BLDC风扇控制原理
MPS方案

May 2019

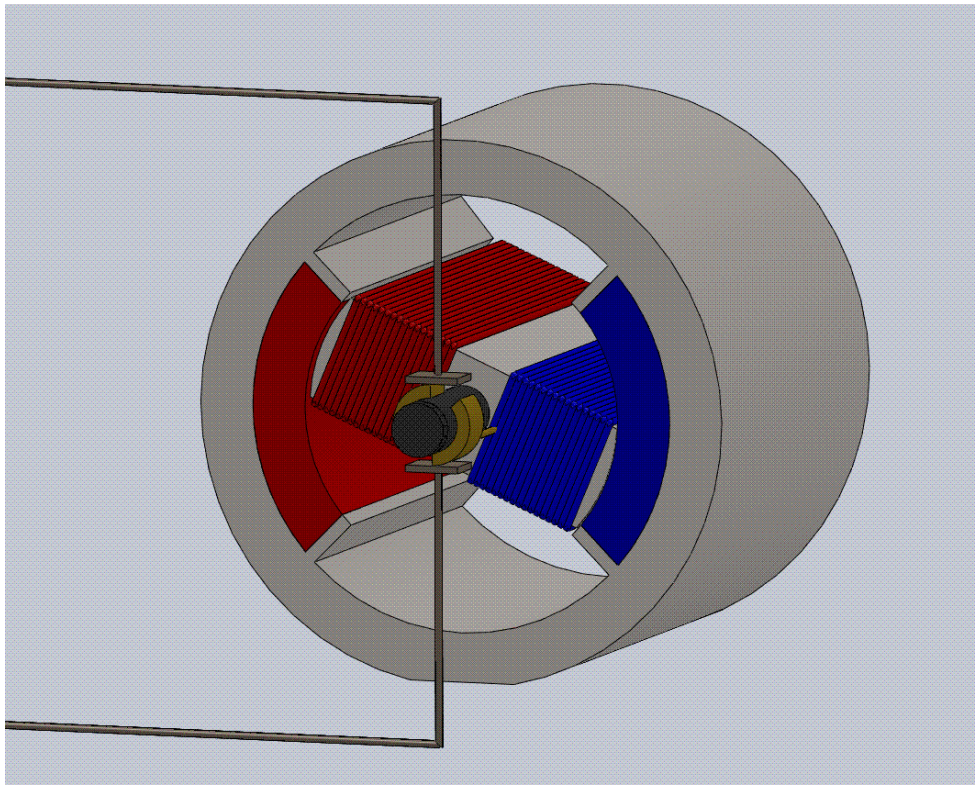
Simple, Easy Solutions™

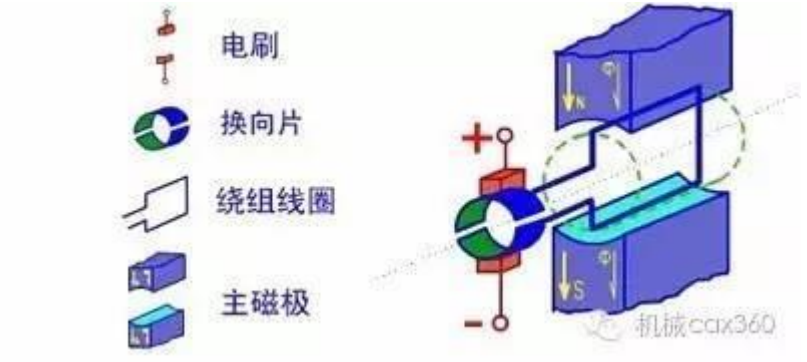
Content

- BLDC单相风扇工作原理
- MPS高度集成单相风扇方案
- 三相风扇的典型控制原理
  - 定子磁场和dq模型
  - FOC 控制
  - SVPWM
- MPS三相风扇方案

