

Intro to Motor and Motor Control

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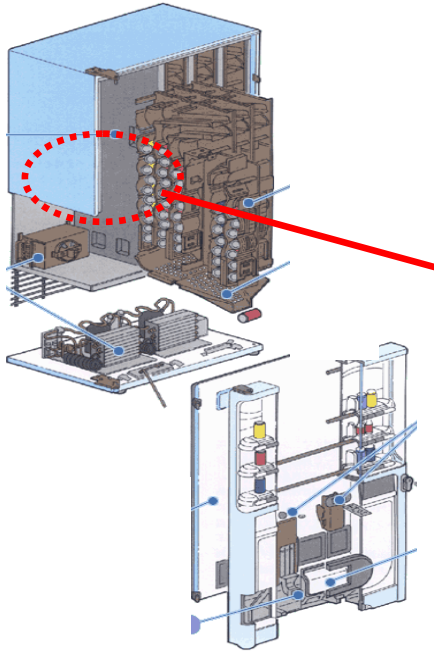
Apr 2012

1. Motor applications

马达的应用

1.1 Used in industrial machinery 1

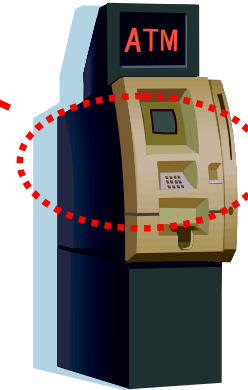
Vending machine



Bill Validate
→ **H-Bridge**

Card feeder
→ **H-Bridge**

Currency equipment



Bill Validate
→ **H-Bridge**

Industrial equipments

Security camera



Fan
→ **H-Bridge**

AF/zoom
→ **Stepper**

Slot machine



Drum
→ **Stepper**

Coin hopper
→ **H-Bridge**

Projector



IRIS, zoom, tilt
→ **Stepper**

1.2 Used in industrial machinery 2

Gate opener



Door motor
→ H-bridge/BLDC

Textile machine



Feeder
→ H-Bridge

Antenna positioning



Positioning motor
→ Stepper

Stage lighting



Angle
→ Stepper

Industrial equipments

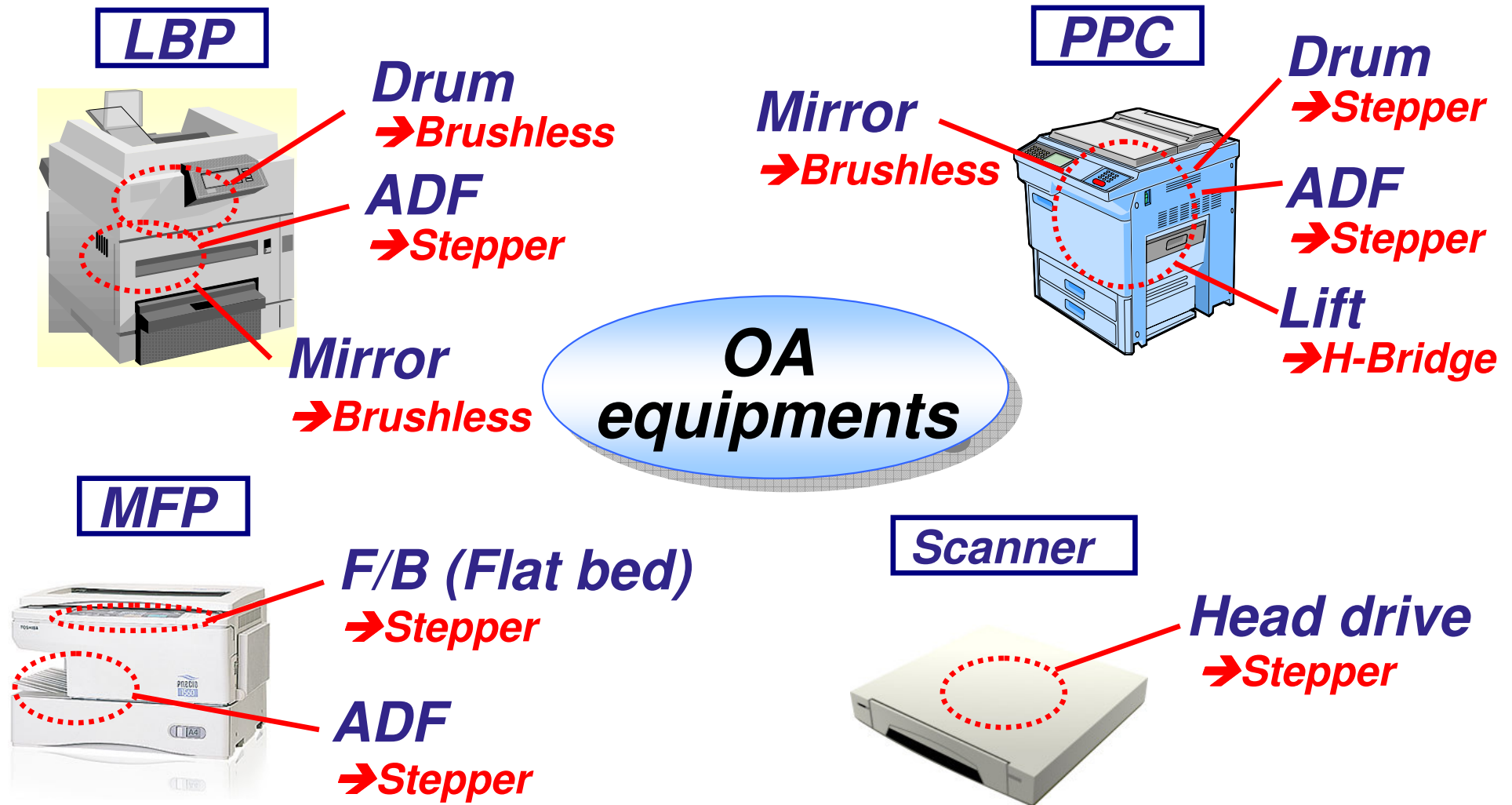
CPAP



Pump
→ H-bridge/ BLDC

1.3 Used in office appliances

➔ *The motors inside the movement*



Stepper :Stepping motor driver, **Brushless** :3phase brushless motor driver, **H-Bridge** :Brush motor driver

1.4 Used in home appliances

Dish washer



Drainage Pump
→ **Brushless**

Air-conditioner

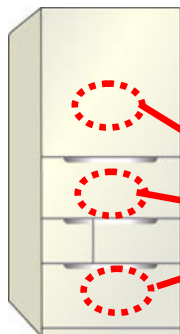


Fans
→ **Brushless**



Home appliance

Refrigerator



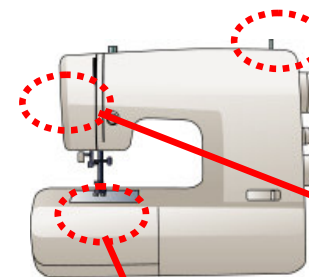
Fans
→ **Brushless**
Dumper
→ **Stepper**

Ventilator



Brushless

Sewing machine



Bobbin
→ **H-Bridge**
Main
→ **H-Bridge**
Cloth feeder
→ **Stepper**

1.5 Used in battery-powered devices

Toy (IR car)



Drive
→H-Bridge

Toy (Toy robot)



Articulation drive
→H-Bridge

**Battery-powered
appliance**

DSC



AF
→H-Bridge
Stepper

Shutter
→H-Bridge

IRIS
→H-Bridge
Stepper

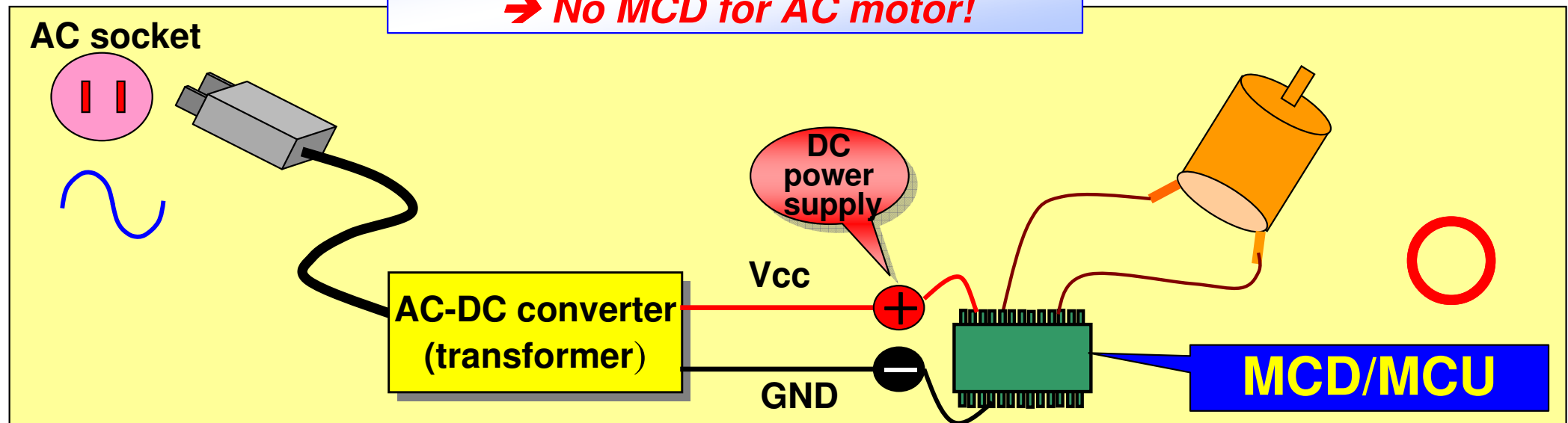
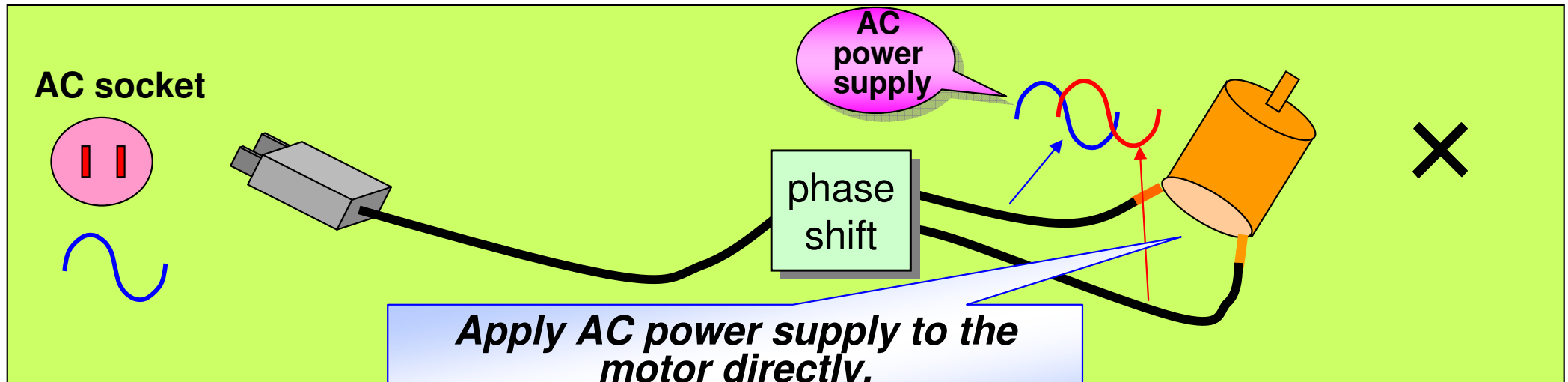
Zoom
→H-Bridge, Stepper

2. DC Motor basic principle

直流马达原理

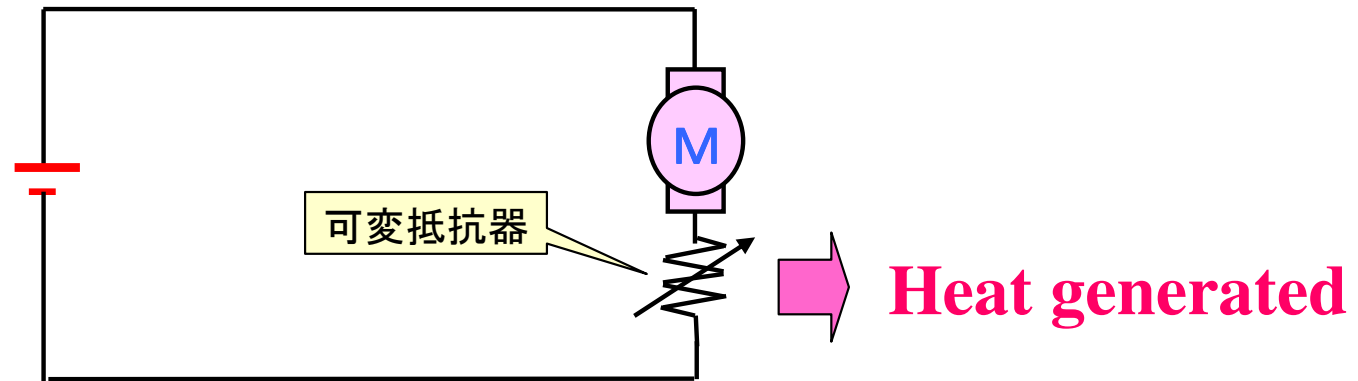
2.1 AC motor and DC motor

➔ *Motor control just for **DC motors** ! (Not for AC motors)*

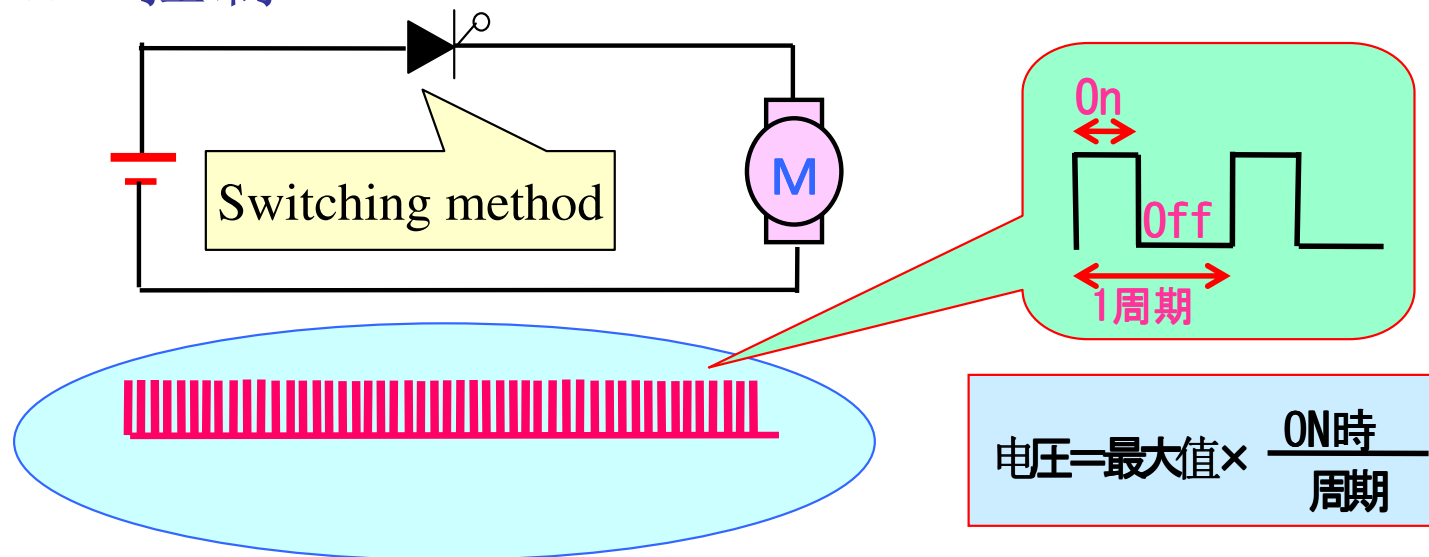


2.2 DC motor speed control

- 阻抗控制

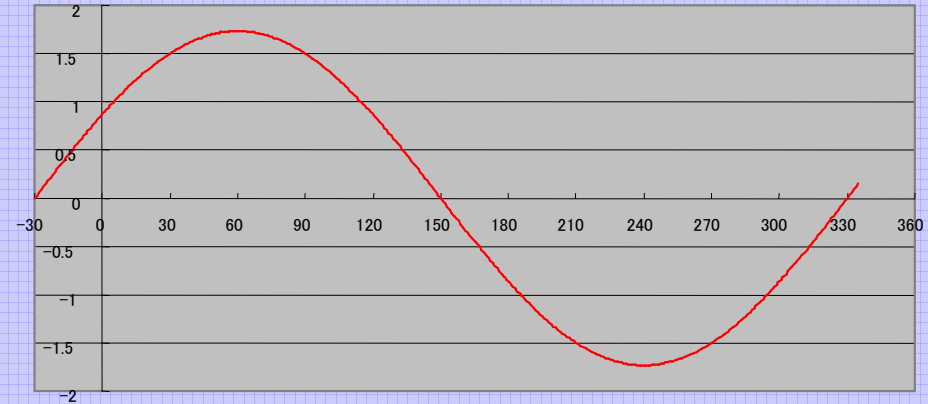
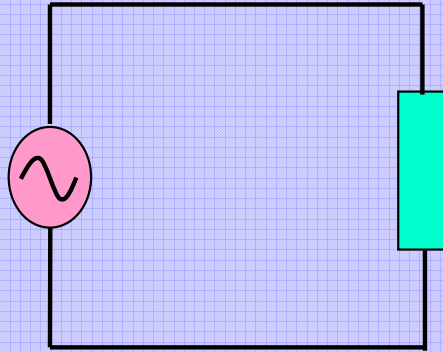


