Speed Control Systems

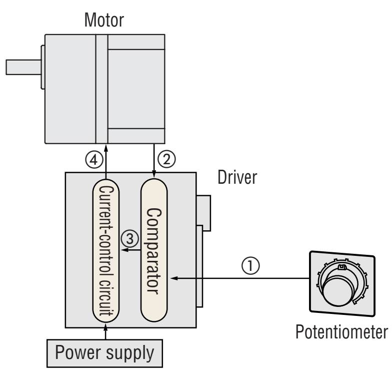
Speed Control Methods of Speed Control Systems

The basic block diagrams and outline of the control methods are shown below. Both brushless DC and AC speed control systems employ a closed-loop control system.

● Brushless DC Motor and Driver System

Control Method

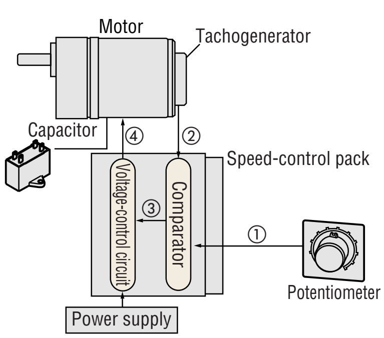
① The speed setting voltage is supplied via a potentiometer.
② The motor speed is sensed and the speed signal voltage is supplied.
③ The difference between the speed setting voltage and speed signal voltage is output.
④ Current determined by the output from the comparator is supplied to the motor so that it will reach the set speed.



● AC Speed Control Motor System

Control Method

① The speed setting voltage is supplied via a potentiometer.
② The motors speed is sensed and the speed signal voltage is supplied.
③ The difference between the speed setting voltage and speed signal voltage is output.
④ A voltage determined by the output from the comparator is supplied to the motor so that it will reach the set speed.



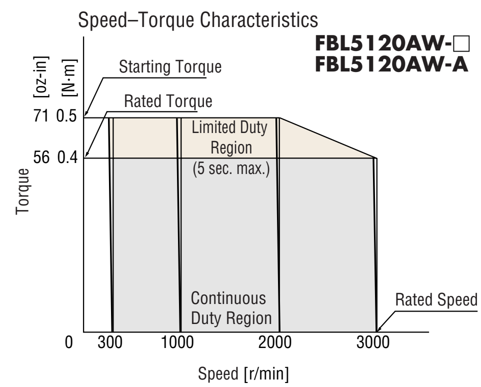
Speed – Torque Characteristics of Speed Control Systems

● Brushless DC Motor and Driver System

The figure bellow illustrates the characteristics of an **FBLⅡ** Series motor. The **BX**, **AXU** and the **AXH** Series motors also have similar characteristics, although their speed control ranges are different.

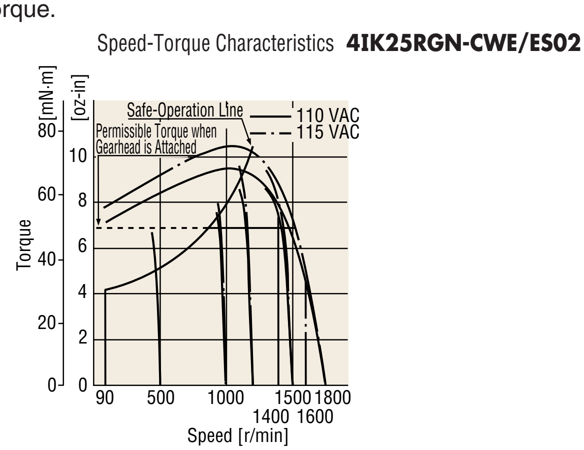
Brushless DC motors operate at rated torque from 300 to 3000 r/min, with a constant starting torque. (With the **AXH** Series, the output torque at the maximum speed is approximately 50% of rated torque.) Unlike AC speed control motors, torque in a brushless DC motor package will not drop at low speeds. Unlike AC speed control motors, which have a limit to continuous use (safe operation line) because of the motor's temperature rise, brushless DC motors can be used continuously at rated torque from high to low speeds.

In addition to areas of continuous use, brushless DC motors also have short-term use areas. The torque generated in the short-term use areas, which is 1.2 times the rated torque (2 times for the **BX** Series), is effective for driving inertia loads. If operated for more than approximately five seconds in the short-term use area, the overload protection function of the driver or control unit may engage and the motor will automatically stop.



● AC Speed Control Motors

The speed-torque characteristic line shown in the figure below is typical for all AC speed control motors. Each set speed changes slightly according to the change in load torque.