Simple, Easy Solutions

单相有刷直流电机工作原理





电刷和换向片实现绕组电流在N,S磁极侧的电流方向保持不变

单相有刷直流电机工作原理

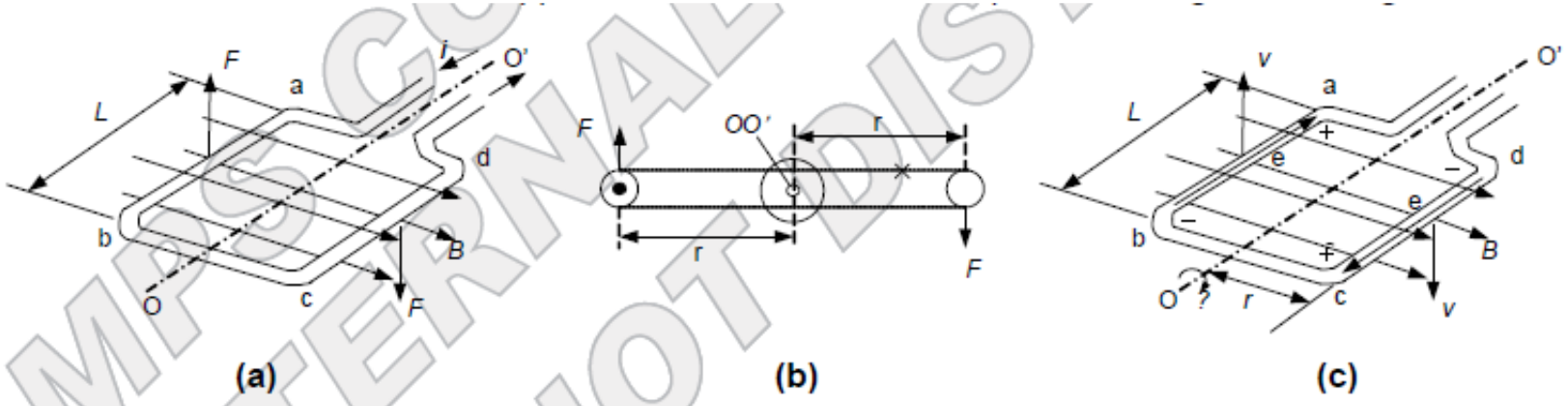


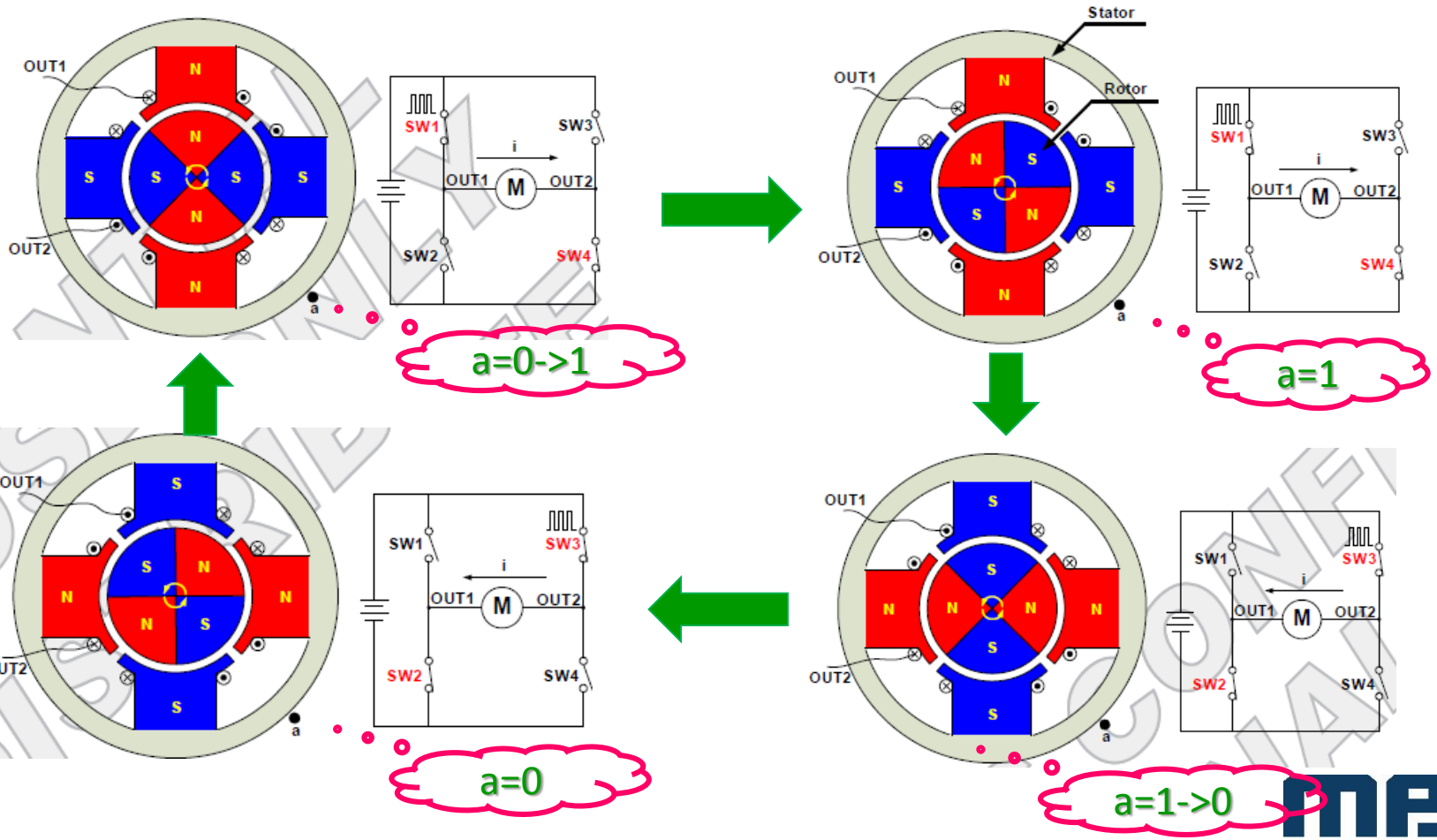
Figure 3—Coil in a Magnetic Field

$$t_d = 2 * F * r = 2 * B * L * I * r = kT * I$$

$$e = B * L * v = B * L * \omega * r = ke * \omega$$

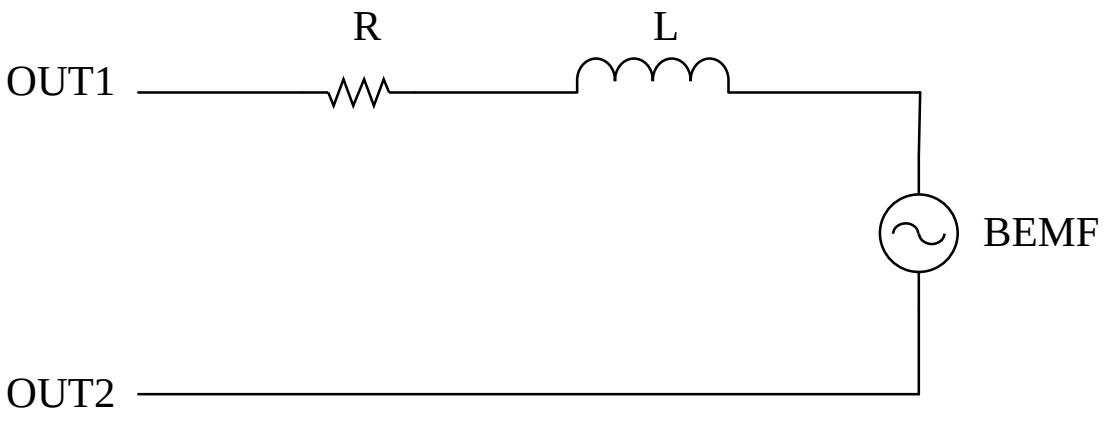
单相无刷直流电机工作原理

- 需要检测转子磁场位置
- 根据位置信息决定通电顺序，以产生持续旋转的磁场
- 调节H桥占空比从而控制绕组电流大小

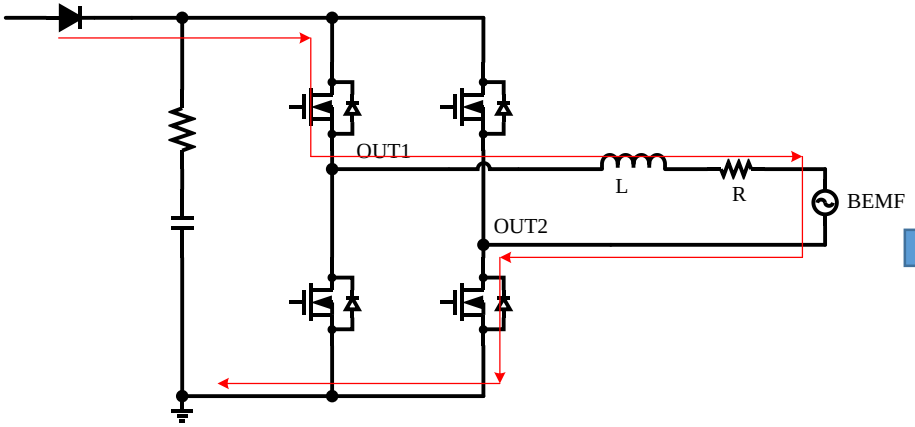


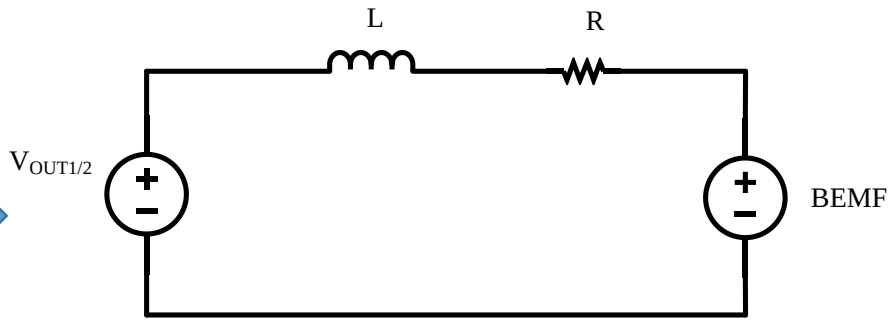
单相无刷直流电机工作原理

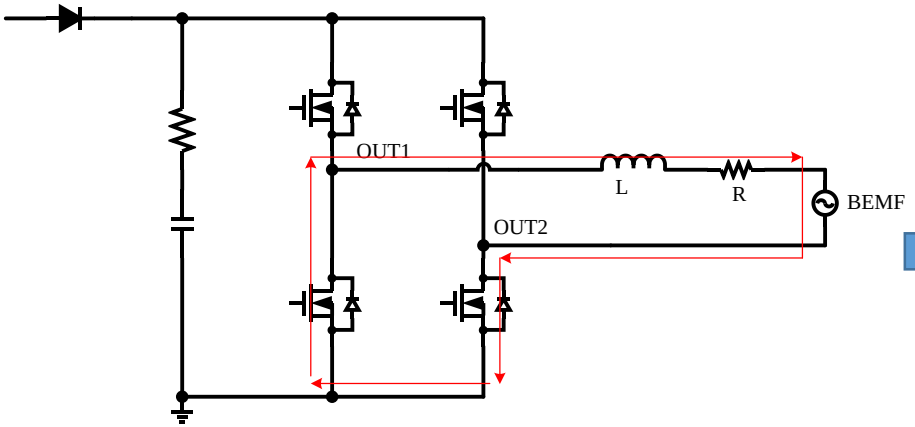
无刷直流风扇的等效电路图

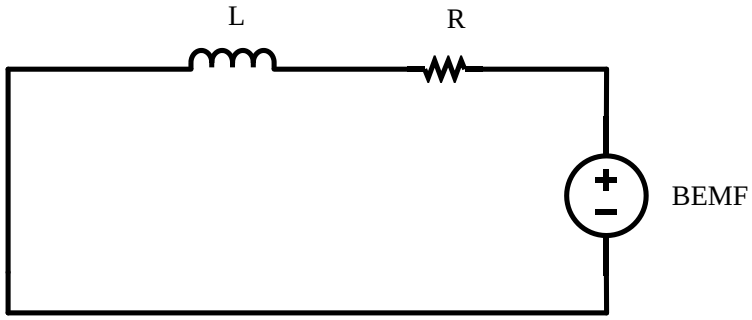


单相无刷直流电机工作原理



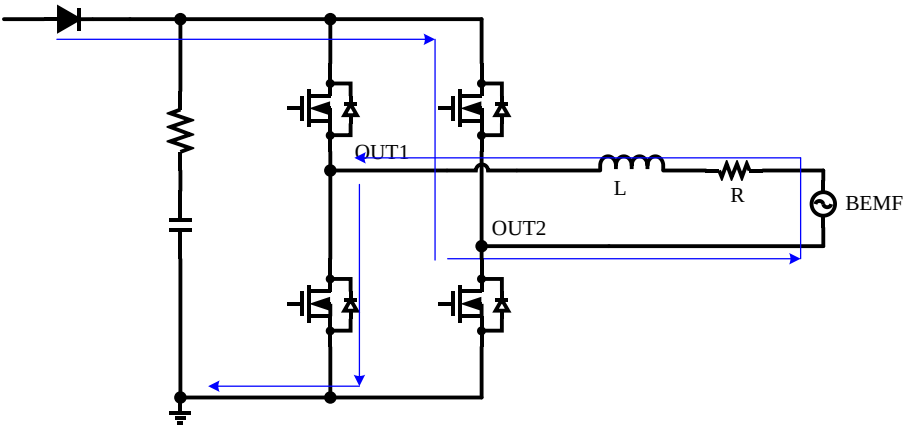


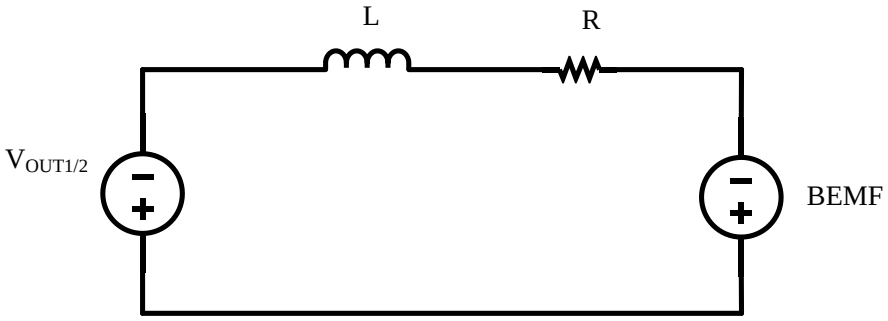


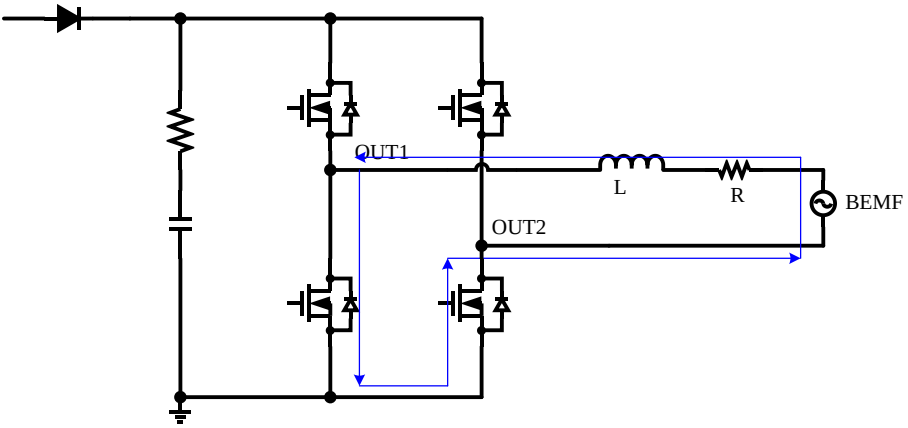


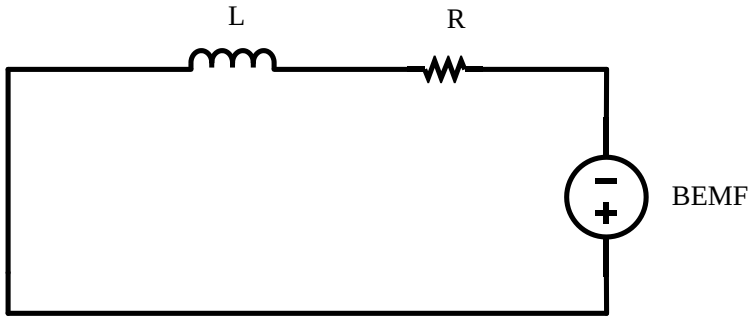
Simple, Easy Solutions

单相无刷直流电机工作原理



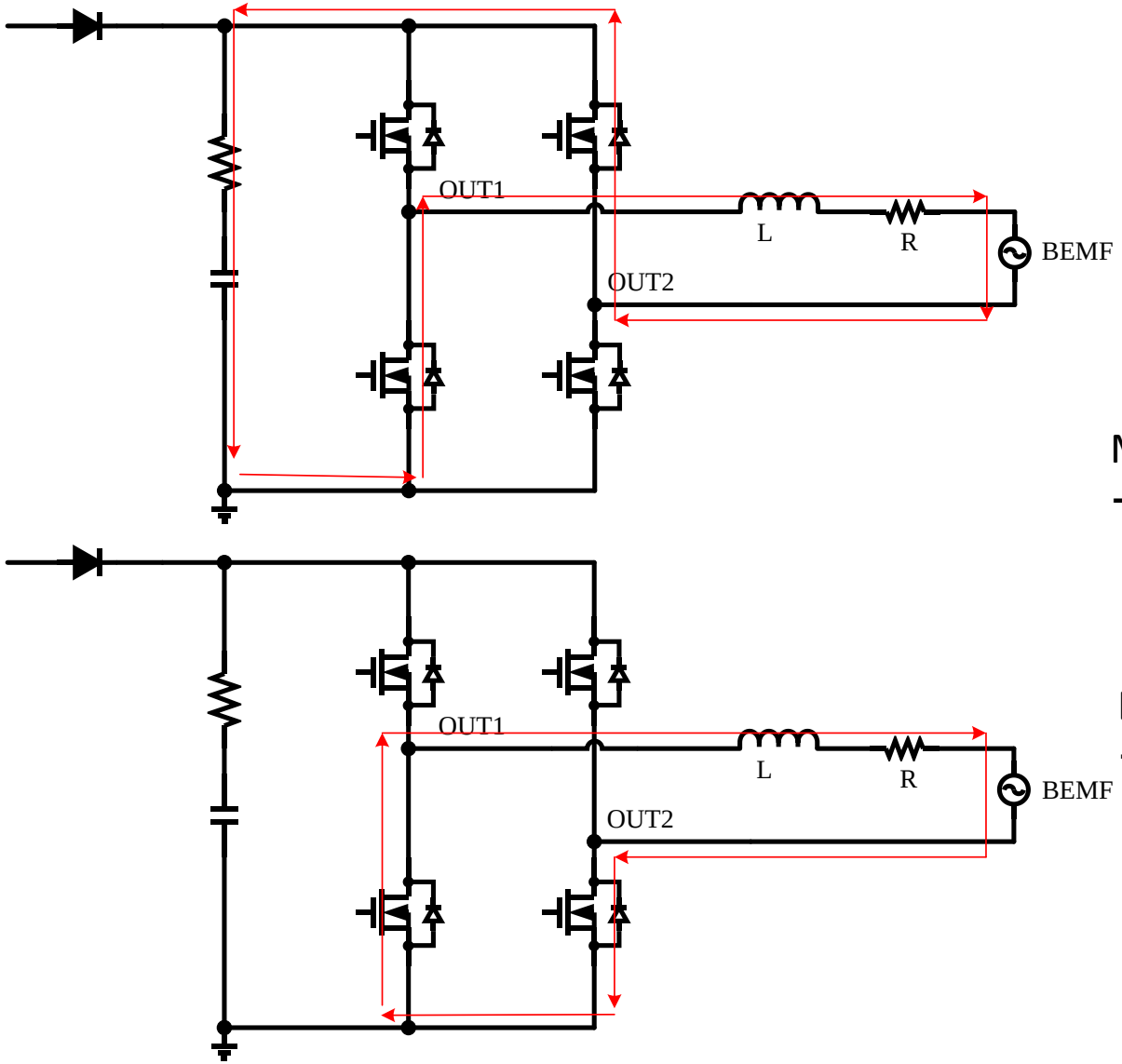






Simple, Easy Solutions

单相无刷直流电机工作原理



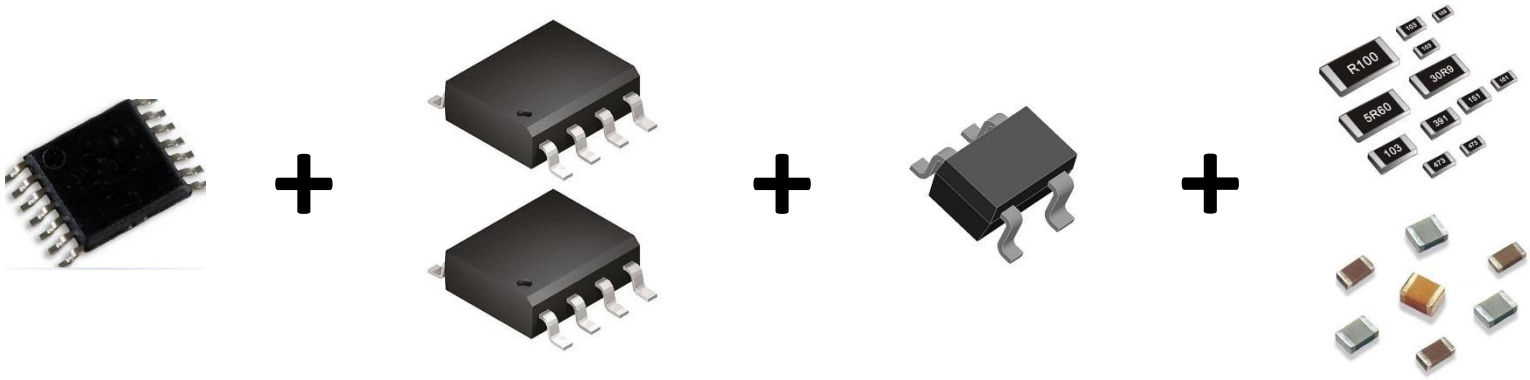
换流：
强制换流→电流反冲

MOS 线性→换流前电流过零
→无电流反冲 （低效率）

Duty减小→换流前电流过零
→无电流反冲

Simple, Easy Solutions

MPS集成方案



Controller+ MOSFET+ Hall+ Several Res+ Several Cap

MP6517A/B, MP6650
TSOT23-6
600mA

MP6616
QFN10-2x3mm
2A

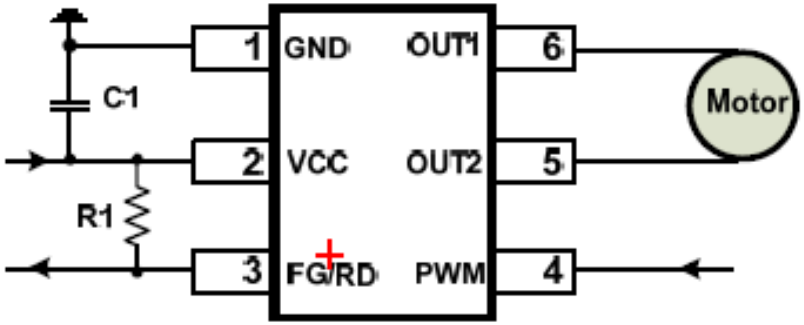
MP6651
SOIC8-SL
1.5A

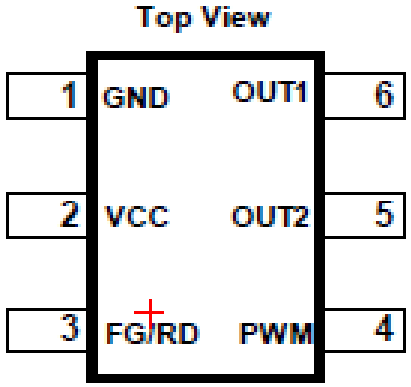
Simple, Easy Solutions

MPS集成方案: MP6517A/B

FEATURES

- On chip Hall sensor
- 3.3V-16V input voltage
- 0.6A continuous current
- Integrated power MOSFETs: HS+LS=850mΩ
- Curve programming
- Rotational speed indicator (FG)
- 12kHz to 48kHz PWM input frequency range,
- 26kHz output frequency
- Soft phase transition
- Built-in pull up resistor on PWM
- Reverse voltage protection
- Locked-Rotor protection and automatic recovery
- Built-in input OVP, UVLO, OTP and automatic recovery

