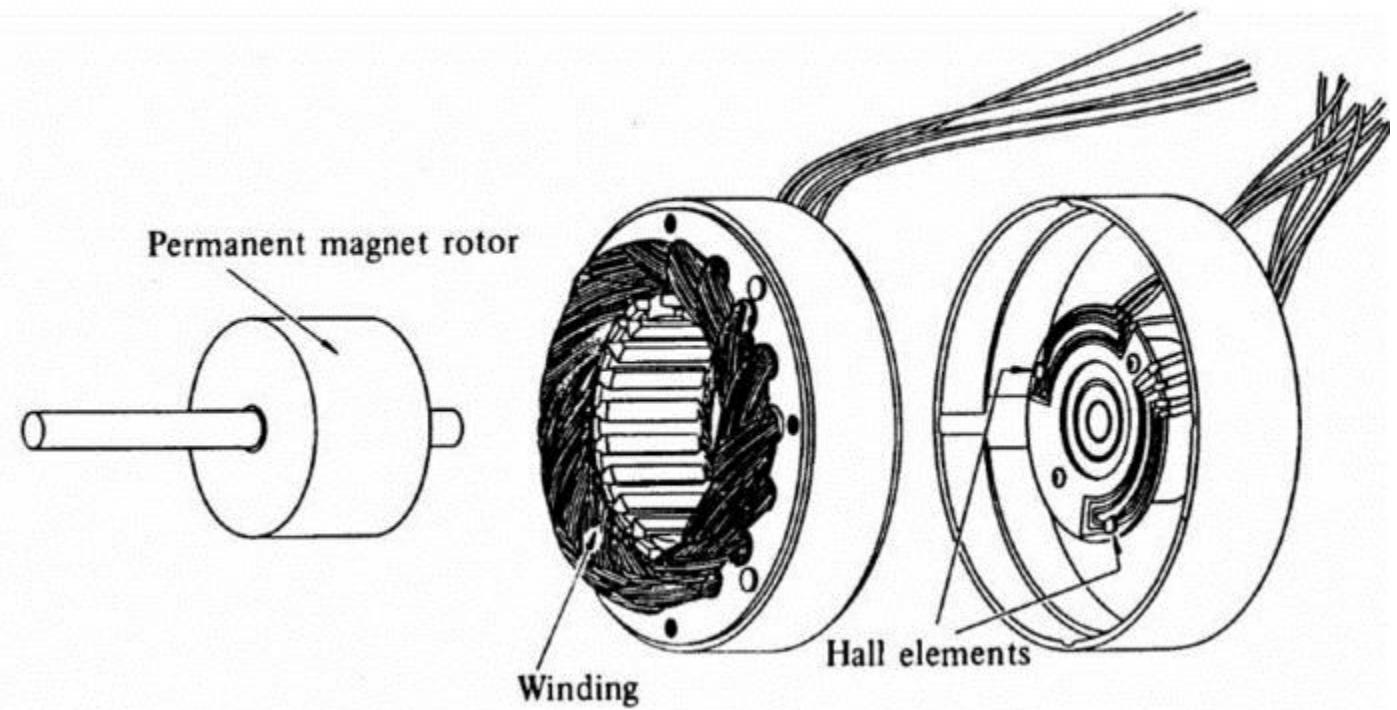
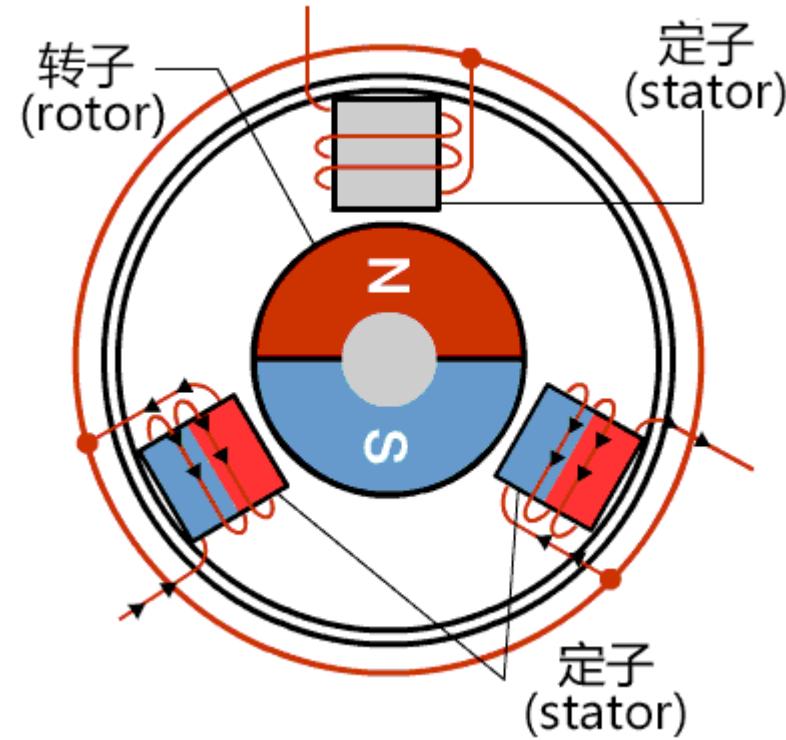
QFN4X4-24 (MP6600)
QFN5X5-24 (MP6500)



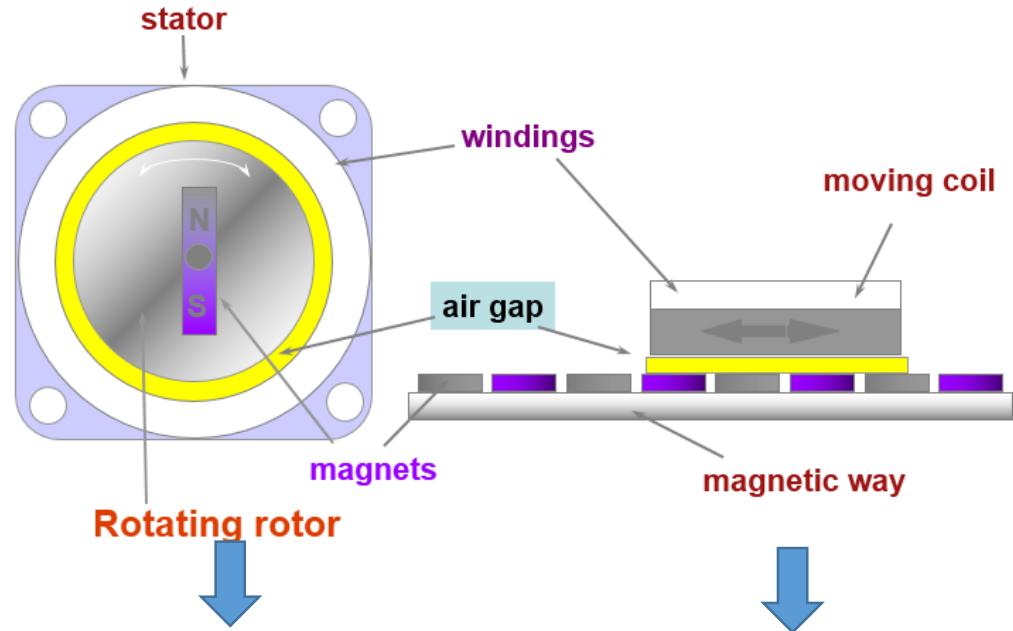
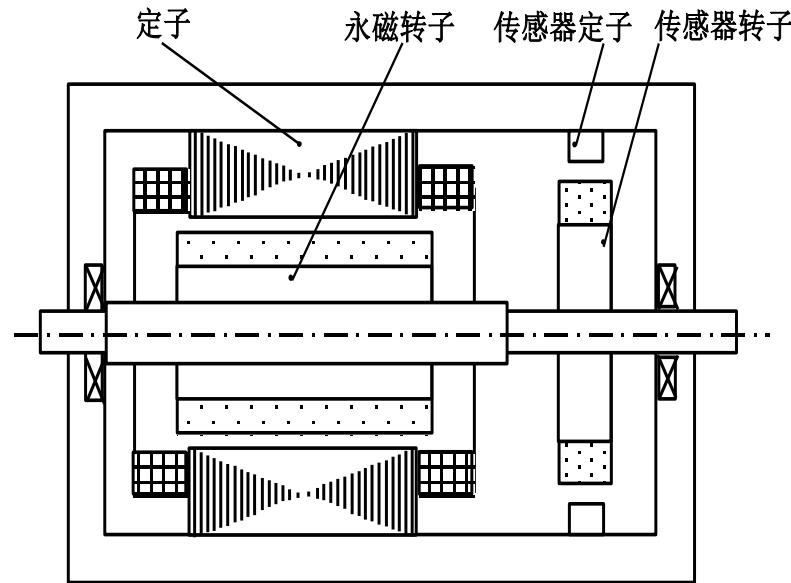
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永磁直流无刷电机