Motor and Fan Sizing
Standard AC Motors
Speed Control Systems
Stepping Motors
Gearheads
Linear Motion
Cooling Fans

◆ Safe Operation Line and Permissible Torque When Using a Gearhead

Input power to the speed control motor varies with the load and speed. The greater the load, and the lower the speed, the greater an increase in motor temperature.
The previous graph displays the relationship between the speed and torque characteristics of an AC speed control motor. The line is referred to as the safe operation line, while the area below the line is called the continuous operation area.
The safe operation line, measured according to motor temperature, indicates its operational limit for continuous usage with the temperature level below the permissible temperature. (In the case of a reversible motor, it is measured via 30-minute operation.)
Whether the motor can be operated at a specific torque and speed is determined by measuring the temperature of the motor case. In general, if the motor's case temperature is 194˚F (90˚C) or below, continuous motor operation is possible, considering the insulation class of motor winding. It is recommended that the motor be used under conditions that keep the motor temperature low, since the motor life is extended with lower motor temperature.
When using a gearhead, be aware that it is necessary to operate below the maximum permissible torque. If the actual torque required exceeds the maximum permissible torque, it may damage the motor/gear and/or shorten its life.

◆ Variable Speed Range (Speed Ratio) and Load Factor

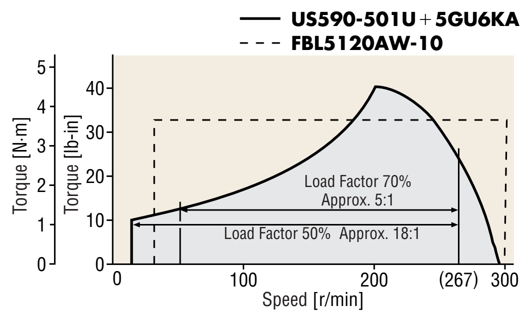
When the ratio of minimum speed and maximum speed of a speed control motor is given as the motor's speed ratio, the speed ratio increases to as much as 18:1 in a range where the load factor (ratio of load torque to starting torque) is small (see the 50% load factor range in the following diagram), This widens the motor's range of operation. If the load factor is high, the speed ratio becomes low.

Load Factor and Speed Ratio

Under conditions of actual use, a motor is often used in combination with a gearhead. The following example assumes such a configuration.

The following table shows the continuous operation range and speed ratio of the **US** Series at load factors of 50% and 70%, respectively, as read from the diagram. Although the speed ratio is 18:1 when the load factor is 50%, it decreases when the load factor is 70%. As shown, generally AC speed control motors do not have a wide operation range (when the load factor is high). To operate your motor over a wide speed range, choose a type that offers high starting torque (i.e., a motor with the next larger frame size).
With a brushless DC motor system, such as in the **FBLII** Series, the operation range remains wide regardless of the load factor, as indicated by the dotted line.

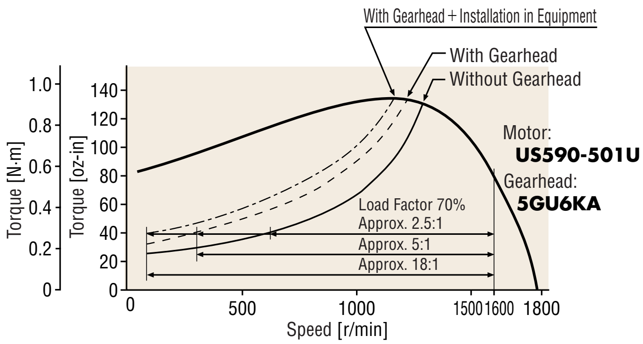
Speed-Torque Characteristics with lower gear ratio



Load Factor [%]	Continuous Operation Range		Speed Ratio
	Minimum Speed [r/min]	Maximum Speed [r/min]	
50	15	267	Approx. 18:1
70	50		Approx. 5:1

Speed Ratio with/without Gearhead

Because the speed control motor's continuous operation range is limited by motor temperature, the continuous operation range will widen if the motor's efficiency of heat dissipation is improved and the temperature rise is curbed. In that case, a motor with a gearhead will have a higher speed ratio than a motor used alone at the same load factor of 70%, as shown in the diagram below. The speed ratio will increase further if the motor with a gearhead is installed in the equipment, since the equipment itself serves as a heat sink.