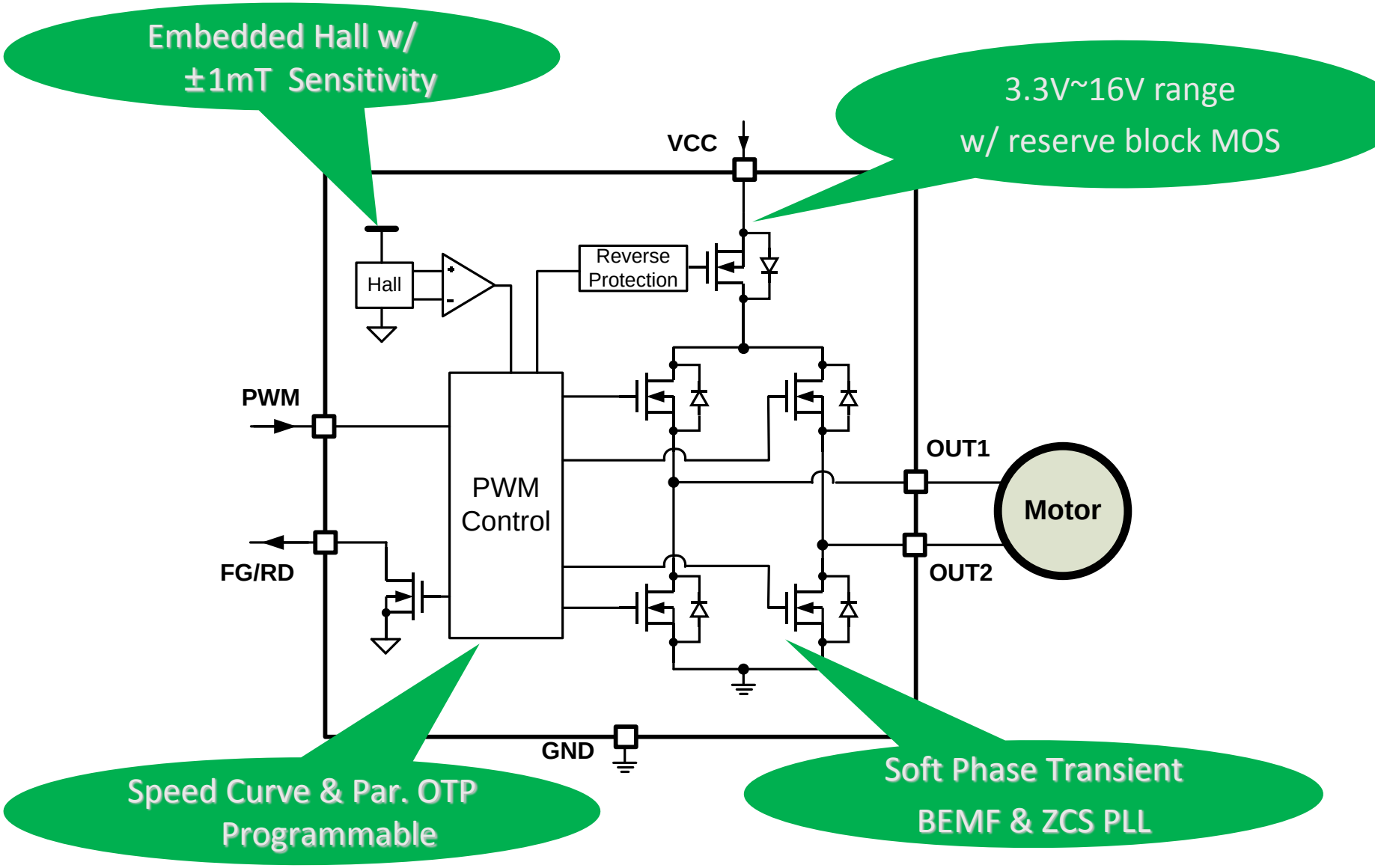




TSOT23-6

Simple, Easy Solutions

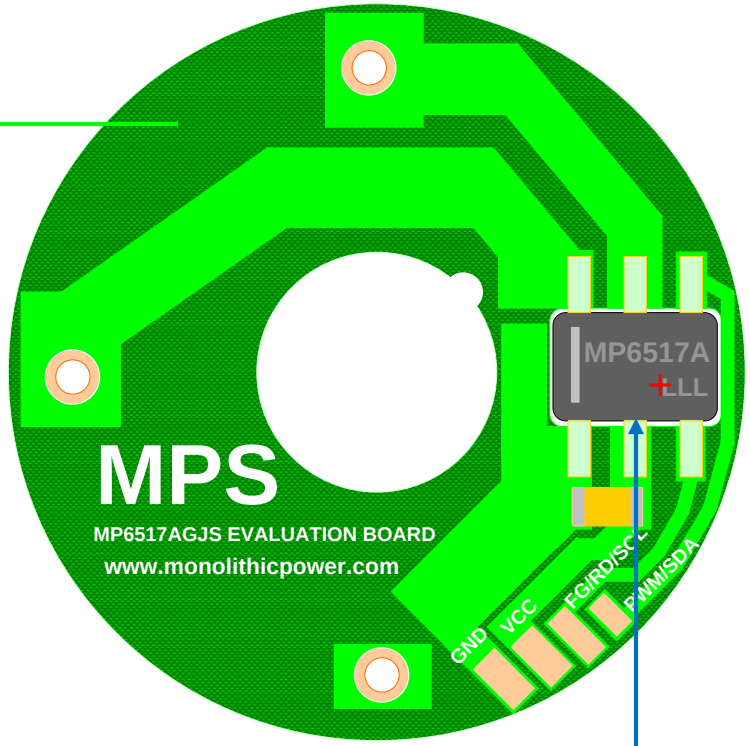
MPS集成方案: MP6517A/B



Simple, Easy Solutions

MPS集成方案: MP6517A/B

Very Clear BOM and PCB



Straight Lead TSOT23-6

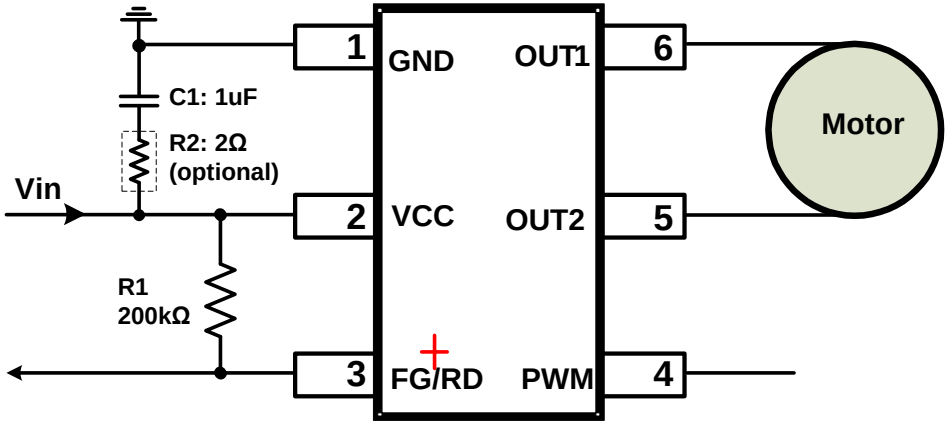
Rotor Magnet

Simple, Easy Solutions

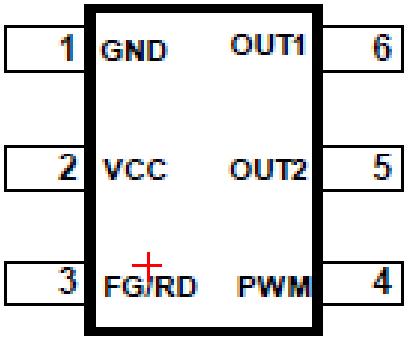
MPS集成方案: MP6650

FEATURES

- On-chip Hall sensor
- Wide 3.3V to **18V** input voltage
- Up to 600mA continuous current
- Integrated power MOSFETs: 740mΩ (HS + LS)
- Programmable speed curve
- **Soft startup** time programmable
- Soft on/off phase transition
- Rotational speed indicator (FG)
- **2kHz to 100kHz** PWM input frequency range
- Fixed 26kHz output switching frequency
- Input line reverse voltage protection (RVP)
- Rotor deadlock (RD) protection and automatic recovery
- Built-In input OVP, UVLO, OTP and automatic recovery



Top View



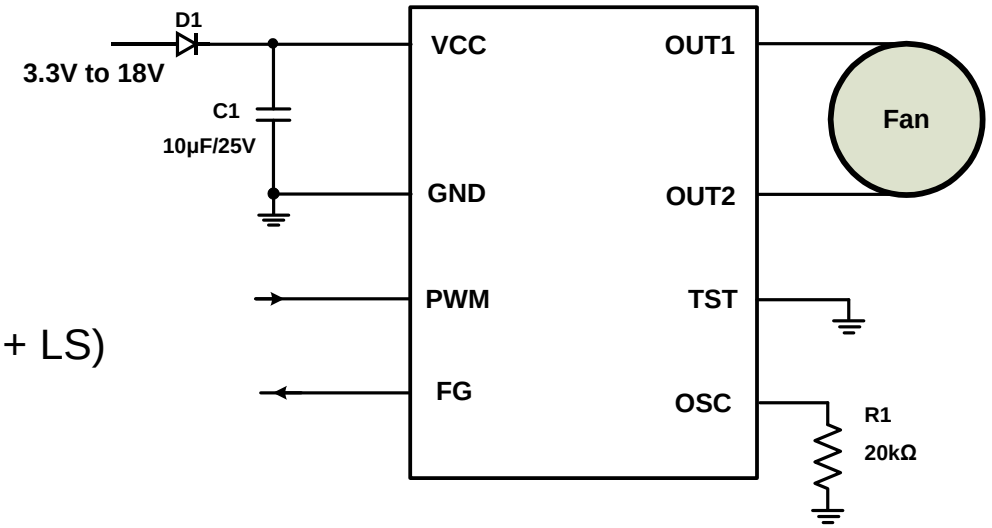
TSOT23-6

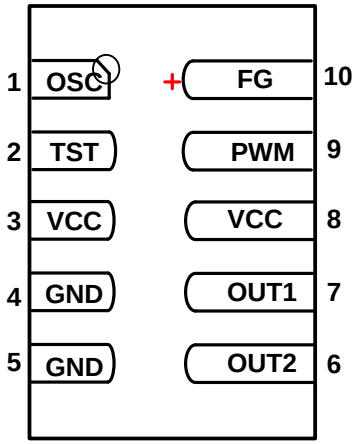
Simple, Easy Solutions

MPS集成方案: MP6616

FEATURES

- On-chip Hall sensor
- Wide 3.3V to 18V input voltage
- Up to **2A continuous current**
- Integrated power MOSFETs: 100mΩ (HS + LS)
- **Speed close-loop control**
- Soft startup time programmable
- Soft on/off phase transition
- Hall leading angle programmable (±45°)
- Rotational speed indicator (FG)
- 2kHz to 100kHz PWM input frequency range
- Fixed 27kHz output switching frequency
- Rotor deadlock (RD) protection and automatic recovery
- Built-In Input OVP, UVLO, OTP





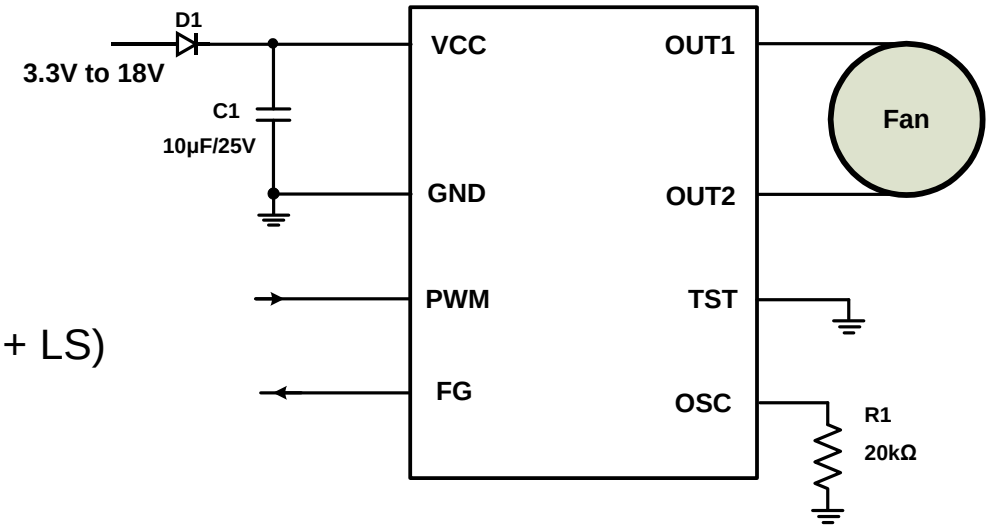
QFN10-2x3mm

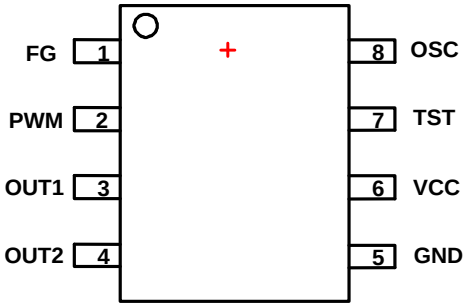
Simple, Easy Solutions

MPS集成方案: MP6651

FEATURES

- On-chip Hall sensor
- Wide 3.3V to 18V input voltage
- Up to **1.5A continuous current**
- Integrated power MOSFETs: 100mΩ (HS + LS)
- **Speed Open-loop control**
- Soft startup time programmable
- Soft on/off phase transition
- Hall leading angle programmable (±45°)
- Rotational speed indicator (FG)
- 2kHz to 100kHz PWM input frequency range
- Fixed 27kHz output switching frequency
- Rotor deadlock (RD) protection and automatic recovery
- Built-In Input OVP, UVLO, OTP





