FANUC AC SERVO MOTOR αC*i* series

DESCRIPTIONS

B-65362EN/01

In this manual we have tried as much as possible to describe all the various matters.
However, we cannot describe all the matters which must not be done, or which cannot be done, because there are so many possibilities.
Therefore, matters which are not especially described as possible in this manual should be regarded as ”impossible”.

SAFETY PRECAUTIONS

This "Safety Precautions" section describes the precautions which must be observed to ensure safety when using FANUC servo motors (including spindle motors).
Users of any servo motor model are requested to read this manual carefully before using the servo motor.
The users are also requested to read this manual carefully and understand each function of the motor for correct use.
The users are basically forbidden to do any behavior or action not mentioned in the "Safety Precautions." They are invited to ask FANUC previously about what behavior or action is prohibited.

Contents

1.1 DEFINITION OF WARNING, CAUTION, AND NOTE

This manual includes safety precautions for protecting the user and preventing damage to the machine. Precautions are classified into Warning and Caution according to their bearing on safety. Also, supplementary information is described as a Note. Read the Warning, Caution, and Note thoroughly before attempting to use the machine.

> ⚠ **WARNING**
> Applied when there is a danger of the user being injured or when there is a damage of both the user being injured and the equipment being damaged if the approved procedure is not observed.

> ⚠ **CAUTION**
> Applied when there is a danger of the equipment being damaged, if the approved procedure is not observed.

> **NOTE**
> The Note is used to indicate supplementary information other than Warning and Caution.

- Read this manual carefully, and store it in a safe place.

1.2 WARNING

⚠ WARNING

- Be safely dressed when handling a motor.

Wear safety shoes or gloves when handling a motor as you may get hurt on any edge or protrusion on it or electric shocks.

- Use a crane or lift to move a motor from one place to another.

Motors are heavy. When moving them, use a crane or lift as required. (For the weight of motors, refer to their respective specification manuals.)
When moving a motor using a crane or lift, use a hanging bolt if the motor has a corresponding tapped hole, or textile rope if it has no tapped hole. If a motor is attached with a machine or any other heavy stuff, do not use a hanging bolt to move the motor as the hanging bolt and/or motor may get broken.
When moving a motor, be careful not to apply excessive force to its windings as the windings may break and/or their insulation may deteriorate.

- Do not touch a motor with a wet hand.

A failure to observe this caution is vary dangerous because you may get electric shocks.

- Before starting to connect a motor to electric wires, make sure they are isolated from an electric power source.

A failure to observe this caution is vary dangerous because you may get electric shocks.

- Do not bring any dangerous stuff near a motor.

Motors are connected to a power line, and may get hot. If a flammable is placed near a motor, it may be ignited, catch fire, or explode.

- Be sure to ground a motor frame.

To avoid electric shocks, be sure to connect the grounding terminal in the terminal box to the grounding terminal of the machine.

- Do not ground a motor power wire terminal or short-circuit it to another power wire terminal.

A failure to observe this caution may cause electric shocks or a burned wiring.

* Some motors require a special connection such as a winding changeover. Refer to their respective motor specification manuals for details.

- Connect power wires securely so that they will not get loose.

A failure to observe this caution may cause a wire to be disconnected, resulting in a ground fault, short circuit, or electric shock.

⚠ WARNING

- Do not supply the power to the motor while any terminal is exposed.

A failure to observe this caution is very dangerous because you may get electric shocks if your body or any conductive stuff touches an exposed terminal.

- Do not get close to a rotary section of a motor when it is rotating.

A rotating part may catch your cloths or fingers. Before starting a motor, ensure that there is no stuff that can fly away (such as a key) on the motor.

- Before touching a motor, shut off the power to it.

Even if a motor is not rotating, there may be a voltage across the terminals of the motor.
Especially before touching a power supply connection, take sufficient precautions.
Otherwise you may get electric shocks.

- Do not touch any terminal of a motor for a while (at least 5 minutes) after the power to the motor is shut off.

High voltage remains across power line terminals of a motor for a while after the power to the motor is shut off. So, do not touch any terminal or connect it to any other equipment. Otherwise, you may get electric shocks or the motor and/or equipment may get damaged.

- To drive a motor, use a specified amplifier and parameters.

An incorrect combination of a motor, amplifier, and parameters may cause the motor to behave unexpectedly. This is dangerous, and the motor may get damaged.

- Do not touch a motor when it is running or immediately after it stops.

A motor may get hot when it is running. Do not touch the motor before it gets cool enough. Otherwise, you may get burned.

- Be careful not get your hair or cloths caught in a fan.

Be careful especially for a fan used to generate an inward air flow.
Be careful also for a fan even when the motor is stopped, because it continues to rotate while the amplifier is turned on.

- Ensure that motors and related components are mounted securely.

If a motor or its component slips out of place or comes off when the motor is running, it is very dangerous.

- When designing and assembling a machine tool, make it compliant with EN60204-1.

To ensure the safety of the machine tool and satisfy European standards, when designing and assembling a machine tool, make it compliant with EN60204-1. For details of the machine tool, refer to its specification manual.

1.3 CAUTION

⚠ CAUTION

- FANUC motors are designed for use with machines. Do not use them for any other purpose.

If a FANUC motor is used for an unintended purpose, it may cause an unexpected symptom or trouble. If you want to use a motor for an unintended purpose, previously consult with FANUC.

- Ensure that a base or frame on which a motor is mounted is strong enough.

Motors are heavy. If a base or frame on which a motor is mounted is not strong enough, it is impossible to achieve the required precision.

- Be sure to connect motor cables correctly.

An incorrect connection of a cable cause abnormal heat generation, equipment malfunction, or failure. Always use a cable with an appropriate current carrying capacity (or thickness). For how to connect cables to motors, refer to their respective specification manuals.

- Ensure that motors are cooled if they are those that require forcible cooling.

If a motor that requires forcible cooling is not cooled normally, it may cause a failure or trouble. For a fan-cooled motor, ensure that it is not clogged or blocked with dust and dirt. For a liquid-cooled motor, ensure that the amount of the liquid is appropriate and that the liquid piping is not clogged. For both types, perform regular cleaning and inspection.

- When attaching a component having inertia, such as a pulley, to a motor, ensure that any imbalance between the motor and component is minimized.

If there is a large imbalance, the motor may vibrates abnormally, resulting in the motor being broken.

- Be sure to attach a key to a motor with a keyed shaft.

If a motor with a keyed shaft runs with no key attached, it may impair torque transmission or cause imbalance, resulting in the motor being broken.

1.4 NOTE

NOTE

- Do not step or sit on a motor.

If you step or sit on a motor, it may get deformed or broken. Do not put a motor on another unless they are in packages.

- When storing a motor, put it in a dry (non-condensing) place at room temperature (0 to 40 °C).

If a motor is stored in a humid or hot place, its components may get damaged or deteriorated. In addition, keep a motor in such a position that its shaft is held horizontal and its terminal box is at the top.

- Do not remove a nameplate from a motor.

If a nameplate comes off, be careful not to lose it. If the nameplate is lost, the motor becomes unidentifiable, resulting in maintenance becoming impossible. For a nameplate for a built-in spindle motor, keep the nameplate with the spindle.

- Do not apply shocks to a motor or cause scratches to it.

If a motor is subjected to shocks or is scratched, its components may be adversely affected, resulting in normal operation being impaired. Be very careful when handling plastic portions, sensors, and windings, because they are very liable to break. Especially, avoid lifting a motor by pulling its plastic portion, winding, or power cable.

- Do not conduct dielectric strength or insulation test for a sensor.

Such a test can damage elements in the sensor.

- When testing the winding or insulation resistance of a motor, satisfy the conditions stipulated in IEC60034.

Testing a motor under a condition severer than those specified in IEC60034 may damage the motor.

- Do not disassemble a motor.

Disassembling a motor may cause a failure or trouble in it.
If disassembly is in need because of maintenance or repair, please contact a service representative of FANUC.

- Do not modify a motor.

Do not modify a motor unless directed by FANUC. Modifying a motor may cause a failure or trouble in it.

- Use a motor under an appropriate environmental condition.

Using a motor in an adverse environment may cause a failure or trouble in it. Refer to their respective specification manuals for details of the operating and environmental conditions for motors.

NOTE

- Do not apply a commercial power source voltage directly to a motor.

Applying a commercial power source voltage directly to a motor may result in its windings being burned. Be sure to use a specified amplifier for supplying voltage to the motor.

- For a motor with a terminal box, make a conduit hole for the terminal box in a specified position.

When making a conduit hole, be careful not to break or damage unspecified portions. Refer to an applicable specification manual.

- Before using a motor, measure its winding and insulation resistances, and make sure they are normal.

Especially for a motor that has been stored for a prolonged period of time, conduct these checks. A motor may deteriorate depending on the condition under which it is stored or the time during which it is stored. For the winding resistances of motors, refer to their respective specification manuals, or ask FANUC. For insulation resistances, see the following table.

- To use a motor as long as possible, perform periodic maintenance and inspection for it, and check its winding and insulation resistances.

Note that extremely severe inspections (such as dielectric strength tests) of a motor may damage its windings. For the winding resistances of motors, refer to their respective specification manuals, or ask FANUC. For insulation resistances, see the following table.

MOTOR INSULATION RESISTANCE MEASUREMENT

Measure an insulation resistance between each winding and motor frame using an insulation resistance meter (500 VDC). Judge the measurements according to the following table.

Insulation resistance	Judgment
100 MΩ or higher	Acceptable
10 to 100 MΩ	The winding has begun deteriorating. There is no problem with the performance at present. Be sure to perform periodic inspection.
1 to 10 MΩ	The winding has considerably deteriorated. Special care is in need. Be sure to perform periodic inspection.
Lower than 1 MΩ	Unacceptable. Replace the motor.

PREFACE

This manual describes the specifications and characteristics of the αC*i* series servo motors. The manual consists of the following parts:

I. Specifications for the αC*i* series

This chapter provides general notes on the use of the αC*i* series and explains how to select the optimum motor for a given application. This chapter also provides the specifications common to each model of the a series, concerning the sensors, internal brakes, plug connectors, and so forth.

II. FANUC AC SERVO MOTOR αC*i* series

This chapter explains how to specify a certain αC*i* series servo motor and provides specifications, dimensions, and data sheets for the entire range of αC*i* series servo motors.

Although this manual provides information on sensor signal outputs, it does not describe connection to a servo amplifier or NC. For details of these connections, refer to the “FANUC SERVO AMPLIFIER α*i* series Descriptions (B-65282EN)”. and “FANUC SERVO MOTOR α*i* series Maintenance Manual (B-65285EN)”.

Related manuals

The following four kinds of manuals are available for FANUC SERVO MOTOR αC*i* series. In the table, this manual is marked with an asterisk (*).

Document name	Document number	Major contents	Major usage	
FANUC AC SERVO MOTOR αC*i* series DESCRIPTIONS	B-65362EN	Specification Characteristics External dimensions Connections	Selection of motor Connection of motor	*
FANUC SERVO AMPLIFIER α*i* series DESCRIPTIONS	B-65282EN	Specifications and functions Installation External dimensions and maintenance area Connections	Selection of amplifier Connection of amplifier	
FANUC AC SERVO MOTOR α*i*s series FANUC AC SERVO MOTOR α*i* series FANUC AC SPINDLE MOTOR α*i* series FANUC SERVO AMPLIFIER α*i* series MAINTENANCE MANUAL	B-65285EN	Start up procedure Troubleshooting Maintenance of motor	Start up the system (Hardware) Troubleshooting Maintenance of motor	
FANUC AC SERVO MOTOR α*i*s series FANUC AC SERVO MOTOR α*i* series PARAMETER MANUAL	B-65270EN	Initial setting Setting parameters Description of parameters	Start up the system (Software) Tuning the system (Parameters)	

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I. SPECIFICATIONS FOR THE αC*i* SERIES

1 GENERAL

The FANUC AC servo motor αC*i* series is suitable for application to the feed axes of machine tools. These motors have the following features:

High cost-effectiveness

High cost-effectiveness has been achieved. Although a low-power amplifier is used, high acceleration is offered.

Compact

The use of the latest ferrite magnet, combined with an optimized mechanical design, reduces both the overall length and weight. The result is compact, lightweight servo motors.

Excellent waterproofing

The use of waterproof connectors and FANUC's unique stator seal provide excellent waterproofing, ensuring that no liquid, such as coolant, can enter the motor.

Smooth rotation

Further improvements have been made to the unique magnetic pole shape to minimize torque ripple. The result is extremely smooth rotation.

Controllability

The use of the latest servo software maintains controllability even when a disturbance occurs.

High-performance sensor

High-resolution pulse coder αA1000*i* or αI1000*i* is used in the standard configuration, enabling precise positioning.

Powerful brake

A powerful brake with an increased holding torque is available as an option. The brake uses an asbestos-free design.

Models

αC4/3000*i*, αC8/2000*i*, αC12/2000*i*, αC22/2000*i*, αC30/1500*i*
The αC*i* series includes models αC4*i* and αC8*i*, both of which are compatible with a series models α4*i* and α8*i* in their installation size, and models αC12*i*, αC22*i*, and αC30*i*, which are compatible with series models α12*i*, α22*i*, and α30*i* in their installation size.

2 PRECAUTIONS ON USE

2.1 APPLICABLE AMPLIFIERS

The FANUC αC*i* series AC servo motors can be driven using FANUC α*i* series servo amplifiers.

Amplifier model \ Motor model		αC*i*	αC4/3000*i*	αC8/3000*i*	αC12/2000*i*	αC22/2000*i*	αC30/1500*i*
1-axis	SVM1-20*i*	TYPE I Outline	O	O	O		
	SVM1-40*i*	TYPE II Outline				O	
	SVM1-80*i*	TYPE II Outline					O
2-axis	SVM2-20/20*i*	TYPE I Outline	L/M	L/M	L/M		
	SVM2-20/40*i*	TYPE II Outline	L	L	L	M	
	SVM2-40/40*i*	TYPE II Outline				L/M	
	SVM2-40/80*i*	TYPE II Outline				L	M
	SVM2-80/80*i*	TYPE II Outline					L/M
	SVM2-80/160*i*	TYPE III Outline					L
3-axis	SVM3-20/20/20*i*	TYPE I Outline	L/M/N	L/M/N	L/M/N		
	SVM3-20/20/40*i*	TYPE II Outline	L/M	L/M	L/M	N	

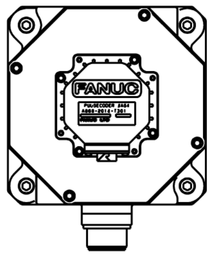
(*1) Two servo amplifier is required for a motor.
(*2) TYPEs I to III indicate the outlines of servo amplifier modules. See “SERVO AMPLIFIER α*i* series DESCRIPTIONS (B-65282EN)” for details.