Brushless motor is a motor with permanent-magnet rotor and a wound stator



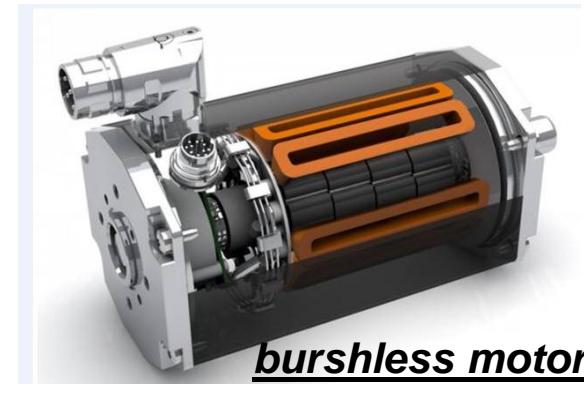
永磁直流无刷电机 – 结构



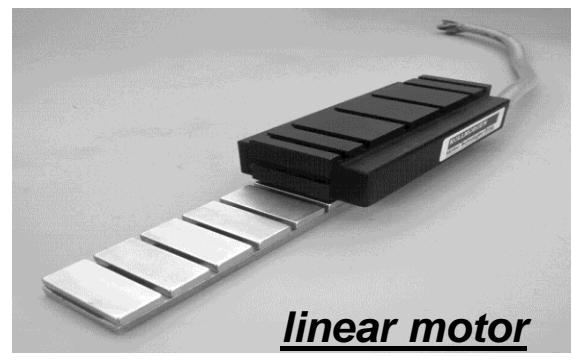
Inner rotor motor



Outer rotor motor



brushless motor



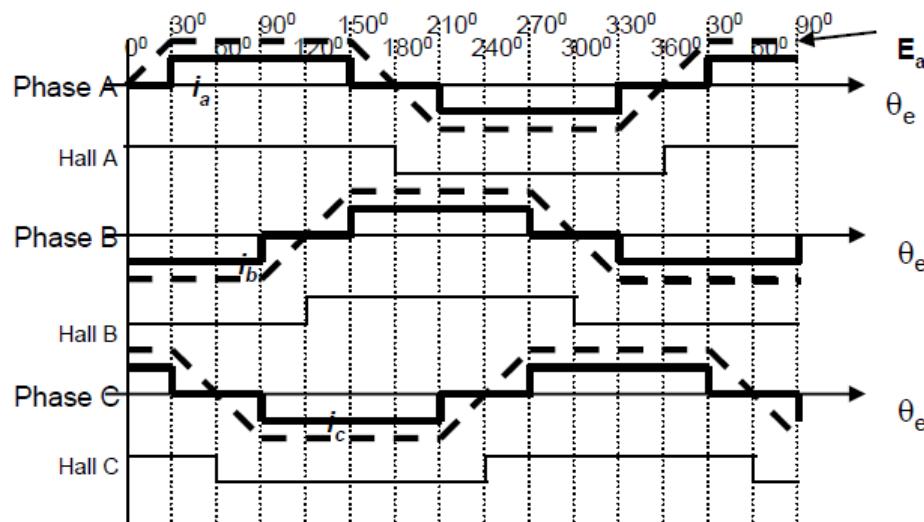
linear motor

永磁直流无刷电机：BLDC VS. PMSM

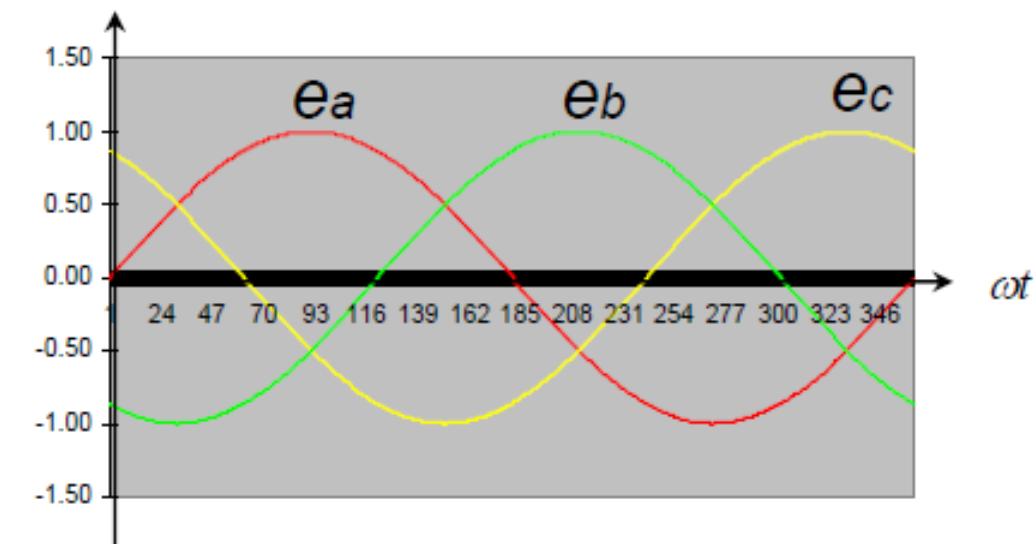
BLDC : 无刷直流电机 (Brushless Direct Current)

PMSM : 永磁同步电动机 (Permanent-Magnet Synchronous Motor)

Both (typically) have permanent-magnet rotor and a wound stator, but BLDC is a PM brushless motor with trapezoidal back EMF and PMSM is a PM brushless motor with sinusoidal back EMF.



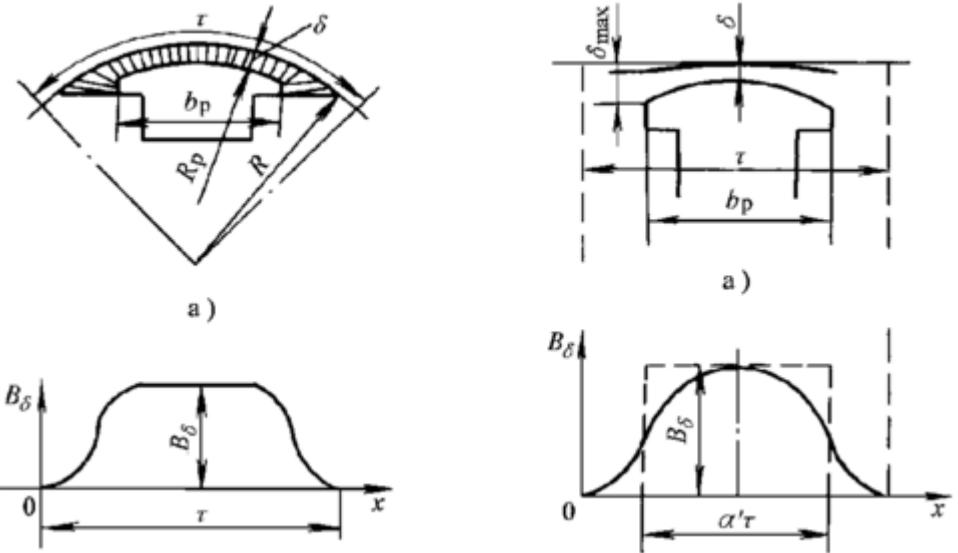
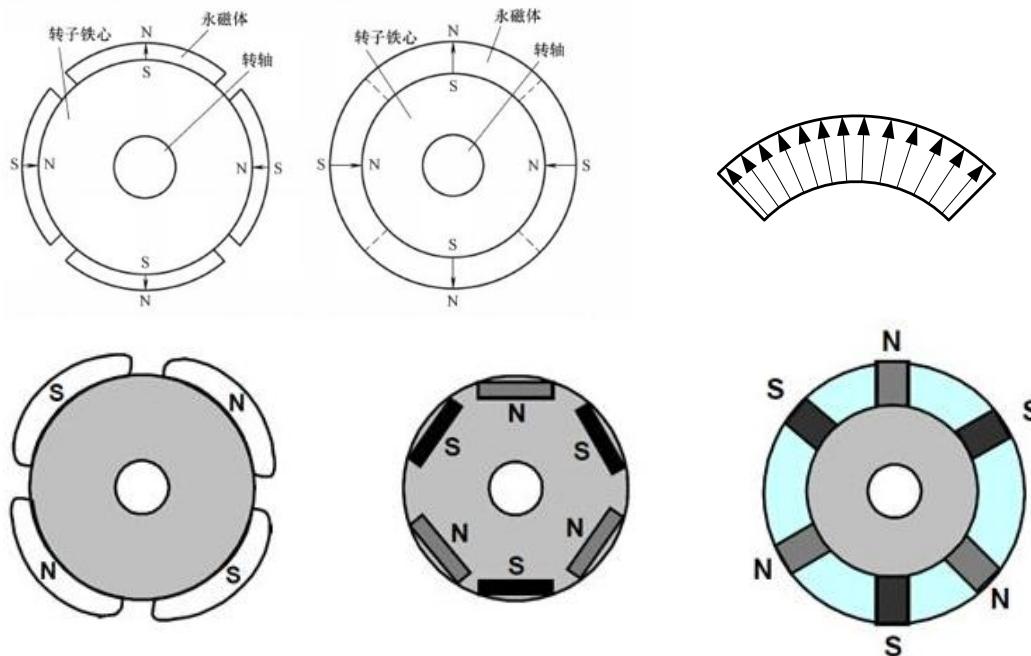
Back EMF of BLDC Motor