- PWM控制

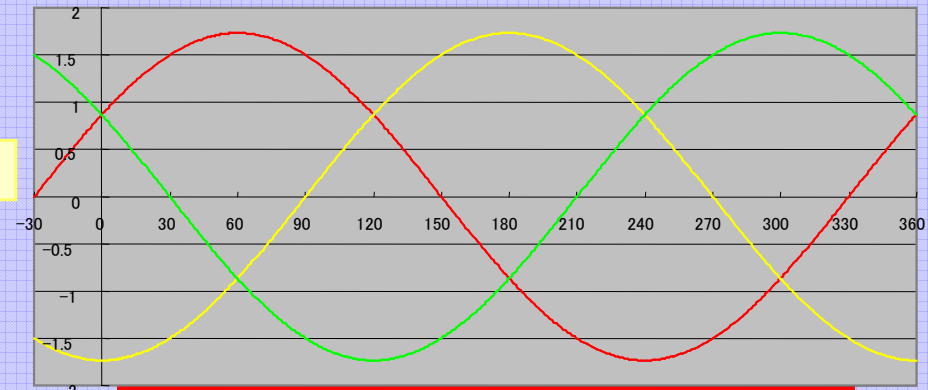
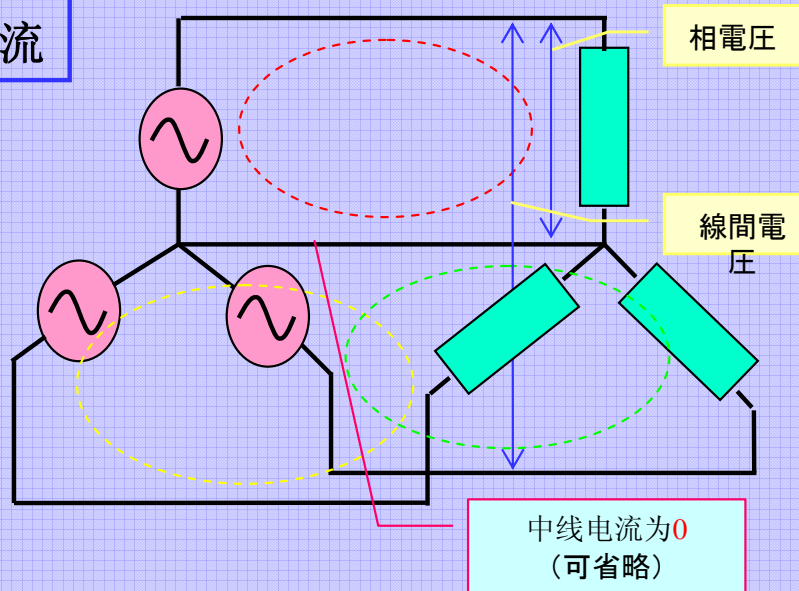


2.3 Single phase AC and three phase AC

单相交流



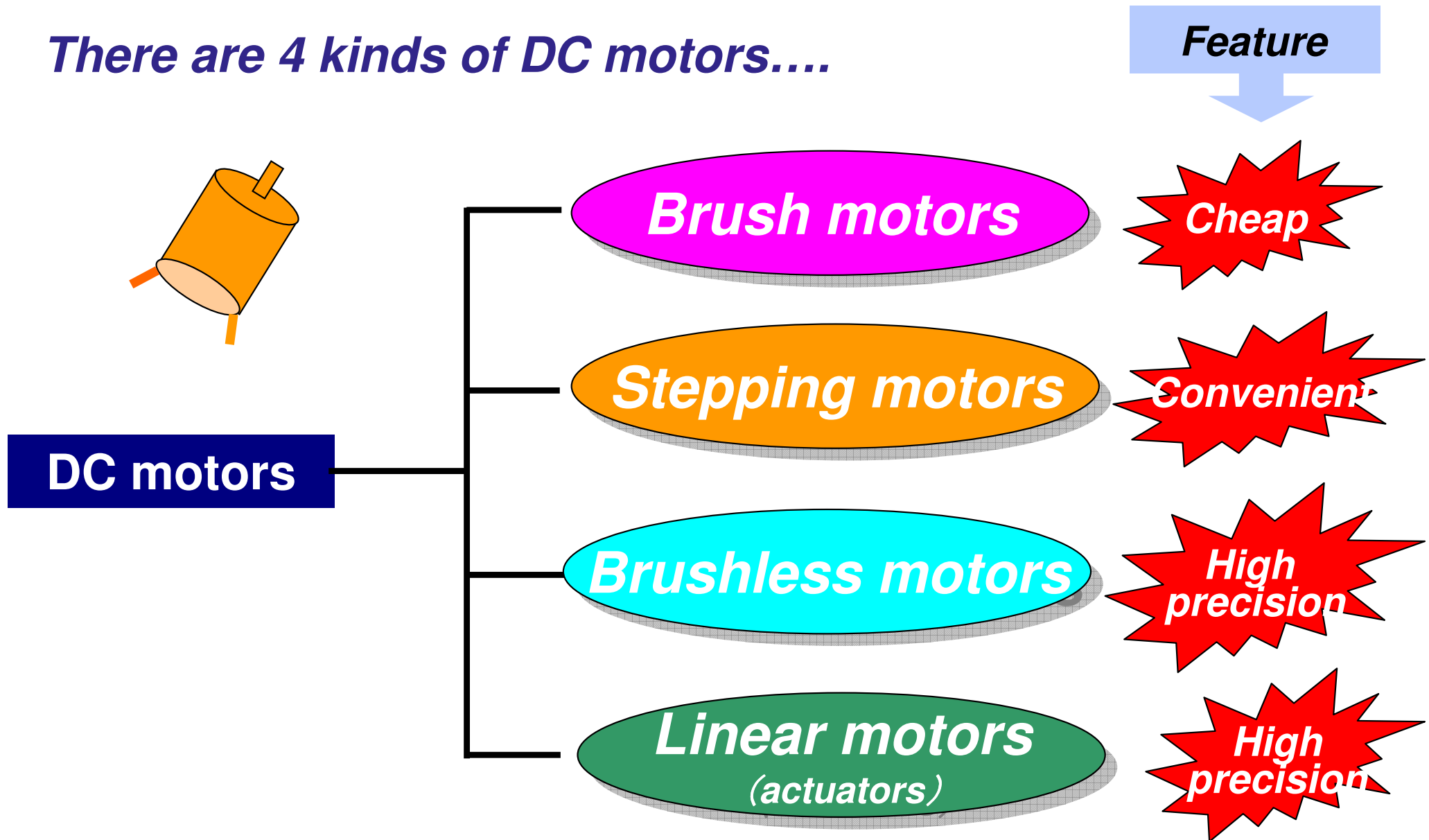
三相交流



三相交流波形 (各相之和为0)

2.4 Which kind of DC motors?

There are 4 kinds of DC motors....

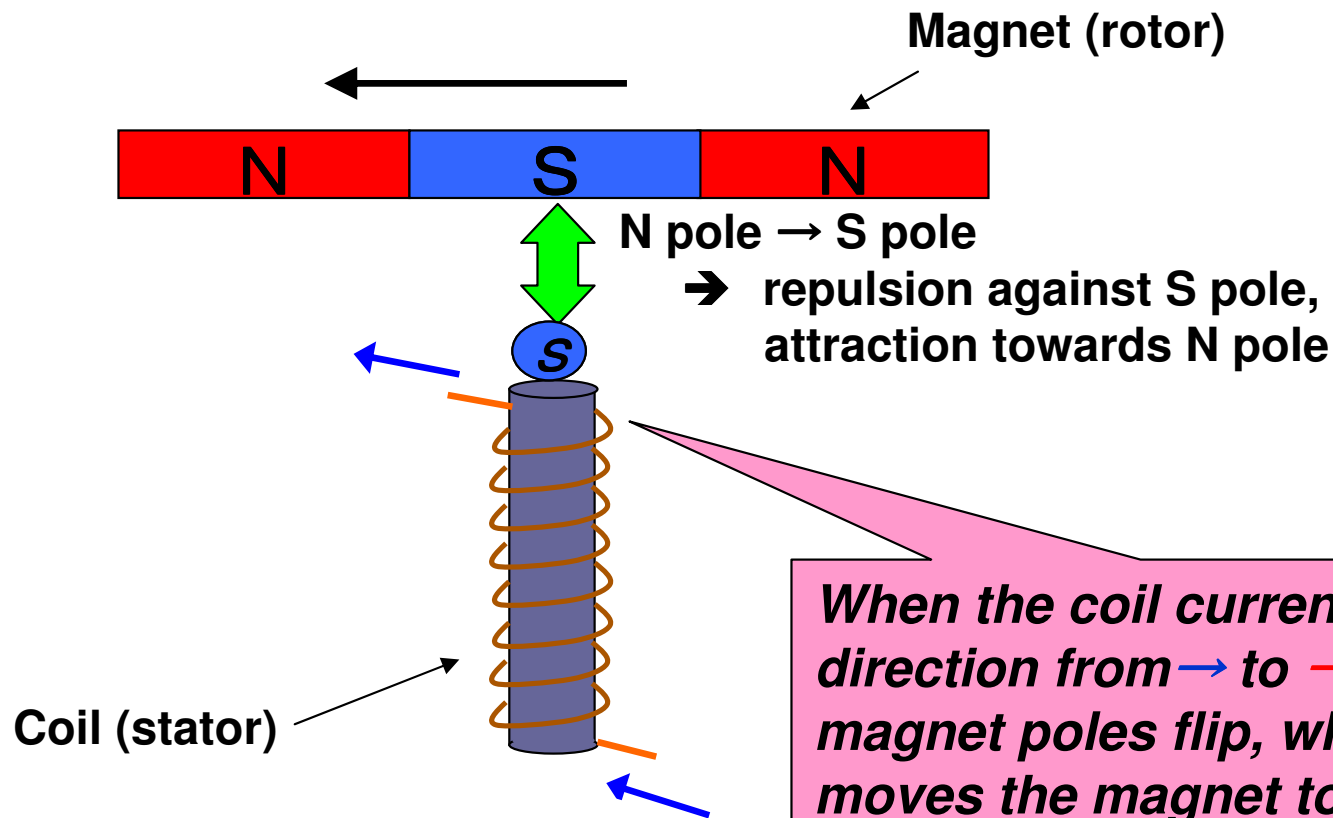


2.5 Motor basic principle

Point Lesson

The motor is rotated by a magnet, whose power is generated using a coil.

Ex.

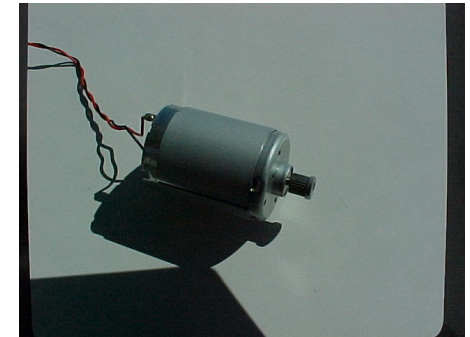
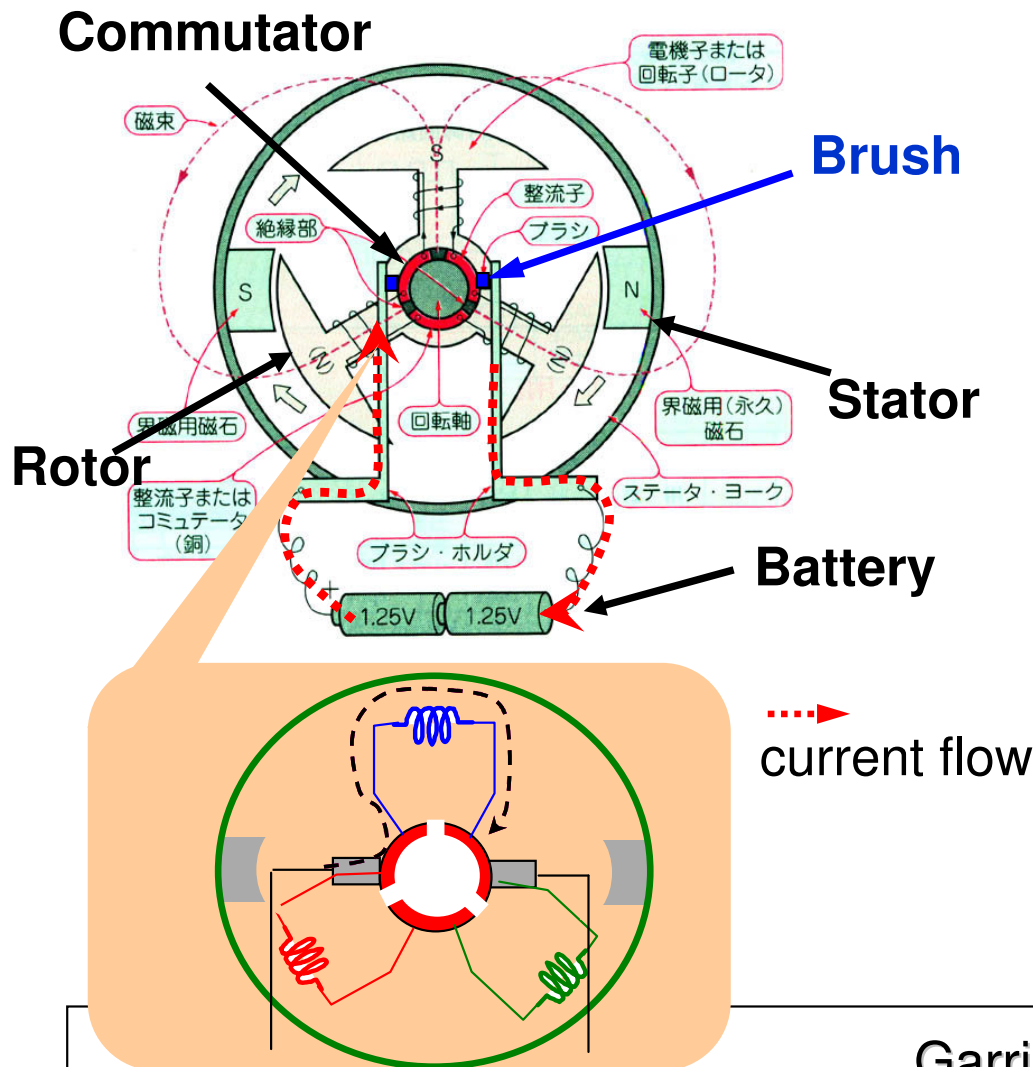


3. DC brushed motor

直流有刷马达

3.1 This is the DC brushed motor

Brushed motors



[How to drive]

The motor is constituted rotor and stator.

- 1) By bringing the brush into contact with the commutator, current flows from the positive of the battery to the negative via the commutator, the brush and a coil.
- 2) As the commutator rotates, the coil to be electrified switches. Repeating this operation rotates the motor.