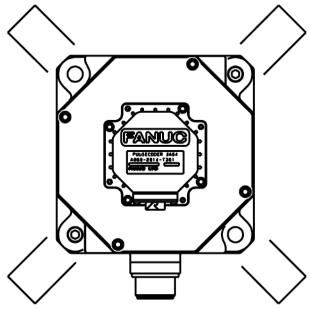
> ⚠ **CAUTION**
> 1 If a motor is used in a combination other than those listed above, it may become broken.
> 2 For details on the servo amplifier module (SVM), refer to "FANUC Servo Amplifier α*i* series Descriptions" (B-65282EN).
> 3 If you want to use a motor in combination with the α or β series servo amplifier, consult with FANUC.

2.2 INSTALLATION

The servo motor contains αi precision sensor, and is carefully machined and assembled to provide the required precision. Pay attention to the following items to maintain the precision and prevent damage to the sensor.

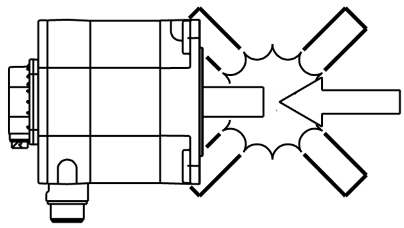
- Secure the servo motor uniformly using four bolt holes provided on the front flange.



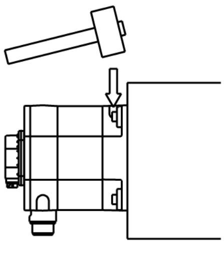


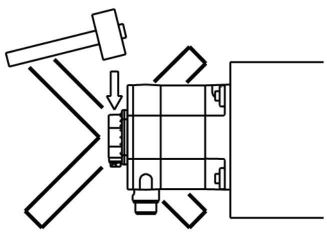
- Ensure that the surface on which the machine is mounted is sufficiently flat.

- When mounting on the machine, take care not to apply a shock to the motor.



- When it is unavoidable to tap the motor for adjusting the position, etc., use a plastic hammer and tap only the front flange if possible.

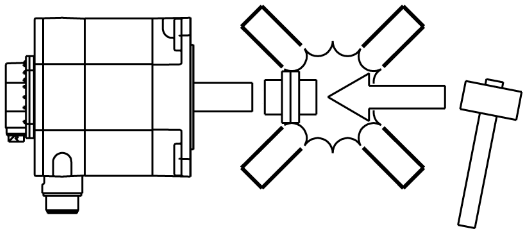




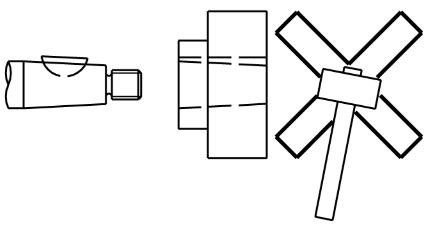
2.3 COUPLING

A precision sensor is directly connected to the servo motor shaft.
Pay attention to the following items to prevent damage to the sensor.

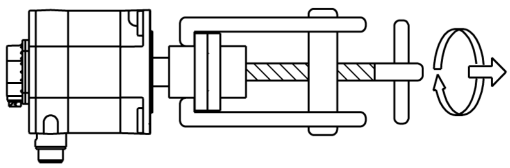
- When connecting the power transmission elements such as a gear, a pulley and a coupling to the shaft, take care not to apply a shock to the shaft.



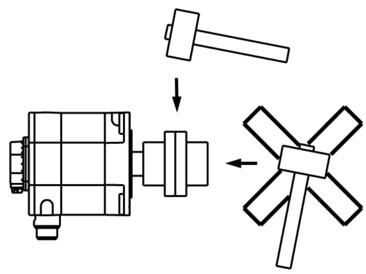
- Generally, in the case of straight shaft, use a span ring for connection with the shaft.
- In the case of tapered shaft, match the tapered surface with the power transmission element and fix by tightening the screw at the end. When the woodruff key is too tight, don't tap it with a hammer. Use the woodruff key mainly for positioning, and use the tapered surface for torque transmission. Machine the tapered surface of the power transmission element so that over 70% of the whole surface is contacted.



- To remove the connected power transmission element, be sure to use a jig such as a gear puller.



- When tapping slightly to remove the tightly contacted tapered surface, tap in the radial direction to prevent a shock in the axial direction.



- Suppress the rotary unbalance of the connected power transmission element to the level as low as possible. It is usually believed that there is no problem in the symmetrical form. Be careful when rotating continuously the asymmetrical different form power transmission element. Even if the vibration caused by the unbalance is as small as 0.5G, it may damage the motor bearing or the sensor.

2.4 AXIS LOAD

The allowable axis load of the motor shaft is as follows.

Motor model	Radial load	Axial load	Front bearing (reference)
αC4/3000*i* αC8/2000*i*	686[N] (70 [kgf])	196[N] (20 [kgf])	6205
αC12/2000*i* αC22/2000*i* αC30/1500*i*	4410[N] (450 [kgf])	1320[N] (135 [kgf])	6208

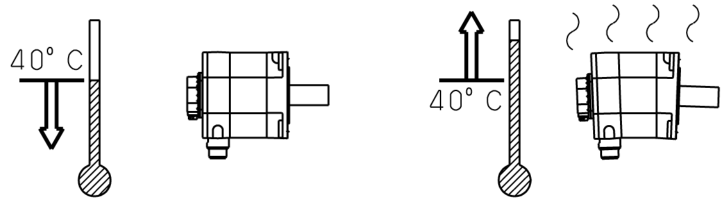
The above values are the reference assuming the use as a feed axis on the typical machine tool.

- The allowable radial load is the value when a load is applied to the shaft end. It indicates the total continuous force applied to the shaft in some methods of mounting (e.g, belt tension) and the force by load torque (e.g., moment/pulley radius).
- The belt tension is critical particularly when a timing belt is used. Too tight belt causes breakage of the shaft or other fault.
  Belt tension must be controlled so as not to exceed the limits calculated from the permissible radial load indicated above.
- In some operation conditions, the pulley diameter and the gear size need to be checked. For example, when using the model α4*i* with a pulley/gear with the radius of 2.5cm or less, the radial load at the occurrence of 17.6Nm (180kgfcm) torque will exceed 686Nm (70kgf). In the case of timing belt, as the belt tension is added to this value, it is thus necessary to support the shaft end.
- Actually, when using a timing belt, a possible fault like a broken shaft can be prevented by positioning the pulley as close to the bearing as possible.
- When there is a possibility of a large load, the machine tool builder needs to examine the life by referring to the shaft diameter, bearing, etc.
- Since the standard single row deep groove ball bearing is used for the motor bearing, a very large axial load can not be used. Particularly, when using a worm gear and a helical gear, it is necessary to provide another bearing.
- The motor bearing is generally fixed with a C-snap ring, and there is a small play in the axial direction. When this play influences the positioning in the case of using a worm gear and a helical gear, for example, it is necessary to fix it with another bearing.
- When a radial load exceeding the allowable radial load is applied, the shaft may be broken due to fatigue failure.

2.5 ENVIRONMENT

Ambient temperature

The ambient temperature should be 0°C to 40°C. When operating the machine at a higher temperature, it is necessary to lower the output power so that the motor temperature does not exceed the specified constant value. (The values in the data sheet are determined for an ambient temperature of 20°C.)



Vibration

When installed in a machine, the vibration applied to the motor must not exceed 5G.

Installation height

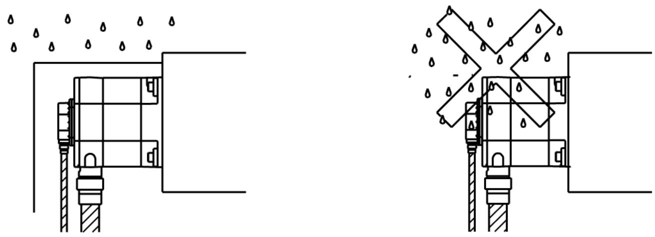
Up to 1,000 meters above the sea level requires, no particular provision for attitude. When operating the machine at a higher level, special care is unnecessary if the ambient temperature is lowered 1°C at every 100m higher than 1,000m. For example, when the machine is installed at a place of 1,500 meters above sea level, there is no problem if the ambient temperature is 35°C or less. For higher temperatures, it is necessary to limit the output power.

If any one of the three environmental conditions specified above is not satisfied, the output must be restricted.

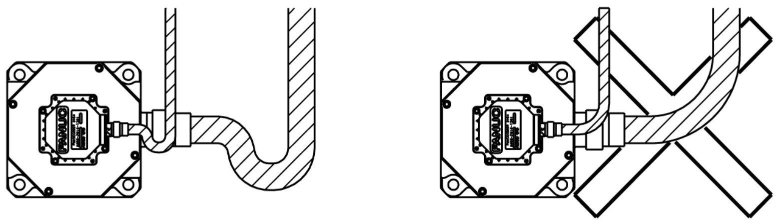
Drip-proof environment

The level of motor protection is such that a single motor unit can satisfy IP65 of the IEC standard. (The connector section for the fan of fan-equipped models is excluded.) However, this standard relates only to short-term performance. So, note the following when using the motor in actual applications:

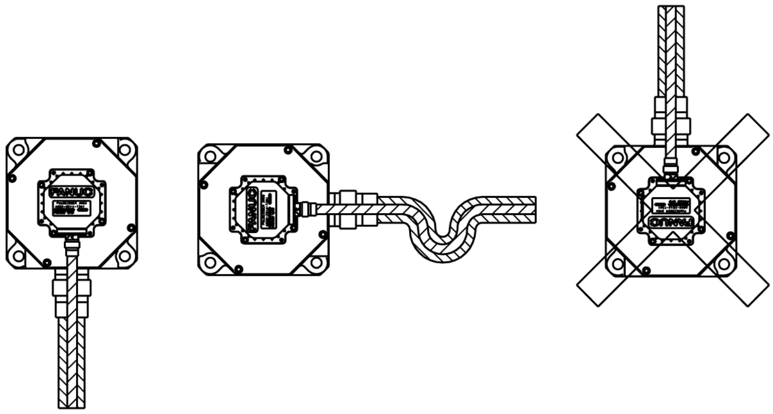
- Protect the motor surface from the cutting fluid or lubricant. Use a cover when there is a possibility of wetting the motor surface. Only the telescopic cover of the sliding part can not completely prevent leakage of the cutting fluid. Pay attention to the drop along the structure body, too.



- Prevent the cutting fluid from being led to the motor through the cable. When the motor connector is used in the up position, put a drip loop in the cable.

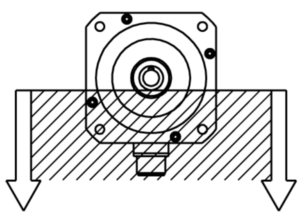


- When the motor connector is up, the cutting fluid is collected in the cable connector through the cable. Turn the motor connector sideways or downward as far as possible. Most of the defects caused by the cutting fluid have occurred in the cable connector. The standard receptacle on the motor side is waterproof. If the cable connector will be subjected to moisture, it is recommended that an R class or waterproof plug be used. Suitable plugs are listed in the cable plug combination recommendations in Chapter 8. (The standard MS plug is not waterproof; water is liable to enter the pin section.)



Shaft attachment section requirements

The motor shaft is sealed to prevent penetration of oil into the motor housing.
However, sealing may not be perfect under severe working conditions.
When oil bath lubrication is provided for the gear engagement, for example, the oil level must be below the lip of the shaft's oil seal. Set the oil level so that oil merely splashes the lip. Thus, as the shaft rotates, the oil seal can repel oil. If, however, pressure is applied continuously while the shaft is stopped, oil may penetrate the lip. When the shaft is always immersed in oil, for example, under the condition that the motor is to be used with the shaft oriented vertically a special design is required. For example, another oil seal could be installed on the machine side, and a drain provided so that oil penetrating that seal can drain off.
When grease is used for lubrication, the oil seal characteristics are usually lost.
In either case, ensure that no pressure is applied to the oil seal lip.



The motor shaft oil seal diameter is as shown below.

Motor mode	Oil seal diameter
αC4/3000*i* αC8/2000*i*	φ24 [mm]
αC12/2000*i* αC22/2000*i* αC30/1500*i*	φ35 [mm]

2.6 ACCEPTANCE AND STORAGE

When the servo motor is delivered, check the following items.

- The motor meets the specifications.
  (Specifications of the model/shaft/sensor)
- Damage caused by the transportation.
- The shaft is normal when rotated by hand.
- The brake works.
- Looseness or play in screws.

FANUC servo motors are completely checked before shipment, and the inspection at acceptance is normally unnecessary. When an inspection is required, check the specifications (wiring, current, voltage, etc.) of the motor and sensor. Store the motor indoors. The storage temperature is -20°C to +60°C. Avoid storing in the following places.

- Place with high humidity so condensation will form.
- Place with extreme temperature changes.
- Place always exposed to vibration.
  (The bearing may be damaged.)
- Place with much dust.

3 INSTRUCTIONS

3.1 DRIVE SHAFT COUPLING

There are four methods for connecting the motor shaft to the ball screw:

- Direct connection through a flexible coupling
- Direct connection through a rigid coupling
- Connection through gears
- Connection through timing belts

It is important to understand the advantages and disadvantages of each method, and select one that is most suitable for the machine.

Direct connection using a flexible coupling

Direct connection by a flexible coupling has the following advantages over connection using gears:

- Even if the angle of the motor shaft to the ball screw changes, it can be compensated to a certain extent.
- Because a flexible coupling connects elements with less backlash, driving noise from joints can be significantly suppressed.