Back EMF of PMSM

永磁直流无刷电机：BLDC VS. PMSM

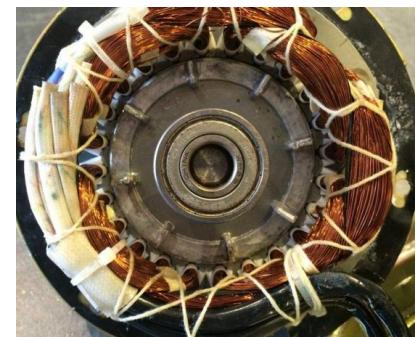
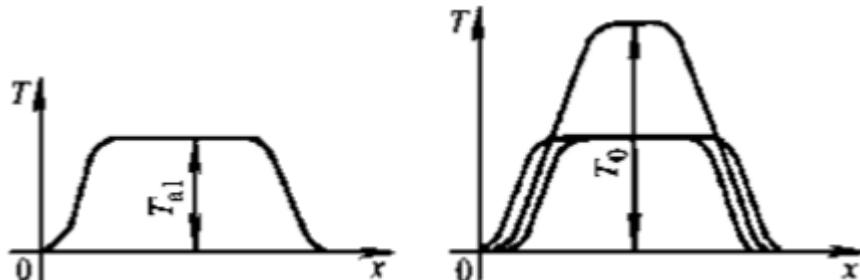
❖ Magnet shape



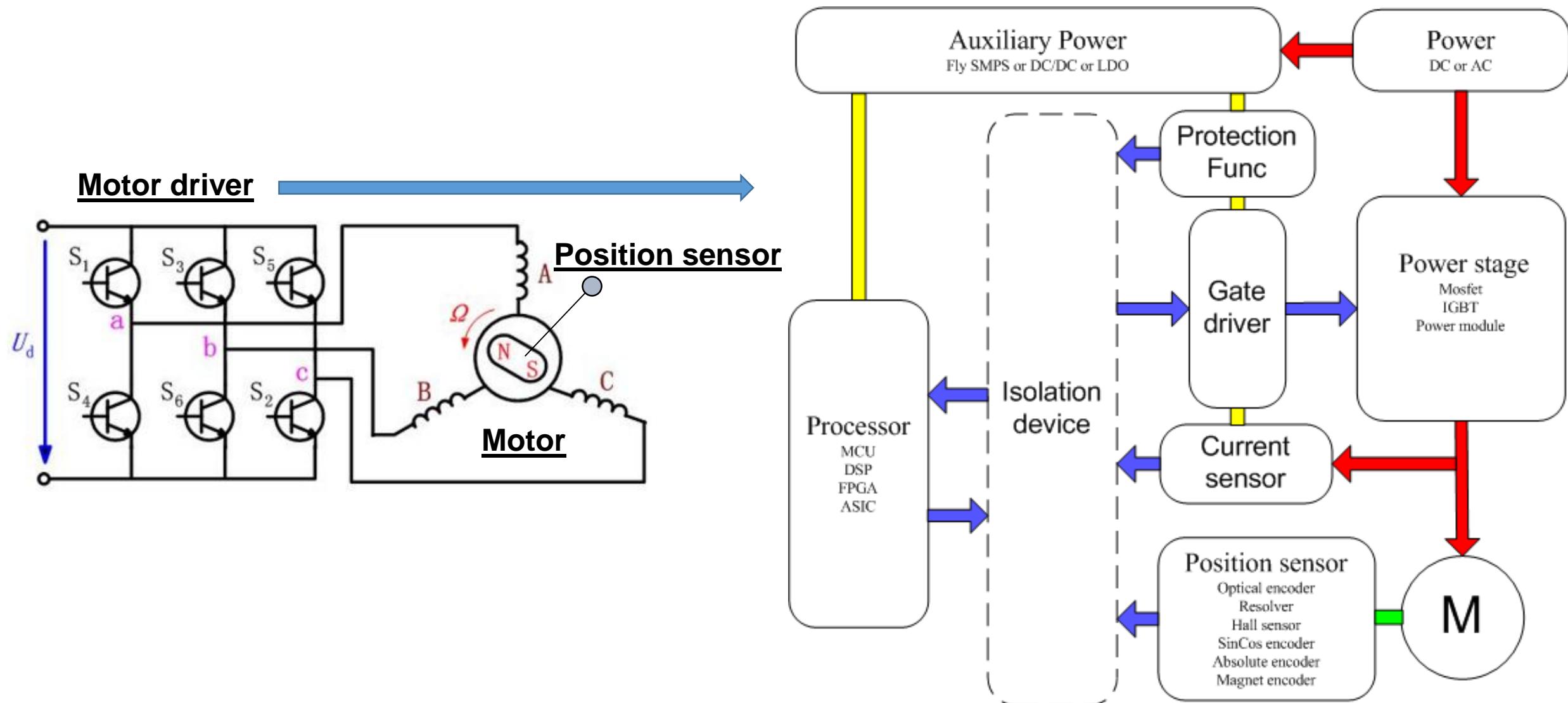
❖ Winding type

$$Q = Z/2mP$$

$$y = Z/2P$$

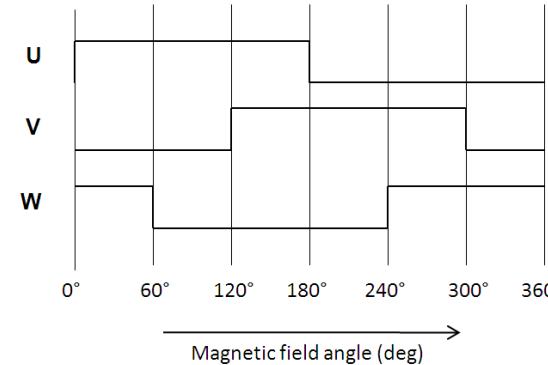
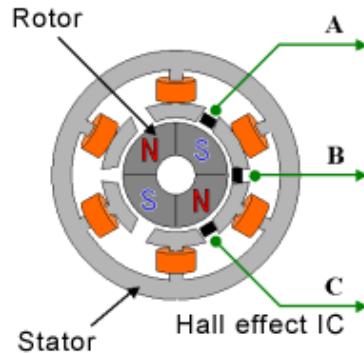


永磁直流无刷电机控制拓扑： BLDC VS.PMSM

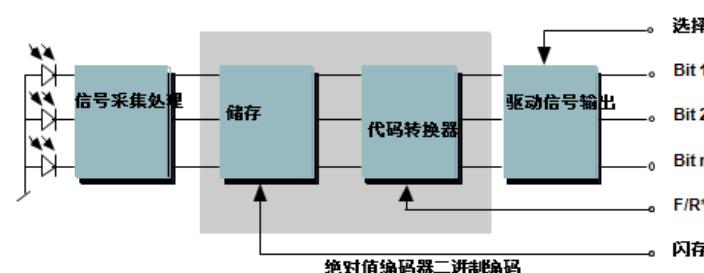
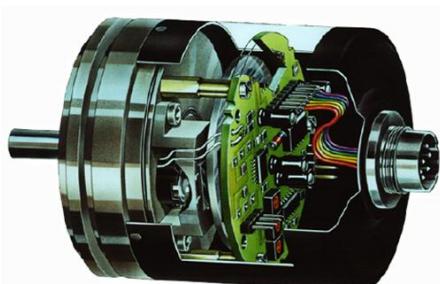
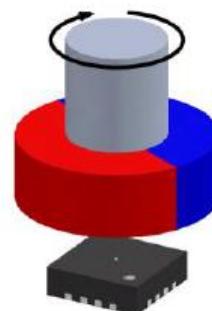
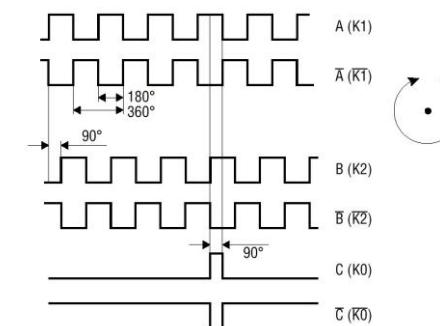
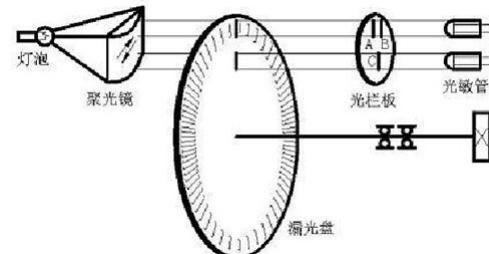