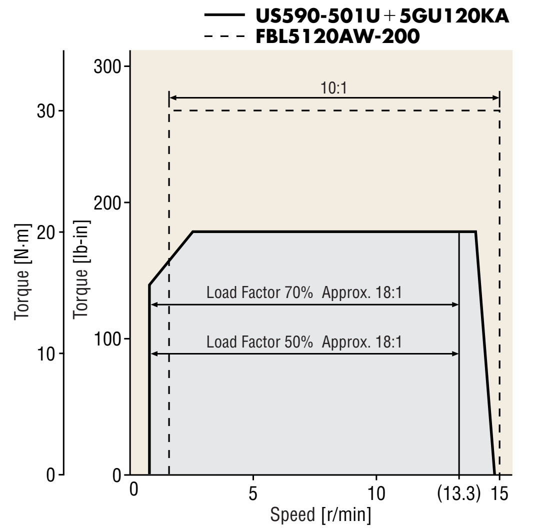
Due to the aforementioned advantage of heat dissipation, when a motor is installed in equipment it can often be operated at variable speeds with a speed ratio of 18:1, as long as the load factor does not exceed 70%.

Speed Ratio when a High Ratio Gearhead is Used

Since the starting torque is also limited by the maximum permissible torque of the gearhead, the load factor of a gearhead with a high gear ratio is determined by the load torque with respect to the maximum permissible torque of the gearhead.

In the previous example, a gearhead with a gear ratio of 6:1 was used. The diagram below shows what happens when a gearhead with a gear ratio of 120:1 is used.

Speed-Torque Characteristics with a High Gear Ratio



The maximum permissible torque of the **5GU120KA**, which has a gear ratio of 120:1, is 177 lb-in (20 N·m). The speed ratios at 50% and 70% load factors are shown in the table below:

Load Factor [%]	Continuous Operation Range		Speed Ratio
	Minimum Speed [r/min]	Maximum Speed [r/min]	
50	0.75	13.3	Approx. 18:1
70			

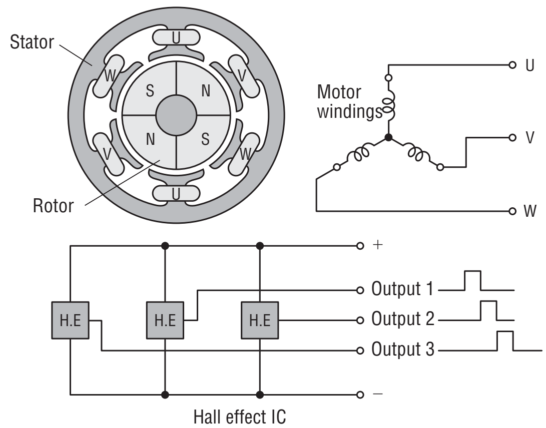
The table above demonstrates that high speed ratios can be obtained by combining a motor with a gearhead having a high gear ratio, in which case the load factor is one of minor concern.

Brushless DC Motor Construction and Principle of Operation

Motor

The construction of a brushless DC motor is similar to that of a standard AC motor, except that the brushless DC motor has a built-in magnetic element or optical encoder for the detection of rotor position. The position sensors send signals to the drive circuit. The brushless DC motor uses three-phase windings in a "star" connection. A permanent magnet is used in the rotor.

Construction of Brushless DC Motor
U: Phase-U winding
V: Phase-V winding
W: Phase-W winding
Rotor: Magnet

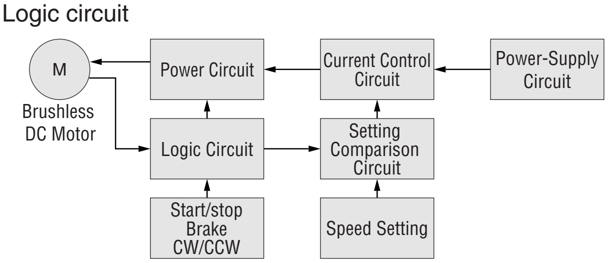


A Hall effect IC is used for the sensor's magnetic element. Three Hall effect ICs are placed within the stator, and send digital signals as the motor rotates.

Brushless DC Motor Drive Circuit

The drive circuit of the brushless DC motor is connected in the configuration shown in the figure below, and is comprised of five main blocks.

- Power circuit
- Current control circuit
- Logic circuit
- Setting comparison circuit
- Power-supply circuit



Power Circuit

This circuit uses six transistors to control the current flow in the motor windings. The transistors provided at the top and bottom turn on and off repeatedly according to a predetermined sequence, thereby controlling the flow of current to the motor windings.

Current Control Circuit

The flow of current to the motor varies according to the size of the load. The current flow to the motor is constantly monitored and controlled so that the speed will not deviate from the specified range.