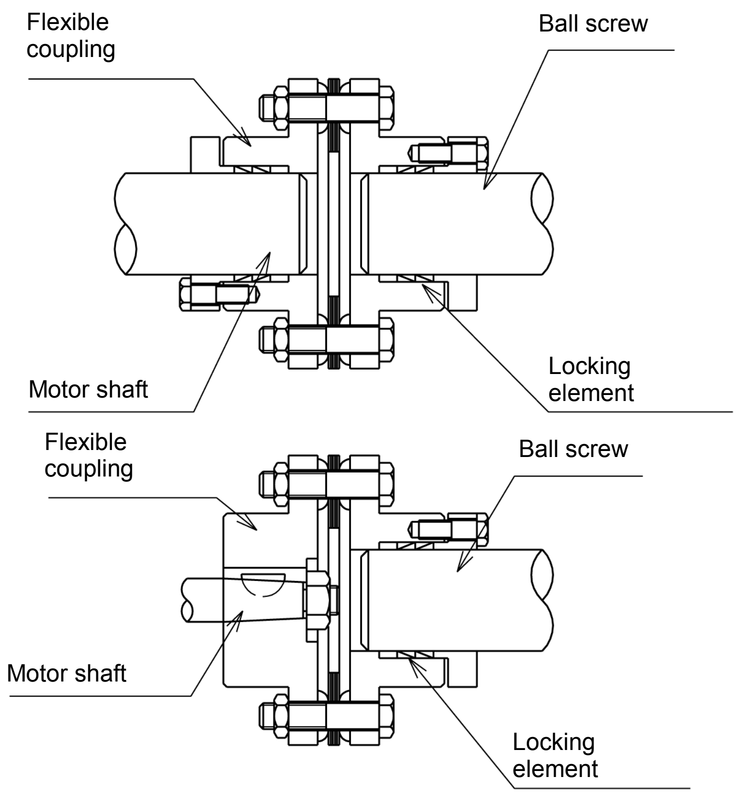
However, this method has the following disadvantages:

- The motor shaft and the ball screw must not slide from each other in the radial direction (for single coupling).
- Loose assembly may result in lower rigidity.

When the motor shaft needs to be connected directly to the ball screw, connecting them using a flexible coupling facilitates adjustment and installation of the motor.

To use a single coupling, the machine needs to be designed so that the centers of the motor shaft and the ball screw are aligned. (In the same way as with a rigid coupling, the use of a single coupling demands that there be almost no relative eccentricity between the axes.)

If it is difficult to align the centers, a double coupling needs to be employed.



Direct connection using a rigid coupling

Direct connection using a rigid coupling has the following advantages over direct connection using a flexible coupling:

- More economical
- The coupling rigidity can be increased.
- If the rigidity is the same as with a flexible coupling, the inertia can be reduced.

However, this method has the following disadvantages:

- The motor shaft and the ball screw must not slide from each other in the radial direction, and the angle of the motor shaft to the ball screw must be fixed.

For this reason, a rigid coupling needs to be mounted very carefully.
It is desirable that the run-out of the ball screw is 0.01 mm or less. When a rigid coupling is used on the motor shaft, the run-out of the hole for the ball screw must be set to 0.01 mm or less by adjusting the tightness of the span ring.
The run-out of the motor shaft and the ball screw in the radial direction can be adjusted or compensated to a certain extent by deflection. Note, however, that it is difficult to adjust or measure changes in the angle. Therefore, the structure of the machine should be such that precision can be fully guaranteed.

Gears

This method is used when the motor cannot be put in line with the ball screw because of the mechanical interference problem or when the reduction gear is required in order to obtain large torque. The following attention should be paid to the gear coupling method:

- Grinding finish should be given to the gear, and eccentricity, pitch error, tooth-shape deviations etc. should be reduced as much as possible. Please use the JIS, First Class as a reference of precision.
- Adjustment of backlash should be carefully performed. Generally, if there is too little backlash, a high-pitched noise will occur during high-speed operation, and if the backlash is too big, a drumming sound of the tooth surfaces will occur during acceleration/deceleration. Since these noises are sensitive to the amount of backlash, the structure should be so that adjustment of backlash is possible at construction time.

Timing belt

A timing belt is used in the same cases as gear connection, but in comparison, it has advantages such as low cost and reduced noise during operation, etc. However, it is necessary to correctly understand the characteristics of timing belts and use them appropriately to maintain high precision.
Generally, the rigidity of timing belt is sufficiently higher than that of other mechanical parts such as ball screw or bearing, so there is no danger of inferiority of performance of control caused by reduction of rigidity by using timing belt. When using a timing belt with a position sensor on the motor shaft, there are cases where poor precision caused by backlash of the belt tooth and pulley tooth, or elongation of belt after a long time becomes problem, so consideration should be given to whether these errors significantly affect precision. In case the position sensor is mounted behind the timing belt (for example, on the ball screw axis), a problem of precision does not occur.
Life of the timing belt largely varies according to mounting precision and tension adjustment. Please refer to the manufacturer's Instruction Manual for correct use.

Connection between the straight shaft and a connecting element

To use a straight shaft that has no key groove, connect the shaft with a coupling using a span ring. Because the span ring connects elements by the friction generated when the screw is tightened, it is free from backlash and the concentration of stress. For this reason, the span ring is highly reliable for connecting elements.
To assure sufficient transmission with the span ring, factors such as the tightening torque of the screw, the size of the screw, the number of screws, the clamping flange, and the rigidity of connecting elements are important. Refer to the manufacturer's specifications before using the span ring. When a coupling or gear is mounted using the span ring, tighten the screws to remove a run-out of the coupling or gear including the shaft.

3.2 MACHINE MOVEMENT PER 1 REVOLUTION OF MOTOR SHAFT

The machine movement per 1 revolution of motor shaft must be determined at the first stage of machine design referring the load torque, load inertia, rapid traverse speed, and relation between minimum increment and resolution of the position sensor mounted on the motor shaft. To determine this amount, the following conditions should be taken into consideration.

- The machine movement per 1 revolution of motor shaft must be such that the desired rapid traverse speed can be obtained. For example, if the maximum motor speed is 1500 min^{-1} and the rapid traverse speed must be 12 m/min., the amount of "L" must be 8 mm/rev. or higher.

- As the machine movement per 1 revolution of motor shaft is reduced, both the load torque and the load inertia reflected to motor shaft also decrease.
  Therefore, to obtain large thrust, the amount of "L" should be the lowest value at which the desired rapid traverse speed can be obtained.

- Assuming that the accuracy of the reduction gear is ideal, it is advantageous to make the machine movement per 1 rev. of motor shaft as low as possible to obtain the highest accuracy in mechanical servo operations. In addition, minimizing the machine movement per 1 rev. of motor shaft can increase the servo rigidity as seen from the machine's side, which can contribute to system accuracy and minimize the influence of external load changes.

- When the machine is operation is characterized by repeated acceleration/deceleration cycles, a heating problem may occur due to the current flow caused by the acceleration and deceleration. Should this occur, the machine travel distance per motor shaft revolution should be modified. Given optimum conditions, the machine travel distance per motor shaft revolution is set such that the motor's rotor inertia equals the load inertia based on motor shaft conversion. For machines such as punch presses and PCB drilling machines, the machine's travel distance per motor shaft revolution should be set so as to satisfy this optimum condition as far as possible, while also considering the rapid traverse rate and increment system.

4 SELECTING A MOTOR

When selecting an applicable motor, the load, rapid traverse feedrate, increment system, and other conditions must be considered. This section describes how to calculate the load and other conditions, showing an example of a table with a horizontal axis.

Motors are subjected to two types of torque: constant load torque (including friction), and cutting power and acceleration/deceleration torque. Calculate the two loads accurately and select a motor that satisfies the following conditions:

Condition 1

The constant load torque including mechanical friction must fall within approximately 70% of the stall torque of a motor.

Even when the machine stops, a motor generates a torque in the state where it balances with load friction, in addition to the vertical axis. If acceleration/ deceleration torque required for actual operation is added when this value is close to the rated torque, the rated torque may be exceeded as the average torque, and the motor is more likely to overheat.

This figure of "within 70% of the continuous torque rating" is for reference only. Determine the appropriate torque based upon actual machine tool conditions.

Condition 2

Acceleration can be made with a desired time constant.

Generally, the load torque helps deceleration. If acceleration can be executed with a desired time constant, deceleration can be made with the same time constant. Calculate the acceleration torque and check that the torque required for acceleration is within the intermittent operating zone of the motor.

Condition 3

In the desired frequency of positioning in raid traverse, the root-mean-square value of a torque including acceleration and deceleration must be sufficiently greater than the stall torque.

The greater the frequency of positioning in rapid traverse, the greater the ratio of acceleration time to the entire operation time. This may overheat the motor. When the acceleration time constant is increased according to the rapid traverse feedrate and positioning frequency constant, the amount of produced heat decreases in inverse proportion to the acceleration time constant.

Condition 4

When the load condition variously changes during a cycle, the calculated root-mean-square value of a torque must be sufficiently greater than the stall torque.

Condition 5

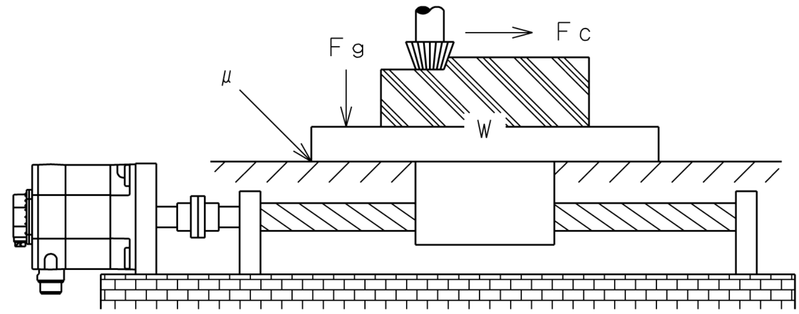
The time for which the table can be moved with the maximum cutting torque (percentage duty cycle and ON time) is within a desired range.

The procedure for selecting a motor is described below:

> **NOTE**
> When handling units, be extremely careful not to use different systems of units. For example, the weight of an object should be expressed in "kgf" in the gravitational system of units because it is handled as "force" or in "kg" in the SI system of units because it is handled as "mass." Inertia is expressed in [kgfcmsec^2] in the gravitational system of units or in [kgm^2] in the SI system of units. In this manual, the gravitational system of units is also written.
> For details on terms, see Sections 4.3 and 4.4.

4.1 CALCULATING CONDITIONS FOR SELECTING A MOTOR

This section describes the procedure for selecting a servo motor best suited for a table with a horizontal axis (figure below).



Sample mechanical specifications of the table and workpiece

W : Weight of movable parts (table and workpiece) =9800[N]=1000[kgf]
w : Weight of movable parts (table and workpiece) =1000[kg]
μ : Friction coefficient of the sliding surface =0.05
η : Efficiency of the driving system (including a ball screw) =0.9
Fg : Gib fastening force (kgf) =490[N]=50[kgf]
Fc : Thrust counter force caused by the cutting force (kgf) =980[N]=100[kgf]
Fcf: Force by which the table is pressed against the sliding surface, caused by the moment of cutting force =294[N]=30[kgf]
Z1/Z2 : Gear reduction ratio = 1/1

Sample specifications of the feed screw (ball screw)

Db : Shaft diameter $=32\times10^{-3}$[m]=32[mm]
Lb : Shaft length =1[m]=1000[mm]
P : Pitch $=8\times10^{-3}$[m]=8[mm]

Sample specifications of the operation of the motor shaft

Ta : Acceleration torque [Nm][kgfcm]
Vm : Motor speed in rapid traverse $=50[s^{-1}]=3000[min^{-1}]$
ta : Acceleration time (s) =0.10[s]
JM : Motor inertia $[kgm^2][kgfcmsec^2]$
JL : Load inertia $[kgm^2][kgfcmsec^2]$
ks : Servo position loop gain $=30[s^{-1}]$

4.1.1 Calculating the Load Torque and Load Inertia

Calculating the load torque

The load torque applied to the motor shaft is generally given by the following equation:

$$Tm = \frac{F \times L}{2\pi\eta} + Tf$$

Tm : Load torque applied to the motor shaft
F : Force required to move a movable part (table or tool post) along the axis
L : Traveling distance of the machine tool per revolution of the motor = P (Z1/Z2)
Tf : Friction torque of the nut of the ball screw or bearing applied to the motor shaft (input if necessary)
η : Efficiency of the driving system (including a ball screw)

F depends on the weight of the table, friction coefficient, whether cutting is in progress, and whether the axis is horizontal or vertical. If the axis is vertical, F also depends on the presence of a counterbalance. For a table with a horizontal axis, F is calculated as follows:
When Tf=0.2[Nm]=2[kgfcm]

When cutting is not executed:
F=μ(W+fg)
Example) F=0.05×(9800+490)=514.5[N]=52.5[kgf]
Tm =(514.5×8×10^{-3}×1)÷(2×π×0.9)+0.2
=0.93[Nm]=9.5[kgfcm]
(L=8×10^{-3}×1,η=0.9)

When cutting is in progress:
F=Fc+μ(W+fg+Fcf)
Example) F=980+0.05× (9800+490+294)=1509[N]=154[kgf]
Tmc =(1509×8×10^{-3}×1)÷(2×π×0.9)+0.2
=2.3[Nm]=23.8[kgfcm]

To satisfy condition 1, check the data sheet and select a motor whose load torque (rated torque at stall) when cutting is not executed is 0.93 [Nm] or higher and the maximum speed is 3000 [min^{-1}] or higher. Considering the acceleration/deceleration conditions, provisionally select α2/5000*i* (rated torque at stall is 2.0 [Nm]).

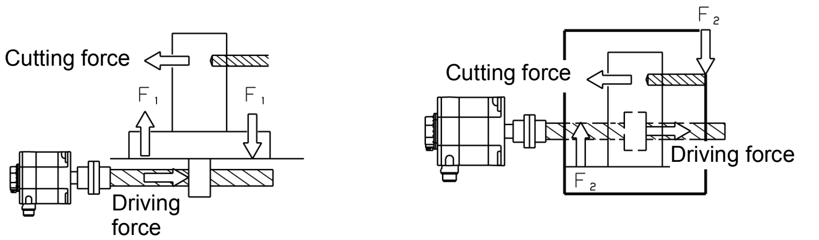
Cautions

When calculating the torque, take the following precautions:

- Allow for the friction torque caused by the gib fastening force (Fg).
  The torque calculated only from the weight of a movable part and the friction coefficient is generally quite small. The gib fastening force and precision of the sliding surface may have a great effect on the torque.