[Features]

<Pros>

- * Low price

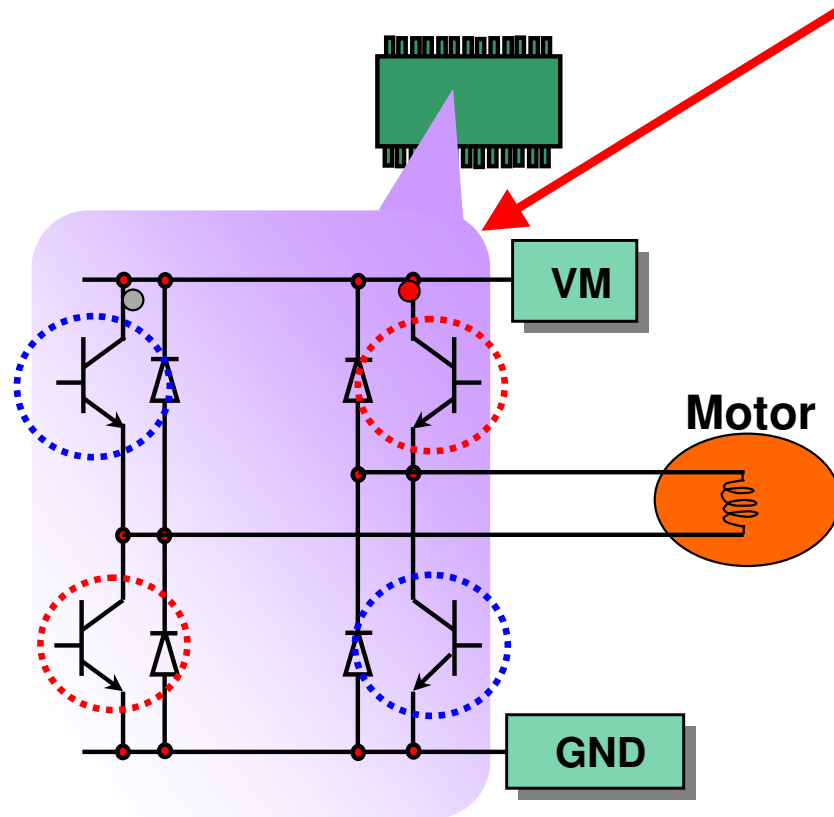
<Cons>

- * Large brush noise, limited life time of the brush

3.2 H-bridge driver

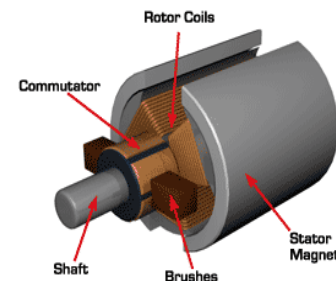
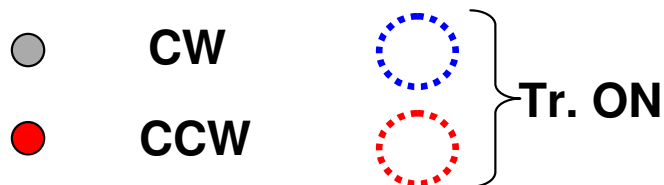
✧ "Bridge driver" (calls it "H-bridge")

4 power transistors/FETs inside
→ 1 H-bridge



◆ What the bridge driver IC can do

- * Can drive the motor in CW, CCW, stop and brake modes.
- * Can change the motor rotation direction.
- * Can control motor speed by PWM operation or same kind of circuit.

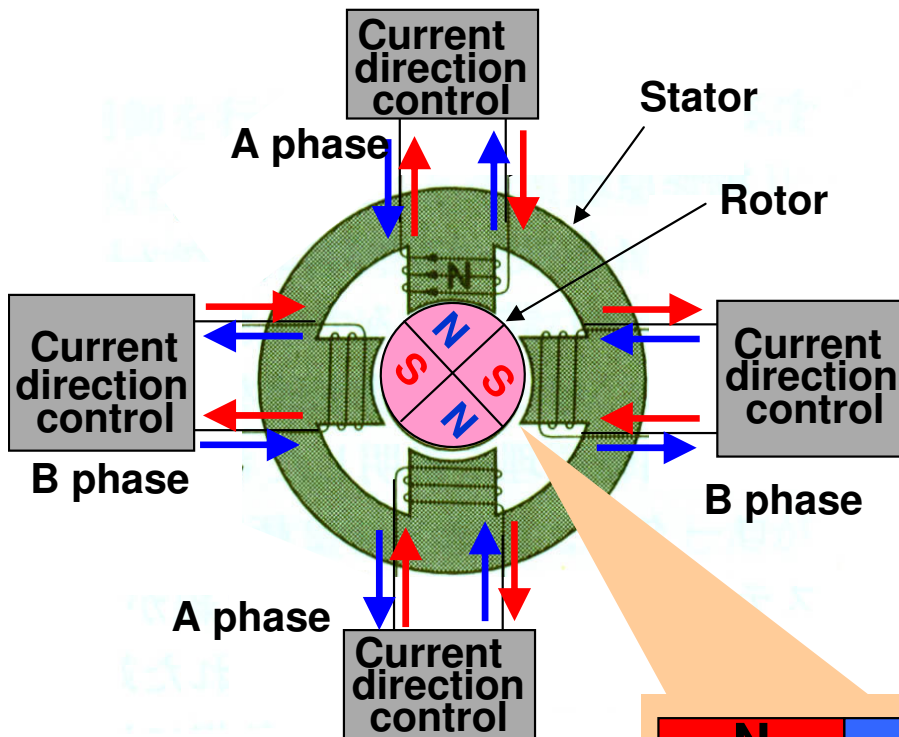


4. DC Stepping motor

直流步进马达

4.1 This is stepping motor

Stepping motors



Ex) 2phase bipolar type

→ CW
← CCW

[How to drive]

- ① As the current flows into the coil, the rotor magnet is repulsed, creating a magnetic field.
- ② The rotor moves when this magnetic field reverts.

[Features]

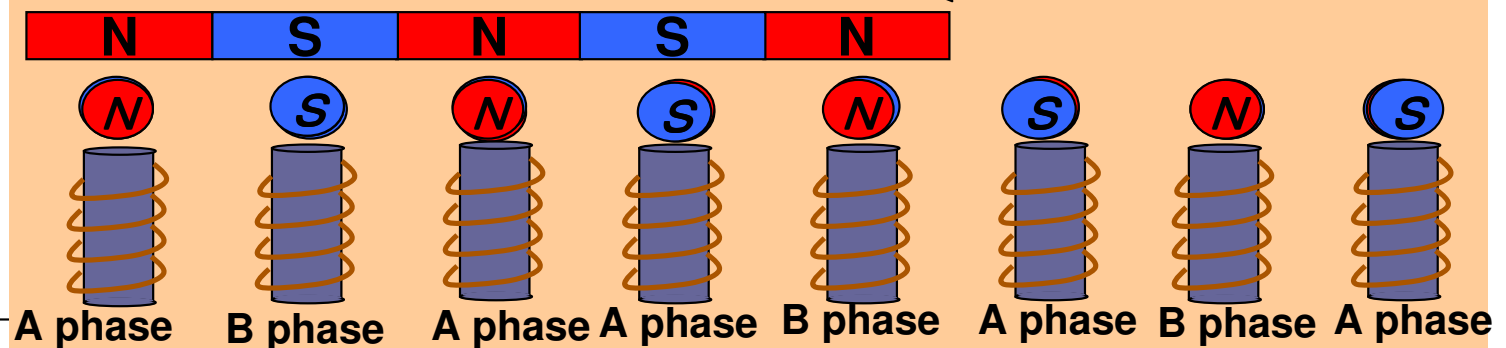
<Pros>

Easy open loop control
+ Easy driving at low speed

<Cons>

Difficult to drive at high speed

Magnet moves step by step !



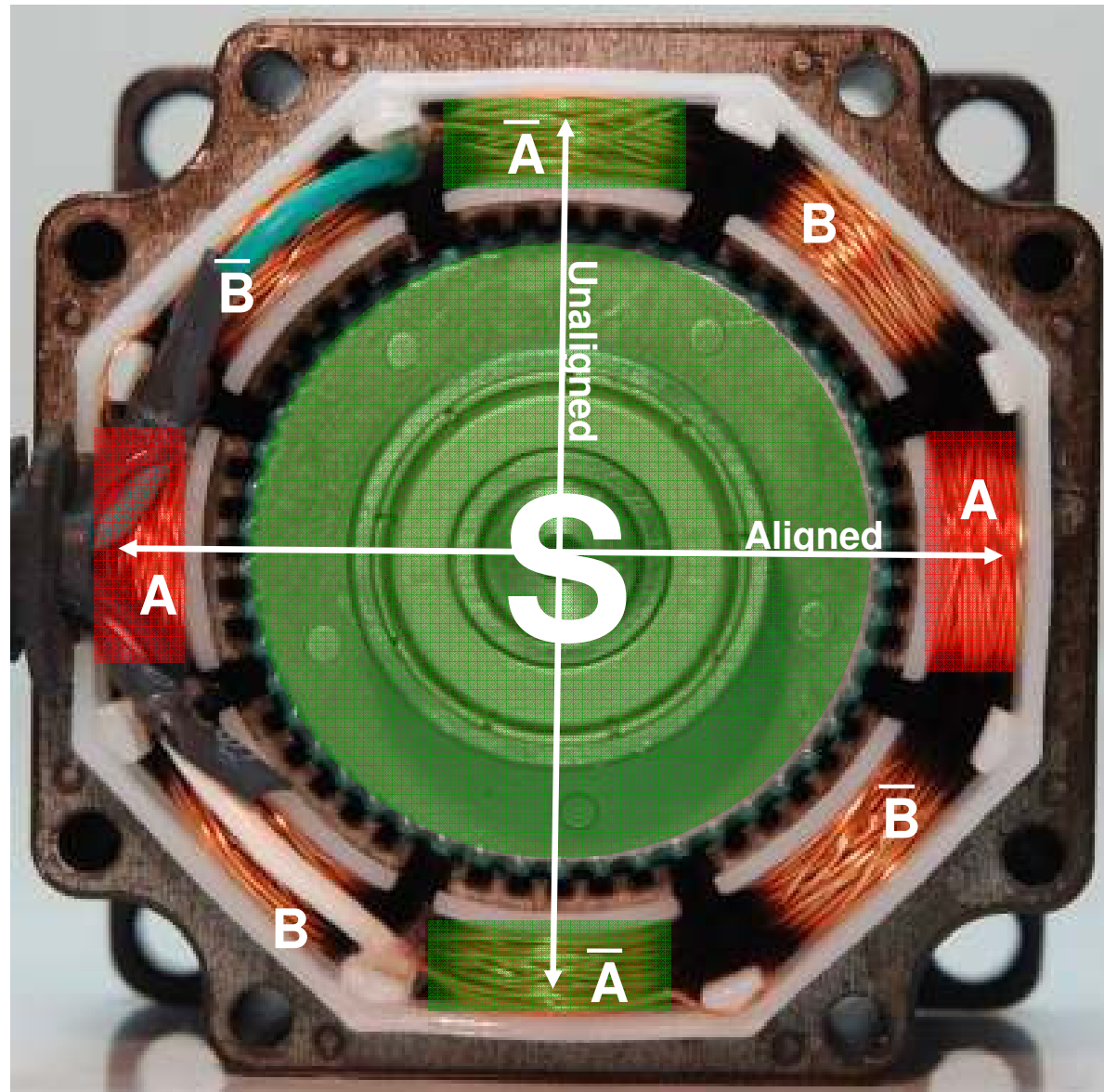
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4.2 Stator-Rotor Tooth Alignment

48 Stator Teeth
50 Rotor Teeth

North Pole

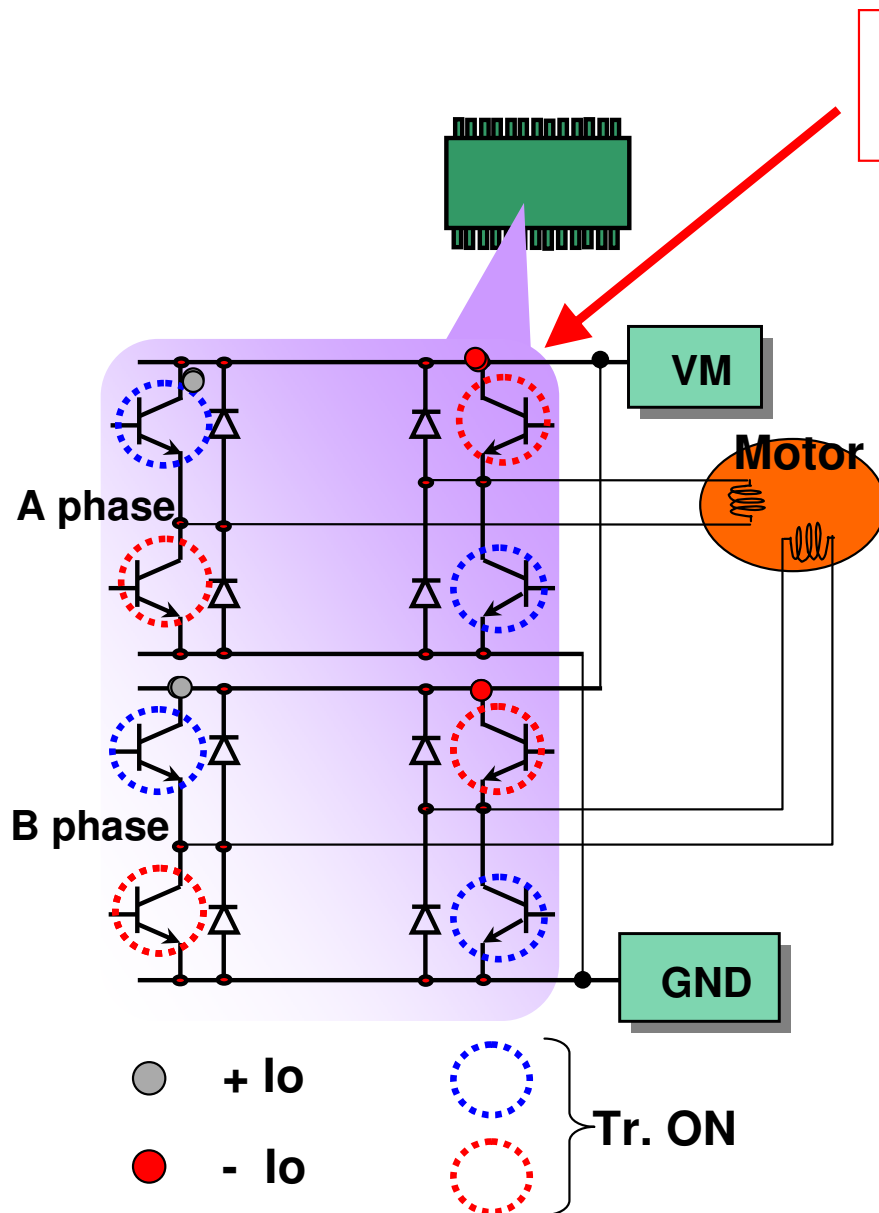
South Pole



Whole Step
(1.8° Rotor Movement)

Half Step
(0.9° Rotor Movement)

4.3 Stepping motor control

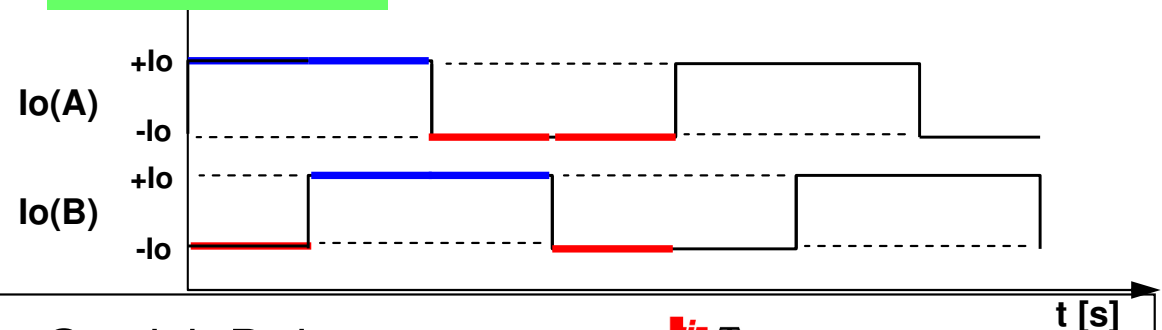


8 power transistors inside! → 2 H-bridges
(2 phase bipolar type)

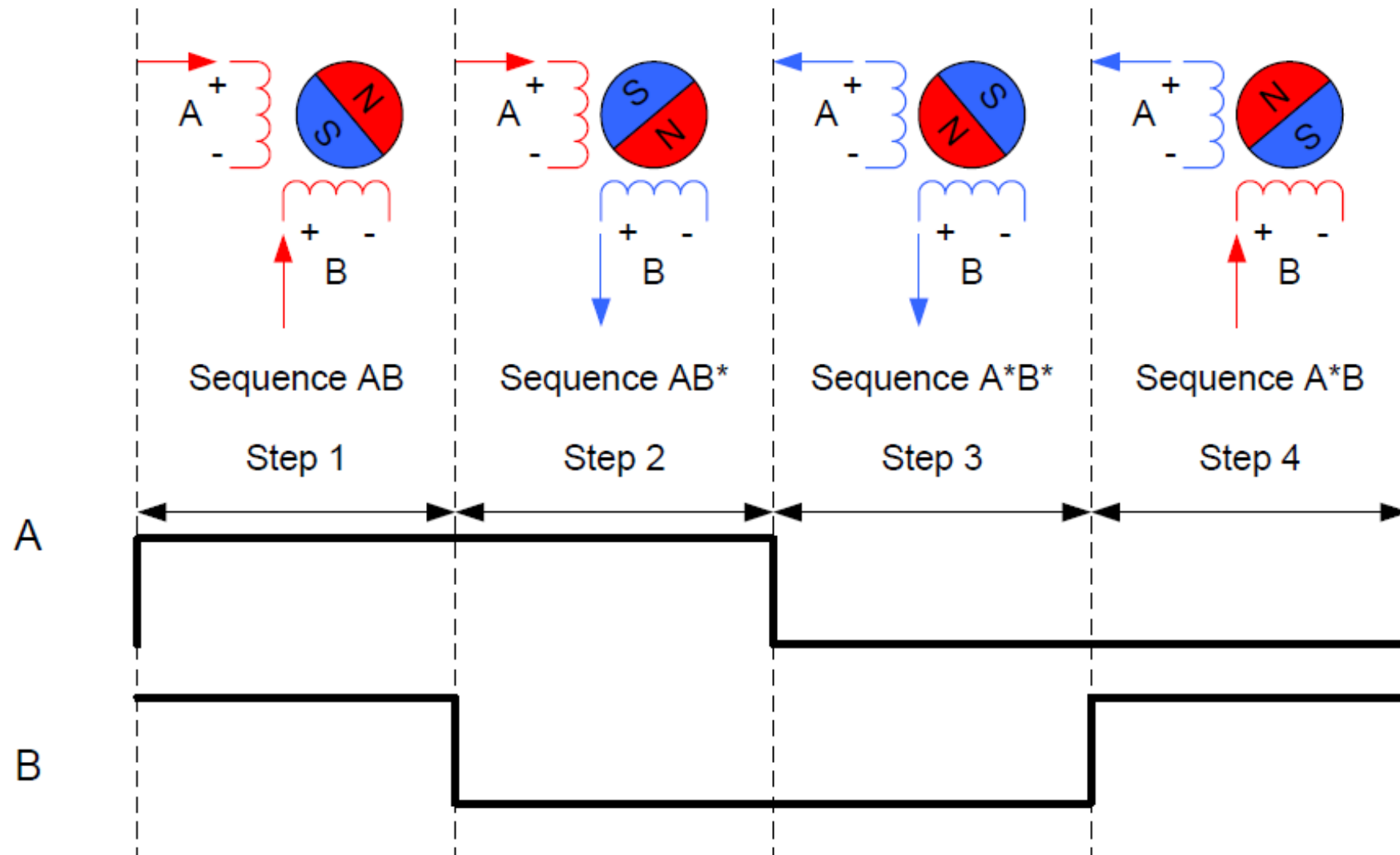
◆ What the stepping motor driver IC can do.

