Speed Control Motors

Brushless Motor's Structure and Principle of Operation

Structure of Brushless Motor



Brushless motors have built-in magnetic component or optical encoder for detecting the rotor position. Each position detector sends signals to the drive circuit. Motor windings are based on three-phase star wiring. The rotor uses permanent magnets.



The detection magnetic component uses a Hall effect IC. Three components are provided on the inner side of the stator and as the rotor turns, each Hall effect IC outputs a digital signal.

Drive Method of Brushless Motors

The motor windings are connected to switching transistors, where six transistors constitute one inverter. The upper and lower transistors are turned ON-OFF alternately and repeatedly according to a specific order to change the direction of current flowing through the windings. The mechanism of how the rotor turns is explained.

Based on the transistor switching sequence shown in the figure below, transistors Tr1 and Tr6 are ON in step ①. In this condition, current flows from phase U to phase W through the windings, with phase U and phase W excited to the N pole and S pole, respectively. This causes the rotor to rotate by 30°. When this operation is repeated 12 times, the rotor turns by one rotation.



Switching Sequences of Individual Transistors

Step Transistor	1	2	3	4	5	6	0	8	9	10	1	12	13
Tr1	ON					ON	ON					ON	ON
Tr2		ON	ON					ON	ON				
Tr3				ON	ON					ON	ON		
Tr4			ON	ON					ON	ON			
Tr5					ON	ON					ON	ON	
Tr6	ON	ON					ON	ON					ON
Phase U	Ν	-	S	S	-	Ν	Ν	-	S	S	-	Ν	Ν
Phase V	-	Ν	Ν	-	S	S	-	Ν	Ν	-	S	S	-
Phase W	S	S	-	Ν	Ν	-	S	S	-	Ν	Ν	-	S

Control Method of Brushless Motors

The drive circuit of a brushless motor is connected to the motor and mainly consists of five blocks according to the structure shown in the figure.

- Power circuit
- Current control circuit
- Logic circuit

Setting comparison circuit

Power supply circuit



◇Power circuit

Current flowing through the motor windings is controlled. Six transistors are used.

The transistors connected on top and below are turned ON-OFF repeatedly according to a specific order to cause current to flow through the motor windings.

⊘Current control circuit

The current flowing through the motor changes depending on the load size. The current flowing through the motor is constantly detected and controlled so that the actual speed will not deviate from the set speed.

♦ Logic circuit

Feedback signals are received from the motor's hall effect IC to detect the rotor position and determine the excitation order of motor windings. These signals are connected to the base of each transistor in the power circuit, to drive the transistors according to a specific order. They are also used to detect the motor speed.

In addition, these signals are used to control such motor commands as Start/ Stop, Brake/Run and CW/CCW.

\diamondsuit Setting comparison circuit

Compare the speed setting signal and motor speed signal. The result is used to check whether the motor speed is higher or lower than the set speed. If the motor speed is higher than the setting, the input to the motor is decreased until the setting speed is restored. If the motor speed is lower, the input to the motor is increased until the setting speed is restored.

◇Power supply circuit

The power supply circuit is used to convert the commercial power supply to the voltage needed to drive the motor and each control circuit.

Technical Reference

Speed – Torque Characteristics of Brushless Motors

The figure below shows an example of characteristics of the **BLE** Series. The characteristics of the **AXU** Series, **BX** Series and **BLH** Series are roughly the same, although the speed control range is different.

With brushless motors, the rated torque and starting torque are constant in a range from 100 to 4000 r/min (for the **BLE** Series and **BLH** Series, the output torque at the maximum speed becomes lower than the rated torque), as shown in the example below. Therefore brushless motors can be used at their rated torque over the entire speed range from low to high without experiencing a torque drop at low speed which is often seen with AC speed control motors. Brushless motors have a limited duty region in addition to a continuous duty region. In the limited duty region, the generated torque corresponds to twice the rated torque (1.2 times the rated torque in the case of the **AXU** Series and **BLH** Series), which is very useful when starting an inertia load. Note that when operation is continued for 5 seconds or more in the limited duty region, the driver's overload protective function will actuate to cause the motor to stop naturally.



Speed Control Method of Speed Control Motors

A basic block diagram illustrating the control method is shown below, accompanied by an overview of the control method. AC speed control motors adopt the closed-loop speed control method, while inverters adopt the openloop speed control method.

AC Speed Control Motor

- ① Speed setting voltage is given from the speed potentiometer.
- (2) The motor speed is detected to give the speed signal voltage.
- (3) The difference between the speed setting voltage and speed signal voltage is output.
- ④ The voltage needed to achieve the set speed is calculated according to the output from the comparator and given to the motor.



 $\diamondsuit Generated Voltage Characteristics of Tachogenerator The tachogenerator directly coupled to the speed control motor generates AC voltage roughly proportional to the motor speed, as shown in the figure below. Accordingly, the motor speed can be calculated by connecting an AC voltmeter between the tachogenerator leads. (For the AC voltmeter, use a unit whose internal impedance is 200 k\Omega or more. Oriental Motor offers a dedicated tachometer as an accessory.)$

Speed Indicators → Page B-154



Inverter

- ♦ Control Method
- The input from the AC power supply is rectified and DC voltage is output.
 A signal indicating the voltage that matches the frequency set by the frequency setting potentiometer is output.
- ③ Voltage of the set frequency is applied to the motor.



Motorized Actuators

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Gearheads

Speed – Torque Characteristics of Speed Control Motors

AC Speed Control Motors

In general, AC speed control motors have the speed - torgue characteristics shown in the figure below.



Inverters

In general, inverters have the speed - torque characteristics shown in the figure below.