- The pre-load of the bearing or nut of the ball screw, pre-tension of the screw, and other factors may make Tc of the rolling contact considerable.
  In a small, lightweight machine tool, the friction torque will greatly affect the entire torque.

- Allow for an increase in friction on the sliding surface (Fcf) caused by the cutting resistance. The cutting resistance and the driving force generally do not act through a common point as illustrated below. When a large cutting resistance is applied, the moment increases the load on the sliding surface.
  When calculating the torque during cutting, allow for the friction torque caused by the load.



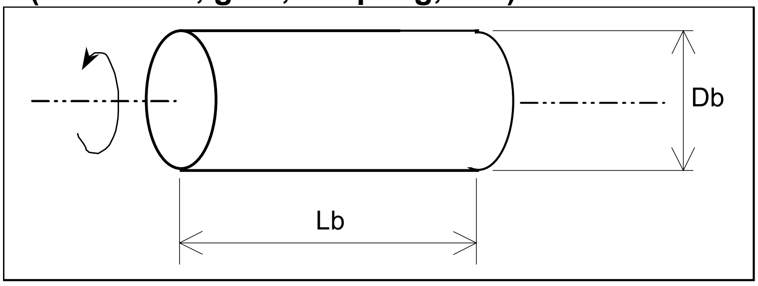
- The feedrate may cause the friction torque to vary greatly. Obtain an accurate value by closely examining variations in friction depending on variations in speed, the mechanism for supporting the table (sliding contact, rolling contact, static pressure, etc.), material of the sliding surface, lubricating system, and other factors.

- The friction torque of a single machine varies widely due to adjustment conditions, ambient temperature, and lubrication conditions. Collect a great amount of measurement data of identical models so that a correct load torque can be calculated. When adjusting the gib fastening force and backlash, monitor the friction torque. Avoid generating an unnecessarily great torque.

Calculating the load inertia

Unlike the load torque, an accurate load inertia can be obtained just by calculation.
The inertia of all objects moved by the revolution of a driving motor forms the load inertia of the motor. It does not matter whether the object is rotated or moved along a straight line. Calculate the inertia values of individual moving objects separately, then add the values together, according to a rule, to obtain the load inertia. The inertia of almost all objects can be calculated according to the following basic rules:

- Inertia of a cylindrical object (ball screw, gear, coupling, etc.)



The inertia of a cylindrical object rotating about its central axis is calculated as follows:

SI unit

$$Jb = \frac{\pi\gamma_b}{32} D_b^4 L_b \qquad [kg \cdot m^2]$$

J_b : Inertia [kgm^2]
γ_b : Weight of the object per unit volume [kg/m^3]
D_b : Diameter of the object [m]
L_b : Length of the object [m]

Gravitational system of units

$$Jb = \frac{\pi\gamma_b}{32 \times 980} D_b^4 L_b \qquad [kgf \cdot cm \cdot s^2]$$

J_b : Inertia [$kgfcms^2$]
γ_b : Weight of the object per unit volume [kg/cm^3]
D_b : Diameter of the object [cm]
L_b : Length of the object [cm]

Example)

When the shaft of a ball screw is made of steel (γ=7.8×10^3[kg/m^3]), inertia Jb of the shaft is calculated as follows:
When D_b=0.032[m], L_b=1[m],
Jb=7.8×10^3×π÷32×0.032^4×1=0.0008[kgm^2] (=0.0082[$kgfcms^2$])

$$(1kg \cdot m^2 = \frac{100}{9.8} kgf \cdot cm \cdot s^2)$$

- Inertia of a heavy object moving along a straight line (table, workpiece, etc.)

SI unit

$$Jb = W \times \left(\frac{L}{2\pi} \right)^2 \qquad [kg \cdot m^2]$$

W : Weight of the object moving along a straight line [kg]
L : Traveling distance along a straight line per revolution of the motor [m]

Gravitational system of units

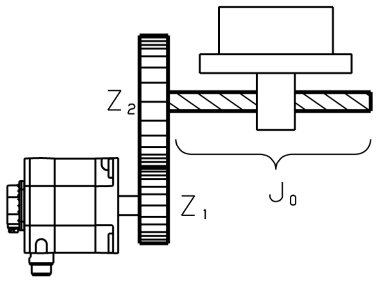
$$Jb = \frac{W}{980} \times \left(\frac{L}{2\pi} \right)^2 \qquad [kgf \cdot cm \cdot s^2]$$

W : Weight of the object moving along a straight line [kgf]
L : Traveling distance along a straight line per revolution of the motor [cm]

Example)

When W is 1000(kg) and L is 8(mm), Jw of a table and workpiece is calculated as follows:
$Jw=1000\times(0.008\div2\div\pi)^2=0.00162$ [kgm^2] $=0.0165$[$kgfcms^2$]

- Inertia of an object whose speed is increased above or decreased below the speed of the motor shaft

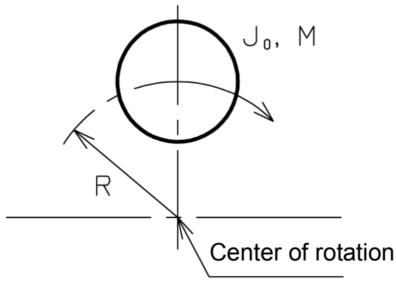


The inertia applied to the motor shaft by inertia Jo is calculated as follows:

$$J = \left(\frac{Z_1}{Z_2} \right)^2 \times J_0 \quad or \quad \left(\frac{1}{Z} \right)^2 \times J_0$$

Jo : Inertia before the speed is changed
Z_1,Z_2 : Number of teeth when the gear connection)
1/Z : Deceleration ratio

- Inertia of a cylindrical object in which the center of rotation is displaced



$$J = J_0 + MR^2$$

J_0 : Inertia around the center of the object
M : Weight of the object
R : Radius of rotation

The above equation is used to calculate the inertia of, for example, a large gear which is hollowed out in order to reduce the inertia and weight.
The sum of the inertia values calculated above is J (load inertia) for accelerating the motor.
In this example, the sum of Jb and Jw obtained in above is load inertia J_L.

$J_L = 0.000803 + 0.00162 = 0.00242$ [kgm^2]

- Note <Limitations on load inertia>

The load inertia has a great effect on the controllability of the motor as well as the time for acceleration/deceleration in rapid traverse. When the load inertia is increased, the following two problems may occur: When a command is changed, it takes more time for the motor to reach the speed specified by the new command. When a machine tool is moved along two axes at a high speed to cut an arc or curve, a larger error occurs.
When the load inertia is smaller than or equal to the rotor inertia of the motor, those problems will not occur. When the load inertia is up to three times the rotor inertia, the controllability may have to be lowered a little. Actually, this will not adversely affect the operation of an ordinary metal cutting machine. If a router for woodworking or a machine to cut a curve at a high speed is used, it is recommended that the load inertia be smaller than or equal to the rotor inertia.
When the load inertia is greater than the rotor inertia by a factor of more than 3 to 5, the controllability of the motor will be adversely affected.
If the load inertia much larger than three times the rotor inertia, an adjustment in the normal range may be insufficient. Avoid using a machine with such a great load inertia.

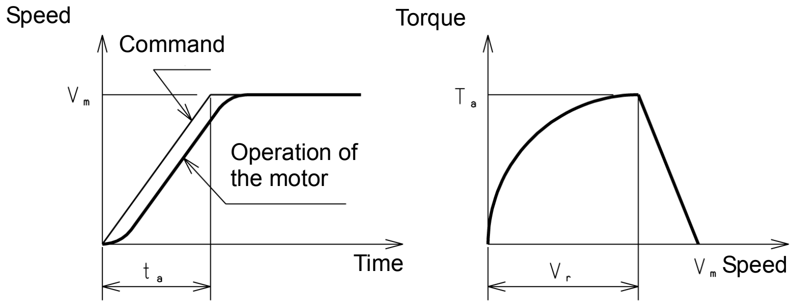
4.1.2 Calculating the Acceleration Torque

Following the procedure described below, calculate the torque required for acceleration:

Calculating acceleration torque : Procedure 1

Assuming that the motor shaft operates ideally in the acceleration/deceleration mode determined by the NC, calculate the acceleration. Multiply the acceleration by the entire inertia (motor inertia + load inertia). The product is the acceleration torque. The equation is given below.

- In linear acceleration/deceleration



$$Ta = Vm \times 2\pi \times \frac{1}{ta} \times J_M \times (1 - e^{-ks \cdot ta})$$

$$+ Vm \times 2\pi \times \frac{1}{ta} \times J_L \times (1 - e^{-ks \cdot ta}) / \eta$$

$$Vr = Vm \times \{1 - \frac{1}{ta \cdot ks}(1 - e^{-ks \cdot ta})\}$$

Ta : Acceleration torque
Vm :Motor speed in rapid traverse
ta : Acceleration time
J_M : Motor inertia
J_L : Load inertia
Vr : Point from which the acceleration torque starts to decrease
ks : Servo position loop gain
η : Machine tool efficiency
e : base of a natural logarithm

Example of calculation)

Try to perform linear acceleration/deceleration under the following condition.

$Vm=3000\ [min^{-1}]=50\ [s^{-1}]$, $ta=0.1\ [s]$, $ks=30\ [s^{-1}]$,

$J_L=0.00242$ [kgm]

Select α2/5000*i*, and calculate its acceleration torque.

J_M motor inertia is 0.00053 (kgfcms^2) when α2/5000*i* is selected, so the load inertia is calculated as follows:

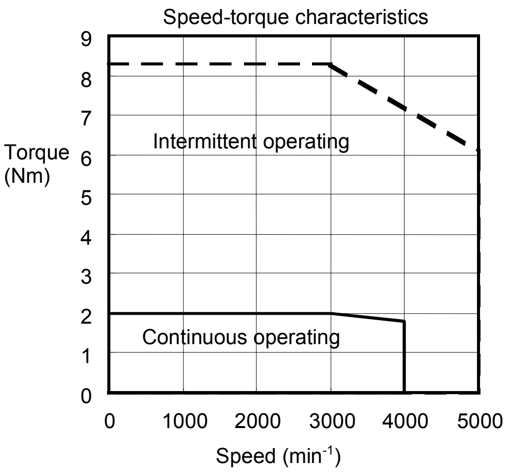
$$Ta=50\times2\pi\times1/0.1\times0.00053\times(1-e^{-30\times0.1})$$
$$+50\times2\pi\times1/0.1\times0.00242\times(1-e^{-30\times0.1})\div0.9$$
$$=9.61[Nm]=98.0[kgfcm]$$

Calculating acceleration torque : Procedure 2

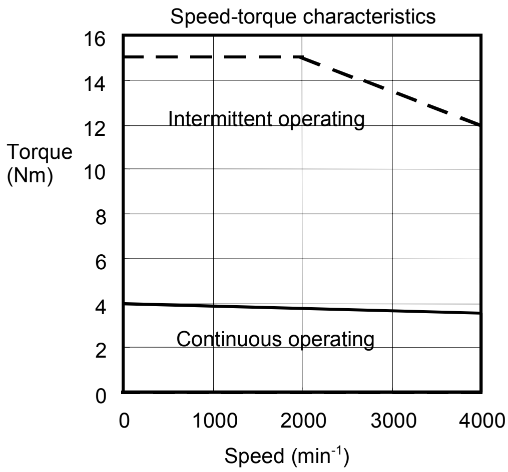
To obtain T (torque) required by the motor shaft, add Tm (friction torque) to Ta acceleration torque.

$T=Ta+Tm$

T=9.61[Nm]+0.93[Nm]=10.54[Nm]



Speed-torque characteristics α2/5000*i*



Speed-torque characteristics α4/4000*i*

The speed-torque characteristics of α2/5000*i* show that the acceleration torque of 10.54 (Nm) is beyond the intermittent operating zone of α2/5000*i* (see the characteristic curve above and data sheet). (The torque is insufficient for α2/5000*i*.)

If the operation specifications of the shaft (for instance, the acceleration time) cannot be changed, a larger motor must be selected. Select an α4/4000*i* (J_M is 0.0014[kgm^2]) and calculate the acceleration torque again.

Ta=12.2[Nm]=124.4[kgfcm]

$Vr=2050[min^{-1}]$

In acceleration, an acceleration torque (Ta) of 13.1[Nm] is required at $2050[min^{-1}]$.

The speed-torque characteristic curve shown above shows that the acceleration is possible with α4/4000*i*. (condition 2)

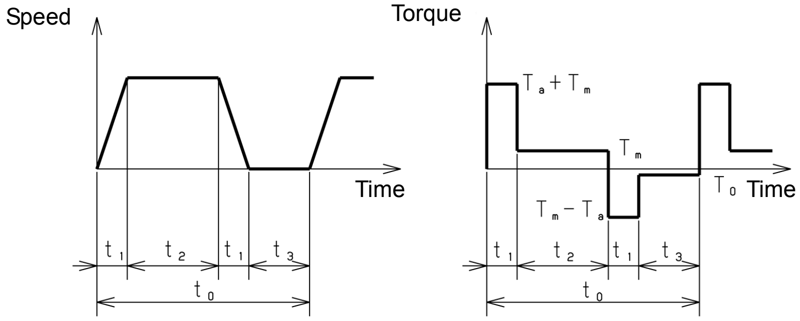
As α2/5000*i* is changed to α4/4000*i*, the size of the attachment flange is increased from 90mm×90mm to 130mm×130mm. If the machine tool does not allow a larger motor, the specifications must be changed. For example, the acceleration time must lengthen.

4.1.3 Calculating the Root-mean-square Value of the Torques

Calculating the frequency of positioning in rapid traverse

Generate an operation cycle which includes rapid traverse. Write the time-speed graph and time-torque graph as shown below.

In a common cutting machine, the frequency of positioning in rapid traverse will cause no problems. In a special machine tool which frequently executes rapid traverse, however, the motor must be checked to see whether it is overheated by the current required for acceleration or deceleration.



From the time-torque graph, obtain the root-mean-square value of torques applied to the motor during the single operation cycle. Check whether the value is smaller than or equal to the torque at stall (condition 3).