- * Can drive the motor in CW, CCW and stop modes.
- * Can keep stopping the motor in one position.
- * Can control how many angle to move the motor.

Ex) CW mode



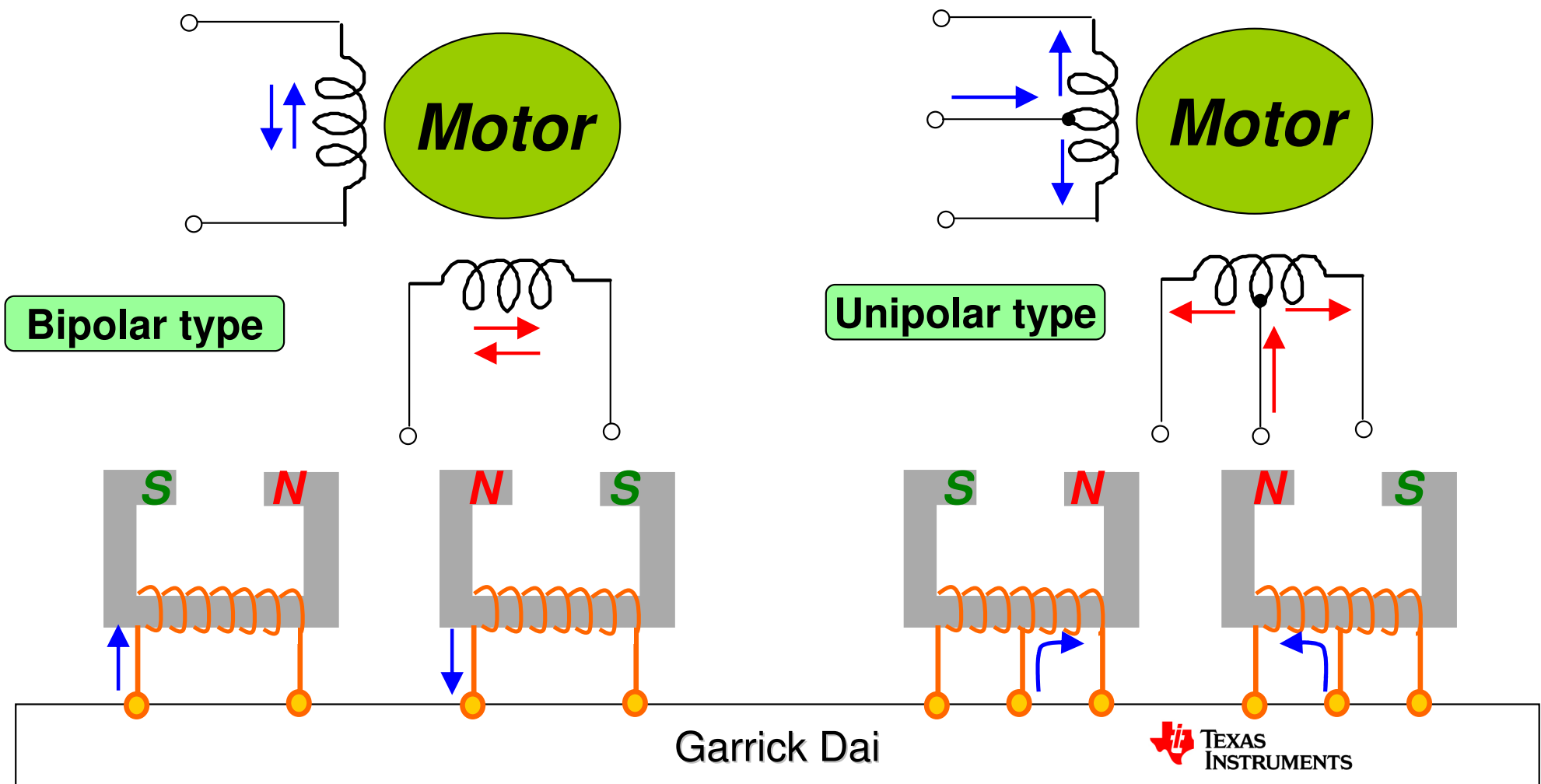
4.4 Stepper motor control



4.5 Unipolar type and Bipolar type

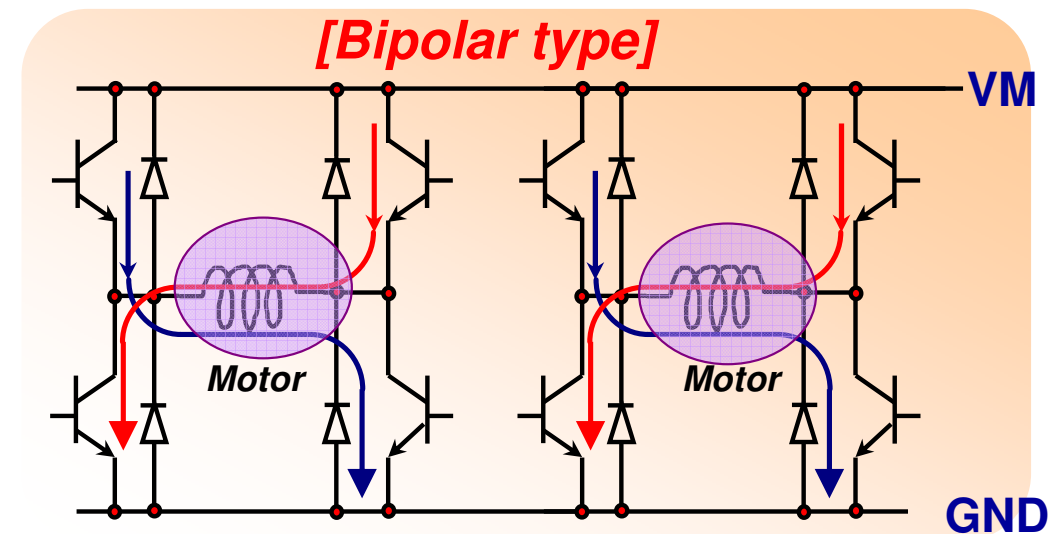
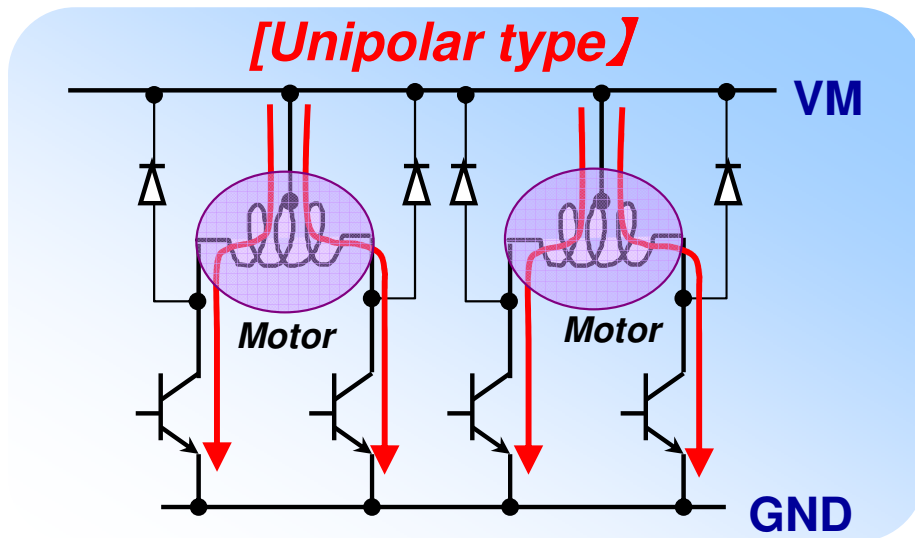
There are 2 kind of type for stepping motor as following.

- Unipolar type : Uni-directional current through the coil
- Bipolar type : Bi-directional current through the coil



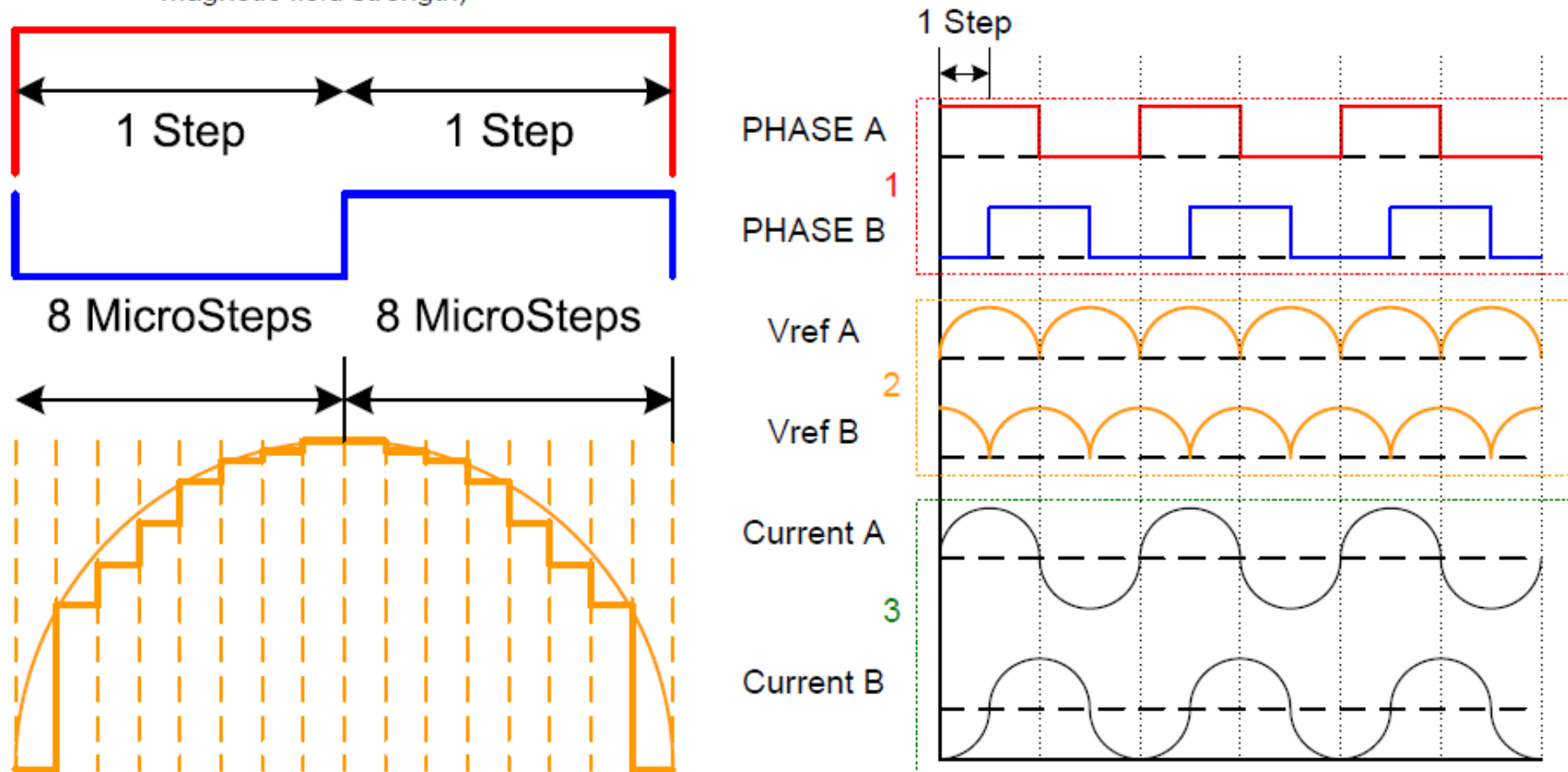
4.6 Unipolar VS Bipolar

| Type | System | Feature |
|----------|--|--|
| Unipolar | One-way current onto the coil (active drive on half of the wave) | Number of power transistors is half of bipolar type |
| Bipolar | Current is flown both ways onto the coil (Full-wave drive) | Magnet power has to be $\sqrt{2}$ that of unipolar. Angular precision is easy to obtain. |

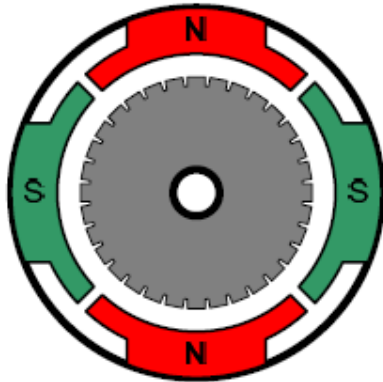


4.7 Micro step drive (realized by external DAC)

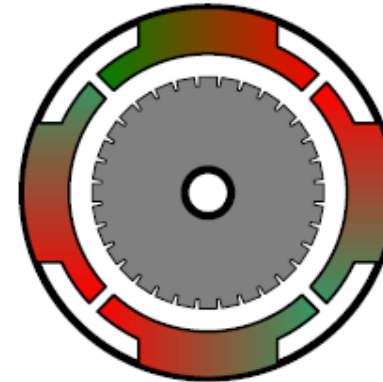
- By varying the current through the windings, stepper motor rotation can be controlled to less than a full step
- How does it work?
 - 1 Each Full Step is divided into multiple microsteps by
 - 2 embedding a waveform with multiple levels of reference voltage (i.e. sine, triangular, rhomboid, etc)
 - 3 which generates a bipolar current waveform with multiple current levels (i.e. multiple degrees of magnetic field strength)



4.8 Micro Step vs Full Step



Full Step



Micro Step

- Provides a higher degree of control than can be obtained if using a DC or brushless DC motor, without the use of closed loop control
 - Stator: Usually made of the electromagnet
 - Rotor: Consists of a permanent magnet teathed structure
 - Polarizing the stator allows for the rotor to lock position.
 - By carefully sequencing the stator polarization, rate of stepping and direction can be controlled
- Full Step
 - Magnetic field is generated with a single current level causing the rotor to lock into a predetermined position
- Fractional stepping or Micro-stepping
 - Magnetic fields are generated with multiple current levels creating a gradient of push/pull which in turn divide a full step into multiple smaller steps (referred to as microsteps)

5. Three phase DC brushless motor (BLDC)

3相直流无刷马达（简称BLDC）

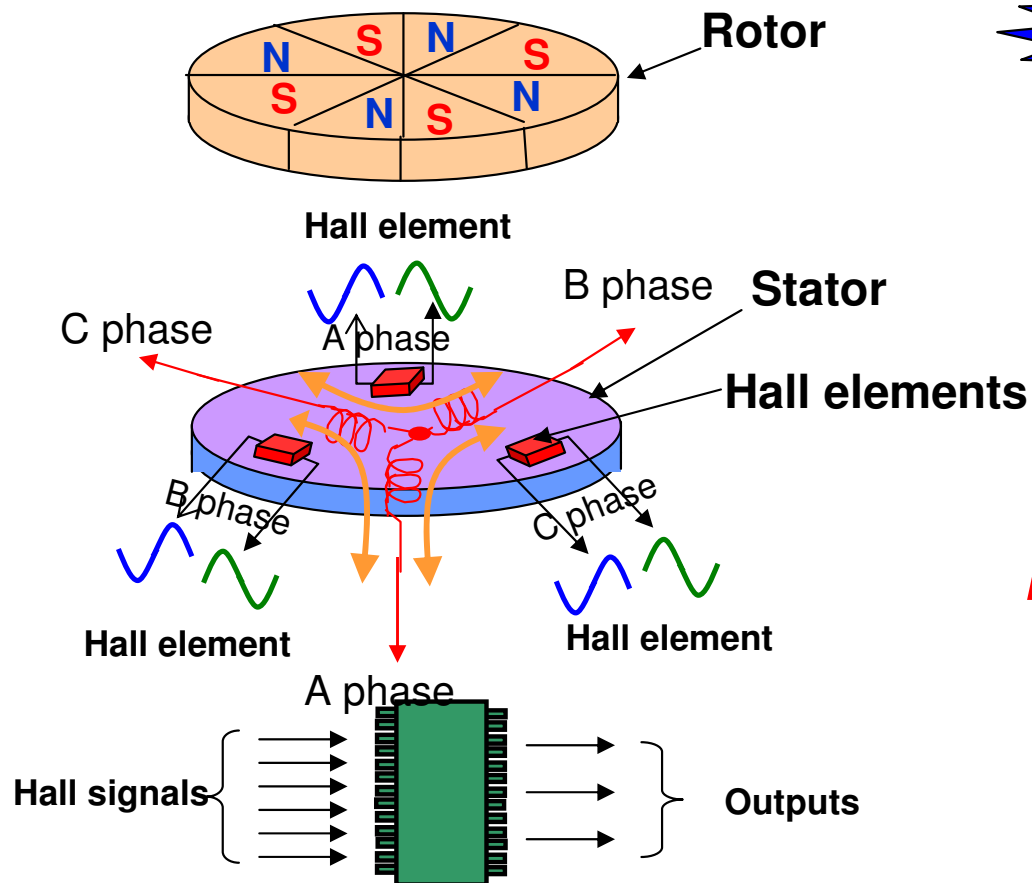
5.1 This is the brushless motor (BLDC)

Brushless motors

No brush like brushed motor → Brushless

✓ Use hall elements → **Hall motor**

✓ Not use hall elements → **Sensorless motor**



1 Point lesson

Hall elements

The element which outputs voltage under magnetism.