Logic Circuit

The logic circuit detects the rotor position by receiving feedback signals from the motor's Hall effect IC and determines the excitation sequence of motor windings. The circuit signal is connected to each transistor base in the power circuit, driving the transistors according to a predetermined sequence. It also detects the motor's speed. The logic circuit is also used to control commands to the motor, including start/stop, brake/run and CW/CCW.

Setting Comparison Circuit

This circuit compares the motor speed signal against the set speed signal in order to determine whether the motor speed is higher or lower than the set speed. The input to the motor is lowered if the motor speed is higher than the set speed, but the input is raised if it is lower than the set speed. In this manner, the speed that has varied is returned to the set speed.

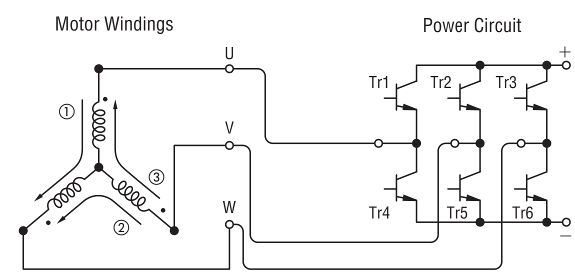
Power Supply Circuit

This circuit converts a commercial power supply into the voltage necessary to drive the motor and control circuits.

Principle of Brushless DC Motor Rotation

The motor windings are connected to switching transistors, six of which make up the inverter. The top and bottom transistors turn on and off, according to a predetermined sequence, to change the direction of current flow in the windings. The mechanism of brushless DC motor rotation can be described as follows:

In step 1 of the transistor's switching sequence, as shown in the following figure, transistors Tr1 and Tr6 are in the "ON" state. At this time the winding current flows from phase U to phase W, and phases U and W are excited so that they become N and S poles, respectively, thus causing the rotor to turn 30°. Repeating such a motion 12 times thereby facilitates rotation of the motor.



Switching Sequences of Individual Transistors

Step / Transistor	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	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	N	—	S	S	—	N	N	—	S	S	—	N	N
Phase V	—	N	N	—	S	S	—	N	N	—	S	S	—
Phase W	S	S	—	N	N	—	S	S	—	N	N	—	S

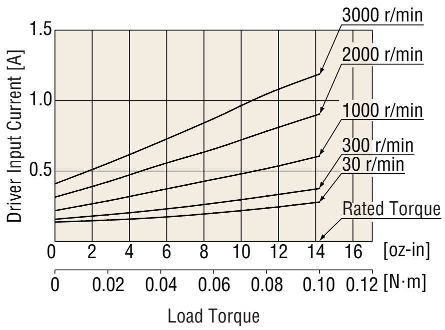
Load Torque – Driver Input Current Characteristics of a Brushless DC Motor and Driver System (reference values)

The driver or control unit input current for brushless DC motors varies with the load torque. Load torque is roughly proportional to the driver input current. These characteristics may be used to estimate load torque from the driver input current. However, this is valid only when the motor is rotating at a steady speed. Starting and bidirectional motion requires greater current input, so the relationship does not apply to such operations.

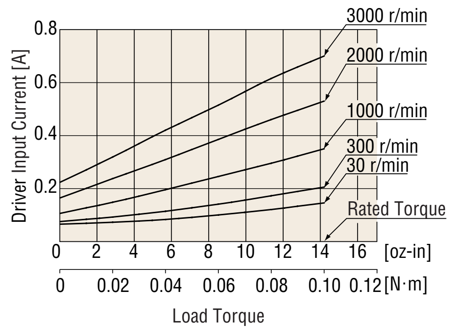
Data for combination type models indicates values for the motor unit only. The box (□) in the model name indicates the gear ratio.

● BX Series

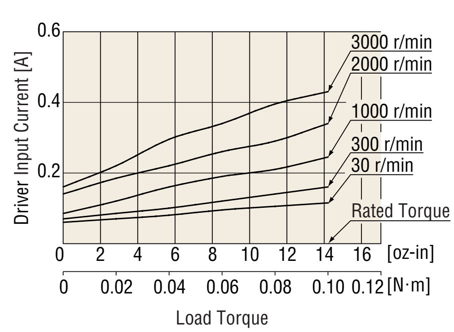
BX230A-□, BX230AM-□
BX230A-A, BX230AM-A



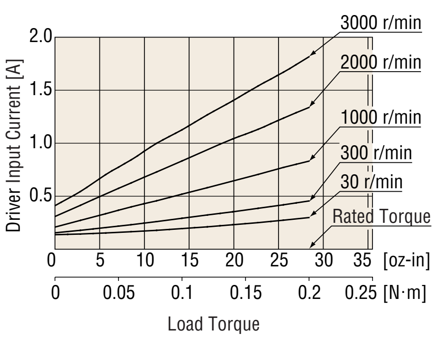
BX230C-□, BX230CM-□ (Single-Phase 200-230 VAC)
BX230C-A, BX230CM-A (Single-Phase 200-230 VAC)