SOIC8-straight lead

Simple, Easy Solutions

BLDC三相电机的典型控制

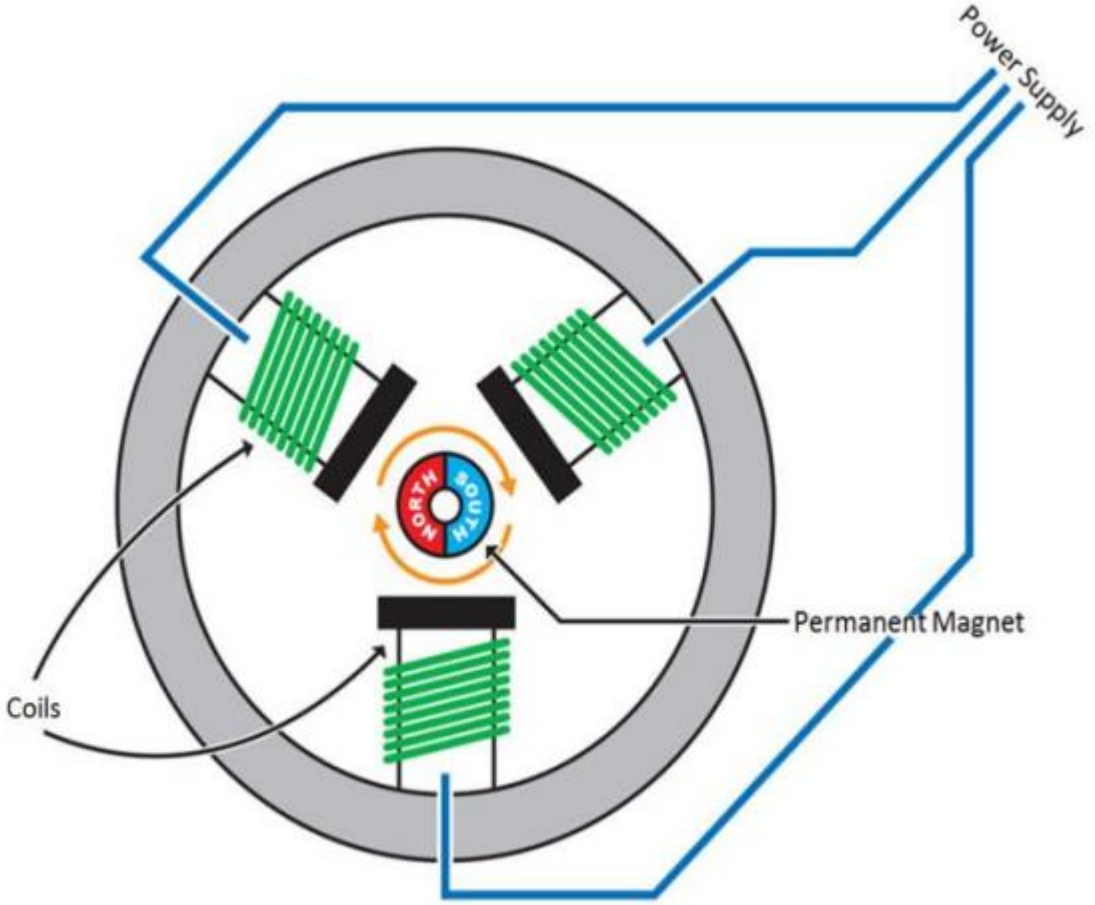
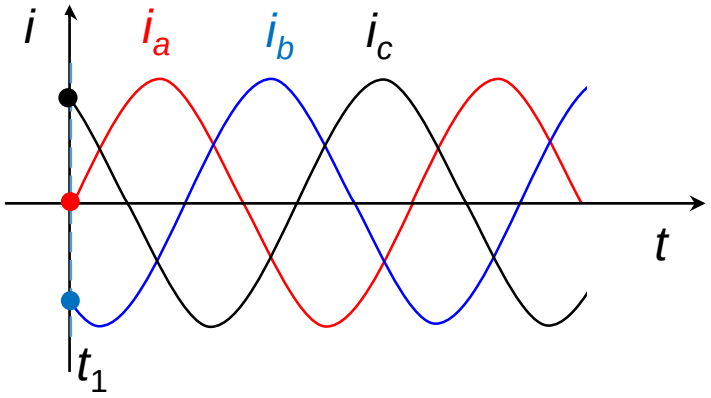
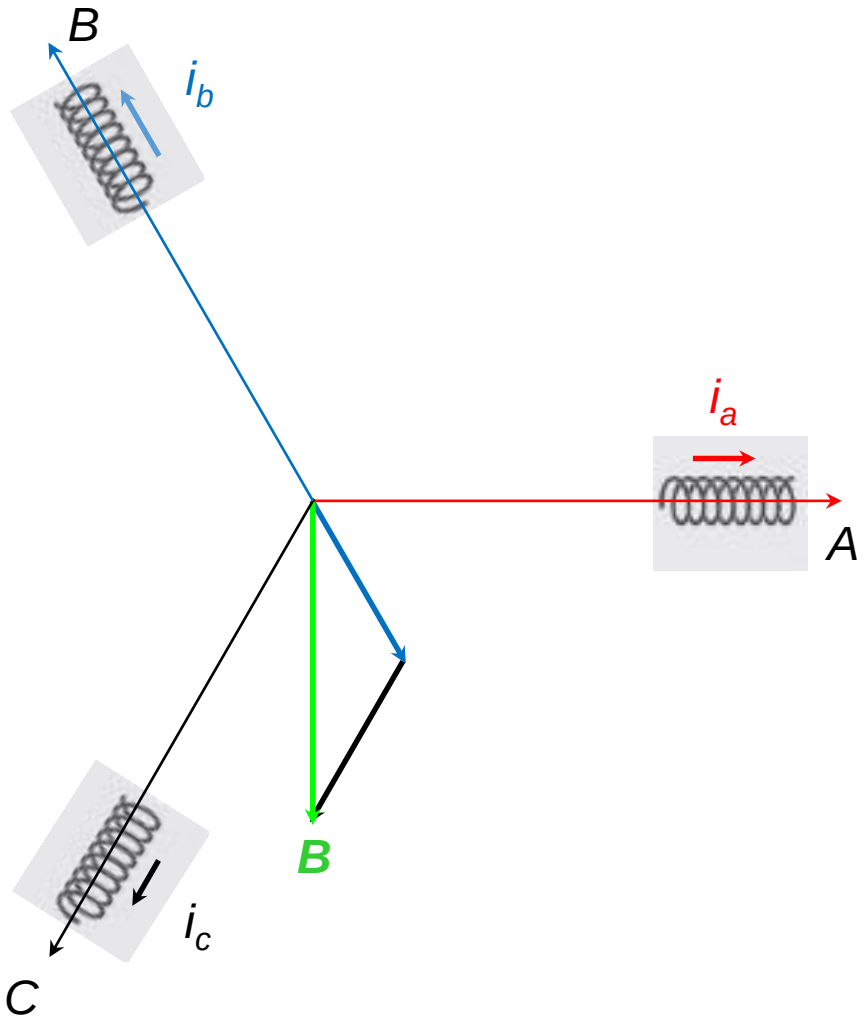