[How to drive]

- 1) Senses rotor position by hall elements, then transfers it to the IC.
- 2) Operates 3 hall signals, then electrifies the motor coils to drive the motor

[Features]

<Pros>

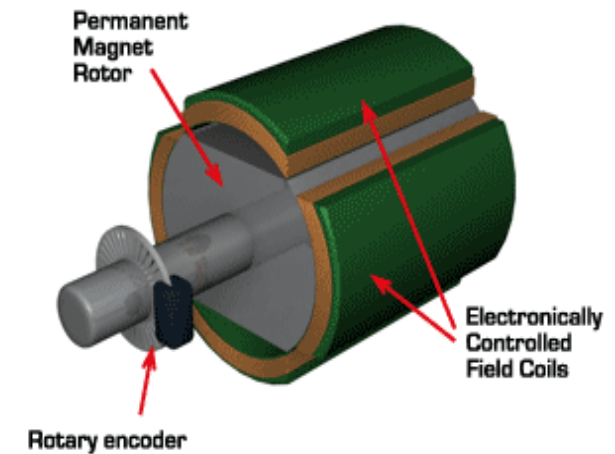
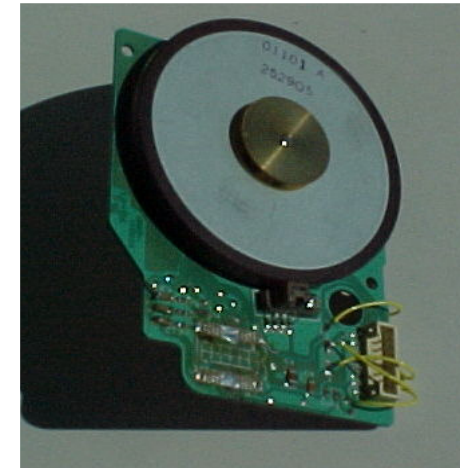
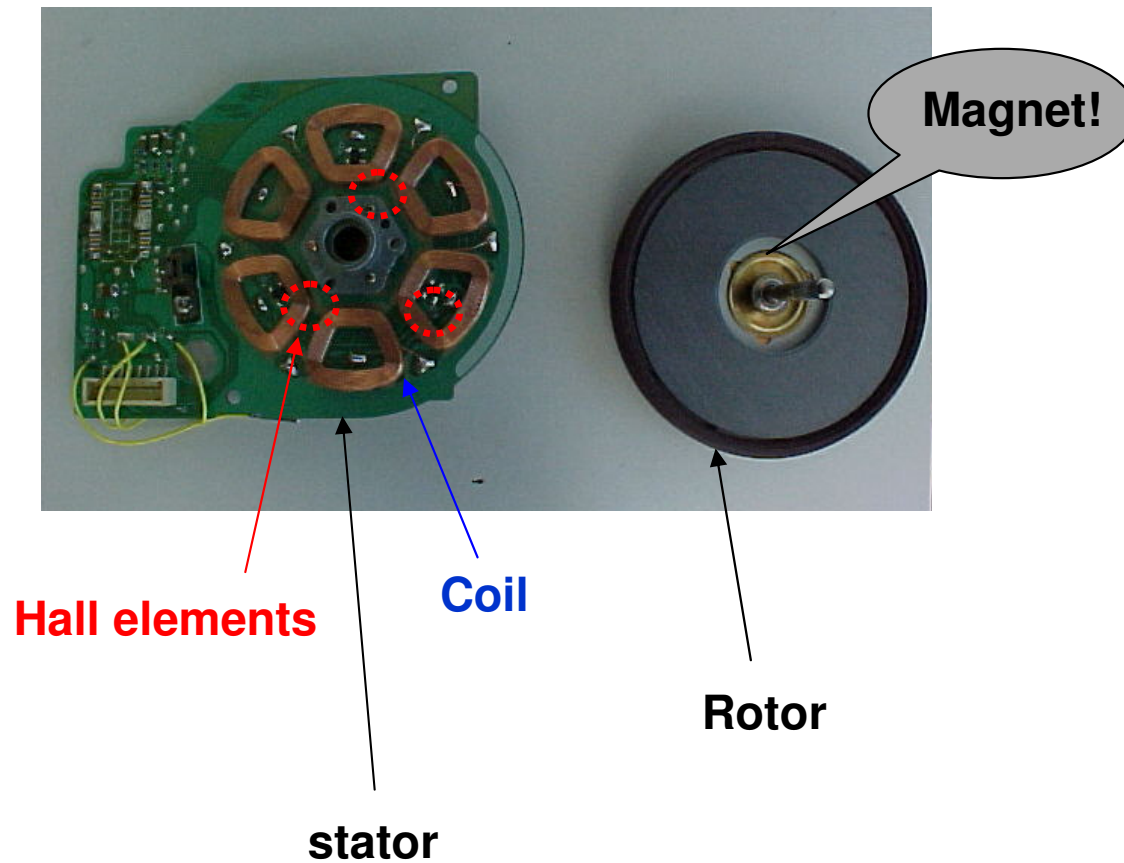
- *) High reliability due to no mechanical contact, high speed drive

<Cons>

- *) High motor cost (mainly magnet)

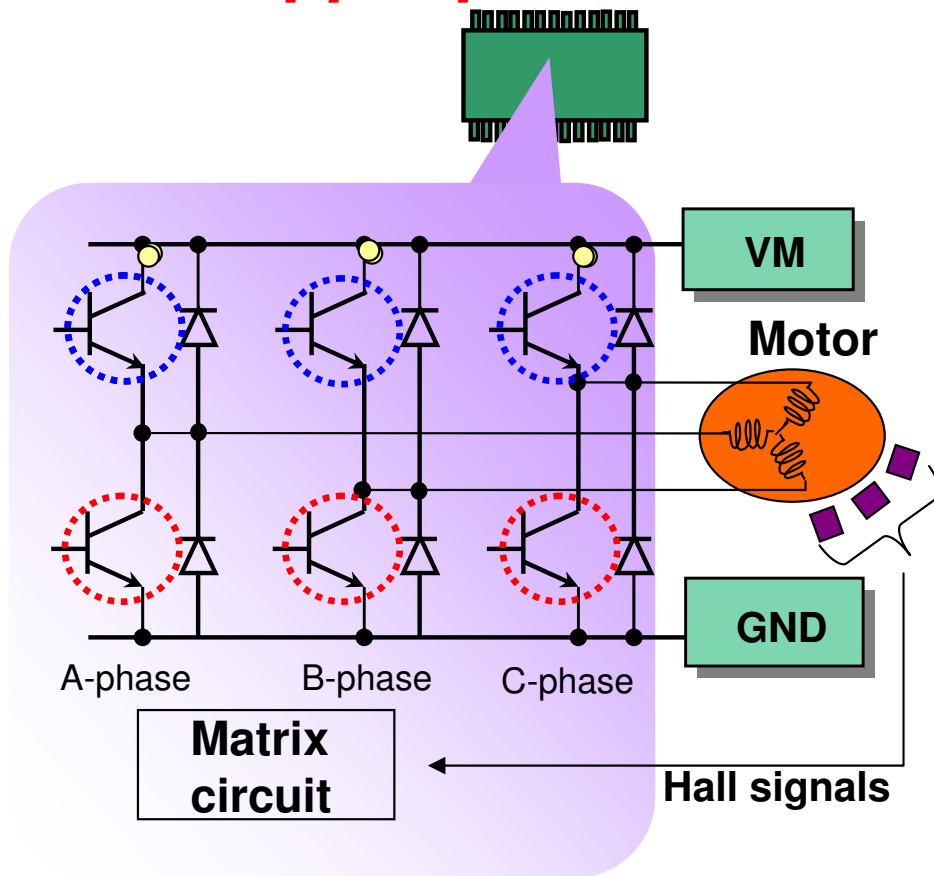
5.2 BLDC structure

Ex.) Capstan motor for VCR



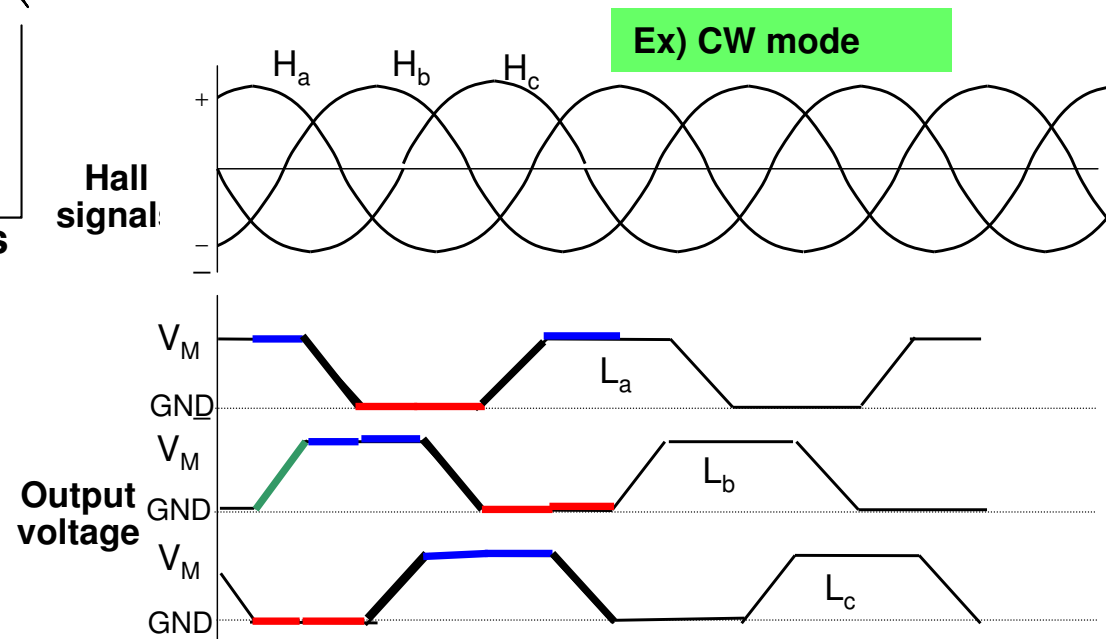
5.3 BLDC control (120° inverter with sensor)

✧ Upper phases: u, v, w , Lower phase: x, y, z .



What the brushless motor driver IC can do.

- * Can drive the motor in CW, CCW, stop and brake modes.
- * Can control motor speed by optional circuit.

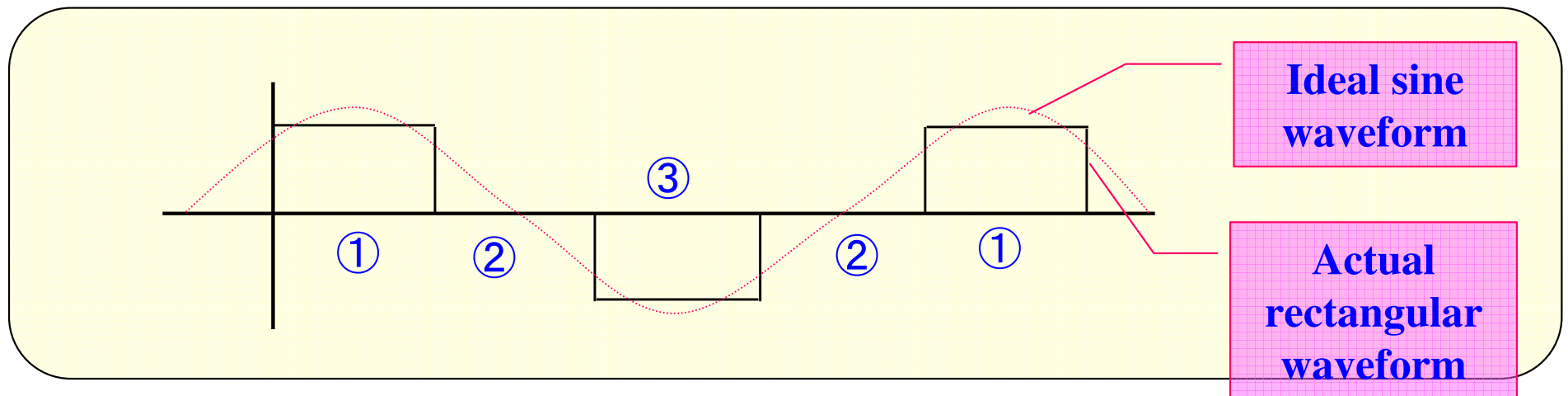
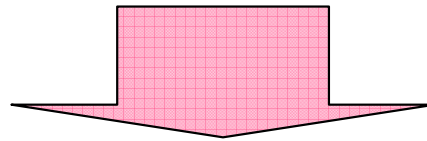
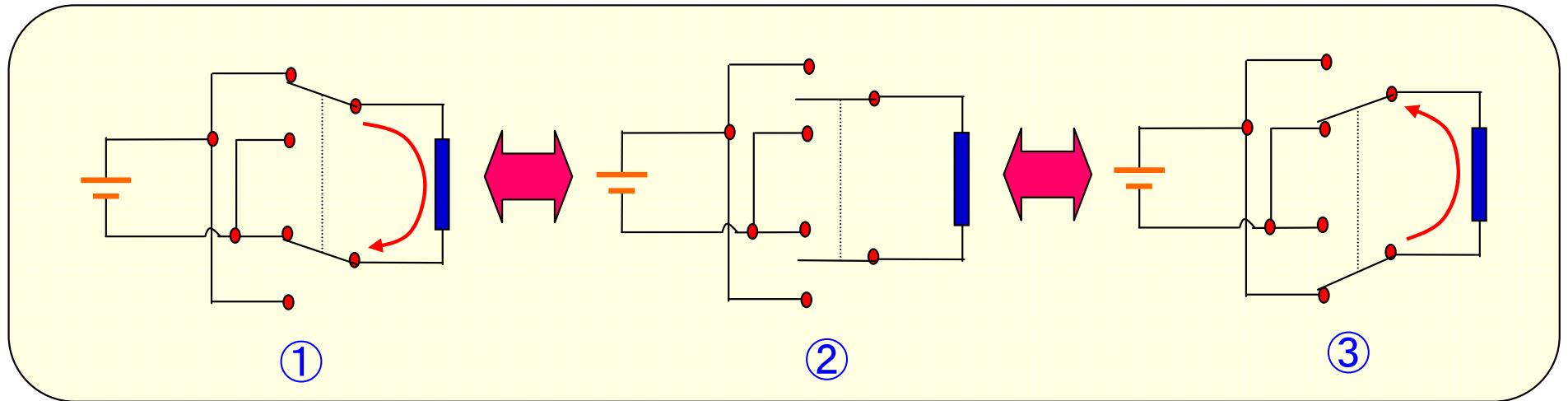