With inverters, the speed is changed by changing the frequency of the voltage applied to the motor. Consequently, the speed also changes according to the load torque just like the characteristics of induction motors.

Speed - Torque Characteristics Inverter/4IK25GN (A) -SW2



♦ Safe-Operation Line and Permissible Torque When Gearhead is Attached

With speed control motors, the input changes according to the load and speed. The larger the load or the lower the speed, the higher the temperature will rise. Speed - torque characteristics graphs of AC speed control motors and inverters indicate the "safe-operation line," and the area below this line is called the continuous duty region.

The safe-operation line, measured by motor's temperature, indicates its limit for continuous operation (30 minutes operation for a reversible motor) with the temperature level below the permissible maximum temperature. Whether or not the motor can be operated at the actual load and speed is judged by measuring the temperature of the motor case. Given the insulation class of the windings, generally continuous operation is possible as long as the motor case temperature is 90°C or less. Note, however, that the lower the motor temperature, the longer the motor will last. Accordingly, we recommend that you use the motor under conditions where its temperature will remain low. If a gearhead is used, make sure the "permissible torque when gearhead is attached" will not be exceeded. If a gearhead is used and the motor is operated at torques beyond the aforementioned torque, the life of the motor may be shortened or the motor may be damaged.

♦ Variable Speed Range (Speed Ratio) and Load Factor When the speed ratio is defined as the ratio of the minimum speed and maximum speed in the variable speed range of an AC speed control motor, the speed ratio becomes as high as 1:15 in a range where the load factor (ratio of the load torque relative to the starting torque) is small (load factor of 40% in the figure below), thereby expanding the scope of operation.

On the other hand, the speed ratio becomes low when the load factor is large.

Load Factor and Speed Ratio

Let us consider the relationship of load factor and speed ratio. When a motor is actually used, it is often combined with a gearhead. Accordingly, the following explanation also uses an example where a motor is combined with a gearhead.

The table below shows the continuous duty regions and speed ratios of the US Series at load factors 20% and 50% based on readings from the graph. The speed ratio can be increased when the load factor is 20%, but the ratio becomes small at 50%. As these figures show, generally AC speed control motors cannot be operated across a wide range. To increase the range of operation, select a motor that has a larger starting torque (motor of the next larger frame size).

This is not the case with brushless motors though, as brushless motors can be operated over a wide range as shown by the dotted lines.



Load factor [%]	Continuous		
	Minimum Speed [r/min]	Maximum Speed [r/min]	Speed Ratio
20	17	348	1:20
50	148	337	1:2

Speed Ratio when Using a Gearhead of High Gear Ratio Since the starting torque is also limited by the maximum permissible torque of the gearhead, when a gearhead with a high gear ratio is used, the load factor corresponds to the load torque relative to the maximum permissible torque of the gearhead.

In the above example, a gearhead of gear ratio 5 was used. Now, let's take a look at what happens when a gearhead of gear ratio 100 is assembled.



The maximum permissible torque of the gearhead **5GU100KB** of gear ratio 100 is 20 N·m. The table below shows the speed ratios at load factors 30% and 50%.

Load factor [%]	Continuous			
	Minimum Speed [r/min]	Maximum Speed [r/min]	Speed Ratio	
30	0.9	17.6	1:20	
50	0.9	17.4	1:19	

As shown, if a gearhead of high gear ratio is combined. the speed ratio can be increased without giving too much consideration to the load factor.



 \blacksquare A number indicating the gear ratio is specified in the box \square in the product name.

For the electromagnetic brake type, old M is entered where the box old m is located within the product name.

A number indicating the desired length of 1 (1 m), 2 (2 m) or 3 (3 m) for the cable included with the product is entered where the box 🗇 is located within the product name.



AXU590A-GU AXU590A-A







BX5120A - S BX5120A - FR BX5120A - A











BX230CII-OS BX230CII-OFR BX230CII-A (Single-Phase 200-230 VAC)



BX460C---S BX460C---FR BX460C--A (Single-Phase 200-230 VAC)



BX5120C--S BX5120C--FR BX5120C--A (Single-Phase 200-230 VAC)



AXU540S-GN AXU540S-A



AXU590S-GU AXU590S-A



BX230C---S BX230C---FR BX230C--A (Three-Phase 200-230 VAC)



BX460C**□**-□S BX460C**□**-□FR

BX460C - A (Three-Phase 200-230 VAC)



BX5120C---S BX5120C---FR BX5120C--A (Three-Phase 200-230 VAC)



lacksquare A number indicating the gear ratio is specified in the box \Box in the product name.

For the electromagnetic brake type, M is entered where the box 🔲 is located within the product name.

Technical Reference





BX6400S - S BX6400S - FR



BX6200C**□**-□S BX6200C**□**-□FR

BX6200C -A (Single-Phase 200-230 VAC)





Driver Input Current [A]

BX6200C -A (Three-Phase 200-230 VAC)

3000 r/min 2.0 2000 r/min 13 1000 r/min 1.(300 r/min 30 r/min 0.5 Rated Torque 0 0.8 0.2 0.4 0.6 Load Torque [N·m]

Selection Calculations

Motors

Motorized Actuators

Cooling Fans

Service Life

Standard AC Motors

Speed Control Motors

Stepping

Motors

Servo

Motors

●BLH Series BLH015K-□

BLH015K-A



BLH5100K, BLH5100KFR BLH5100K-A



BLH230K-D, BLH230K-DFR BLH230K-A



BLH450K-□, BLH450K-□FR BLH450K-A



Linear Heads

Gearheads

Motorized Actuators

Cooling Fans

 $\blacksquare A$ number indicating the gear ratio is specified in the box \square in the product name.

For the electromagnetic brake type, **M** is entered where the box 🔲 is located within the product name.