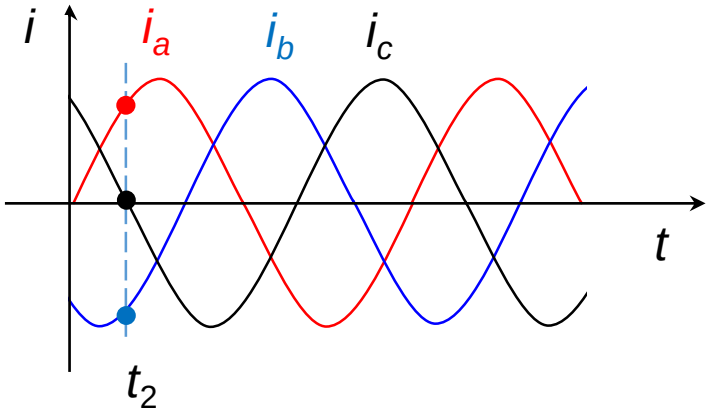
Figure 1: Brushless Motor Construction

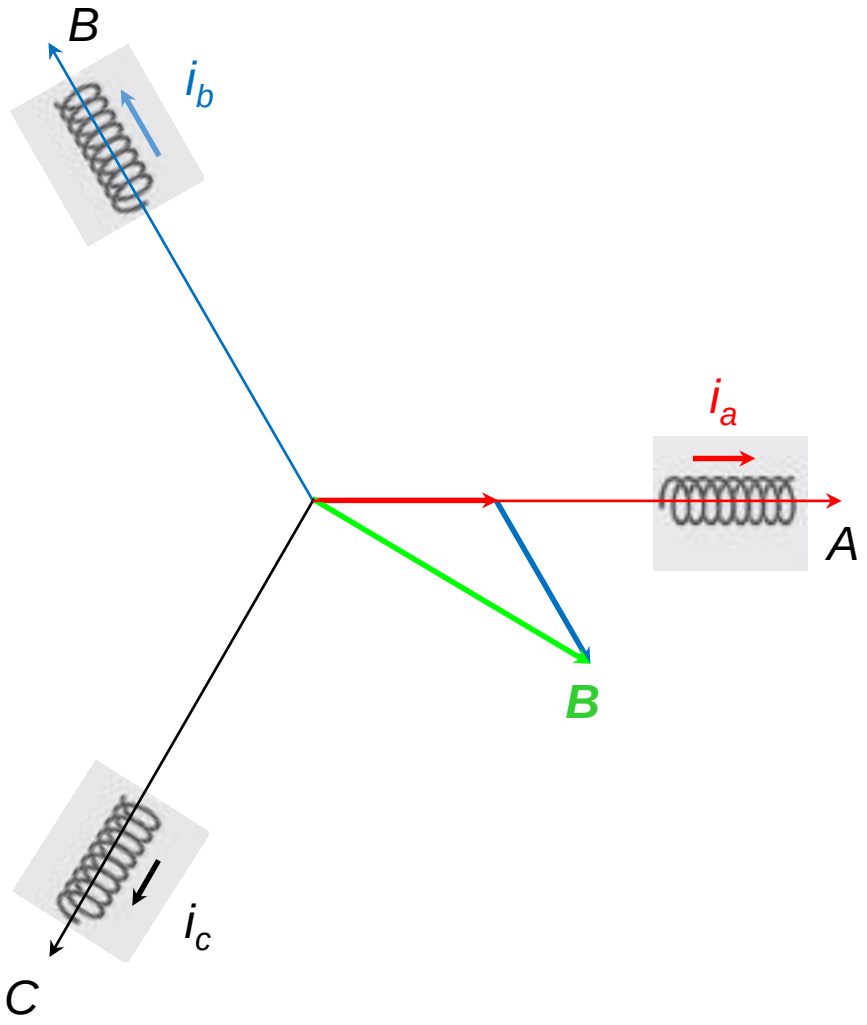
定子磁场



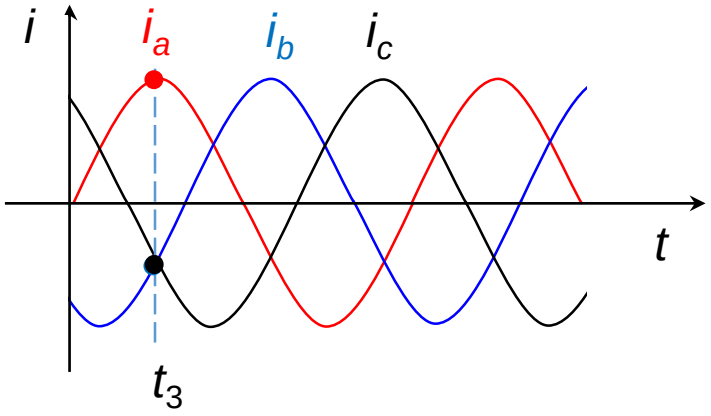


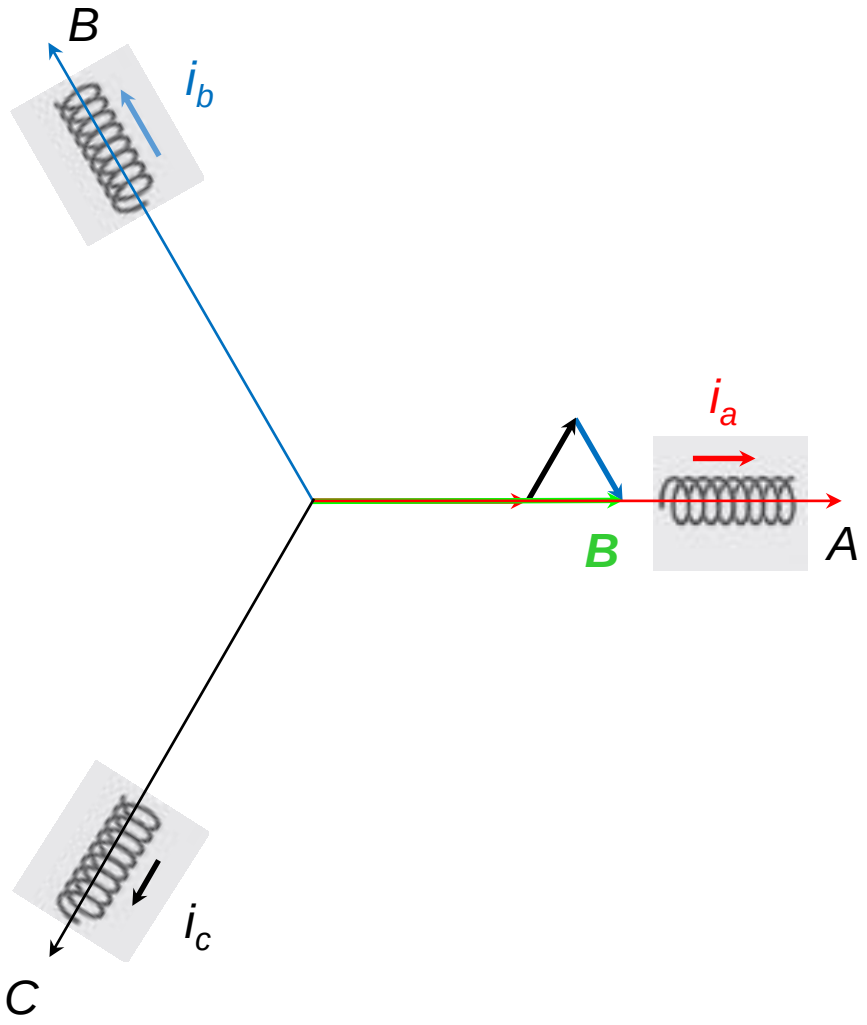
定子磁场



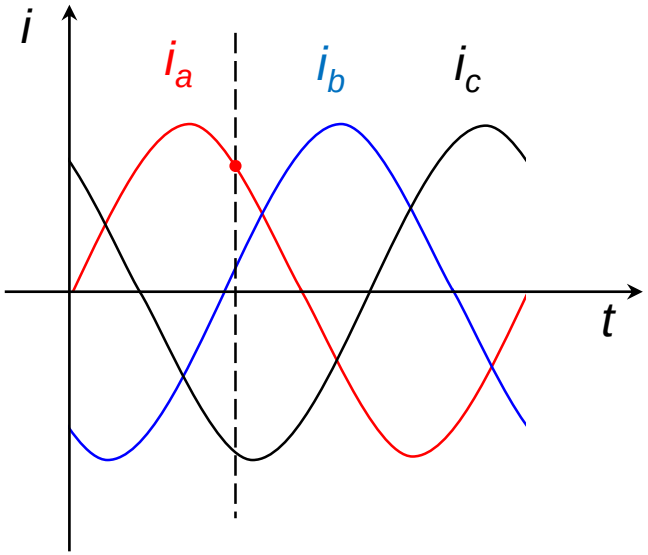


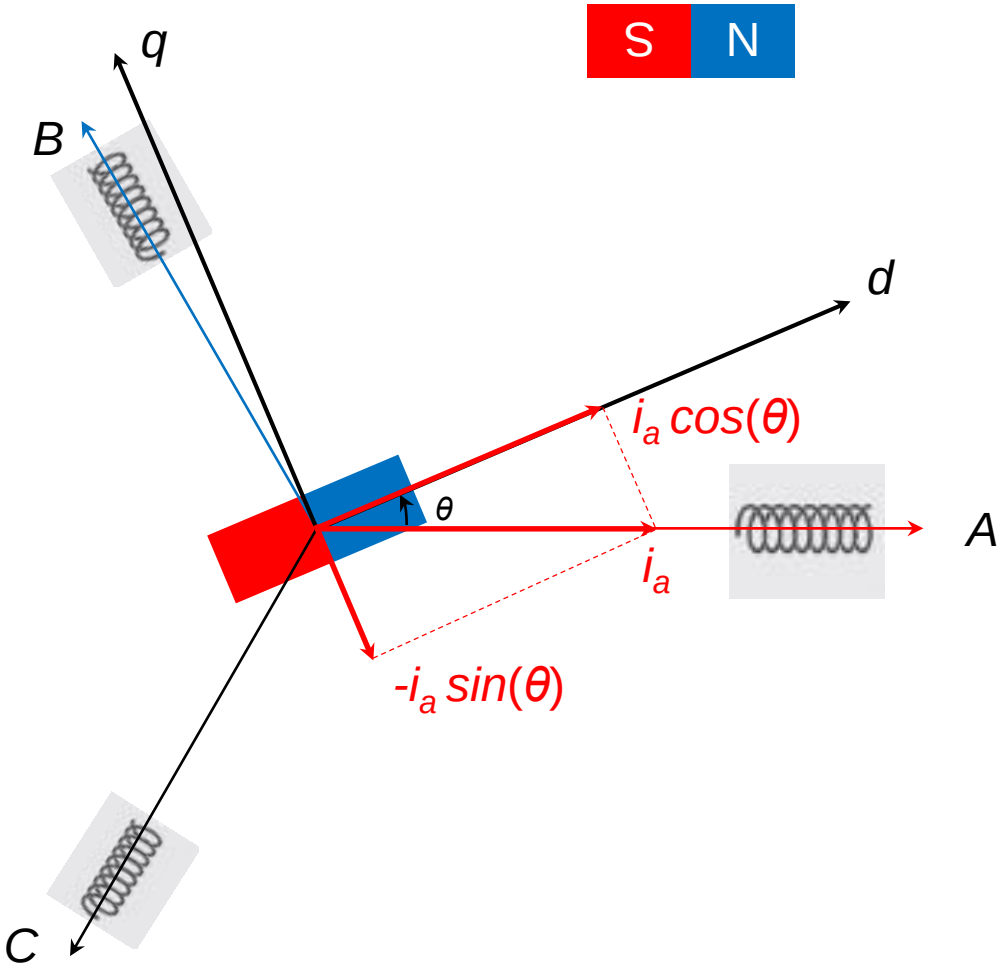
定子磁场





dq模型

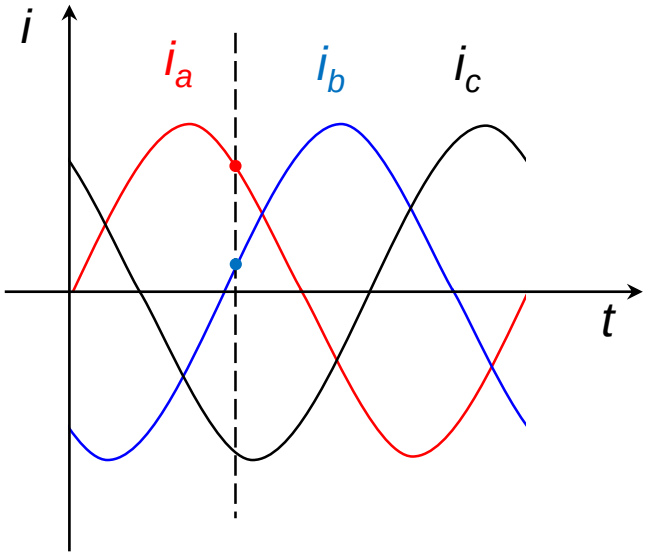


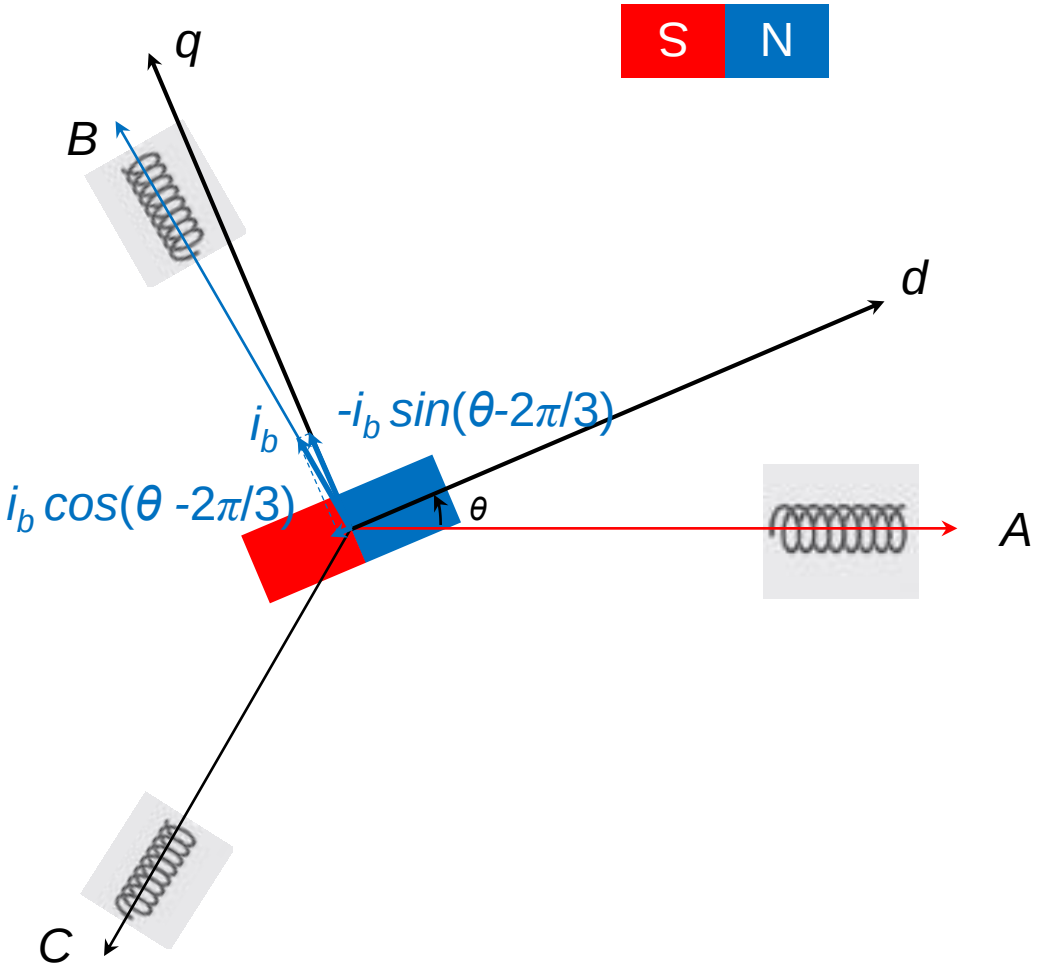


d轴方向与永磁体北极方向一致，q轴为超前90度，d轴与A相的夹角为θ
如图，a相电流可以分别投影到d轴和q轴

Simple, Easy Solutions

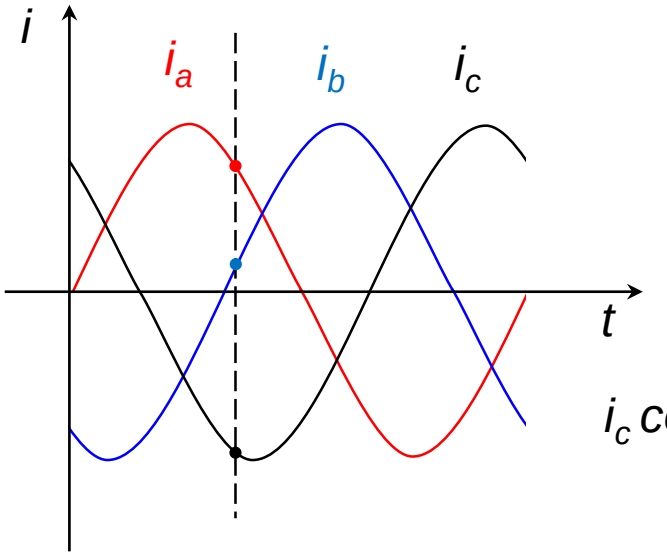
dq变换

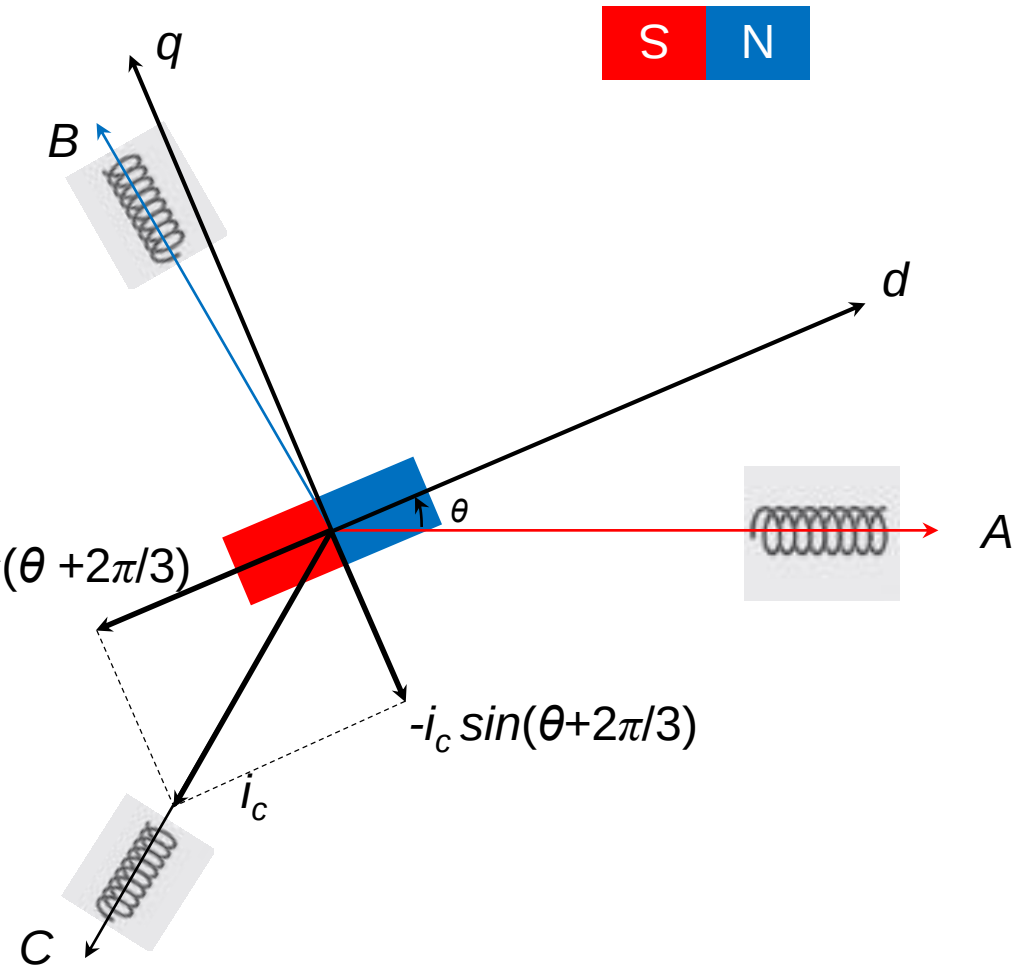




i_b分别投影到d轴和q轴

dq变换





And i_c.

$$i_d = i_a \cos(\theta) + i_b \cos(\theta - 2\pi/3) + i_c \cos(\theta + 2\pi/3)$$
$$i_q = -i_a \sin(\theta) - i_b \sin(\theta - 2\pi/3) - i_c \sin(\theta + 2\pi/3)$$

Simple, Easy Solutions

dq变换

从abc坐标系到dq坐标系得到 **Park transformation [1]**.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} cos(\theta) & cos(\theta - 2\pi/3) & cos(\theta + 2\pi/3) \\ -sin(\theta) & -sin(\theta - 2\pi/3) & -sin(\theta + 2\pi/3) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

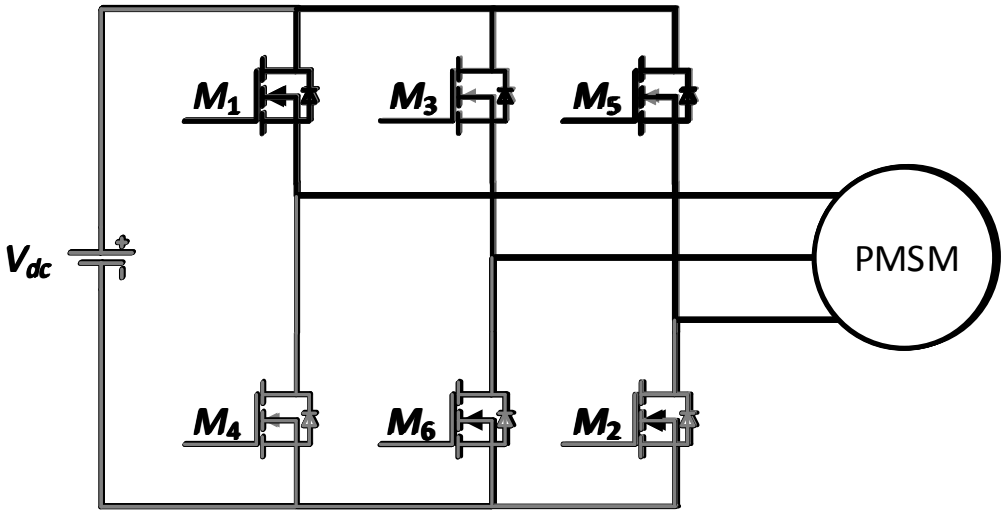
其中系数2/3 是约束条件，保证矢量的幅值不变.