> **NOTE**
> The motor actually rotates, but the determination must be based on the stall torque.

$$Trms = \sqrt{\frac{(Ta + Tm)^2 t_1 + Tm^2 t_2 + (Ta - Tm)^2 t_1 + T_0^{\ 2} t_3}{t_0}}$$

Ta : Acceleration torque
Tm : Friction torque
To : Torque when stopped

When Trms falls within 90% of the stall torque Ts, the servo motor can be used. (The entire thermal efficiency and other margins must be considered.)

Example)

When an α4/4000*i* (Ts=4.0[Nm]=41[kgfcm]) is used under the following conditions:

Ta=12.1[Nm], Tm=To=0.9[Nm], t1=0.1[sec], t2=1.8[sec], 3=7.0[sec]

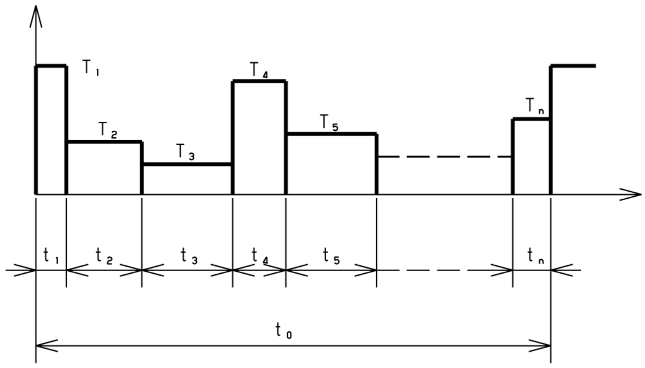
$$Trms = \sqrt{\frac{(12.1 + 0.9)^2 \times 0.1 + 0.9^2 \times 1.8 + (12.1 - 0.9)^2 \times 0.1 + 0.9^2 \times 7}{0.1 + 1.8 + 7}}$$

$= 2.02[Nm] < Ts \times 0.9 = 4.0 \times 0.9 = 3.6[Nm]$

The α4/4000*i* can be used for operation. (Condition 3)

Calculating the torque in a cycle in which the load varies

If the load conditions (cutting load, acceleration/deceleration conditions, etc.) vary widely in a single cycle, write a time-torque graph according to the operation cycle, as in above item. Obtain the root-mean-square value of the torques and check that the value is smaller than or equal to the torque at stall (condition 4).



$$Trms = \sqrt{\frac{T_1^{\,2} t_1 + T_2^{\,2} t_2 + T_3^{\,2} t_3 + \ldots + Tn^{2} t_n}{t_0}}$$

to = $t_1 + t_2 + t_3 + \ldots + t_n$

NOTE

When the motor is being operated at high speed for a comparatively large proportion of the time, you must take the rotating speed of the motor into consideration and evaluate whether output can be specified in terms of a continuous operation torque.

4.1.4 Calculating the Percentage Duty Cycle with the Maximum Cutting Torque

Check that the time for which the table can be moved with the maximum cutting torque, Tmc, (percentage duty cycle and ON time) is within a desired range of cutting time. (Condition 5)
If Tmc (maximum load torque) applied to the motor shaft during cutting, which is obtained in Subsec. 4.1.1, is smaller than the product of torque at stall of the motor (Tc) and a (thermal efficiency), the motor can be used in continuous cutting. If Tmc is greater than the product ($Tmc>Tc\times\alpha$), follow the procedure below to calculate the percentage ratio of time (t_{ON}) Tmc can be applied to the motor to total time (t) of a single cutting cycle. (α is assumed to be 0.9. Calculate the percentage considering the specifications of the machine.)

Calculate the percentage duty cycle, according to the following figure and expressions.

$Tmc<Tc\times\alpha$

Operation can be continued with the maximum cutting torque. (The percentage duty cycle with the maximum cutting torque is 100%.)

$Tmc>Tc\times\alpha$

Calculate the percentage duty cycle, according to the following figure and expressions.

Example)

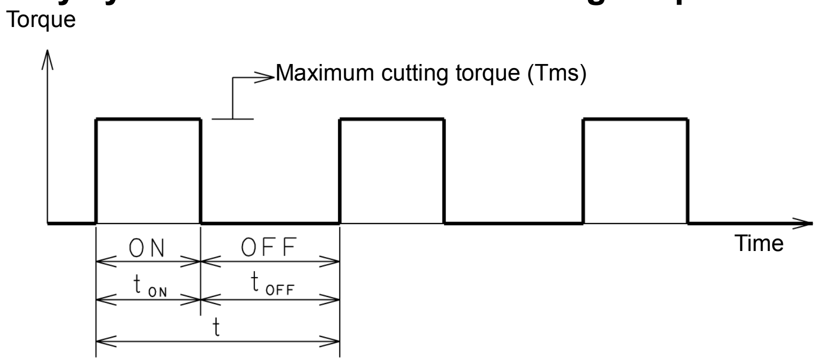
As calculated in Subsec. 4.1.1,

Tmc=2.3[Nm]=23.8[kgfcm], α4/4000*i*:Tc=4.0[Nm]=41[kgfcm]

$Tc\times\alpha=4.0\times0.9=3.6$[Nm]>Tmc=2.3[Nm]

No problems will occur in continuous cutting.

Calculating the percentage duty cycle with the maximum cutting torque



t_{ON} : Time maximum cutting torque (Tmc) is applied
t_{OFF} : Time no maximum cutting torque Tmc is applied
t : Maximum time of a single cutting cycle

Calculate the root-mean-square value of torques applied in a single cutting
cycle as described in Subsec 4.1.3. Specify t_{ON} and t_{OFF} so that the value does not exceed the product of torque at stall of the motor (Ts) and thermal efficiency (α). Then, calculate the percentage duty cycle with the maximum cutting torque as shown below.

Percentage duty cycle with the maximum cutting torque (Tms)

$$= \frac{t_{on}}{t_{on} + t_{off}} \times 100[\%]$$

Example)

Assume that Tms is 5.0[Nm] (Tm = 0.9[Nm]).

$$\sqrt{\frac{5.0^2 t_{on} + 0.9^2 t_{off}}{t_{on} + t_{off}}} < 3.6[Nm] \text{(90\% of rated torque of } \alpha 4/4000i\text{)}$$

Therefore,

$$\frac{t_{on}}{t_{off}} < \frac{1}{1}$$

The ratio of non-cutting time to cutting time must be 1 or greater.
The percentage duty cycle is calculated as follows:

$$\frac{t_{on}}{t_{on} + t_{off}} \times 100 = 50.0\%$$

Finally, the α4/4000*i* that satisfies conditions 1 to 5 is selected.

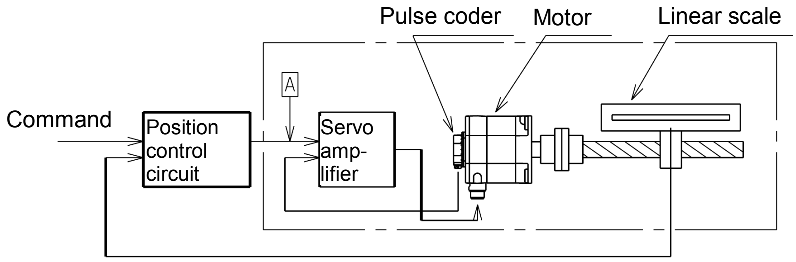
Limitations on ON time

The period during which continuous operation under an overload is allowed is also restricted by the OVC alarm level and overload duty cycle characteristics. Refer to Subsec.4.4.1 for details

4.2 PRECAUTIONS FOR USING LINEAR SCALE

In the case where the machine moves in a linear direction and movement is directly detected by linear scale such as inductosyn, magne-scale etc., special considerations are necessary in comparison with the method where feedback is produced by detecting the motor shaft rotation. This is because the machine movement now directly influences the characteristics of the control system.

Machine system natural frequency



This method is shown in the figure above by block diagram. The response of this control system is determined by the adjustment value (position loop gain) of the position control circuit. In other words, the position loop gain is determined by the specified response time of the control system. In the diagram above, the section enclosed by the broken line is called the velocity loop.
Unless the response time of this section where position signal is detected is sufficiently shorter than the response time determined by the position loop gain, the system does not operate properly. In other words, when a command signal is put into point A, response time of the machine where position signals are detected must be sufficiently shorter than the response time defined by the position loop gain.
When the response of the sensor section is slow, the position loop gain must be reduced to have the system operate normally, and as a result, the response of the whole system is slow. The same problem is caused when inertia is great (see Subsec. 4.1.1)).
The main causes for slow response are the mass of the machine and the elastic deformation of the machine system. The larger the volume, and the greater the elastic deformation, the slower the response becomes.
As an index for estimating the response of this machine system, the natural frequency of the machine is used, and this is briefly calculated by the following equation.

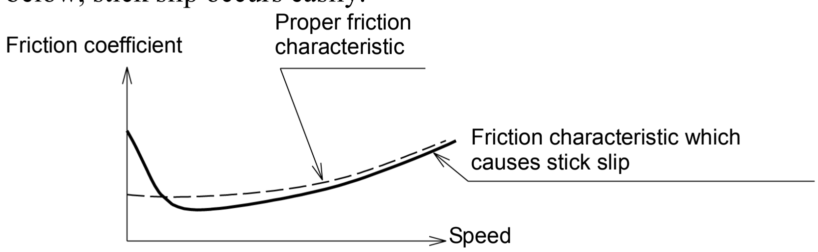
$$W = \frac{1}{2\pi} \times \sqrt{\frac{Km}{J_L}}$$

Wm: Natural frequency
J_L : Load inertia reflected to motor shaft
Km : Rigidity of machine system
(=Torque necessary to elastically deform 1[rad] at the motor shaft when the machine table is clamped.)

The above values can be obtained by calculating the elastic deformation for each section of the driving system. If the value of this natural frequency [Hz] is more than the value of position loop gain [sec^{-1}], it operates normally in most cases. That is to say, when setting 20 [sec^{-1}] as the value of position loop gain, natural frequency of machine system must be more than 20 [Hz].
In this case, attention must be paid to the fact that response becomes a problem for extremely small amounts of movement.
Consequently, the natural frequency should be calculated from the rigidity at extremely small displacement such as less than 10 [μm].

Stick slip

If machine movement causes a stick slip, the control system does not operate normally. That is, it does not stop where it is supposed to, but a phenomenon occurs where it goes beyond and then back within an extremely small range (hunting).
To avoid stick slip, the machine rigidity should be increased, or friction characteristics of the sliding surface should be improved. When the sliding surface friction characteristic is as in the figure below, stick slip occurs easily.



Value of machine overrun (Damping coefficient of machine system)

When the machine is floated by static pressure, etc., there are cases where the machine keeps on moving within the range of backlash although the motor shaft has stopped. If this amount is large, hunting will also occur. To avoid this, backlash should be reduced (especially the backlash of the last mass where position sensor is mounted) and the appropriate damping should be considered.

4.3 HOW TO FILL IN THE SERVO MOTOR SELECTION DATA TABLE

Select a suitable motor according to load conditions, rapid traverse rate, increment system and other factors. To aid in selecting the correct motor, we recommend filling in the "Servo Motor Selection Data Table" on the following page.
This section describes the items to fill in the Servo Motor Selection Data Table.

Servo Motor Selection Data Table

SI unit

Machine		Type	
NC model	FS Power Mate	Spindle motor	

Item			Axis				
Specifications of moving object							
*	Axis movement direction (horizontal, vertical, rotation, slant _ degree)						
*	Weight of moving object (including workpiece, etc.)		kg				
*	Counterbalance		N				
*	Table support (sliding, rolling, static pressure) or friction coefficient						
*	Ball screw	Diameter	mm				
		Pitch	mm				
		Length	mm				
		Rack and pinion (diameter of pinion, traveling distance of the machine tool per revolution of the pinion)					
		Other					
*	Total gear ratio						
Mechanical specifications							
	Traveling distance of the machine tool per revolution of the motor		mm				
	Least input increment of NC (resolution)		mm				
*	Maximum rapid traverse feedrate		mm/min				
	Motor speed in rapid traverse		min^{-1}				
*	Cutting rapid traverse		mm/min				
*1	Motor shaft converted load inertia		kgm^2				
	Inertia of coupling, reduction gear and pulley		kgm^2				
*2	Steady-state load torque		N				
*	Cutting thrust		N				
	Maximum cutting torque (including steady-state load)		N				
	Maximum cutting duty/ON time		%/min				
	Positioning distance		mm				
*3	Required positioning time		sec				
	In-position set value		μm				
	Rapid traverse positioning frequency (continuous, intermittent)		times/min				
	Machine tool efficiency						
Motor specifications and characteristics							
	Motor type (desired size and output)						
	Feedback type (when an absolute, incremental or pulse position sensor is required)						
	Options (when a brake, non-standard shaft, etc. is required)						
	Separate type pulse coder (yes/no)						
	Acceleration/deceleration time in rapid traverse		msec				
	Acceleration/deceleration time in cutting feed (Linear acceleration/deceleration, exponential acceleration/deceleration)		msec				
	Feed-forward during rapid traverse (yes/no)						
	Position loop gain		sec^{-1}				
	Dynamic brake stop distance		mm				
Note	Be sure to fill in units other than the above if used. (Sometimes "deg" is used instead of "mm" for the rotary axis.) * Note required values for selecting the motor. *1 If possible enter the total load inertia. If you enter the inertia of coupling, reduction gear and pulley (motor shaft conversion) in the next item, you can also calculate the total load inertia by adding the weight of the moving object and ball screw values by logical calculation in the case of a linear shaft. *2 Steady-state load torque refers to the steady-state components such as friction (holding torque is included in the case of a gravity shaft) when the motor is rotating at a fixed speed. Enter the state-state load torque as far as possible. If details are unknown, use a value calculated logically from the weight and friction coefficient. Enter the steady-state load torque of the rotary axis in the same way as for load inertia as it cannot be calculated logically. You need not enter the torque required for acceleration/deceleration. *3 Servo delay and setting times must also be taken into consideration in the positioning time.						
Operating patterns/ Remarks	Enter typical operating patterns (time in horizontal column and torque and speed in vertical column, etc.) if they are already known. In cases where the machine tool makes special movements or the motor is rotated continuously, enter as many details as possible. Feel free to enter any other comments.						