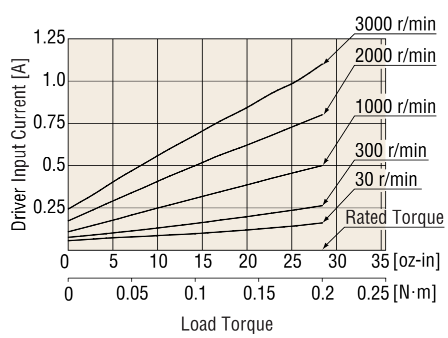
BX230C-□, BX230CM-□ (Three-Phase 200-230 VAC)
BX230C-A, BX230CM-A (Three-Phase 200-230 VAC)



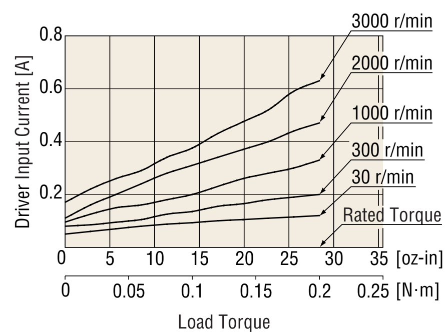
BX460A-□, BX460AM-□
BX460A-A, BX460AM-A



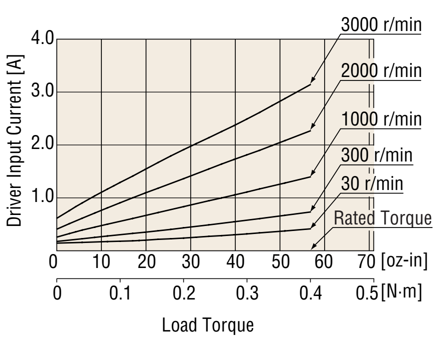
BX460C-□, BX460CM-□ (Single-Phase 200-230 VAC)
BX460C-A, BX460CM-A (Single-Phase 200-230 VAC)



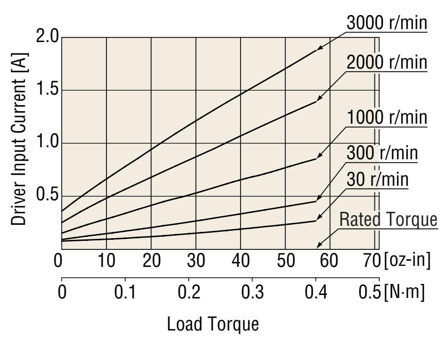
BX460C-□, BX460CM-□ (Three-Phase 200-230 VAC)
BX460C-A, BX460CM-A (Three-Phase 200-230 VAC)



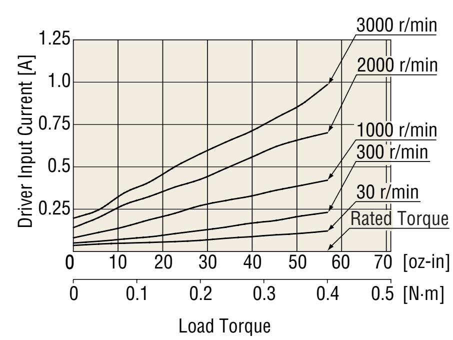
BX5120A-□, BX5120AM-□
BX5120A-A, BX5120AM-A



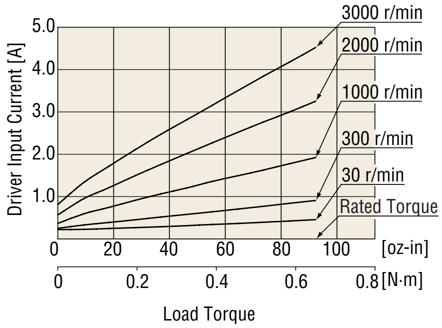
BX5120C-□, BX5120CM-□ (Single-Phase 200-230 VAC)
BX5120C-A, BX5120CM-A (Single-Phase 200-230 VAC)