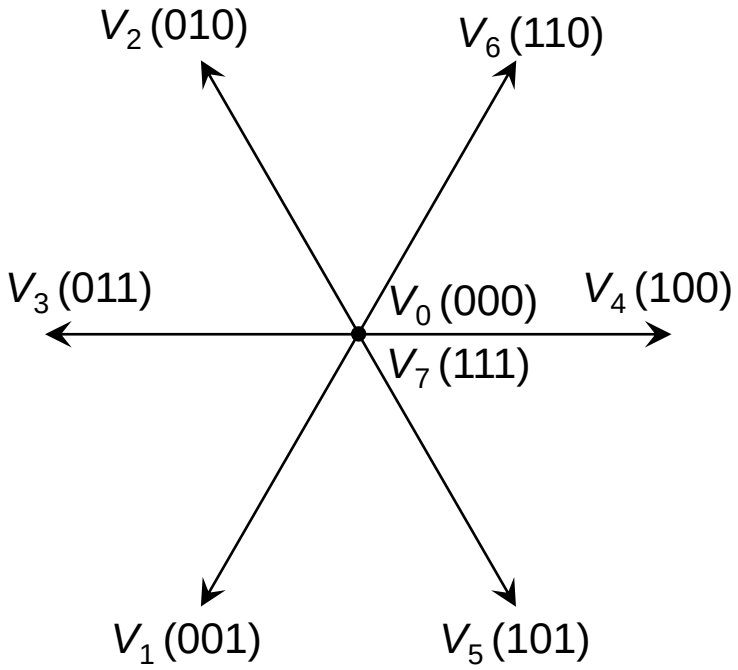
inverse Park transformation

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \frac{3}{2} \begin{bmatrix} cos(\theta) & -sin(\theta) \\ cos(\theta - 2\pi/3) & -sin(\theta - 2\pi/3) \\ cos(\theta + 2\pi/3) & -sin(\theta + 2\pi/3) \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix}$$

SVPWM

根据三相全桥开关管的状态可以分为8种不同的开关状态，每种开关状态产生一个电压矢量，六个非零电压矢量和两个零矢量，将空间分成六个扇区；在每个扇区中，可以通过相邻两个电压矢量的调制可以形成（0,2π）的任意一个位置的电压矢量，就是空间矢量调制
SVPWM （Space Vector Pulse Width Modulation）

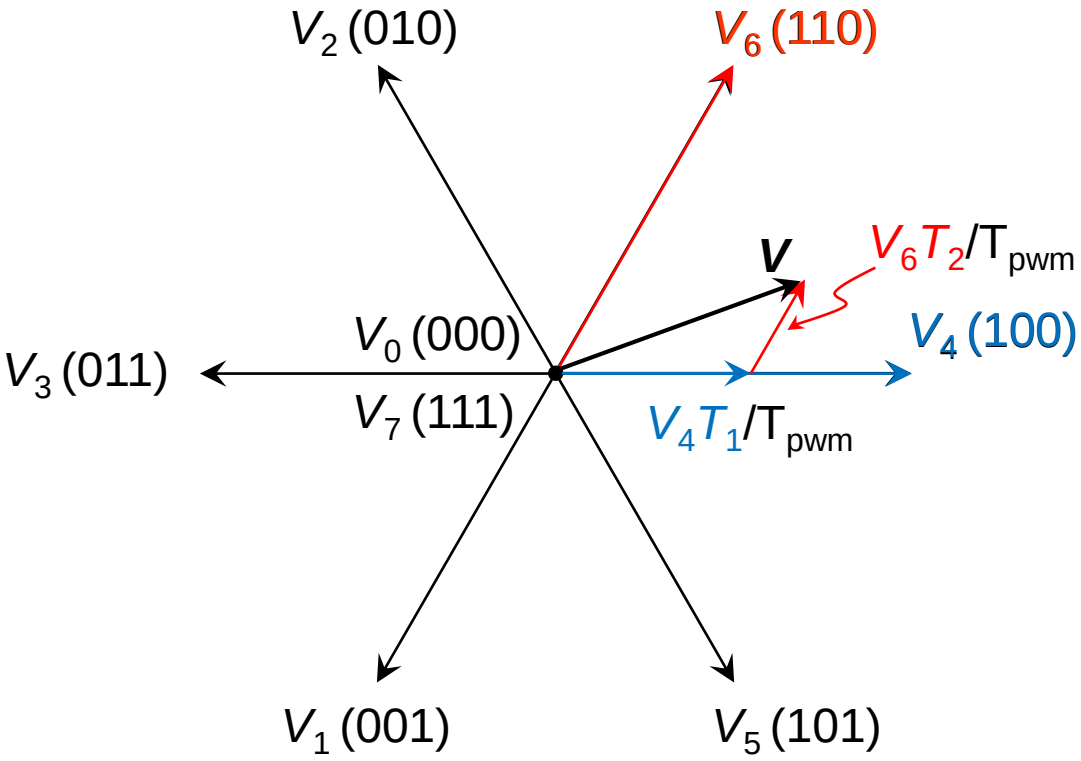


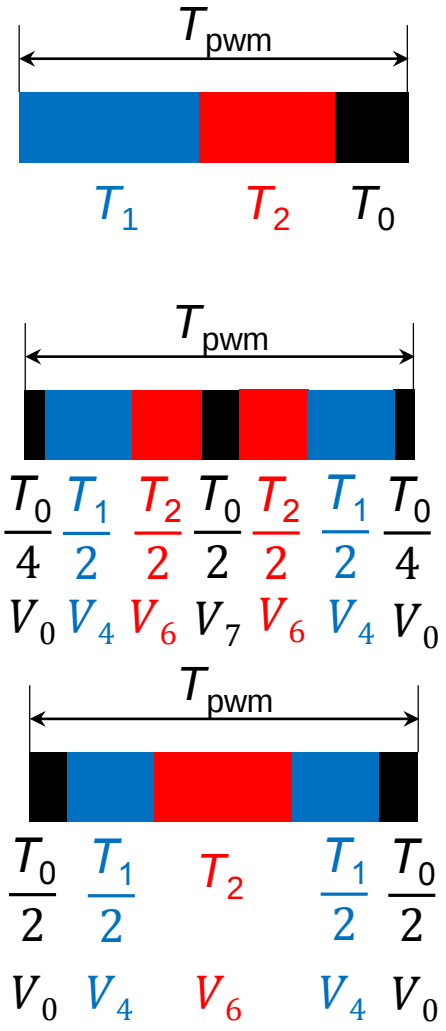


Simple, Easy Solutions

SVPWM

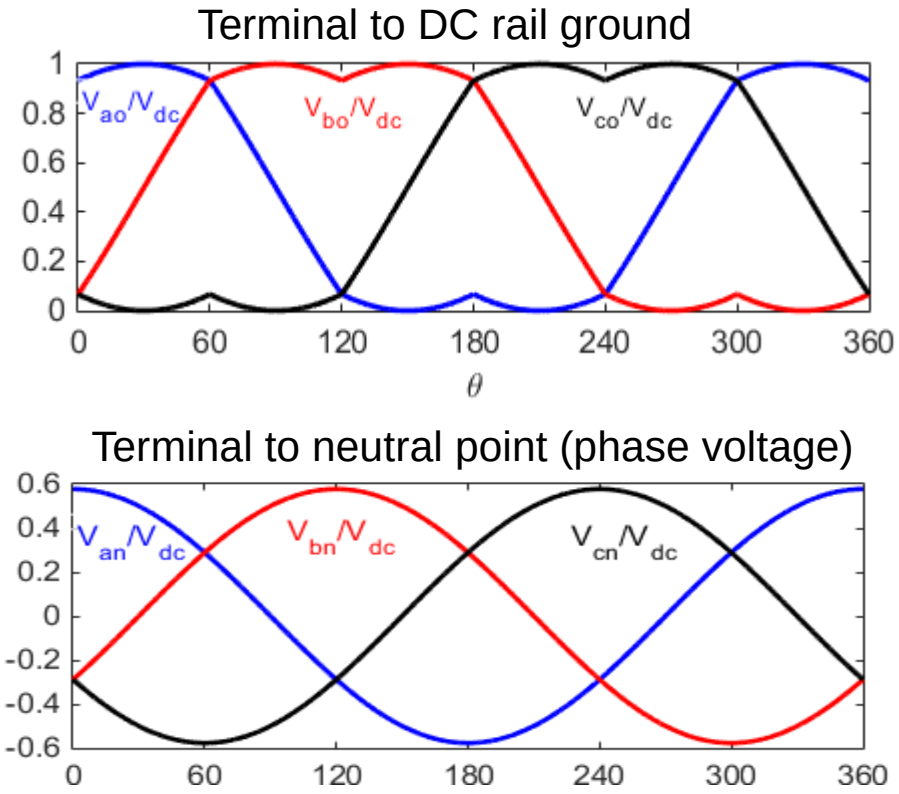
每个扇区中，目标矢量由相邻的两个电压矢量调制而成，剩余的时间可以用零矢量填充.