永磁直流无刷电机反馈：BLDC VS. PMSM

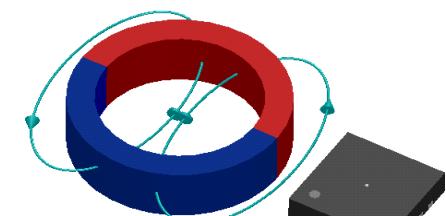
❖ 3 Hall sensor



❖ Incremental encoder or absolute encoder



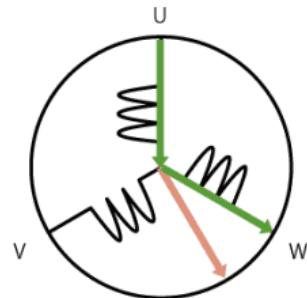
机械工业出版社
http://www.cmpbook.com



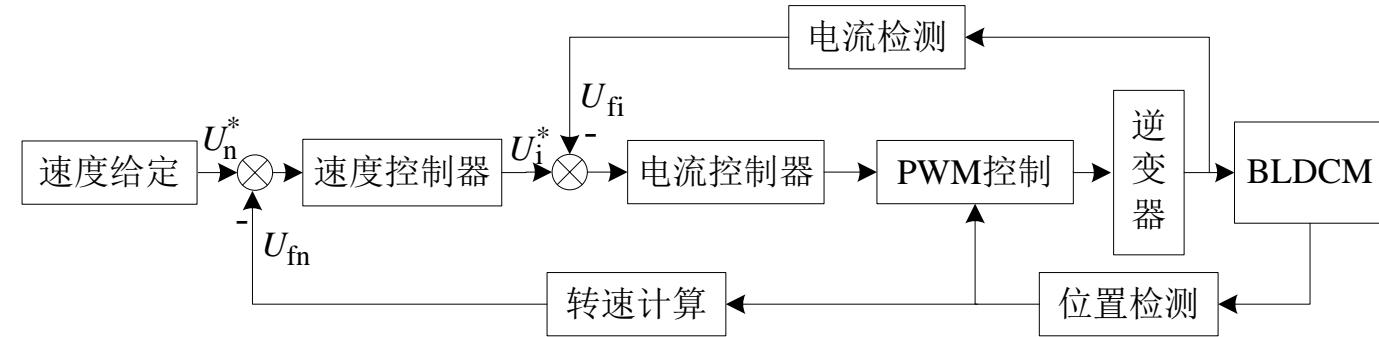
MPS

永磁直流无刷电机控制：BLDC VS. PMSM

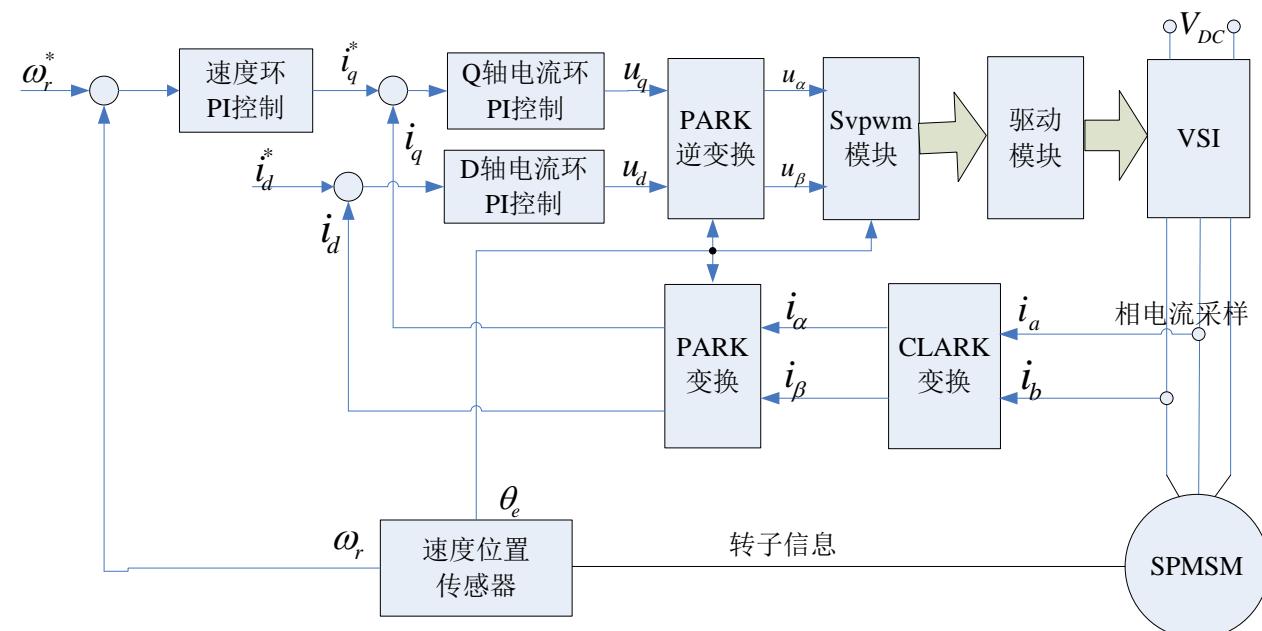
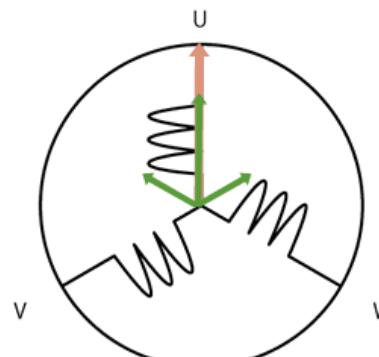
❖ BLDC