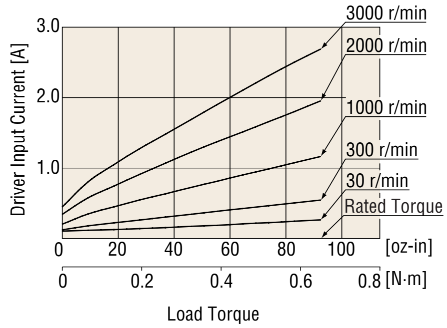
BX5120C-□, BX5120CM-□ (Three-Phase 200-230 VAC)
BX5120C-A, BX5120CM-A (Three-Phase 200-230 VAC)



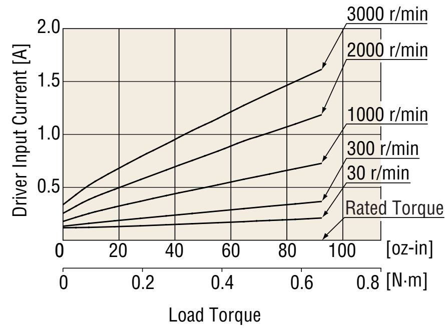
BX6200A-□, BX6200AM-□
BX6200A-A, BX6200AM-A



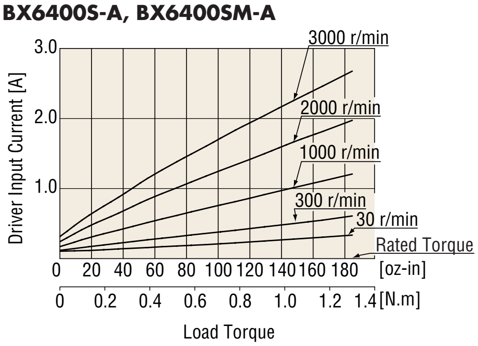
BX6200C-□, BX6200CM-□ (Single-Phase 200-230 VAC)
BX6200C-A, BX6200CM-A (Single-Phase 200-230 VAC)



BX6200C-□, BX6200CM-□ (Three-Phase 200-230 VAC)
BX6200C-A, BX6200CM-A (Three-Phase 200-230 VAC)