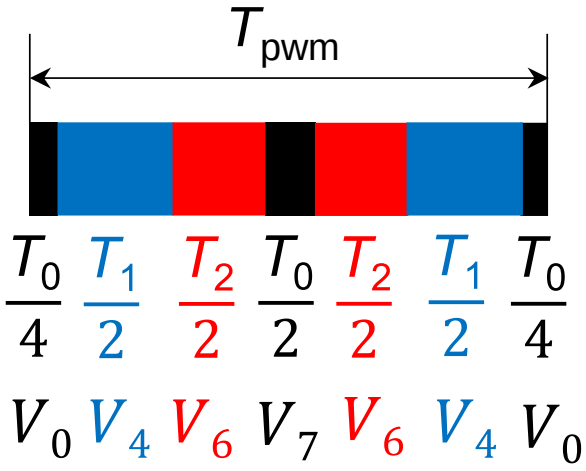


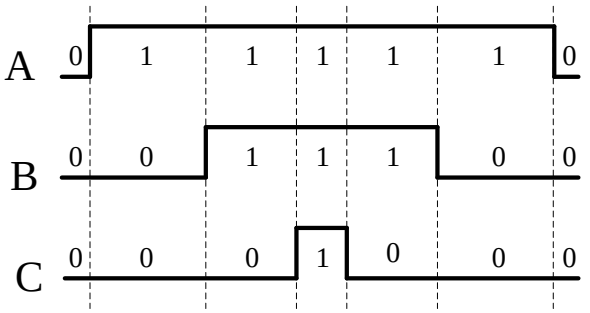
SVPWM

采用V0和V7作为插入零矢量，在PWM开始和结束插入V0矢量，中间插入V7矢量



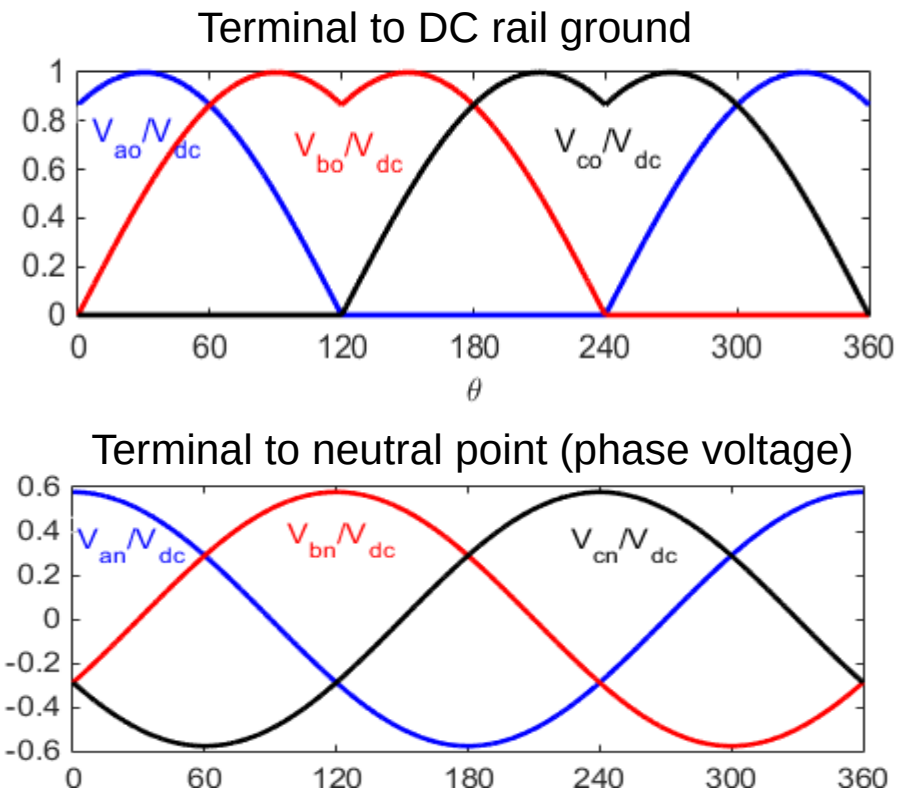
Less harmonics

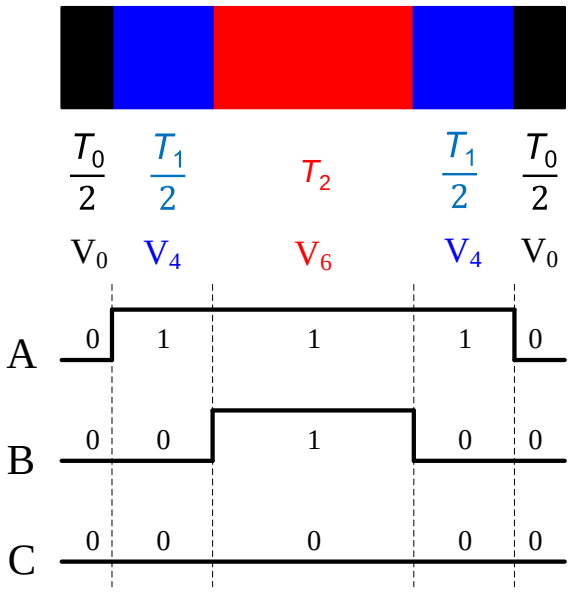




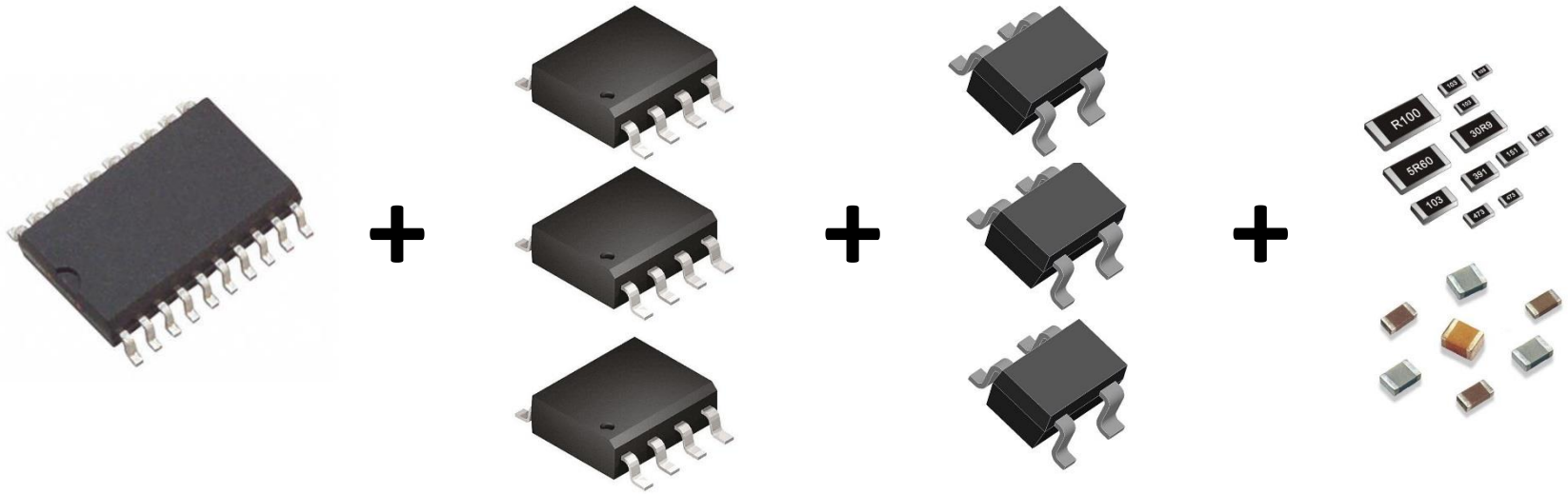
SVPWM

采用V0作为插入零矢量，在PWM开始和结束插入V0矢量



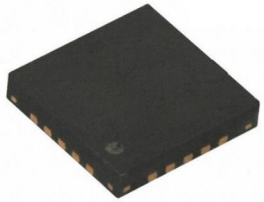


MPS三相BLDC风扇方案

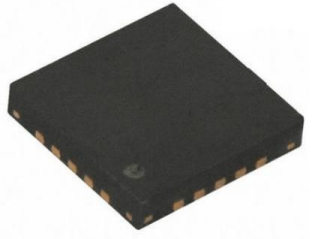


MCU/Controller+ MOSFET+ Hall+ Several Res+ Several Cap

MP6630/MP6630H
5.5V/12V-0.5A
UTQFN2x3mm



MP6631+3/1 Hall
36V/2A
QFN3x4mm



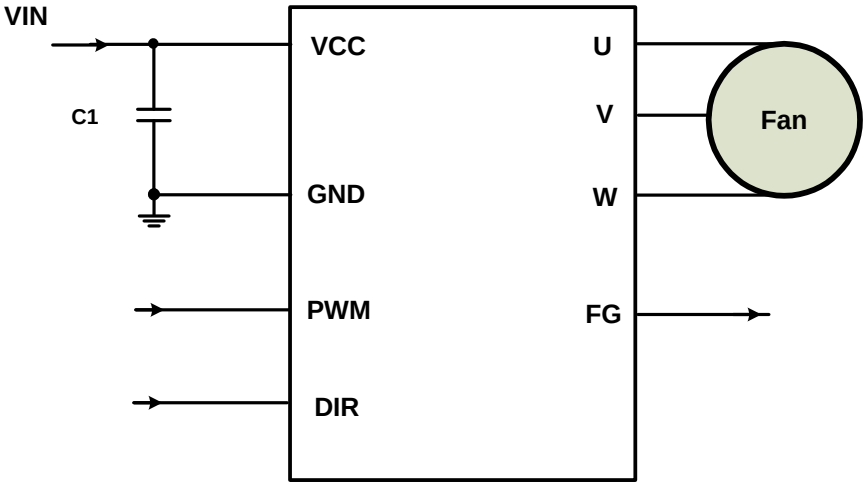
MP6632
55V controller
QFN4x4

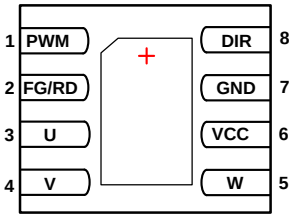
Simple, Easy Solutions

MPS三相BLDC风扇方案

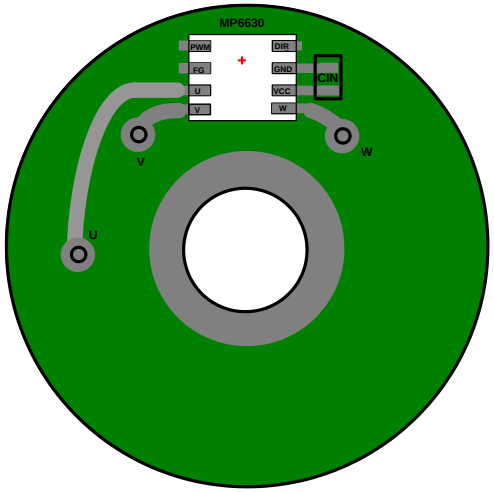
MP6630/MP6630H:
3 phase with 1 on-chip hall

- On-chip Hall sensor
- MP6630: 2V to 5.5V
- MP6630H: 2-12V
- Sine-wave control
- Integrated MOSFET: 450mΩ
- 500mA continuous current
- 2k-100kHz PWM input
- Direction control
- Soft start
- Rotational speed indicator FG signal
- Input line OVP protection
- Rotor deadlocked protection and automatic recovery





UTQFN2x3mm

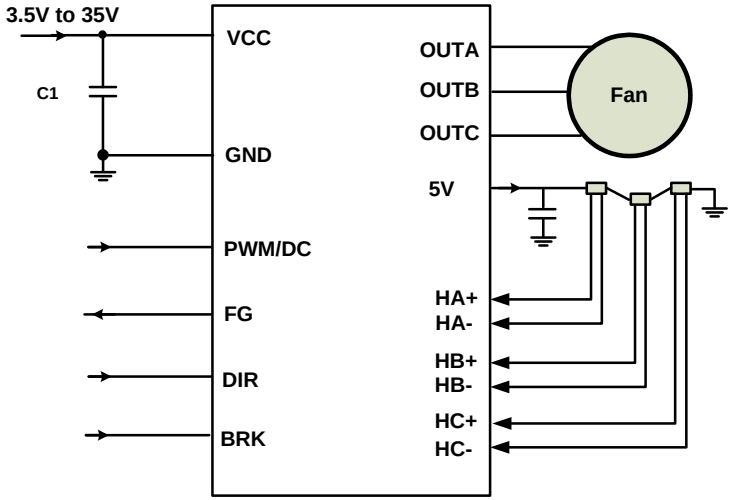


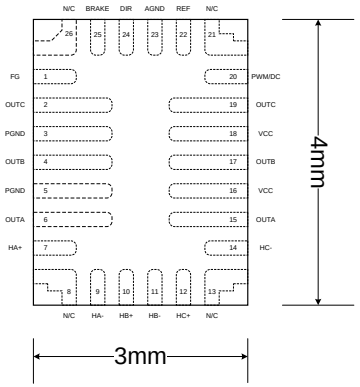
Simple, Easy Solutions

MPS三相BLDC风扇方案

MP6631: 3 phase with 3/1 hall

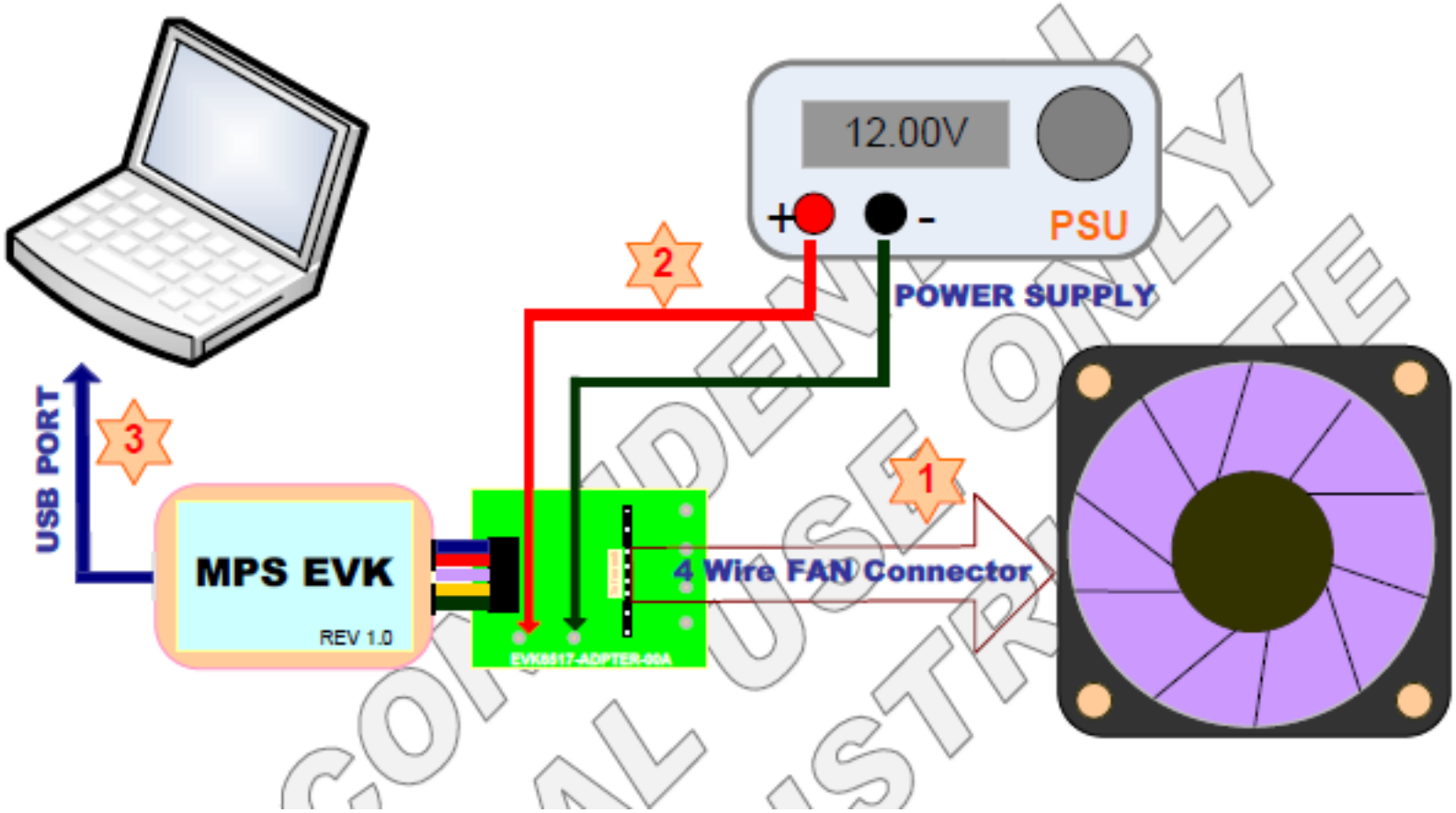
- 3.5V-36V input
- Up to 2A continuous output
- 120mohm Rdson(H+L)
- sine-wave control
- Support DC input or 2k – 100kHz PWM input
- 3 hall or 1 hall element differential input
- Close/Open mode speed control
- Direction/Brake input
- Power saving mode
- 500ms/ 5s lock protection
- Over-current protection
- ABC switching node short protection
- FG/RD output selectable
- 25k/50k/100k/200k switching frequency
- Soft start for low noise and current overshoot