Servo Motor Selection Data Table

Gravitational system of units

Machine		Type	
NC model	FS Power Mate	Spindle motor	

Item			Axis				
Specifications of moving object							
*	Axis movement direction (horizontal, vertical, rotation, slant _ degree)						
*	Weight of moving object (including workpiece, etc.)		kgf				
*	Counterbalance		kgf				
*	Table support (sliding, rolling, static pressure) or friction coefficient						
*	Ball screw	Diameter	mm				
		Pitch	mm				
		Length	mm				
		Rack and pinion (diameter of pinion, traveling distance of the machine tool per revolution of the pinion)					
		Other					
*	Total gear ratio						
Mechanical specifications							
	Traveling distance of the machine tool per revolution of the motor		mm				
	Least input increment of NC (resolution)		mm				
*	Maximum rapid traverse feedrate		mm/min				
	Motor speed in rapid traverse		min^{-1}				
*	Cutting rapid traverse		mm/min				
*1	Motor shaft converted load inertia		$kgfcms^2$				
	Inertia of coupling, reduction gear and pulley		$kgfcms^2$				
*2	Steady-state load torque		kgfcm				
*	Cutting thrust		kgf				
	Maximum cutting torque (including steady-state load)		kgfcm				
	Maximum cutting duty/ON time		%/min				
	Positioning distance		mm				
*3	Required positioning time		sec				
	In-position set value		μm				
	Rapid traverse positioning frequency (continuous, intermittent)		times/min				
	Machine tool efficiency						
Motor specifications and characteristics							
	Motor type (desired size and output)						
	Feedback type (when an absolute, incremental or pulse position sensor is required)						
	Options (when a brake, non-standard shaft, etc. is required)						
	Separate type pulse coder (yes/no)						
	Acceleration/deceleration time in rapid traverse		msec				
	Acceleration/deceleration time in cutting feed (Linear acceleration/deceleration, exponential acceleration/deceleration)		msec				
	Feed-forward during rapid traverse (yes/no)						
	Position loop gain		sec^{-1}				
	Dynamic brake stop distance		mm				
Note	Be sure to fill in units other than the above if used. (Sometimes "deg" is used instead of "mm" for the rotary axis.) * Note required values for selecting the motor. *1 If possible enter the total load inertia. If you enter the inertia of coupling, reduction gear and pulley (motor shaft conversion) in the next item, you can also calculate the total load inertia by adding the weight of the moving object and ball screw values by logical calculation in the case of a linear shaft. *2 Steady-state load torque refers to the steady-state components such as friction (holding torque is included in the case of a gravity shaft) when the motor is rotating at a fixed speed. Enter the state-state load torque as far as possible. If details are unknown, use a value calculated logically from the weight and friction coefficient. Enter the steady-state load torque of the rotary axis in the same way as for load inertia as it cannot be calculated logically. You need not enter the torque required for acceleration/deceleration. *3 Servo delay and setting times must also be taken into consideration in the positioning time.						
Operating patterns/ Remarks	Enter typical operating patterns (time in horizontal column and torque and speed in vertical column, etc.) if they are already known. In cases where the machine tool makes special movements or the motor is rotated continuously, enter as many details as possible. Feel free to enter any other comments.						

4.3.1 Title

Kind of machine tool

Fill in this blank with a general name of machine tools, such as lathe, milling machine, machining center, and others.

Type of machine tool

Fill in this blank with the type of machine tool decided by machine tool builder.

CNC equipment

Fill in this blank with the name of CNC (16*i*-MB, 21*i*-TB, PM*i*-D, etc.) employed.

Spindle motor output

Enter the specifications and output of the spindle motor. (This item is needed when selecting PSM.)

Axis

Fill in this blank with names of axes practically employed in CNC command.
If the number of axes exceeds 4 axes, enter them in the second sheet.

4.3.2 Data

Specifications of moving object

Be sure to enter data in this row. Data entered here is needed for determining the approximate motor load conditions (inertia, load torque).

- Axis movement direction

Enter the movement directions of driven parts such as the table and tool post (e.g. horizontal, vertical). Write their angle from the horizontal level if their movement directions are slant (e.g. slant 60°).

- Mass(weight) of driven parts

Enter the mass(weight) of driven parts, such as table, tool post, etc. by the maximum value including the weight of workpiece, jig, and so on. Do not include the weight of the counter balance in the next item in this item.

- Counter balance

Enter the weight of the counter balance in the vertical axis, if provided.
Enter whether the counter balance is made by a weight or force as this influences inertia.

- Table support

Enter the type of table slide (e.g. rolling, sliding or static pressure).
Enter a special slide way material like Turcite, if used. Also enter the friction coefficient value. This item is significant in estimating the friction coefficient for calculating mainly the load torque.

- Feed screw

Enter the diameter, pitch, and axial length of the lead screw in order.
If a rack and pinion or other mechanism is used, also enter the traveling distance of the machine tool per revolution of the pinion.

- Total gear ratio

Enter the gear ratio between the ball screw and the servo motor, gear ratio between the final stage pinion and the servo motor in case of the rack pinion drive, or gear ratio between the table and the motor in case of rotary table.

Mechanical specifications

Enter basic data that is required for selecting the motor.
For details on how to calculate each of the items, see 4.1 to 4.2.
Pay special attention to the unit for calculating and expressing torque.

- Movement per rotation of motor

Enter the movement of the machine tool when the motor rotates one turn.

Example

- When the pitch of ball screw is 12 mm and the gear ratio is 2/3,
  12mm × 2/3 = 8 mm
- When the gear ratio is 1/72 in rotary table ;
  360° × 1/72 = 5°

- Least input increment CNC

Enter the least input increment of NC command. (The standard value is 0.001 mm.)

- Rapid traverse rate

Enter the rapid traverse rate required for machine tool specifications.

- Motor speed in rapid traverse

Enter the motor speed during rapid traverse.

- Cutting rapid traverse

Enter the rapid traverse rate required for machine tool specifications.

- Motor shaft converted load inertia

Enter a load inertia applied by the moving object reflected on the motor shaft.
Do not include the inertia of the motor proper in this value. For details on this calculation, see 4.1.1.
In the case of a linear shaft, enter the load inertia calculated by logical calculation if you enter the next item. In the case of a rotary shaft, however, the load inertia cannot be calculated by logical calculation.
Enter values to two digits past the decimal point. (e.g. 0.2865 → 0.29)

- Inertia of coupling, reduction gear and pulley

Enter load inertia applied on transfer mechanisms other than couplings, moving objects and ball screw.
Enter values to two digits past the decimal point. (e.g. 0.2865 → 0.29)

- Steady-state load torque

Enter the torque obtained by calculating the force applied for moving the machine tool and state-state components such as friction (including holding torque in the case of a gravity shaft) reflected on the motor shaft when it is rotating at a fixed speed. (Do not include any torque required for acceleration/deceleration in this item.) If details are unknown, use a value calculated logically from the weight and friction coefficient. Enter the steady-state load torque of the rotary axis in the same way as for load inertia as it cannot be calculated logically.
If the load torque values differ during lifting and lowering in the vertical axis, enter both values. Also, if the load torque values differ during rapid traverse and cutting feed, enter a notice to that effect.
Since torque produced in low speed without cutting may be applied even when the motor has stopped, a sufficient allowance is necessary as compared with the continued rated torque of the motor. Suppress this load torque so that it is lower than 70% of the rated torque.

- Cutting thrust

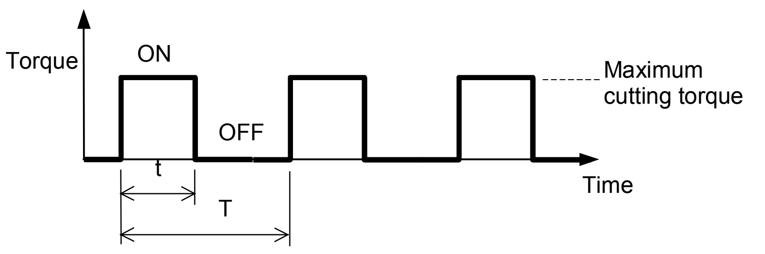
Enter the maximum value of the force applied during cutting by the force in the feed axis direction.

- Maximum cutting torque

Enter the torque value on the motor shaft corresponding to the maximum value of the above cutting thrust. When you enter this value, add the steady-state load to the motor shaft converted value for the cutting thrust.
Since the torque transfer efficiency may substantially deteriorate to a large extent due to the reaction from the slideway, etc. produced by the cutting thrust, obtain an accurate value by taking measured values in similar machine tools and other data into account.

- Maximum cutting duty / ON time

Enter the duty time and ON time with the maximum cutting torque in the above item applied.



ON : Time that the maximum cutting torque is applied
OFF : Time when cutting torque is not applied
Duty : (t/T) × 100 [%]
ON time = t [min]

- Positioning distance

Enter the distance as a condition required for calculating the rapid traverse positioning frequency.
When an exclusive positioning device is used, enter this value together with the desired positioning time below.

- Required positioning time

Enter the required positioning time when an exclusive positioning device is used.
When the device is actually attached on the machine tool, note that servo delay and setting times must also be taken into consideration in the positioning time.

- In-position set value

Enter the in-position set value as a condition required for calculating the above positioning times when an exclusive positioning device is used.
Note that the positioning time changes according to this value.

- Rapid traverse positioning frequency

Enter the rapid traverse positioning frequency by the number of times per minute.
Enter whether the value is for continuous positioning over a long period of time or for intermittent positioning within a fixed period of time. (This value is used to check the OVC alarm and whether the motor is overheated or not by a flowing current during acceleration/deceleration, or to check the regenerative capacity of the amplifier.)

- Machine tool efficiency

This value is used for calculating the transfer efficiency of motor output on a machine tool. (Standard value is 0.9.)
Generally, a drop in transfer efficiency is expected if a reduction gear having a large deceleration rate is used.

Motor specifications and characteristics

- Motor type

Enter the motor type, if desired.

- Feedback type

Enter the specifications (absolute/increment or number of pulses: 1,000,000) of the feedback sensor (pulse coder) built into the motor.

- Options

Enter options such as a motor brake and non-standard shaft, if required.

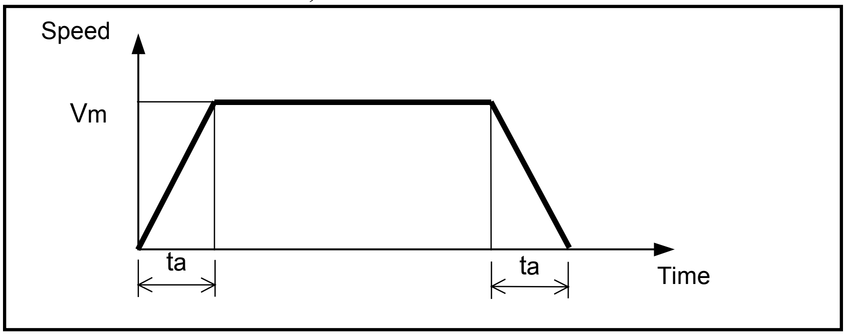
- Separate type pulse coder

Enter the name of the separate type pulse coder, if used.

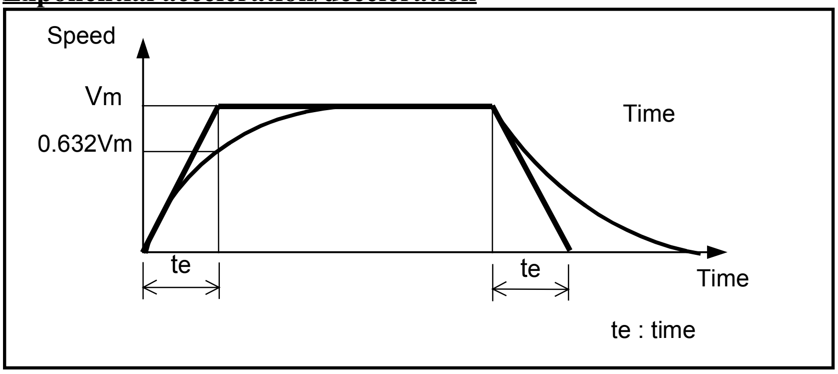
- Acceleration/deceleration time constant (at rapid traverse or cutting feed)

The acceleration/deceleration time is determined according to the load inertia, load torque, motor output torque, and working speed. For details of calculations, refer to Subsec. 4.1.2 and 4.1.3.
The acceleration/deceleration mode at rapid traverse is generally linear acceleration/deceleration in FANUC's CNC.
The acceleration/deceleration mode at cutting feed is linear acceleration/deceleration or exponential acceleration/deceleration.

Linear acceleration/deceleration
For details of calculations, refer to Subsec. 4.1.2 and 4.1.3.



Exponential acceleration/deceleration



- Feed-forward during rapid traverse

Enter whether or not feed-forward control is used.
Generally, feed-forward control can reduce the delay time in executing servo commands. However, overheating of the motor is more likely to occur as a higher torque is required for acceleration/ deceleration. Since mechanical shock increases by only the No.1 time constant, generally also set the No.2 acceleration/deceleration time constant or FAD time constant when using feed-forward control.

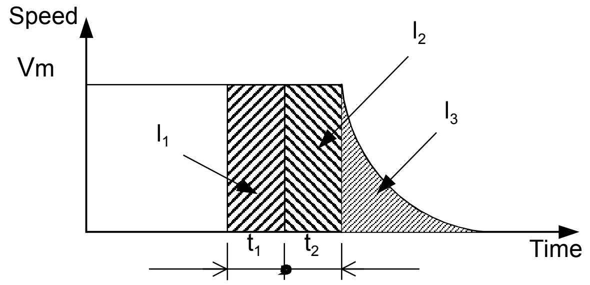
- Position loop gain

Fill in this blank with a value which is considered to be settable judging it from the inertia value based on experiences.
Since this value is not always applicable due to rigidity, damping constant, and other factors of the machine tool, it is usually determined on the actual machine tool. If the position sensor is

mounted outside the motor, this value is affected by the machine tool rigidity, backlash amount, and friction torque value. Enter these values without fail.

- Dynamic brake stop distance

This is coasting distance when the machine tool is stopped by dynamic braking with both ends of the motor power line shorted, if the machine tool is in trouble.
There are two ways of shortening this dynamic brake stop distance, the emergency stop distance shortening function, and the emergency stop distance shortening function (additional hardware is required) effective during power interruptions.