通电模式	通电相位	合成磁通
1	U → W	↓
2	U → V	↗
3	W → V	↖
4	W → U	↗
5	V → U	↖
6	V → W	↖

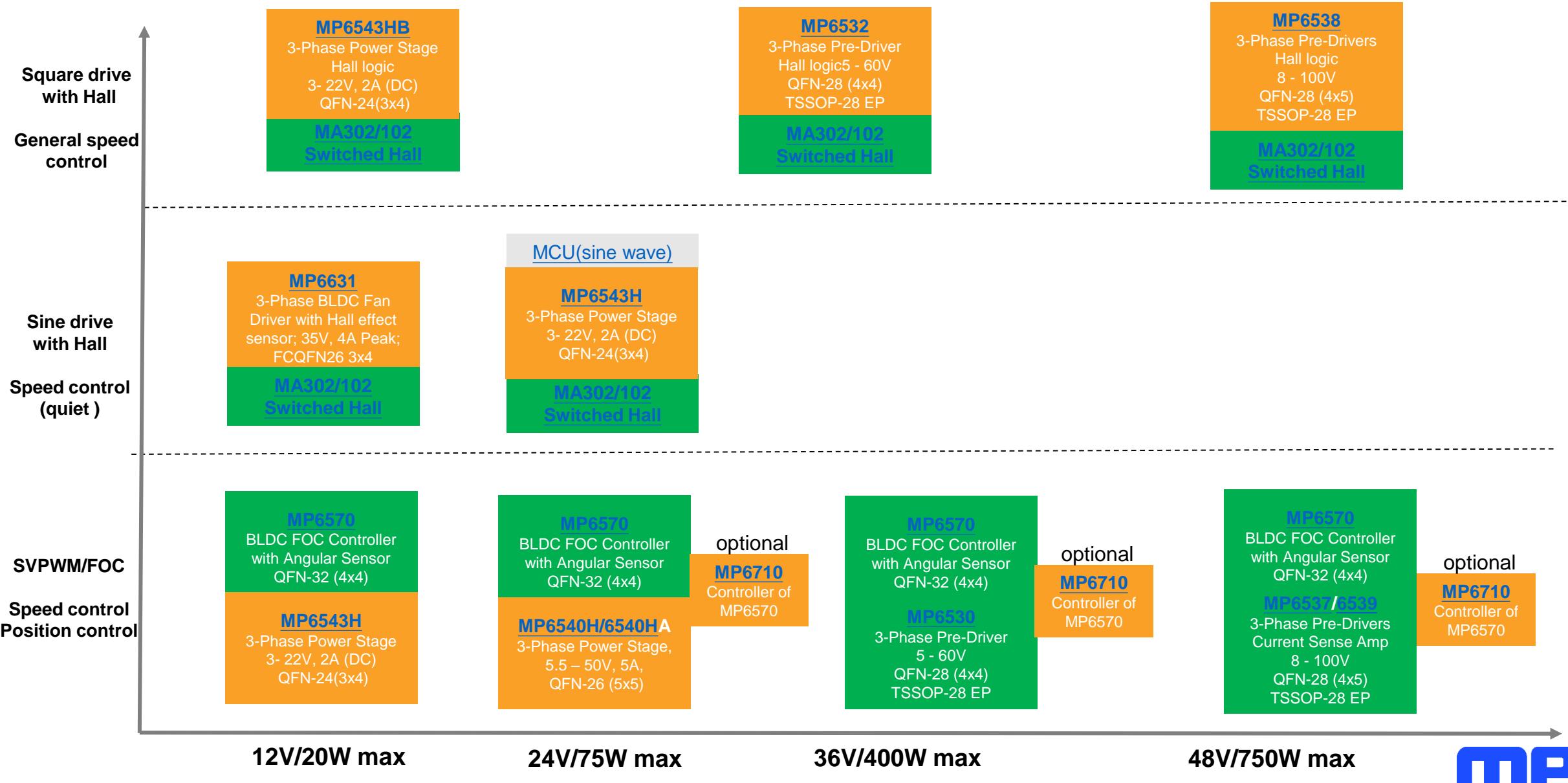


❖ PMSM



mPS

BLDC solution



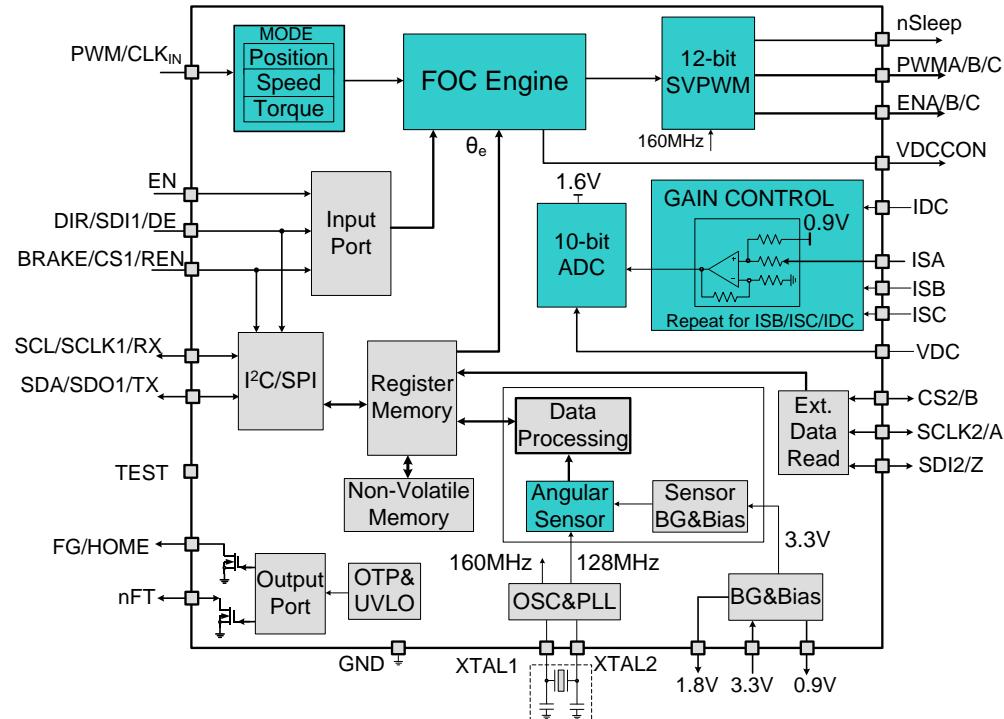
MP6570 一体化电机集成方案

Features

- 3.3V Typical Vcc
- 13-14bit Resolution Angle Sensor
- FOC Control
- Position/Speed/Torque Mode
- I2C/SPI/RS485 Interface
- PWM/Clock Input Mode
- 10-bit ADC w/ Programmable Gain
- 1kHz to 80kHz Switching Frequency
- Selectable Internal/External Oscillator
- Support External Sensor Input
- 16 Programmable Slaver Address
- Non-Volatile Memory
- Standby Mode
- Coasting/Fast/Close-Loop Brake Mode
- Input-Bus Voltage & Current Protection
- OCP/Lock/Power Stage Fault Protection

Applications

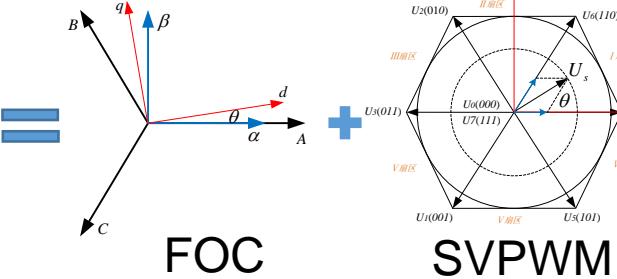
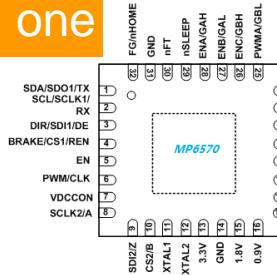
- 3-phase BLDC motor
- 3-phase PMSM motor