Application Tips

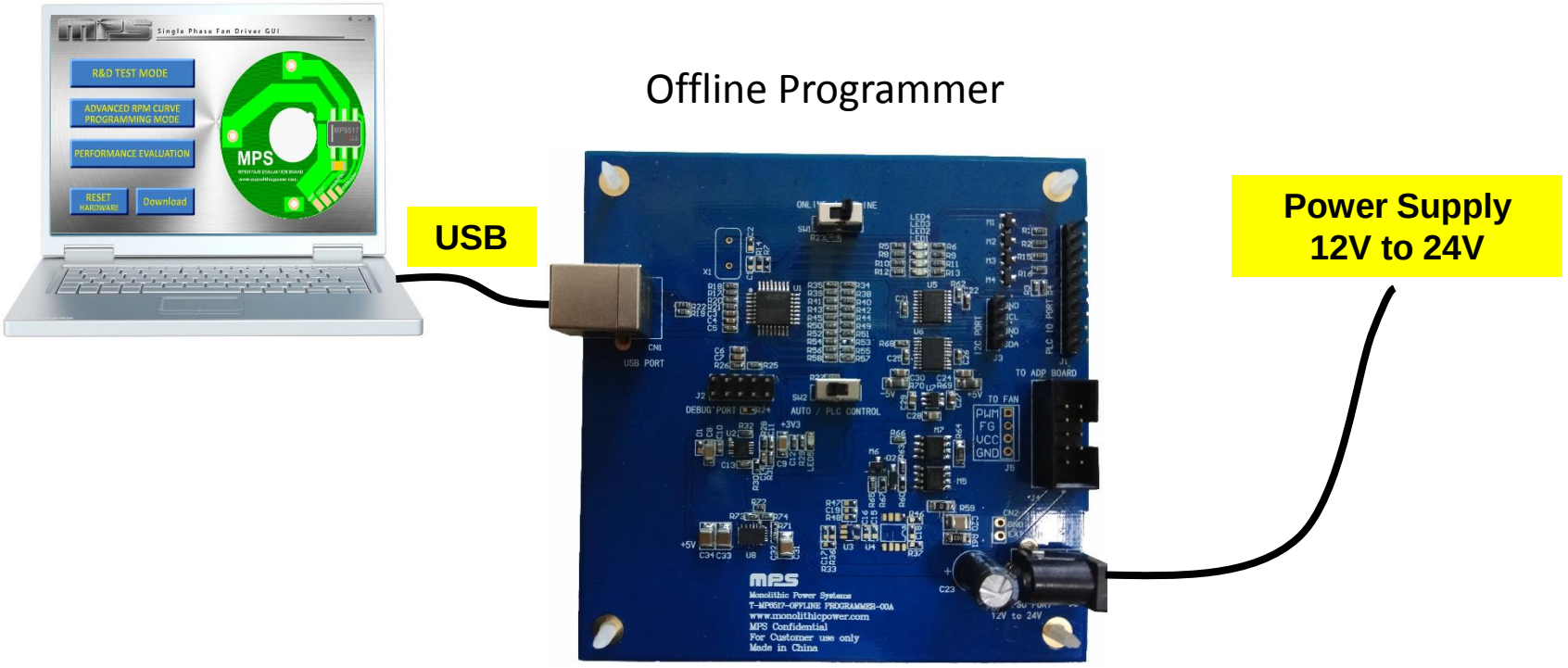
Dongle, GUI, and offline programmer



Application Tips

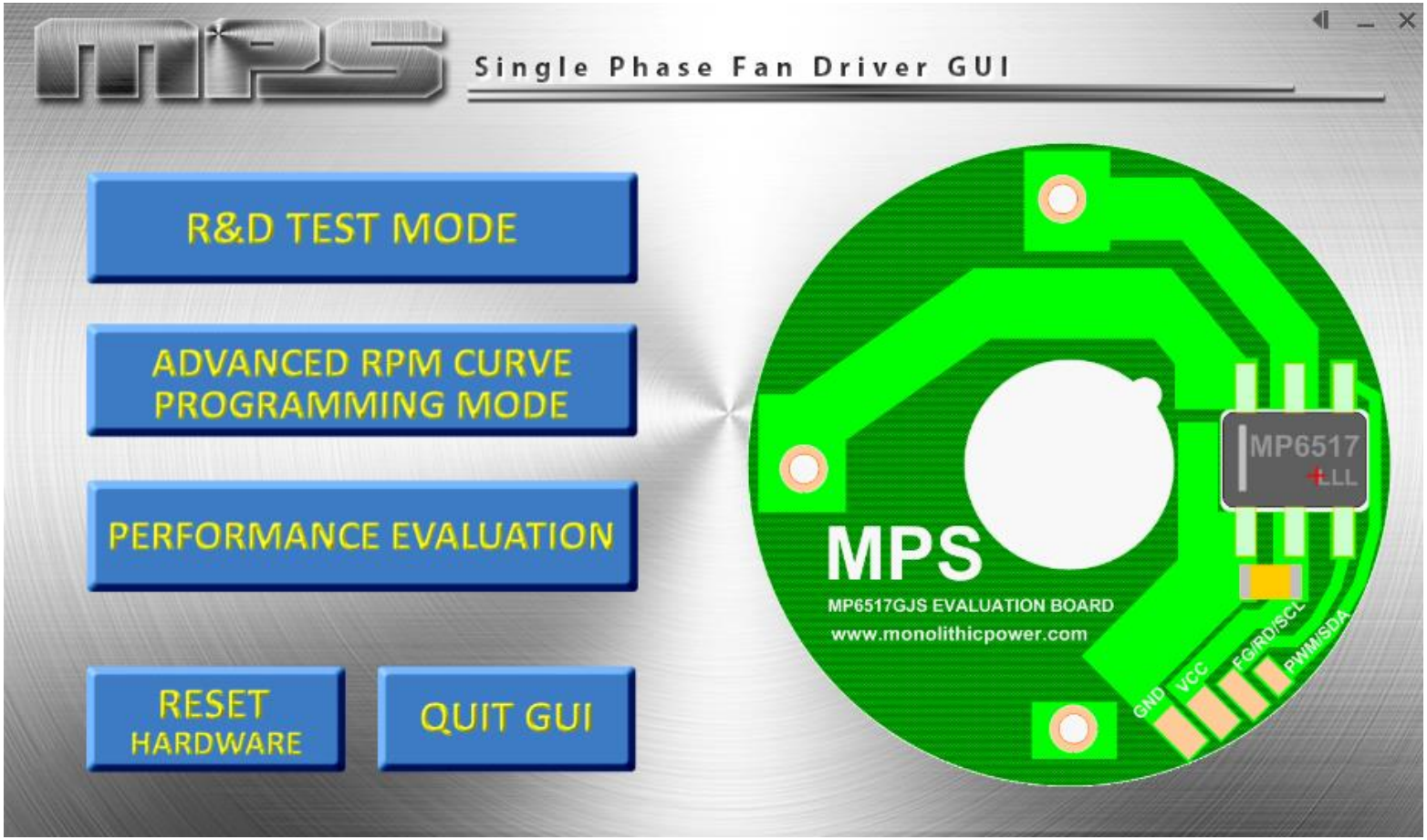
Dongle, GUI, and offline programmer

Hardware setup



Application Tips

Home Page



Simple, Easy Solutions

Application Tips

充磁方式 Methods of Magnetization

內外徑輻射充磁
Radial Magnetised

多極充磁
Multi-poles Magnetised

輻射取向多極充磁
Multi-poles Magnetised
Radial Orientation

徑向充磁
Diametic Magnetised

厚度方向充磁
Magnetised Through its Heigh

軸向充磁（厚度方向充磁）
Axial Magnetised

軸向多極充磁
Axil Magnetised Multi-poles

單面多極充磁
Single Surface Multi-poles
Magnetised

單面扇形充磁
Sectors on One Surface
Magnetised

瓦型磁石輻射狀充磁
Tile-type Magnet Radial
Magnetised

雙面多極充磁
Double Surface Multi-poles
Magnetised

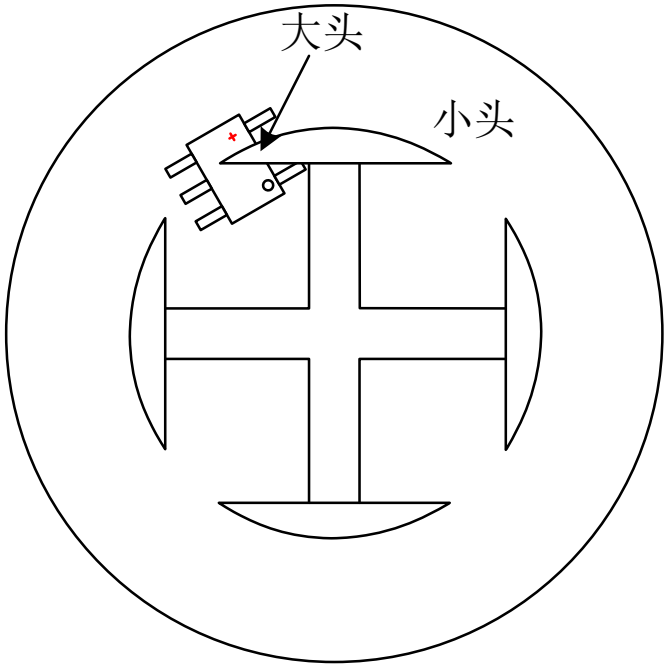
瓦型磁石徑向充磁
Tile-type Magnet Diametic
Magnetised

Simple, Easy Solutions

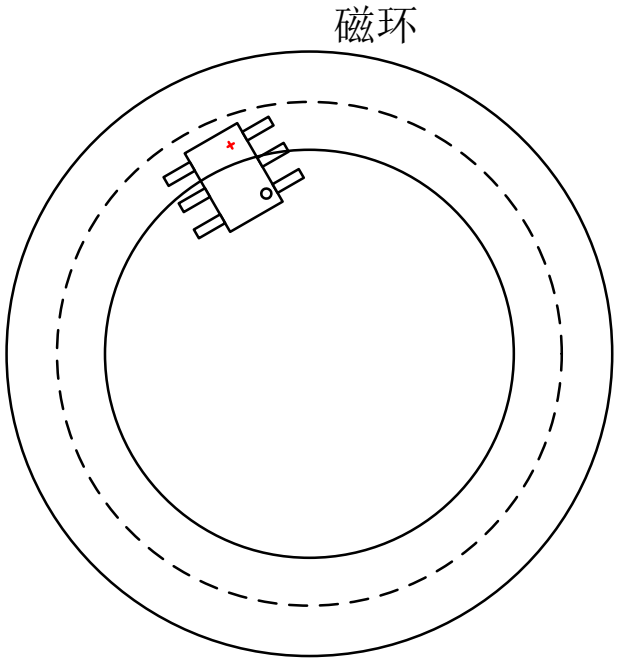
Application Tips

Hall位置

Hall 感应点靠近定子大头侧



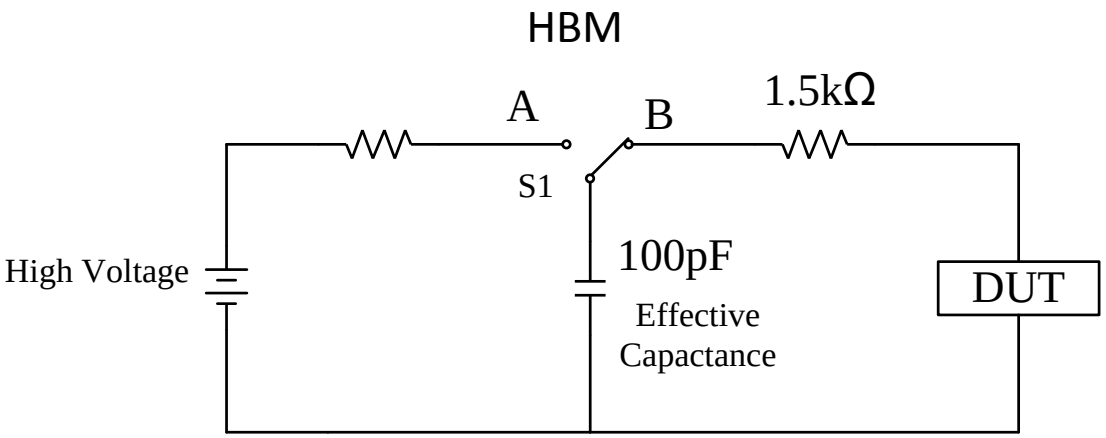
Hall 感应点在磁环的内径和外径的1/4 到1/2处

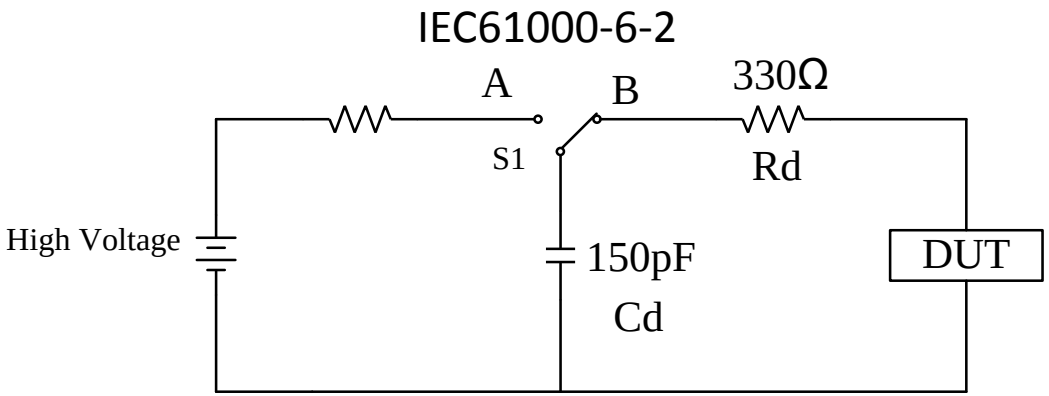


Simple, Easy Solutions

Application Tips

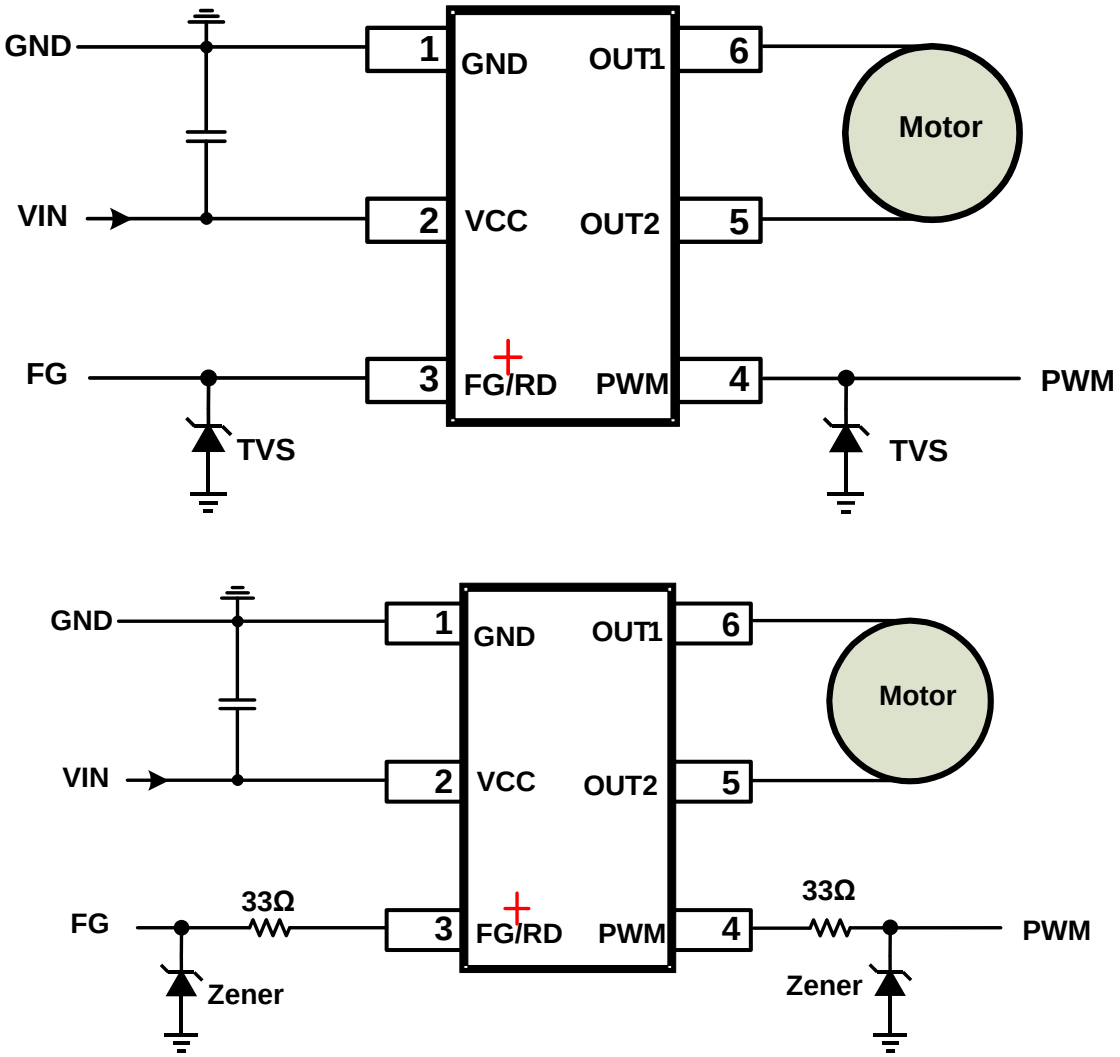
系统级ESD （IEC61000-6-2）：外壳和引出线的ESD测试





Application Tips

PWM和FG引出线，ESD能力较弱，需要加强ESD



Simple, Easy Solutions

Thank you

Simple, Easy Solutions