Vm : Rapid traverse rate, mm/sec or deg /sec
l_1 : Coasting distance due to delay time t_1 of receiver
l_2 : Coasting distance due to deceleration time t_2 of magnetic contactor (MCC)
l_3 : Coasting distance by dynamic braking after magnetic contactor has been operated
(t_1+t_2) is usually about 0.05 seconds.

$$\text{Coasting distance due} = Vm \times (t_2 + t_2) + (Jm + J_L) \times (A \times No + B \times No^3) \times L$$
$[mm]$ *or* [deg]

Jm : Motor inertia [kgm^2] [$kgfcms^2$]
J_L : Load inertia [kgm^2] [$kgfcms^2$]
No : Motor speed at rapid traverse [min^{-1}]
L : Machine movement on one-rotation of motor [mm] or [deg] (No/60×L=Vm)
A : Coefficient A for calculating the dynamic brake stop distance
B : Coefficient B for calculating the dynamic brake stop distance

For details of A and B, see the table on the following page.

Coefficients for calculating the dynamic brake stopping distance

SI unit

Model	A	B	Jm(kgm^2)
αC4/3000*i*	8.0×10^{-2}	1.6×10^{-7}	0.0014
αC8/2000*i*	3.0×10^{-2}	8.2×10^{-8}	0.0026
αC12/2000*i*	1.8×10^{-2}	1.7×10^{-7}	0.0062
αC22/2000*i*	3.8×10^{-2}	1.6×10^{-8}	0.012
αC30/1500*i*	2.1×10^{-2}	1.2×10^{-8}	0.017

Gravitational system of units

Model	A	B	Jm(kgfcms^2)
αC4/3000*i*	7.9×10^{-3}	1.6×10^{-8}	0.014
αC8/2000*i*	2.9×10^{-3}	8.0×10^{-9}	0.026
αC12/2000*i*	1.8×10^{-3}	1.6×10^{-8}	0.063
αC22/2000*i*	3.7×10^{-3}	1.5×10^{-9}	0.12
αC30/1500*i*	2.0×10^{-3}	1.2×10^{-9}	0.17

The values of A and B are calculated by assuming that the resistance of the power line is 0.05Ω per phase. The values will vary slightly according to the resistance value of the power line.
The coefficient above values are applicable when the αi series servo amplifier is being used. The coefficient may change, depending on the type of the servo amplifier. Contact FANUC when using the β series servo amplifier.

4.4 CHARACTERISTIC CURVE AND DATA SHEET

Performance of each motor model is represented by characteristic curves and data sheet shown below.

4.4.1 Performance Curves

The typical characteristic curves consist of the following.

Speed-torque characteristics

These are known as operating curves and describe the relationship between the output torque and speed of the motor. The motor can be operated continuously at any combination of speed and torque within the prescribed continuous operating zone.
Within the intermittent operating zone outside the continuous operating zone, the motor must intermittently be used using the duty cycle curve.
The limit of continuous operating zone is determined under the following conditions.

- The ambient temperature for the motor is 20°C.
- The drive current of the motor is pure sine wave.

And this zone may be limited by the thermal protection of mounted precision instrument. (pulse coder)
The torque within the continuous operating zone decreases by 0.19% for the αC*i* series according to the negative temperature coefficient of magnetic materials every time the temperature increases by 1°C after it exceeds 20°C. The intermittent operating zone may be limited by the motor input voltage.
The following table shows the values at 200 V.

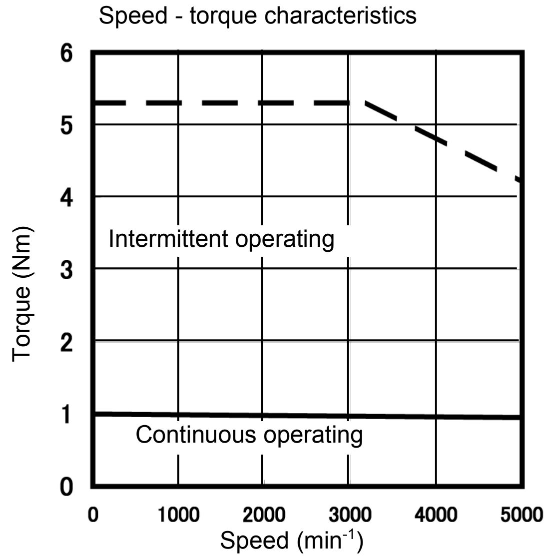


Fig.4.4.1(a) Example of α1/5000*i*

Overload duty characteristic

These are known as duty cycle curves and used to determine the load time (ON time) and the ratio of the load time (duty). During the load time, the motor does not overheat or generate an overcurernt (OVC) alarm when used under an intermittent overload condition. These curves are determined according to the motor temperature limit and soft function of monitoring overcurrent.

The overload duty characteristic determined according to the motor temperature limit is represented with a curve within a relatively long time range of at least about 100 seconds of the load time. That determined according to the soft function of monitoring overcurrent is represented with a curve within a relatively short time range of up to about 100 seconds. The final overload duty characteristic is represented with the curve described using either characteristic value, whichever is shorter (see Subsec. 4.4.3). For the soft function of monitoring overcurrent, the settings differ depending on the motor. If the motor is in the overload status at a motor speed of about 0, an overcurrent (OVC) alarm may be issued for a time shorter than described.

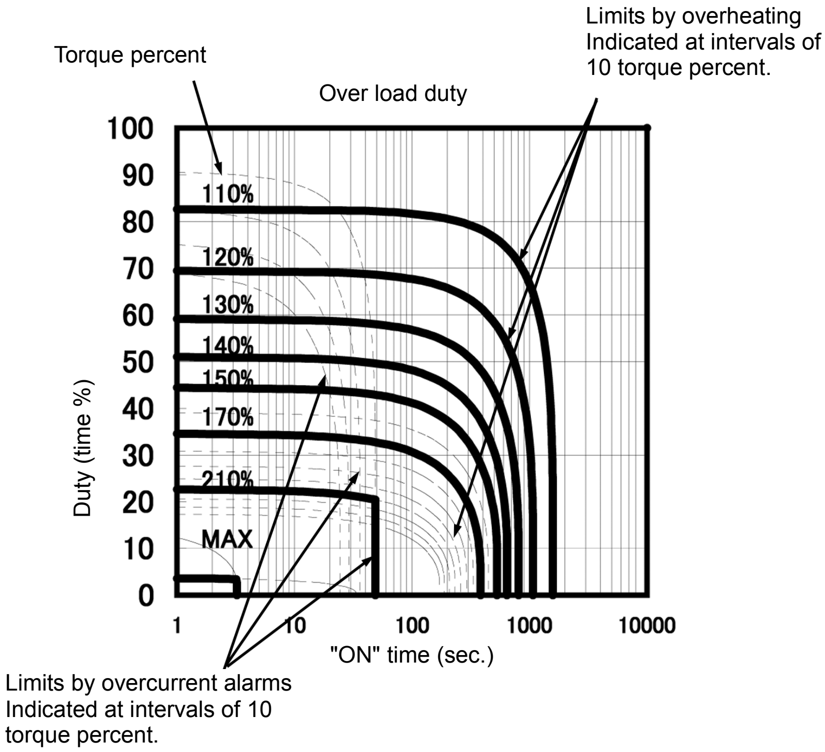


Fig.4.4.1(b) Example of α1/5000*i*

4.4.2 Data Sheet

The data sheet gives the values of motor parameters relating to the performance.
The values of parameters are those under the following conditions.

- The ambient temperature for the motor is 20°C.
- The drive current of the motor is pure sine wave.

Important parameters on the data sheet are defined as follows :

Rating rotation speed : Nmax[min^{-1}]

Maximum speed at which the motor can continuously operate

Maximum rotation speed : Nlim[min^{-1}]

Maximum speed at which the motor can operate

Stall torque : Ts[Nm]

Torque that allows the motor to operate continuously at 0 min^{-1}.

Continuous RMS current at stall TENV : Is [Arms]

Maximum effective current value that allows the motor to operate continuously at 0 min^{-1}.

Torque constant : Kt [Nm/Arms] [kgfcm/Arms]

This is known as torque sensitivity and represents the torque developed per ampere of phase current. This value is a motor-specific constant, and is calculated by the flux distribution and location of coils in the armature, and the dimensions of the motor.
The torque constant decreases by 0.19% for the αC*i* series according to the temperature coefficient of the magnet every time the temperature of the magnet increases by 1°C after it exceeds 20°C.

Back EMF (electromotive force) constant: Kv [Vrms·sec] ([Vrms·sec/rad])

This indicates the strength of a permanent magnet and is a motor-specific constant. This is the voltage generated when the rotor is externally and mechanically rotated.
Back EMF is a motor-specific constant, and is also calculated by the flux distribution and location of coils in the armature, and the dimensions of the motor. Expressed in [min^{-1}] units, back EMF has the dimensions of [Vrms/min^{-1}]. The relationship can be given as:
[Vrms·sec/rad] = [9.55×Vrms/min^{-1}] (9.55=60/2/π)
The back EMF constant is indicated as the RMS voltage per phase, so multiple by $\sqrt{3}$ to obtain the actual terminal voltage.
The relationship between the torque constant (Kt) and back EMF constant (Kv) can also be given as:

SI unit

$$Kt \quad [N \cdot m / Arms] = 3Kv \quad [Vrms \cdot \mathrm{sec} / rad]$$

Gravitational system of units

$$Kt \quad [kgf \cdot cm / Arms] = 30.6Kv \quad [Vrms \cdot \mathrm{sec} / rad]$$

For this reason, when back EMF constant (Kv) drops lower than the demagnetization of the magnet, the torque constant (Kt) also drops by the same ratio.

Mechanical time constant : tm [sec]

This is a function of the initial rate of rise in velocity when a step voltage is applied. It is calculated from the following relationship.

$$tm = \frac{Jm \cdot Ra}{Kt \cdot Kv}$$

Jm : Rotor inertia [kgm^2]
Ra : Resistance of the armature [Ω]

Thermal time constant : tt [min]

This is a function of the initial rate of rise of winding temperature at rated current. It is defined as the time required to attain 63.2 percent of the final temperature rise.

Static friction : Tf [Nm] [kgfcm]

This is the no-load torque required just to rotate the rotor.

4.4.3 How to Use Duty Cycle Curves

Servo motors can be operated in the range exceeding continuous rated torque depending on thermal time constant.
The overload duty characteristic indicates the relationship between the duty (%) in which the motor does not overheat or generate an overcurernt (OVC) alarm and the "ON" time (load time) (see the description of "Overload duty characteristic" in Subsec. 4.4.1). The calculation procedure is shown below:

1 Calculate Torque percent by formula (b) below.
2 Motor can be operated at any point on and inside the curve (according to the limits by overheating or overcurrent alarms) corresponding to the given over load conditions obtained form 1.
3 Calculate t_F by formula (a)

$$t_F = t_R \times \left(\frac{100}{Dutypercent} - 1 \right) --- (a)$$

$$TMD = \frac{Load\ torque}{Continuous\ rated\ torque} --- (b)$$

t_F : "OFF" time
t_R : "ON" time

The values of t_R and t_F obtained form the above mentioned procedure shows the ones limited by motor thermal conditions.
Note that thermal protection devices such as a circuit breaker and thermal circuit are incorporated into the drive amplifier. These devices also impose a restriction on motor usage.

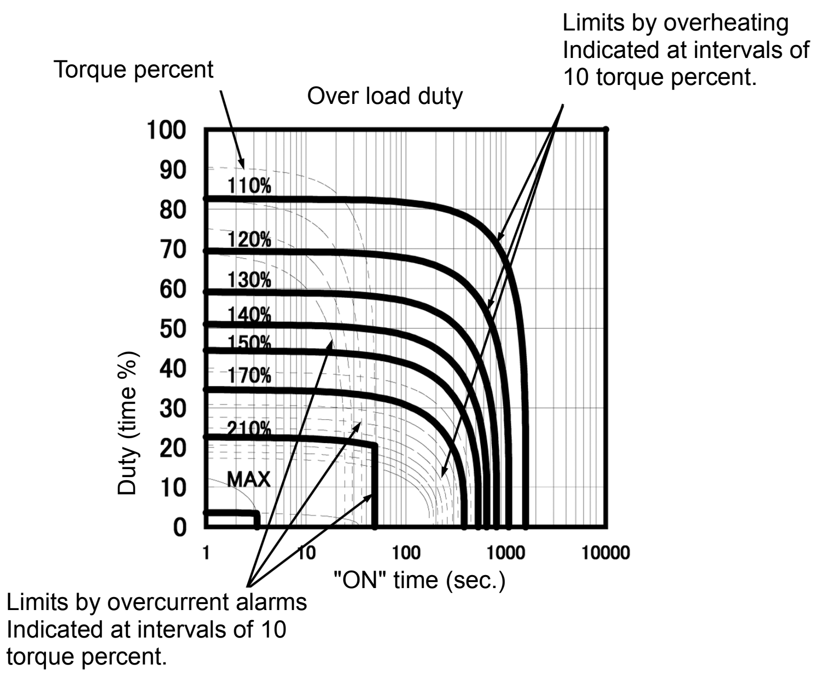


Fig.4.4.3 Example of α1/5000*i*

5 CONDITIONS FOR APPROVAL RELATED TO THE IEC60034 STANDARD

5.1 APPLICABLE MOTORS

This chapter describes the conditions the following FANUC αC*i* series AC servo motors must clear before they can be approved for the IEC60034 standard.
For details on EMC compliance authorization, refer to the separate manual "Compliance with EMC Directives"

5.1.1 200 VAC Input Types

The following FANUC AC servo motor αC*i* series can comply with the IEC60034 standard if you follow the descriptions in this chapter. The TUV mark is printed on the nameplates of the following motors.

αC*i* series

Model name	Motor specification number
αC4/3000*i*	A06B-0221-Bx0x
αC8/2000*i*	A06B-0226-Bx0x
αC12/2000*i*	A06B-0241-Bx0x
αC22/2000*i*	A06B-0246-Bx0x
αC30/1500*i*	A06B-0251-Bx0x

5.2 DRIVES

5.2.1 200 VAC Input Types

The FANUC αC*i* series AC servo motors can be driven only by the FANUC servo amplifiers for 200 to 230 VAC.

5.3 POWER CABLE CONNECTORS

The motor power cable and brake fan unit must be connected using the connectors and cable clamps specified below.