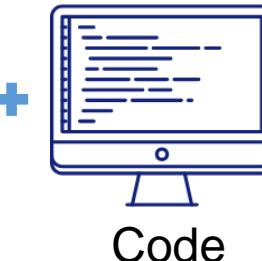
MP6570 一体化电机集成方案

Easy to Design

All in one



FOC



SVPWM



Code



Encoder

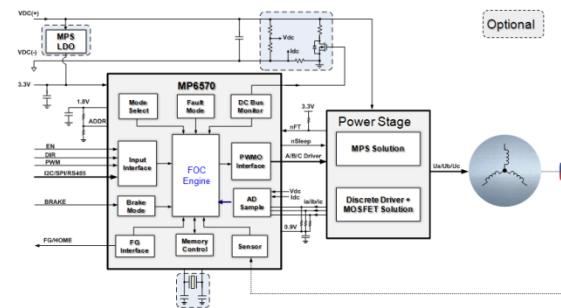
Small package

QFN 4X4 - 32



Friendly GUI

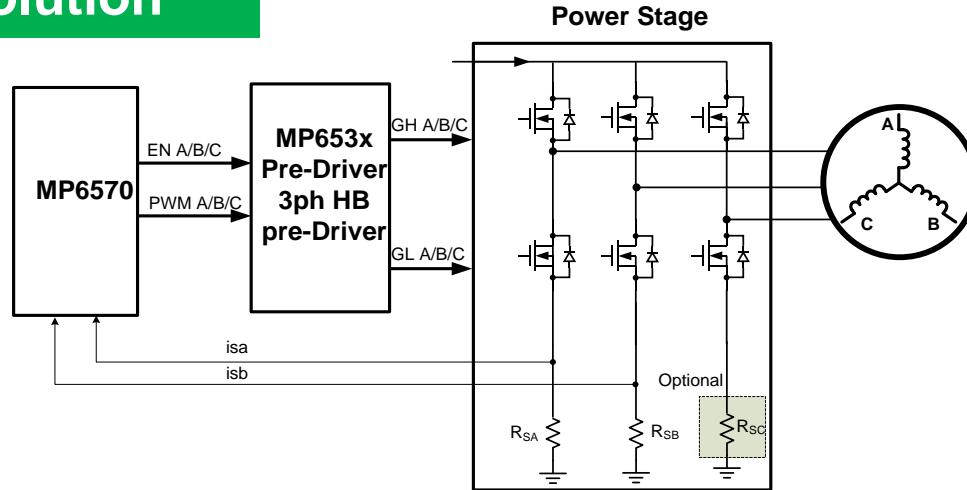
Easy of use



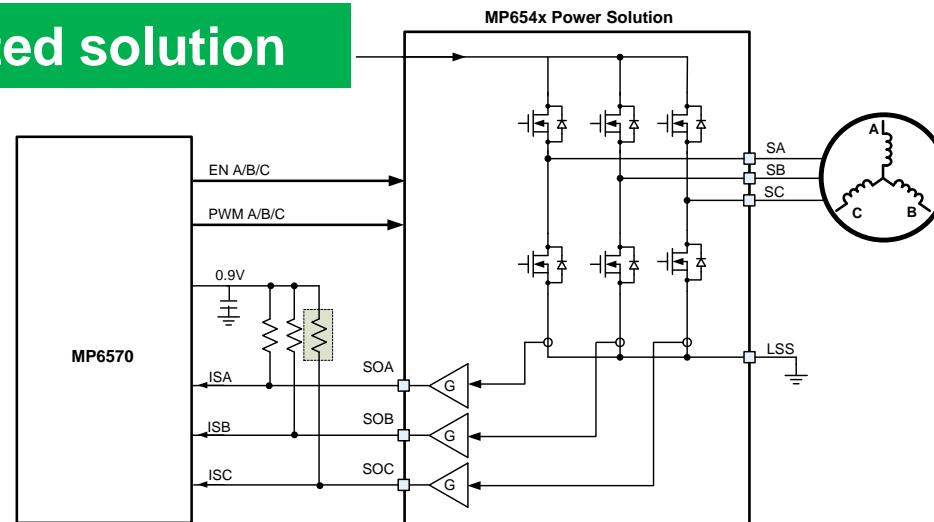
mPS

MP6570 一体化电机集成方案

Pre-driver + mos solution



MP654X full integrated solution

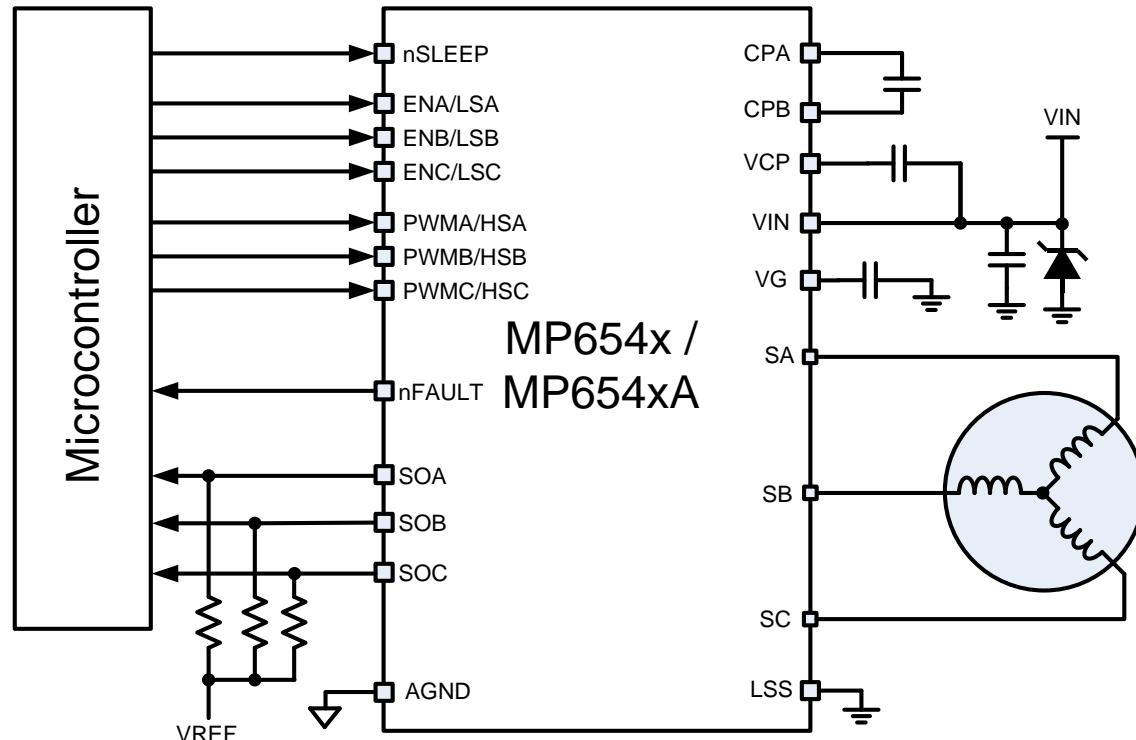


MPQ6541/MPQ6541A/MP6540/MP6540H/MP6542:3相功率模块

FEATURES

Three integrated half-bridge drivers

- **MP6540:** 5.5V to 35V, 3A Continuous Current
- **MP6540H:** 5.5V to 50V, 5A Continuous Current
- **MPQ6541/MPQ6541A:** 4.75V to 45V, 8A Continuous Current ; 13mΩ /FET Rds (on);
 - MPQ6541 PWM & ENBL inputs
 - MPQ6541A: HS & LS inputs
- **MP6542:** 4.5 to 35V, 11A Continuous Current 10mΩ /FET Rds(on)
- EN/PWM Logic Inputs (MP654x)
- HS/LS Logic Inputs (MP654xA)
- Internal Charge Pump Supports 100% Duty Operation
- UVLO and Thermal Shutdown Protection
- Over current Protection
- Integrated Bi-directional Current Sense Amp
- Available in 5x5 or 6x6mm FCQFN packages



Applications

- 3-Phase Brushless DC Motors and Permanent Magnet Synchronous Motors



MP6543H:22V 2A 三相功率模块

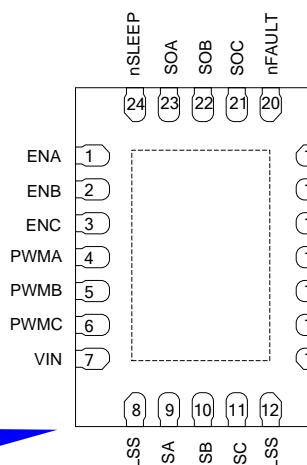
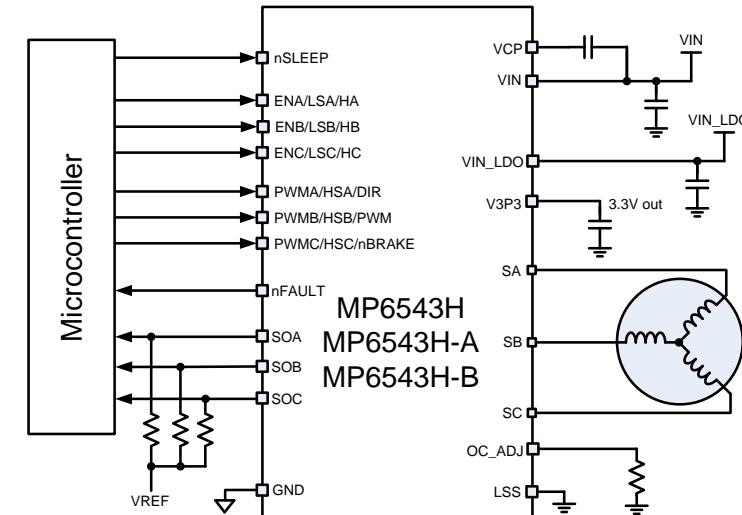
FEATURES

- 3V to 22V Operating Supply Voltage
- Three integrated half-bridge drivers
- 2A Continuous Output Current
- MOSFET On-Resistance: 110mΩ per FET
- **MP6543H**: PWM & ENBL inputs
- **MP6543H-A**: HS & LS inputs
- **MP6543H-B**: Hall Signal Interface
- Built-In 3.3-V, 100-mA LDO Regulator
- Internal Charge Pump for 100% Duty Cycle
- Automatic Synchronous Rectification
- Integrated Bi-directional Current Sense Amp