6. Sensored and sensorless BLDC rectangular wave (120° inverter) control

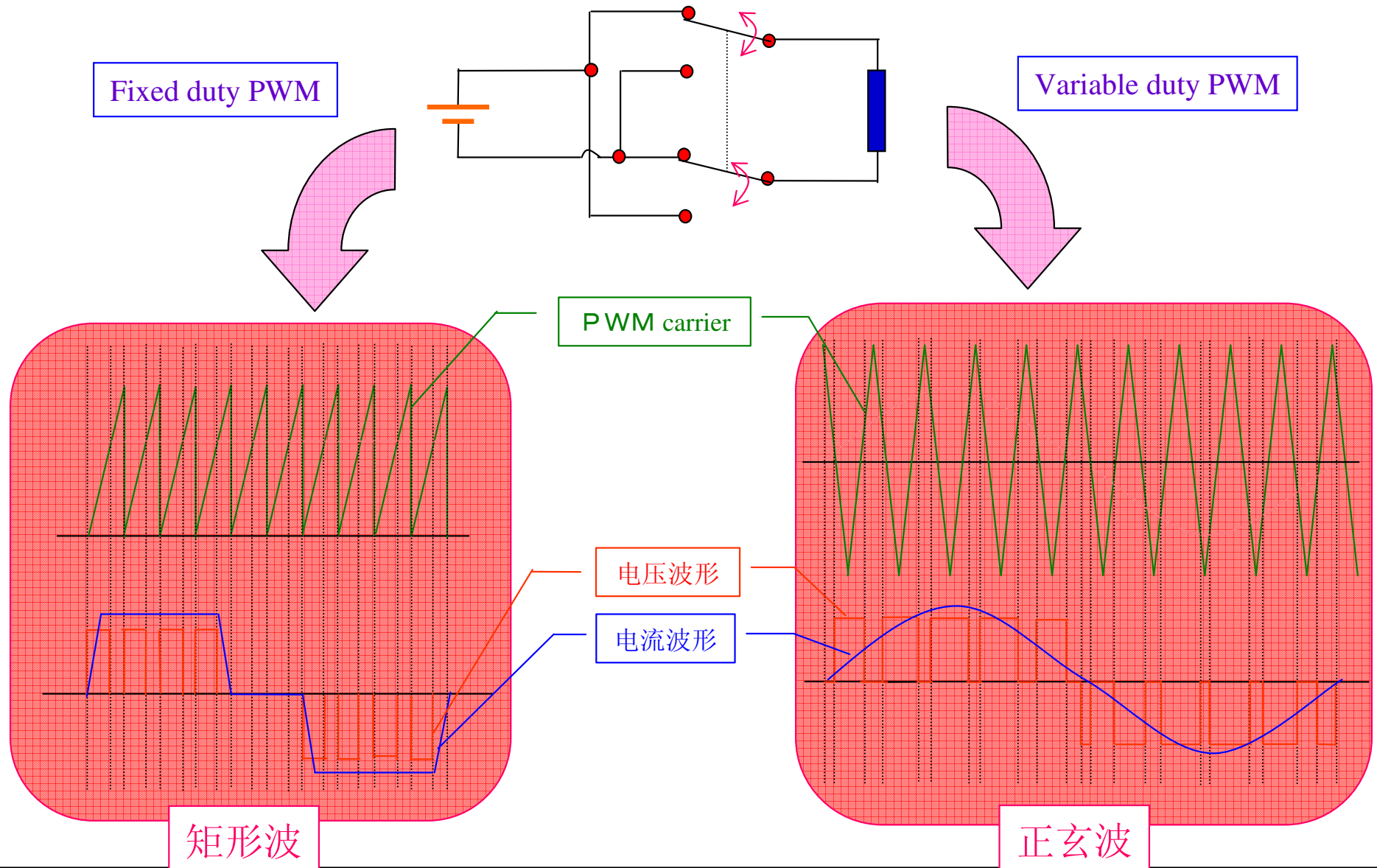
有/无传感器直流无刷马达
方波**120**度变频控制

[Return](#)

6.1 Single phase inverter theory

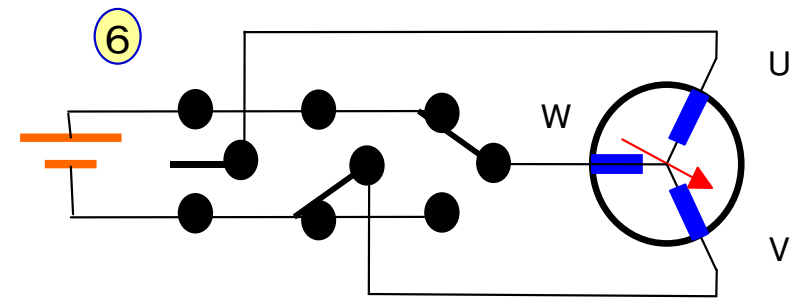
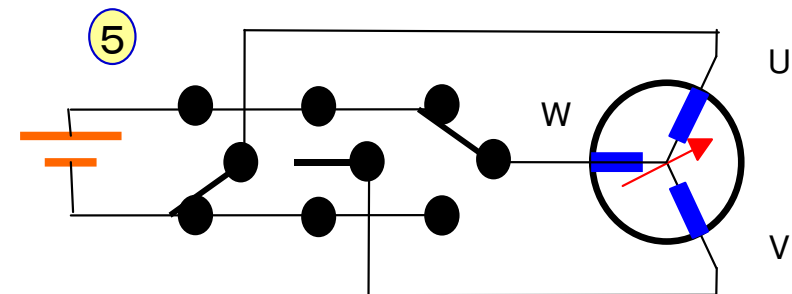
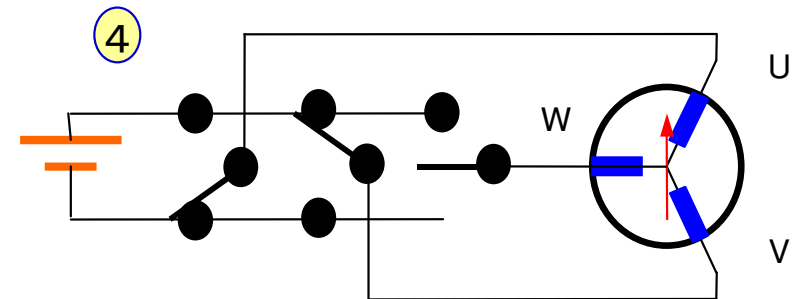
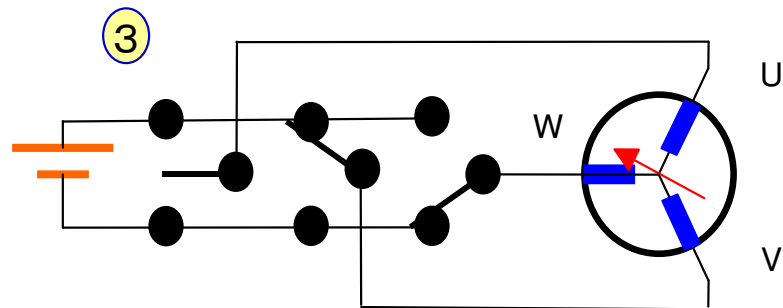
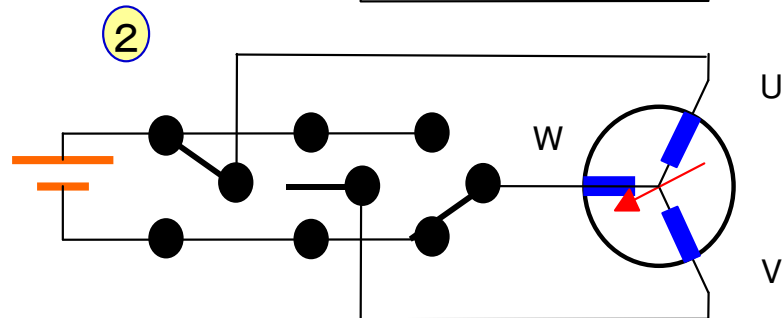
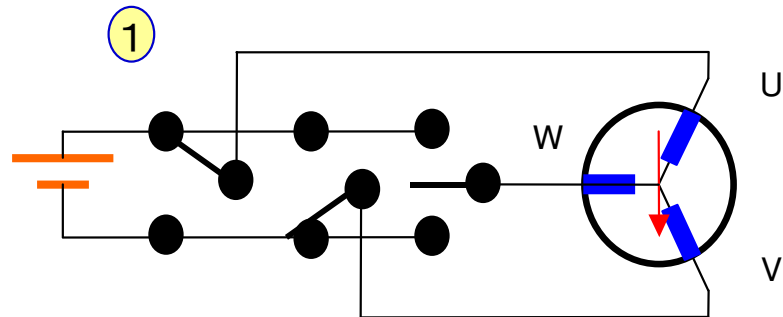


6.2 Rectangular wave and sine wave



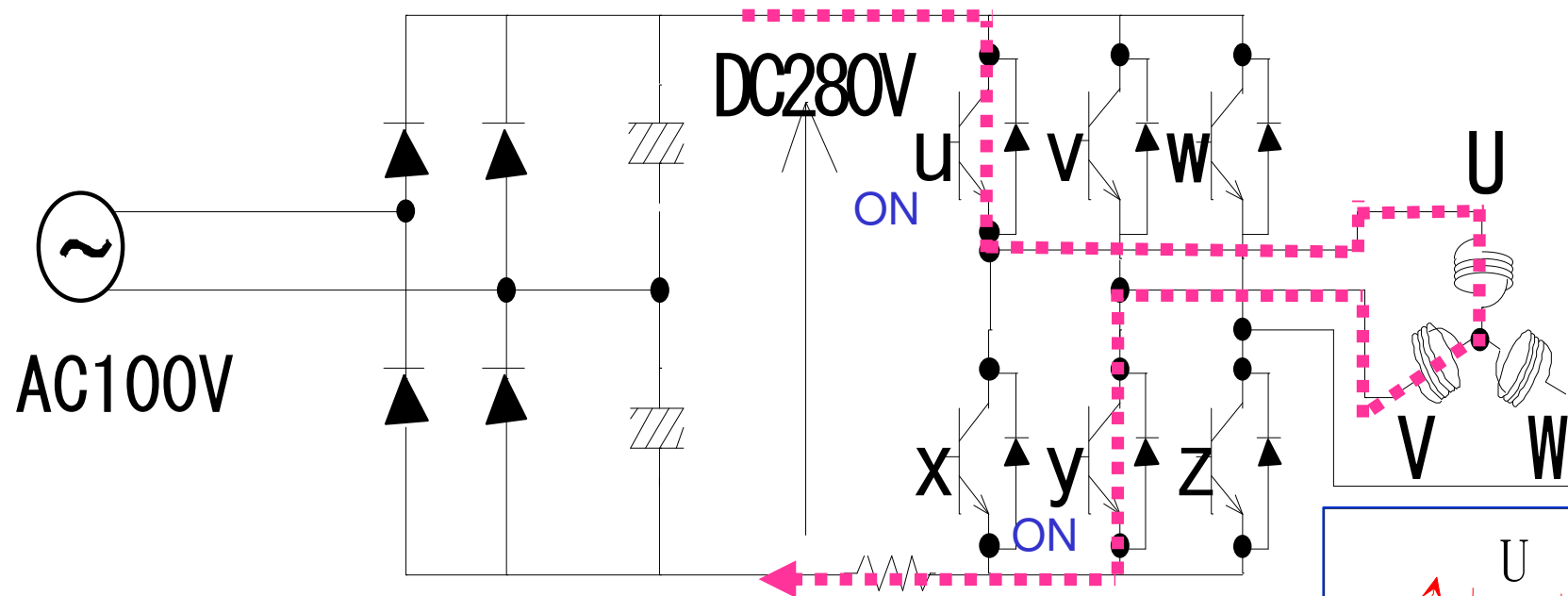
6.3 Rectangular wave(120° inverter) control