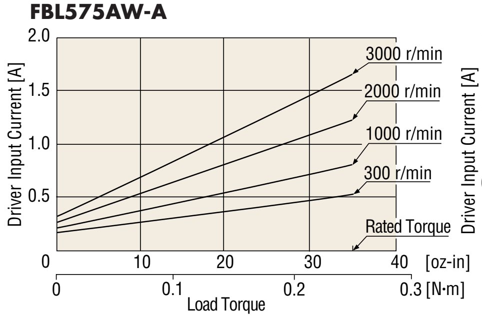


BX6400S-□, BX6400SM-□
BX6400S-A, BX6400SM-A

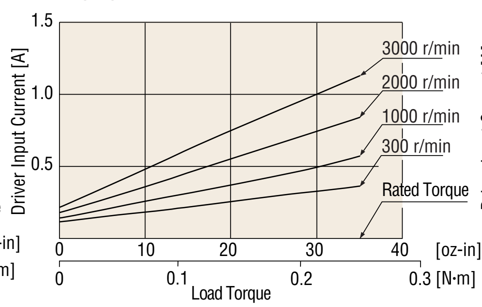


FBLⅡ Series

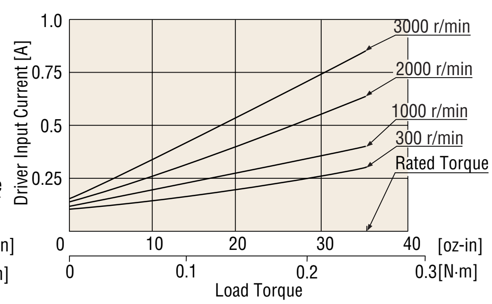
FBL575AW-□
FBL575AW-A



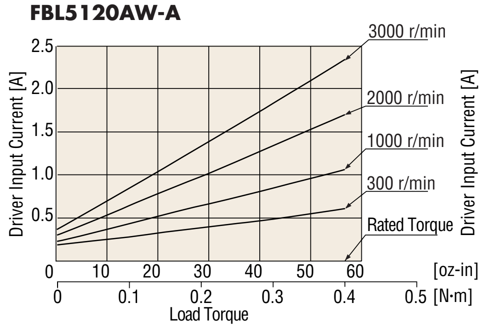
FBL575CW-□
FBL575CW-A



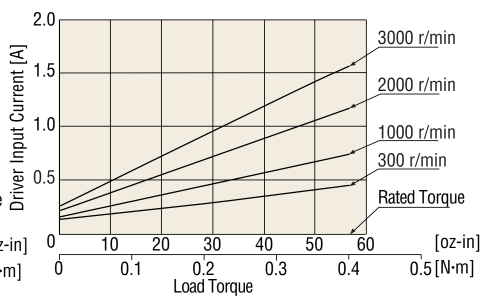
FBL575SW-□
FBL575SW-A



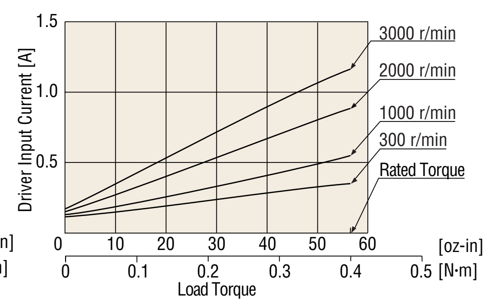
FBL5120AW-□
FBL5120AW-A



FBL5120CW-□
FBL5120CW-A

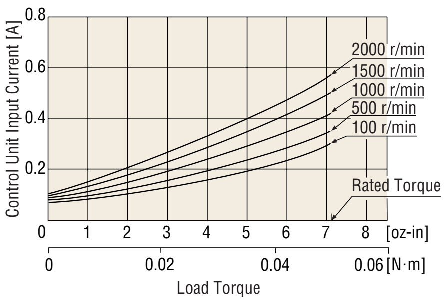


FBL5120SW-□
FBL5120SW-A

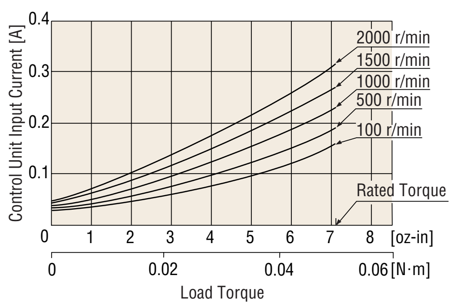


AXU Series

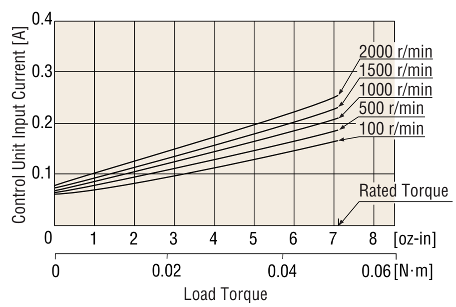
AXU210A-GN
AXU210A-A



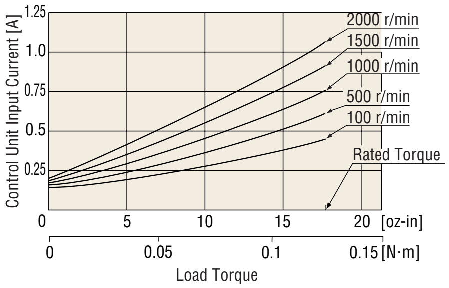
AXU210C-GN
AXU210C-A



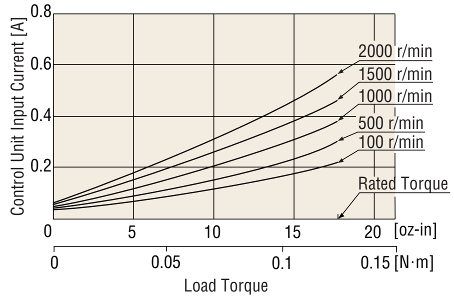
AXU210S-GN