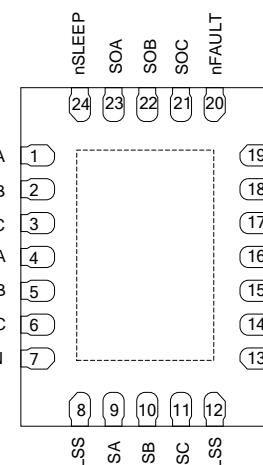
Applications

- 3-Phase Brushless DC Motors and Permanent Magnet Synchronous Motors

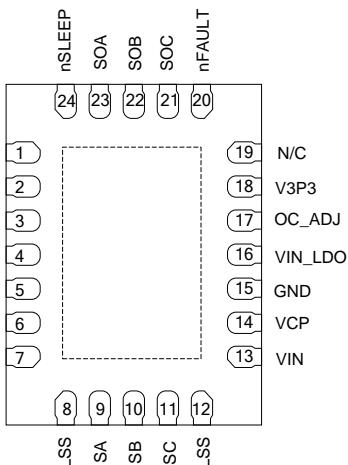
New
Released



MP6543H



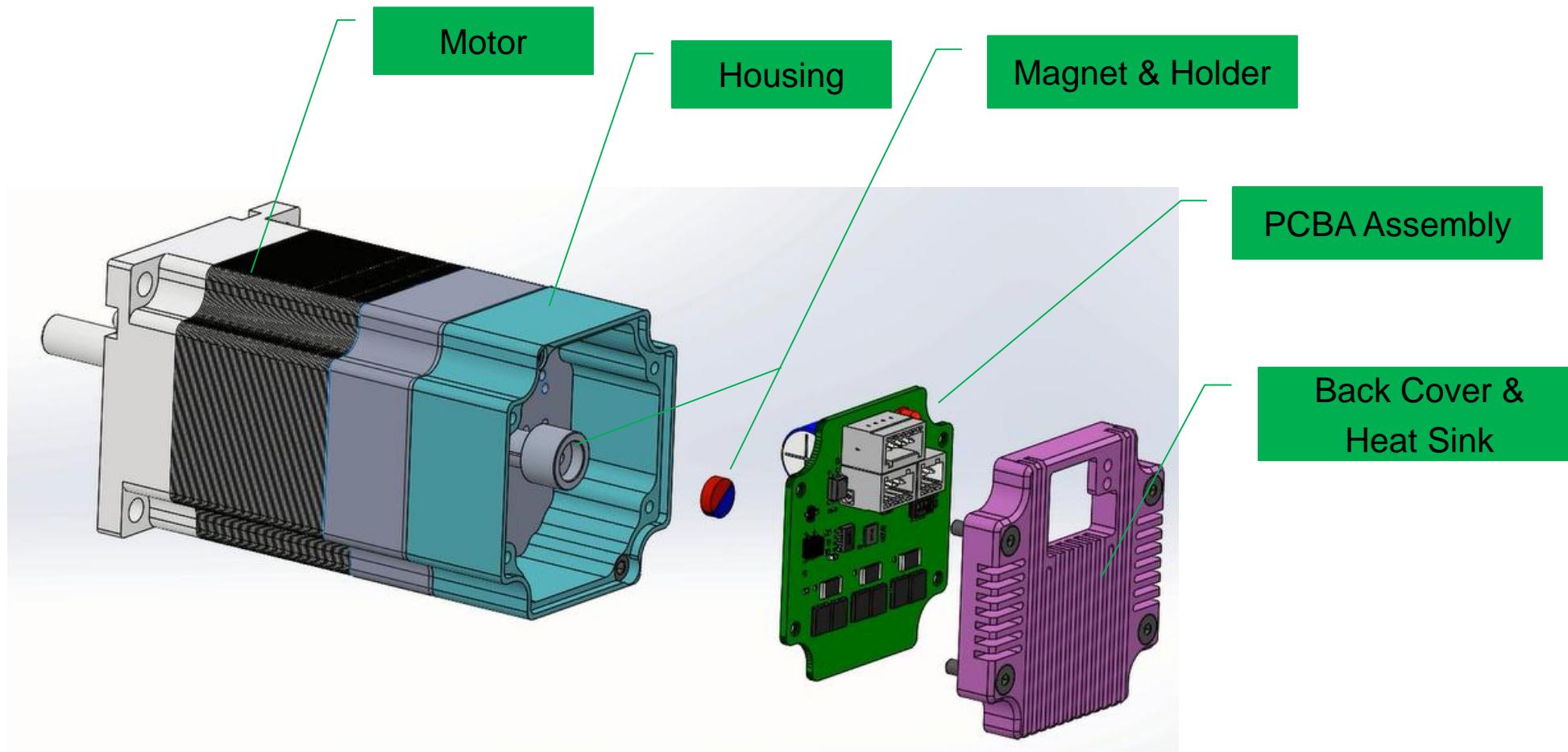
MP6543H-A



MP6543H-B

mPS

MP6570 一体化电机集成方案



MP6570 超紧凑方案

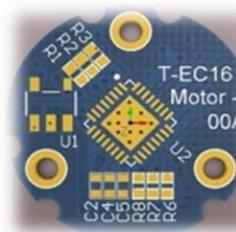
MP6570+ MP6536 + MP2013A

- Support power up to 24W, 5V-12V, Peak current 5A
- Interface digital IO or I2C, SPI



Upgrade solution

MP6570+ MP6543 + MP2013A



Micro motor

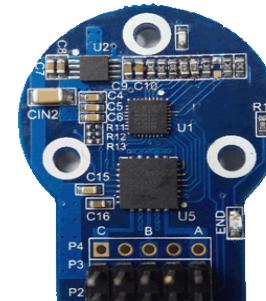
MP6570+ MP6540H + MP2013A

- Support power up to 50W, 5V-18V, Peak current 10A
- Interface digital IO or I2C, SPI



More power solution

MP6570+ MP6541/2 + MP2013A



Gimbal motor

MP6570+ MP6541 + MP2013A/MPM3510

- Support power up to 80W, 24V, Peak current 12A



mPS

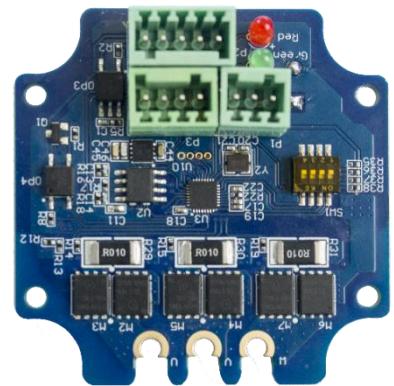
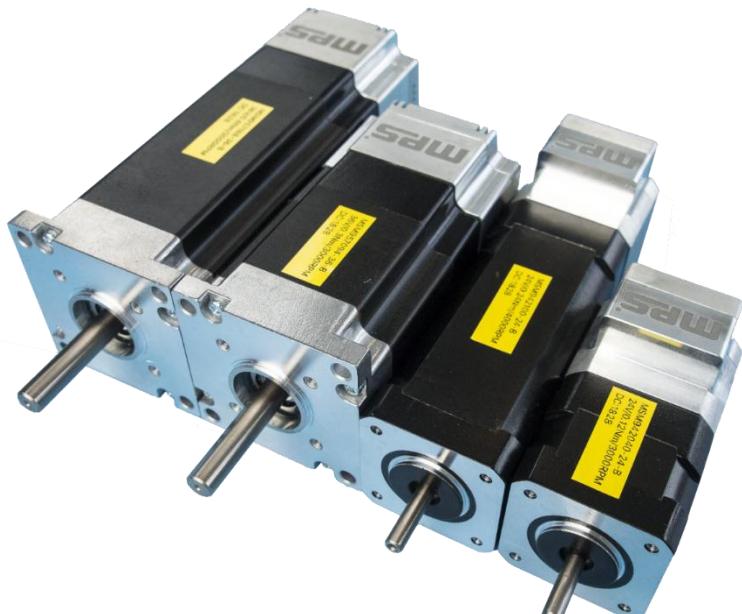
MP6570 柔性方案和MPS智能电机

MP6570+ MP6530/MP6531A/MP6537/MP6539 + Mos + MP2013A

- Support power up to 200W, 24V, Peak current based on mos
- Interface digital IO or RS485 + RS485 receiver
- MCU with CAN + CAN R/T or simple MCU with RS485 +RS485 receiver

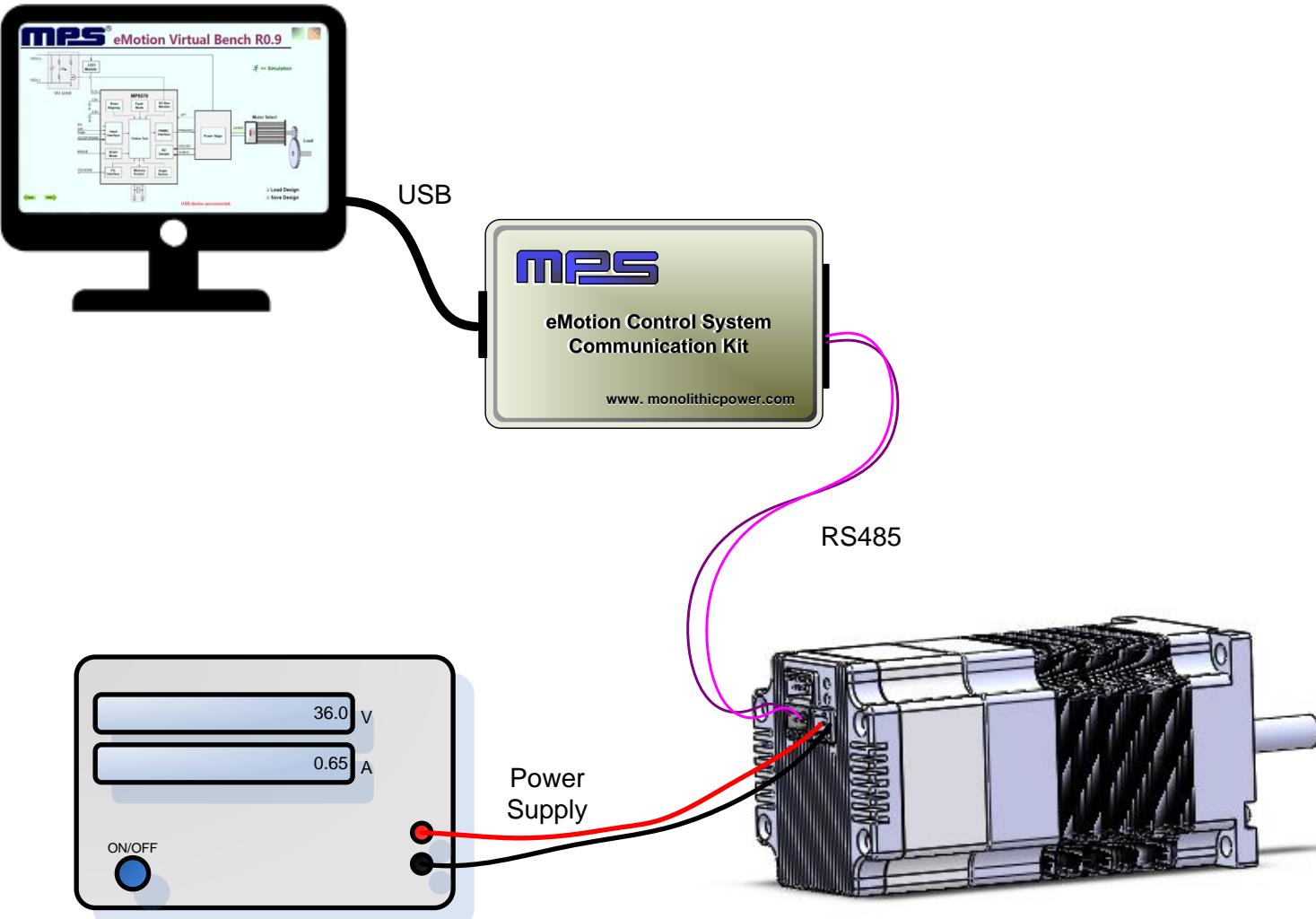
MP6570+ 3x MP1921+ MP4420H + MP2013A

- Support power up to 200W, 24V, Peak current based on mos
- Interface digital IO or RS485 + RS485 receiver
- MCU with CAN + CAN R/T or simple MCU with RS485 +RS485 receiver