— : motor coil

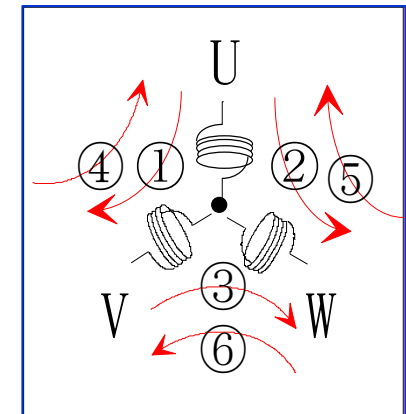


6.4 Rectangular wave control diagram

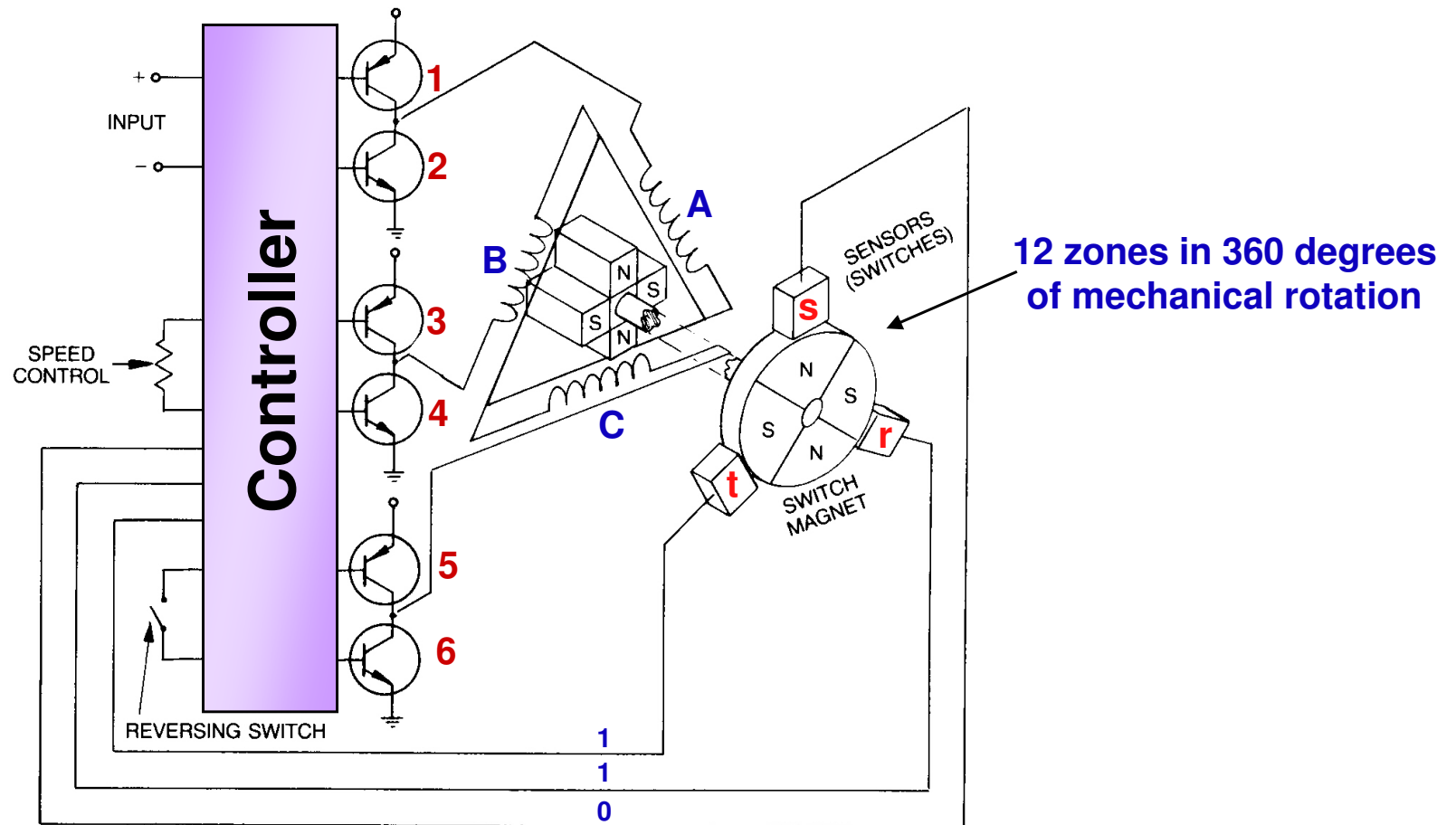
.....➤ : phase current



1 : u → y 2 : u → z 3 : v → z
4 : v → x 5 : w → x 6 : w → y

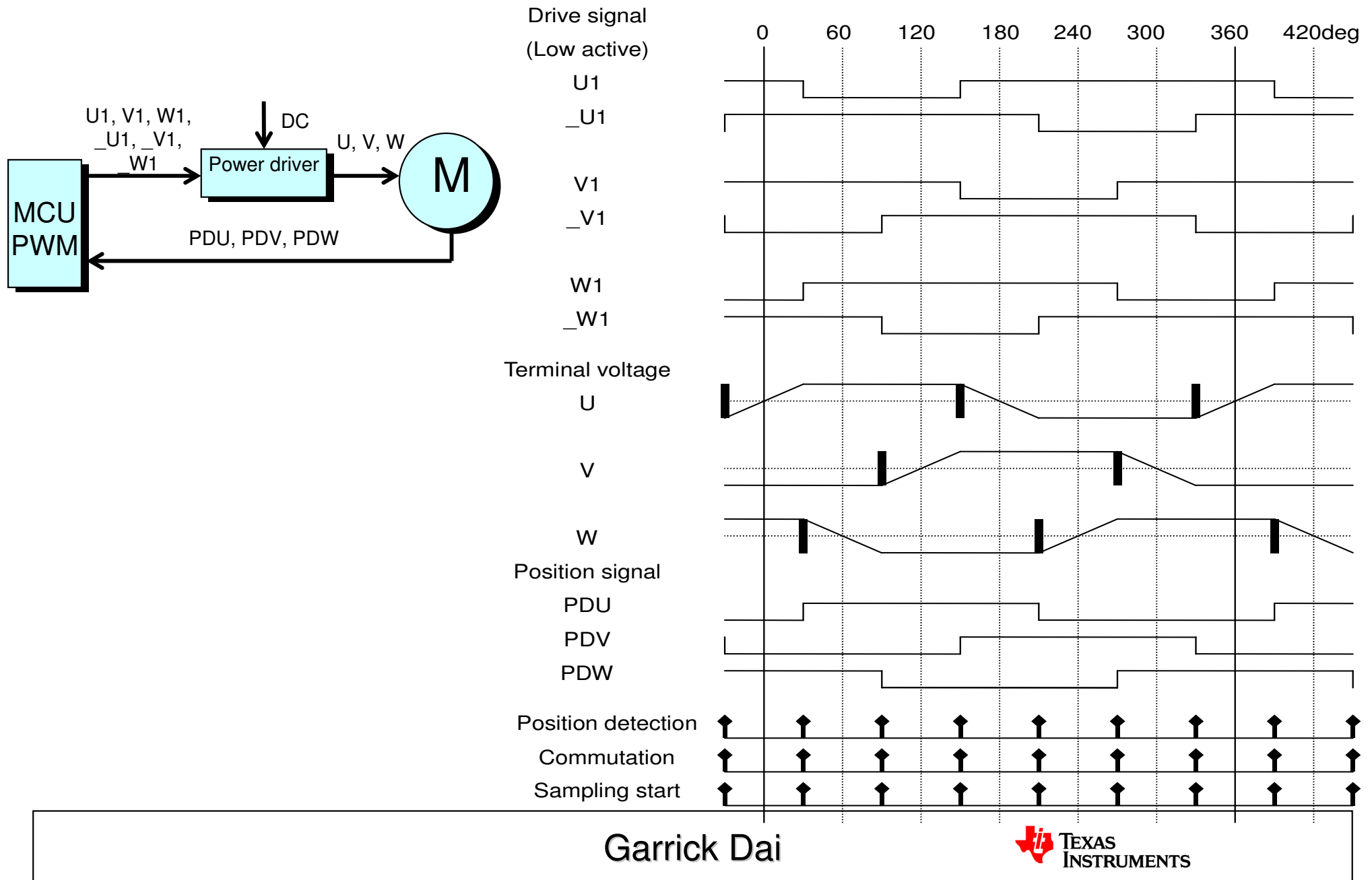


6.5 Sensored BLDC control

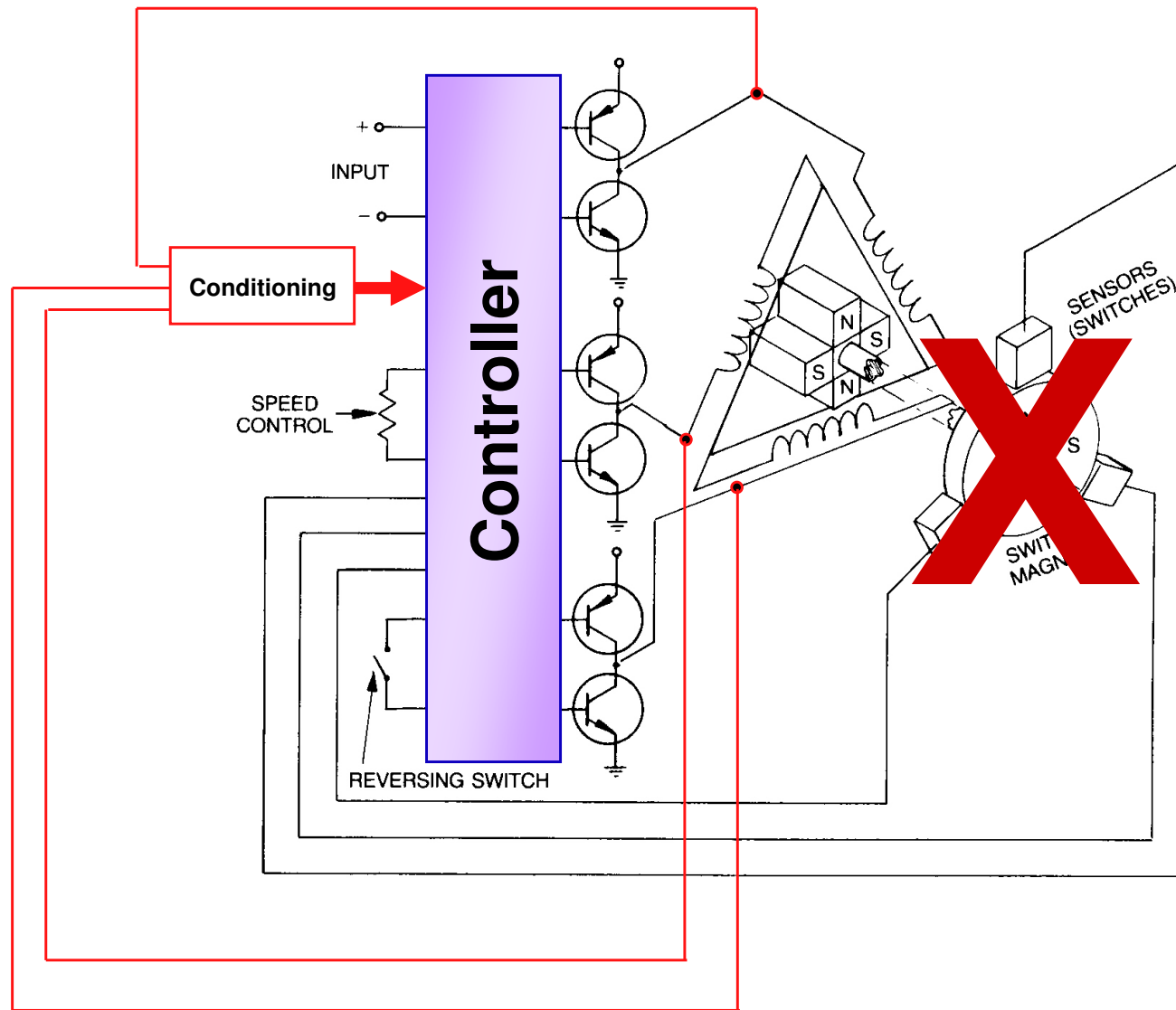


Source: Eastern Air Devices, Inc. Brushless DC Motor Brochure

6.6 Timing chart for sensored BLDC by S/W

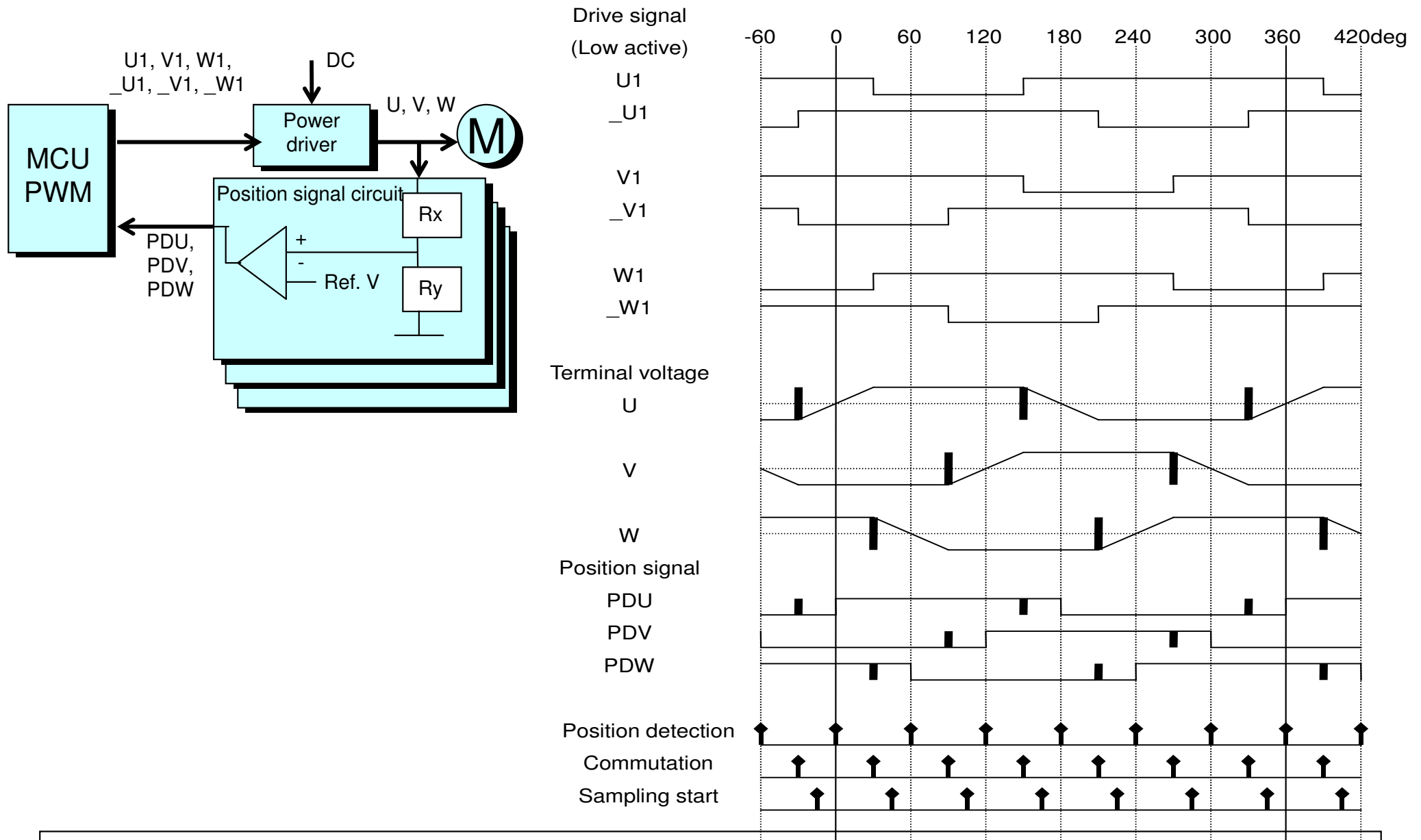


6.7 Sensorless BLDC control



Source: Eastern Air Devices, Inc. Brushless DC Motor Brochure

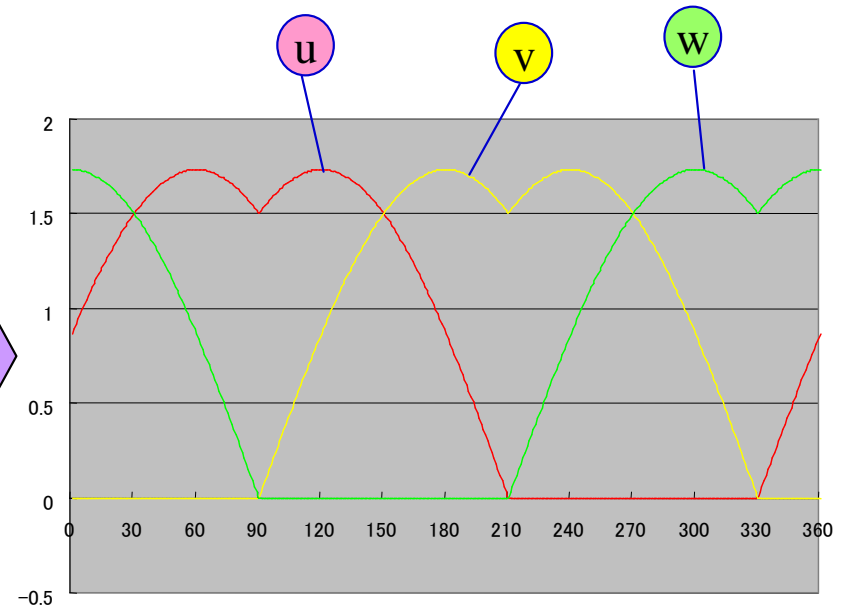
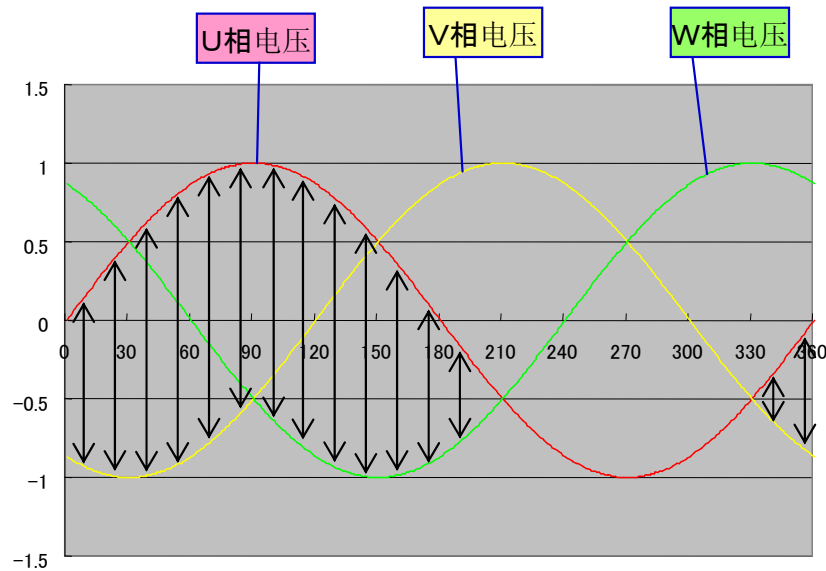
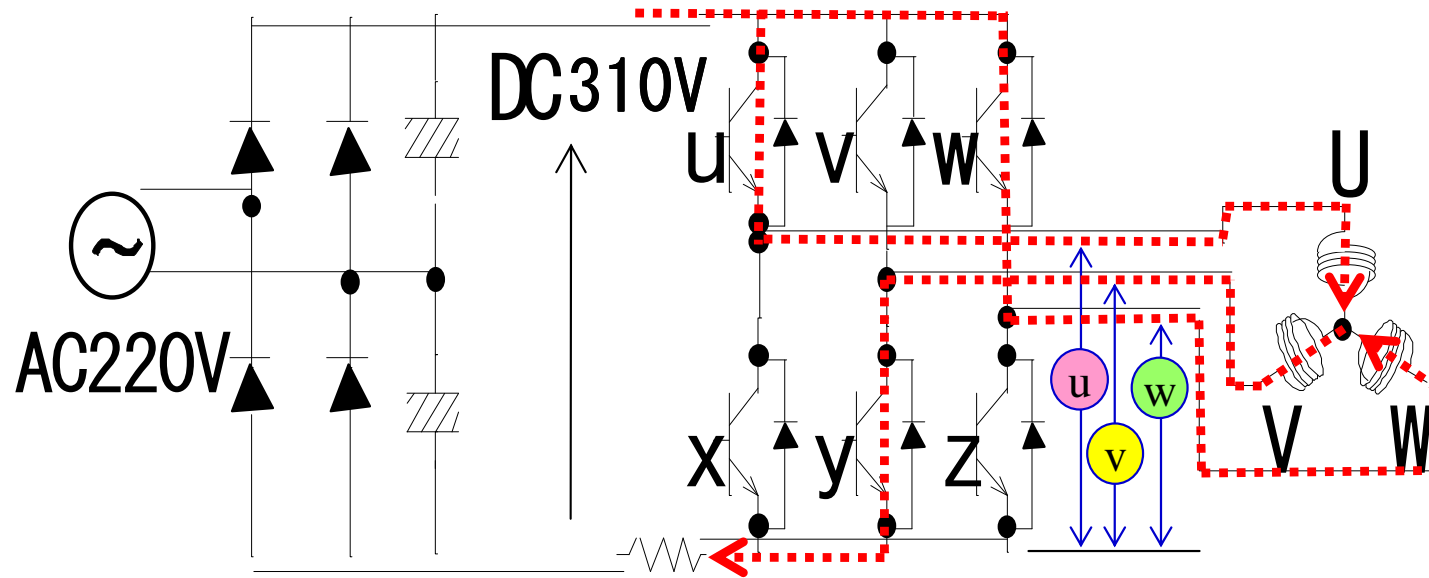
6.8 Timing chart for sensorless BLDC by S/W