AXU210S-A



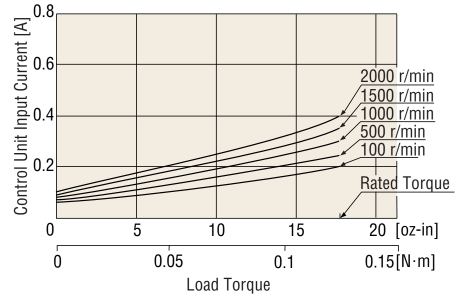
AXU425A-GN
AXU425A-A



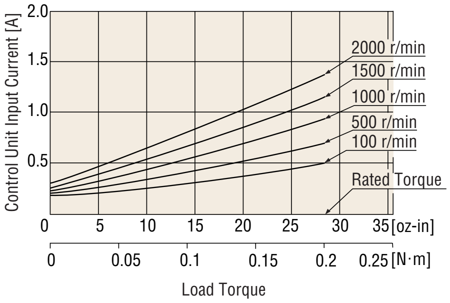
AXU425C-GN
AXU425C-A



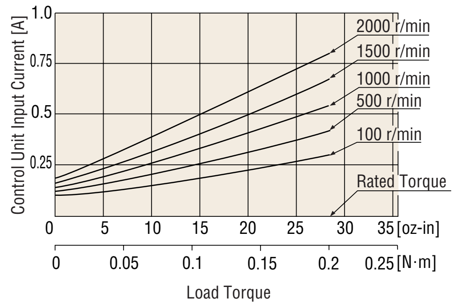
AXU425S-GN
AXU425S-A



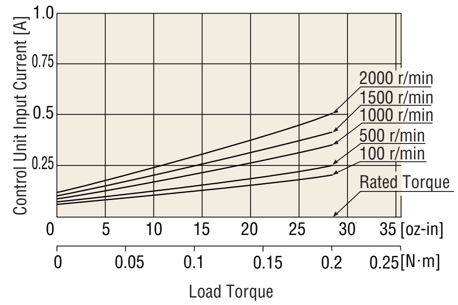
AXU540A-GN
AXU540A-A



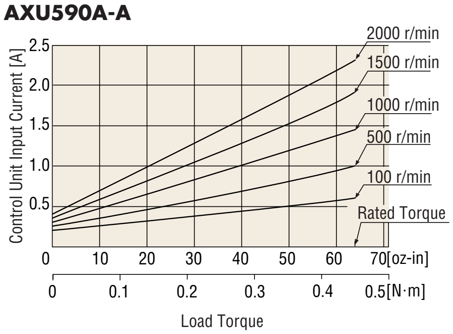
AXU540C-GN
AXU540C-A



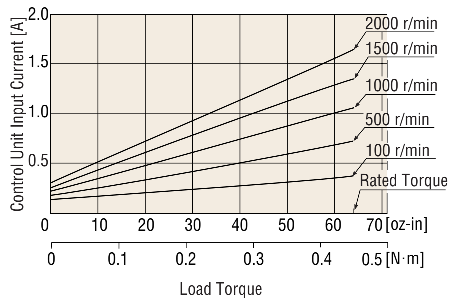
AXU540S-GN
AXU540S-A



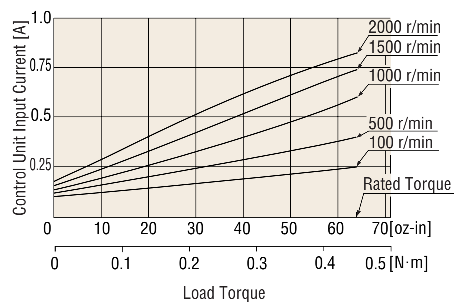
AXU590A-GU
AXU590A-A



AXU590C-GU
AXU590C-A

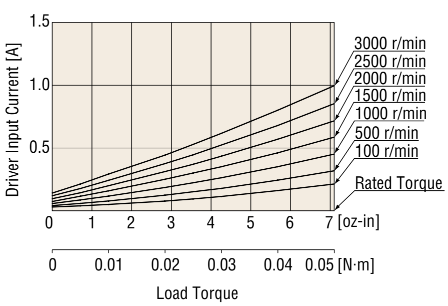


AXU590S-GU
AXU590S-A

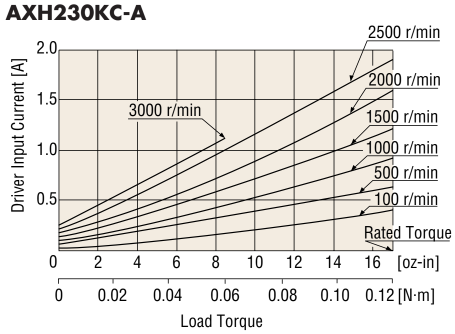


● AXH Series

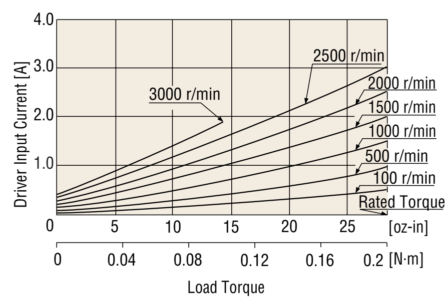
AXH015K-□
AXH015K-A



AXH230KC-□
AXH230KC-A



AXH450KC-□
AXH450KC-A



AXH5100KC-□
AXH5100KC-A