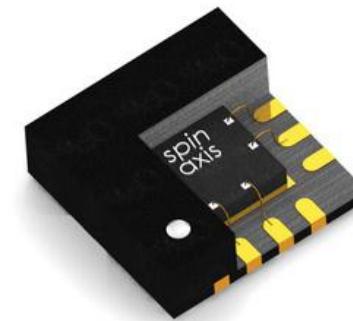
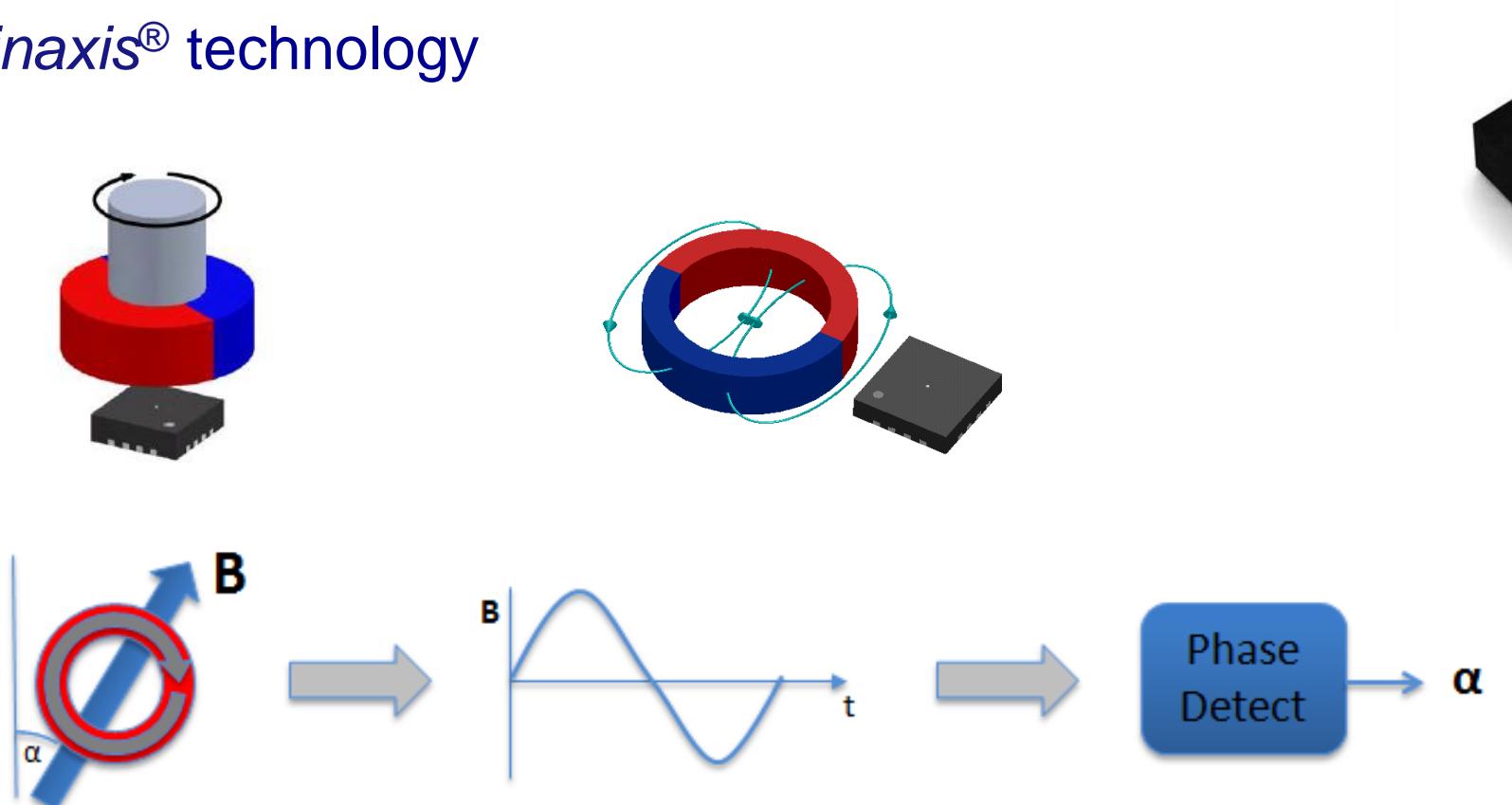
mPS

MPS智能电机套件

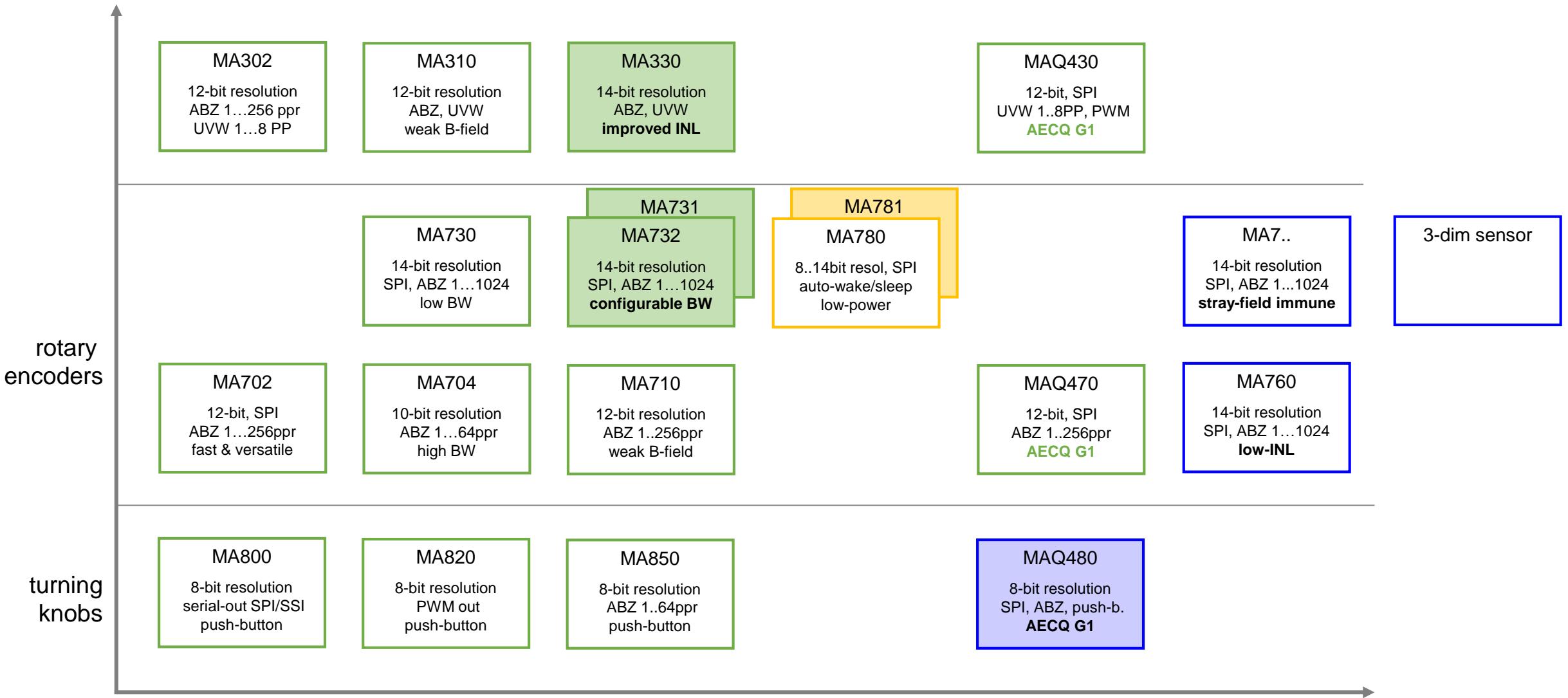


mPS

Family of integrated angle sensors based on
Spinaxis® technology



MPS 磁编产品路线图



MPS 磁编产品选型表

Application	Part	Distinct features
Replacement of 3 Hall switches for BLDC commutation	MA102	UVW output
Human/machine interface. Speed < 200 rpm	MA800	SPI output
	MA820	ABZ output
	MA850	PWM output (to make an analog output)
All purpose encoder	MA704	10 bit High bandwidth (3 kHz) - suitable for closed loop control
	MA702	12 bit Medium Bandwidth (390 Hz) - suitable for slow closed loop control
	MA710	12 bit at low field, Low bandwidth (90 Hz)
	MA730	14 bit Low bandwidth (20 Hz)
	MA732	10-14 bit selectable, 1024 PPT , low INL
All purpose encoder for BLDC (UVW output)	MA302	Same as 702 but with UVW
	MA310	Same as 710 but with UVW
	MA330	Same as MA732 with UVW
Low power	MA780	Options for cycling the power



谢谢！

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