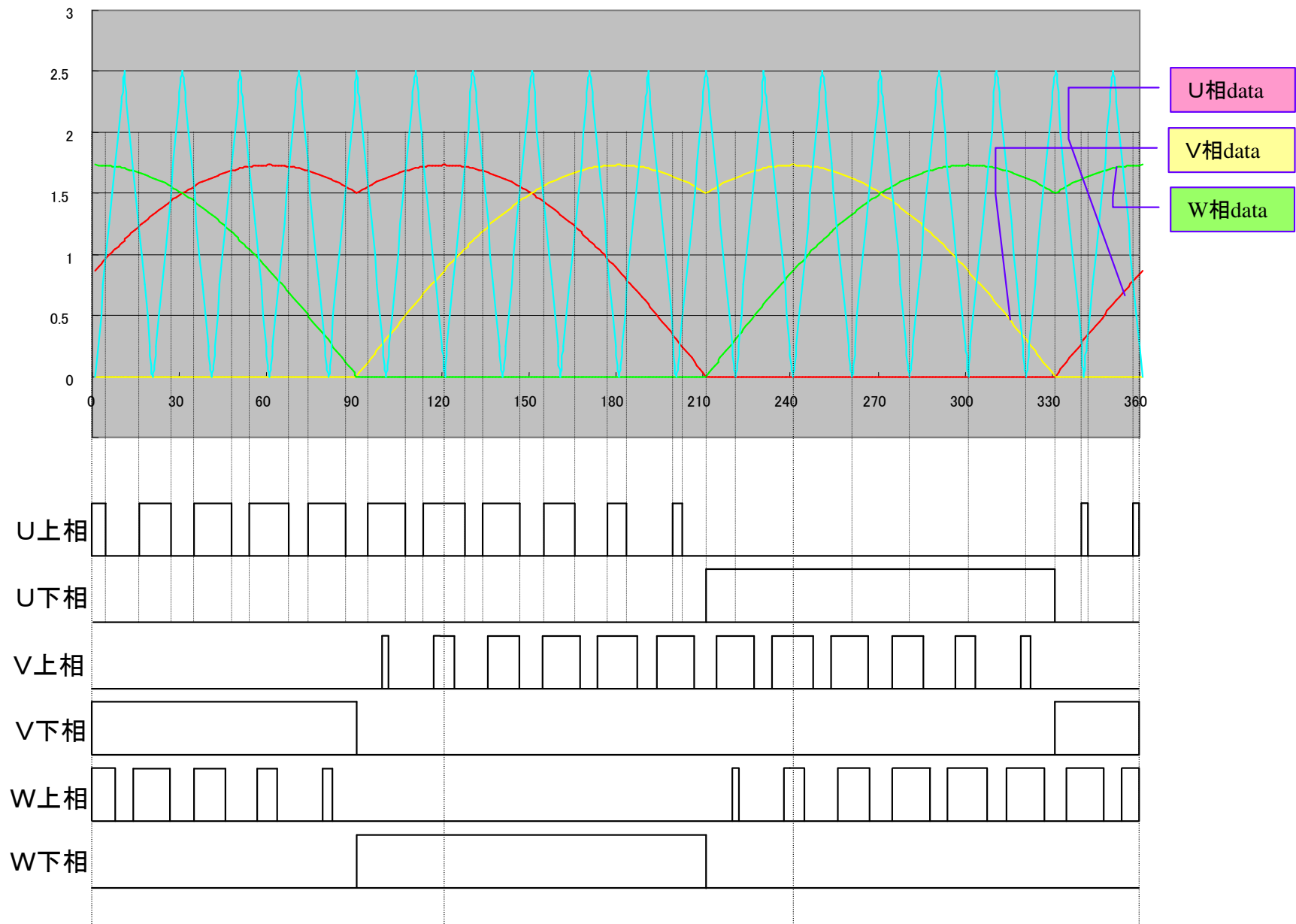
7. Sensored BLDC sine wave(180° inverter) control

有传感器直流无刷马达正弦波
180度变频控制

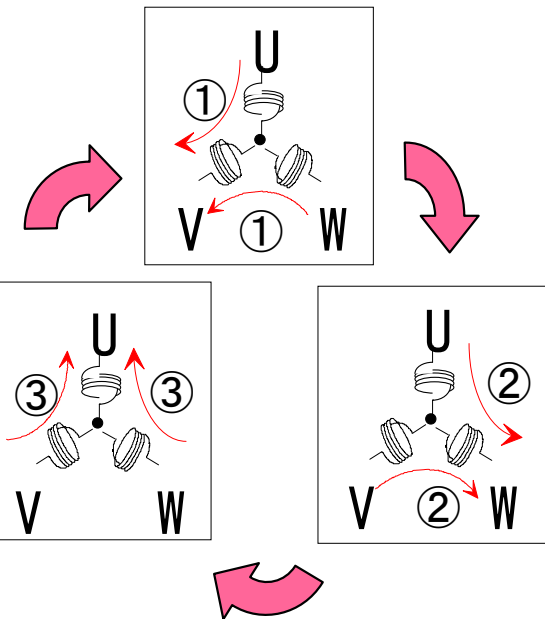
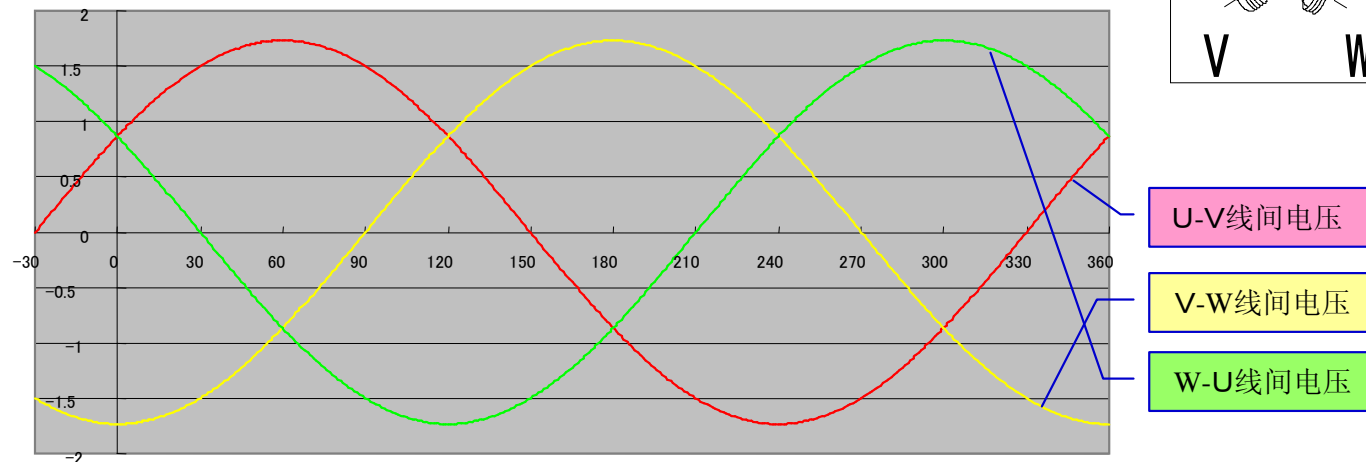
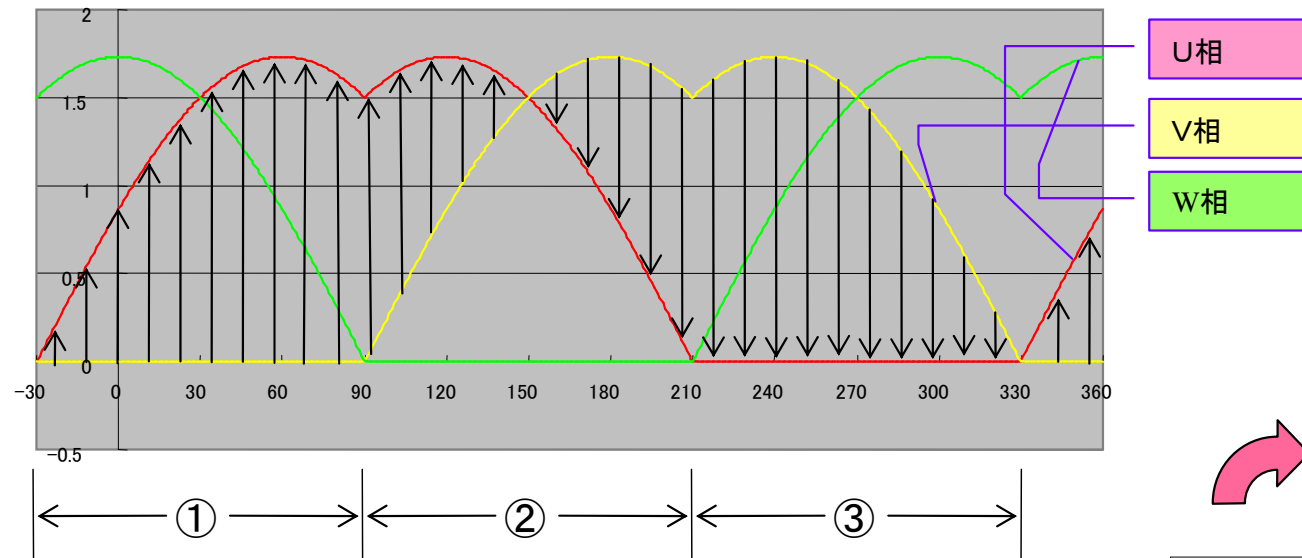
7.1 Sine wave (180° inverter) control



7.2 Sine wave PWM waveform



7.3 Sine wave phase voltage waveform



8. Sensored BLDC Vector Inverter Control

有位置传感器的直流无刷
马达矢量变频控制

8.1 Vector inverter block diagram (sensored)

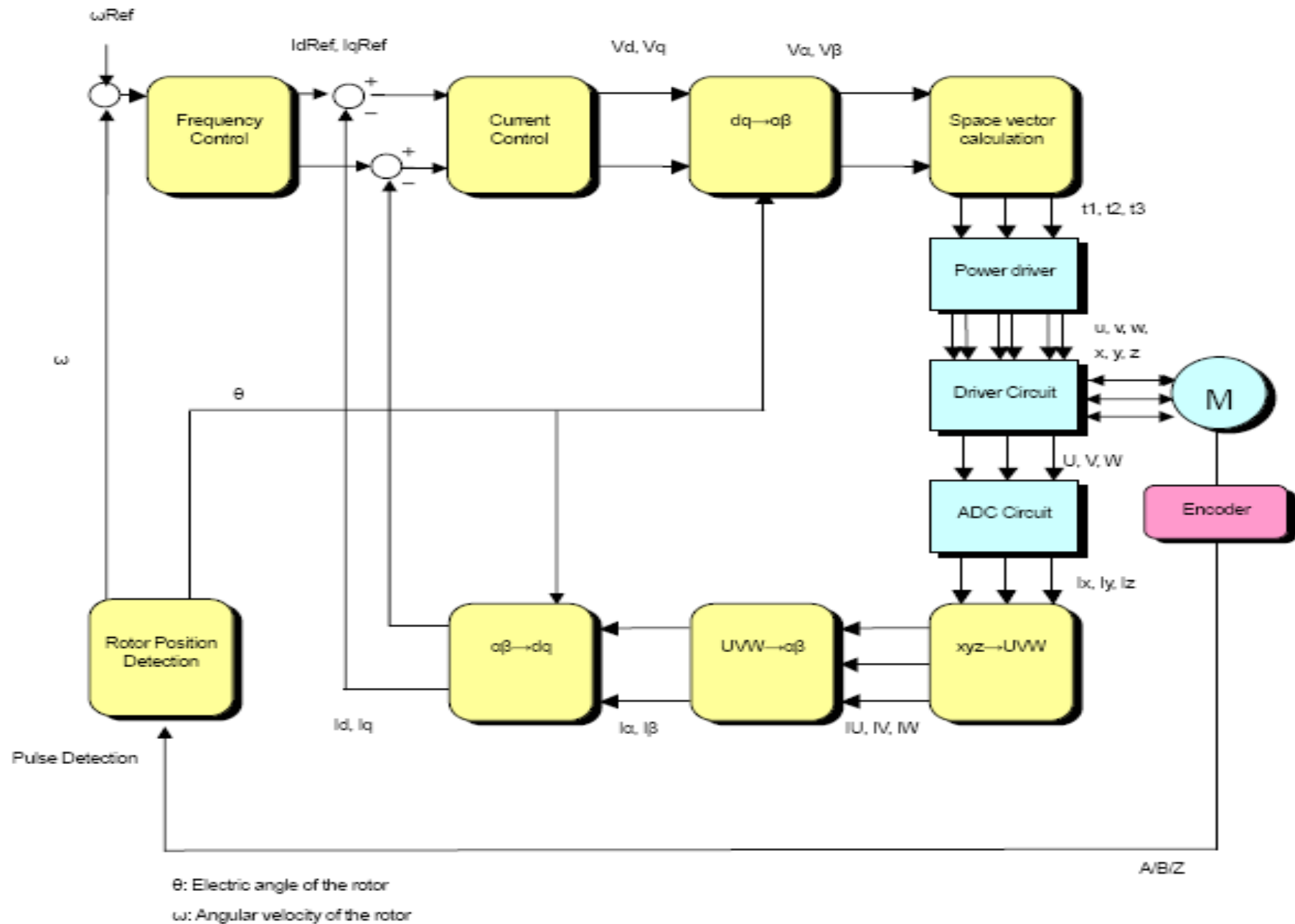


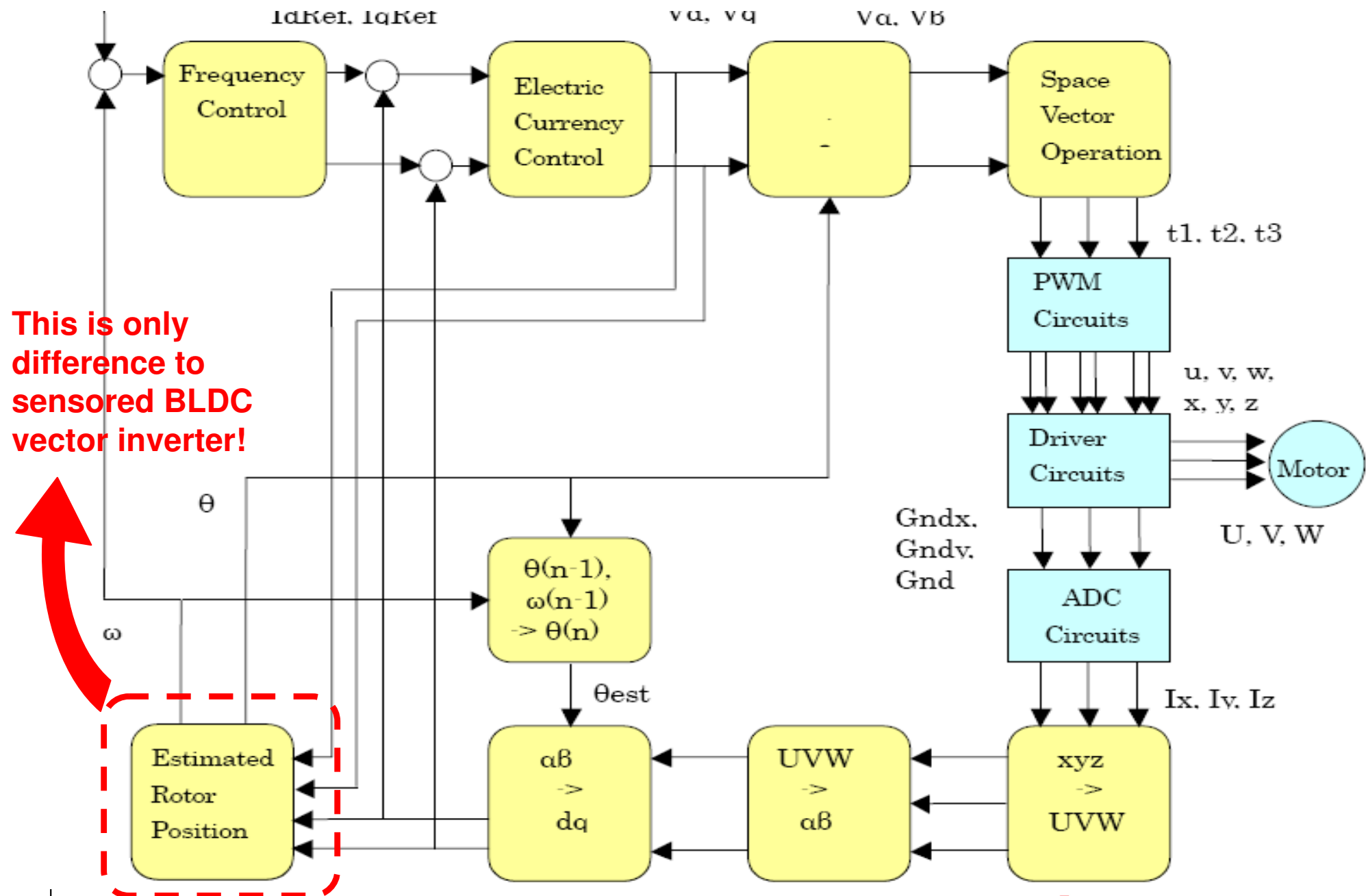
Figure 1 Control Block Diagram

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9. Sensorless BLDC Vector Inverter Control

无位置传感器的直流无刷
马达矢量变频控制

9.1 Vector inverter block diagram (sensorless)



Q & A

~ The End ~

Garrick Dai