Cable type	Motor model name	Plug connector maker specification		Cable clamp specification	Connector maker name
For Power	αC4/3000*i* αC8/2000*i*	Straight	H/MS3106A18-10S-D-T(10)	H/MS3057-10A(10)	Hirose Electric
		L-shape type	H/MS3108A18-10S-D-T(10)		
	αC12/2000*i* αC22/2000*i* αC30/1500*i*	Straight	JL04V-6A22-22SE-EB	JL04-2022CK-(14) JL04-2428CK-(20)	Japan Aviation Electronics Industry
		L-shape type	JL04V-8A22-22SE-EB		
24V brake	Common to all models	Straight	JN1DS04FK2 (Japan Aviation Electronics Industry)		Japan Aviation Electronics Industry
		L-shape type	JN1FS04FK2 (Japan Aviation Electronics Industry)		

* Also see Section 8.

- TUV have certified that the plug connector and cable clamp mentioned above, when combined with the FANUC αC*i* series servo motors, satisfy the VDE0627 safety standard. As indicated in the table below, several manufacturers offer other plug connectors. For information about whether the plug connectors satisfy the safety standard when combined with the FANUC αC*i* series servo motors, contact the corresponding manufacturer. Contact the manufacturers if you require details of their products.

Manufacturer	Product series name
Hirose Electric (HRS)	H/MS310 TUV-conforming series
Japan Aviation Electronics Industry (JAE)	JL04V series
DDK Ltd. (DDK)	CE05 series

- If a cable or conduit hose seal adapter is used, consult an appropriate connector maker.

5.4 APPROVED SPECIFICATIONS

The following specifications are approved for the IEC60034 standard.

5.4.1 Motor Speed (IEC60034-1)

The rated-output speed and allowable maximum speeds of motors are as listed below.
The rated-output speed is the speed which specifies the rated output.
The allowable maximum speeds are specified in such a way that the approval conditions of the IEC60034-1 standard, as they relate to rotational speed, are satisfied.
When the allowable maximum speeds are used, the characteristics are not guaranteed.

Motor model	Rated-output speed [min^{-1}]	Allowable maximum speed [min^{-1}]
αC4/3000*i*	3000	3000
αC8/2000*i* αC12/2000*i* αC22/2000*i*	2000	2000
αC30/1500*i*	1500	1500

5.4.2 Output (IEC60034-1)

The rated output is guaranteed as continuous output only for the rated-output speed. The output in an intermittent operation range is not specified. When rated output increases due the use of an external fan, the servo motor does not comply with the IEC60034 standard. Note, however, that this poses no problem if the fan is used for the purpose of cooling, and the motor is used with output held at the current output rating.

The approved output of each model is as listed in II-2, "Specifications and Characteristics" (described later).

5.4.3 Protection Type (IEC60034-5)

Motor protection confirms to IP65.

IP6x: Completely dust-proof machine
This structure completely prevents dust from entering the machine.

IPx5: Sprinkle-proof machines
A sprinkle-proof machine shall not suffer inadvertent influence when they are exposed to water sprinkled from nozzles at any angle to the machine.

The conditions of the IPx5 type test are as follows:
Nozzle inside diameter..6.3 [mm]
Amount of sprinkled water .... 12.5 [liters/minute]
Water pressure at the nozzle ....30 [kPa]
Sprinkle time per a surface of 1 m^2...............................1 [minute]
Minimum required time .... 3 [minutes]or more
Distance between the nozzle and machine .. Approximately 3 [m]

> ⚠ **CAUTION**
> IPx5 evaluates machines for waterproofness in a short-term test as described above, allowing chances that the machines may get dry after the test. If a machine is exposed to liquids other than water or so continuously to water that it cannot get dry, it may suffer inadvertent influence even if the degree of exposure is low.

5.4.4 Cooling Method (ICE60034-6)

The motor cooling methods are as listed below.

IC code	Method
IC410	Fully closed; cooled by a natural air flow

5.4.5 Mounting Method (IEC60034-7)

The motors can be mounted by the following methods.
IMB5:Flange mounting with the shaft facing sideways(from the rear)
IMV1:Flange mounting with the shaft facing upward(from the rear)
IMV3:Flange mounting with the shaft facing downward(from the rear)

5.4.6 Heat Protection (IEC60034-11)

The heat protection type is as listed below:
T P 2 1 1

1 : Temperature rise limit category 1 for heat protection
1 : Stop only at stage 1 (no warning)
2 : Protection for gradual and abrupt overload

5.4.7 Grounding (IDC60204-1)

For each servo motor, continuity between the ground terminal and housing of the power connector has been checked based on the IEC60204-1 safety standard and it has been ensured that it satisfies the standard.

5.4.8 Remarks

For details on EMC compliance authorization, refer to the separate manual "Compliance with EMC Directives"

6 FEEDBACK SENSOR

6.1 BUILT-IN SENSOR

All AC servo motors feature a Pulsecoder (optical encoder).
The Pulsecoder outputs position information and an alarm signal.
The following lists the available Pulsecoders are compatible.

Pulsecoder type	Resolution [Division/rev]	Absolute/ incremental	Applicable motor
αA1000*i*	1,000,000	Absolute	All models
αI1000*i*	1,000,000	Incremental	

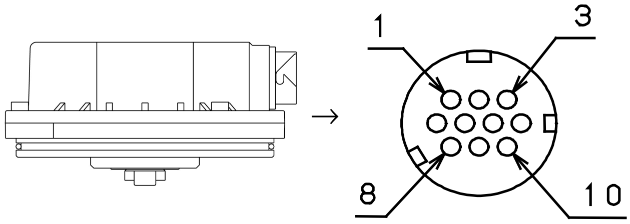
6.2 ABSOLUTE-TYPE PULSE CODER

When the NC is turned off, the Pulsecoder position detection function is backed up by battery. So, when the NC is next turned on, the operator does not have to perform reference position return.
For backup, a battery unit must be installed in the NC or servo amplifier.
If a low-battery indication appears on the NC, renew the battery as soon as possible.
For the αC*i* series Pulsecoder, the function is backed up for about 10 minutes by a backup capacitor when the battery is removed. In the backup status, the battery can be replaced when the power to the NC or servo amplifier is off.
The operator does not also have to perform reference position return after replacing the feedback cable or servo amplifier.

6.3 SENSOR INPUT/OUTPUT SIGNALS

6.3.1 Layout of Connector Pins

The signals of the αC*i* series Pulsecoder are arranged as follows:



Signal name	Pin No.	
	αA1000*i*	αI1000*i*
RD	6	6
*RD	5	5
+5V	8,9	8,9
0V	7,10	7,10
Shield	3	3
+6V	4	-

6.3.2 Connector Kits

For information on connectors and crimping jigs required for creating a feedback cable, see Section 8.2, "CONNECTORS ON THE CABLE SIDE."

6.4 SEPARATE TYPE POSITION SENSOR

For detecting a position by attaching directly to a ball screw or a machine, use a separate type position sensor. Pay attention to the following items when using the separate type position sensor.

- Increase the machine rigidity between the servo motor and the position sensor to minimize mechanical vibration. If the machine rigidity is low or the structure vibrates, poor performance, over shoot is likely to occur.

- Generally, when the separate type sensor is used, the influence of gear, ball screw pitch error or table inclination is decreased and the positioning accuracy and geometrical accuracy (roundness, etc.) are increased, but the smoothness may deteriorate due to the elasticity in the machine between the servo motor and the position sensor.

- It is necessary to use the built-in Pulsecoder with a resolution equal to or finer than that of the separate type position sensor.

To connect the separate type position sensor to the NC, connect only the signals described in the connecting manual.
When the other signal is connected, the unit may malfunction.
FANUC provides the following external position (rotary) sensor.

6.4.1 Separate Type Pulsecoder Type and Specifications

Separate type Pulsecoder are available. Features and rapid traverse-related limitations are the same as the built-in Pulsecoder.

Pulsecoder αA1000S

A860-0372-T001

1,000,000 P/rev (Up to 4000 min^{-1})

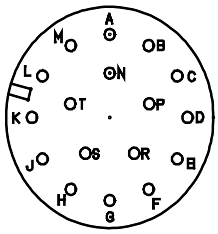
6.4.2 Separate Type Pulsecoder Specifications

Pulsecoder αA1000S

Item		Specification
Power voltage		5 [V]±5%
Current consumption		Up to 0.3 [A]
Working temperature range		0 to +60 [°C]
Resolution		1,000,000 [/rev.]
Maximum speed of rotation		4000 [min^{-1}]
Input shaft inertia		Up to 1×10^{-4} [kgm^2]
Input shaft startup torque		Up to 0.1 [Nm]
Input shaft allowable load	Radial	100 [N]
	Axial	50 [N]
Shaft diameter runout		0.02×10^{-3}[m]
Structure		Dust-proof, drip-proof (IP55 or equivalent: when water-proof connector is fitted)
Vibration resistance acceleration		5 [G] (50 to 2,000[Hz])
Weight		Approx. 0.75 [kg]

6.4.3 Input Signals and Layout of Connector Pins of Separate Type Pulsecoder

Pulsecoder αA1000S



3102A20-29P

Signal name	Pin No. αA1000S 3102A20-29P
SD	A
*SD	D
REQ	F
*REQ	G
+5V	J,K
0V	N,T
Shield	H
+6VA	R
0VA	S

6.4.4 External Dimensions of Separate Type Pulsecoder

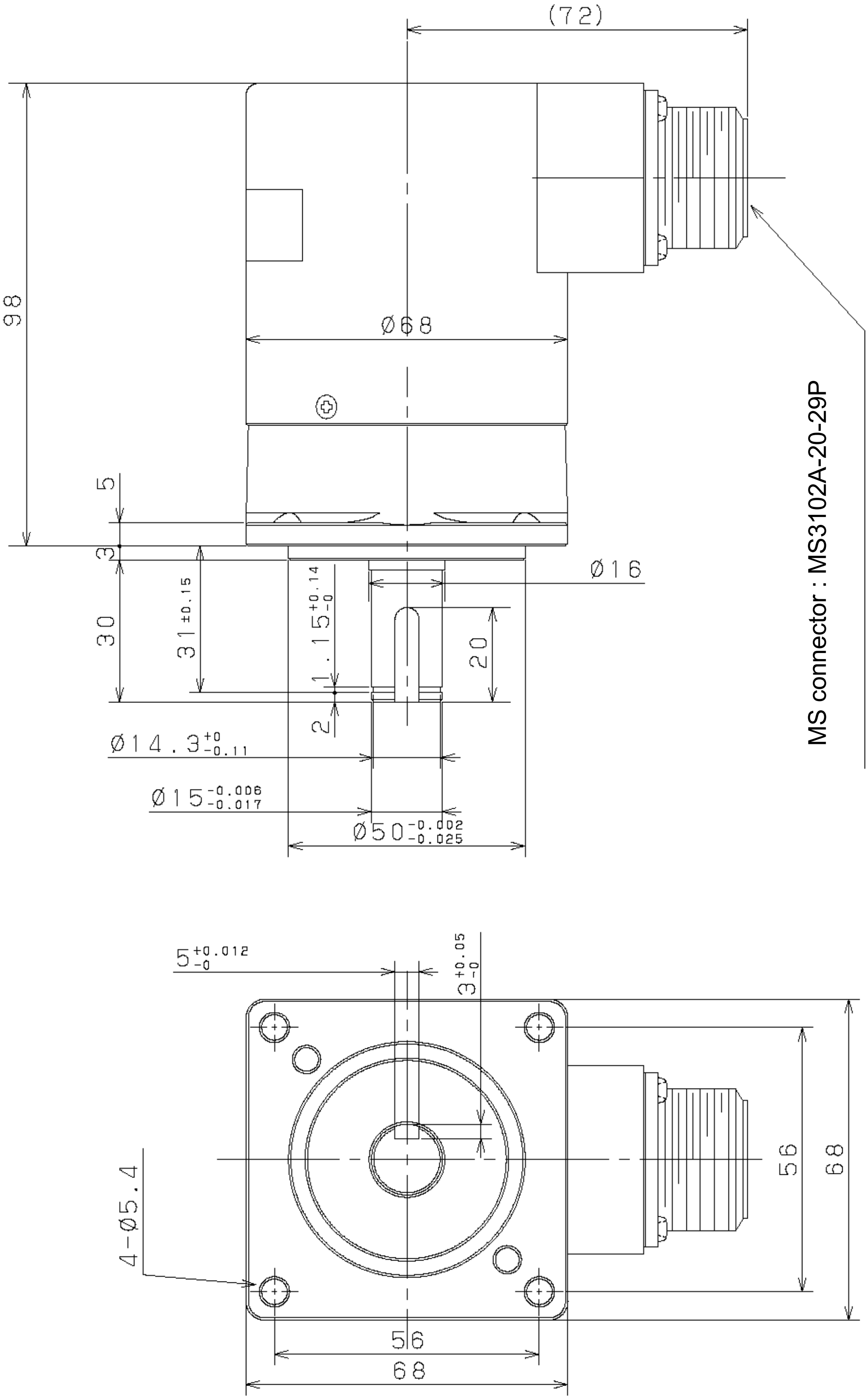


Fig.6.5.4 Pulsecoder αA1000S

7 BUILT-IN BRAKE

Some models of the AC servo motor αC*i* series use motors that contain a holding brake to prevent falling along a vertical axis.
This chapter explains the specifications of built-in brakes and gives cautions.
The motor with a built-in brake differs from that with no brake in outside dimensions. For the outside dimensions, refer to the outline drawing of each motor model.

7.1 BRAKE SPECIFICATIONS

The specifications of built-in brakes are listed below.

Motor model		Unit	αC4/3000*i* αC8/2000*i*	αC12/2000*i* αC22/2000*i* αC30/1500*i*
Brake torque		Nm	8	35
		kgf·cm	82	357
Response time	Release	msec	160	160
	Brake	msec	30	30
Power supply	Voltage	VDC	24 (±10%)	
	Current	A	1.1	1.2
	Wattage	W	26	29
Weight increase		kg	Approx. 2.2	Approx. 6.0
Inertia increase		kg·m^2	0.00007	0.0006
		kgf·cm·s^2	0.0007	0.006

The values shown above are standard values at 20°C.

7.2 CAUTIONS

⚠ CAUTION

Pay attention to the following points when motors with built-in brakes are used.

1 A built-in brake is used as a holding brake to prevent falling along an axis at servo off. This brake functions as a brake at an emergency stop or power failure, but cannot be used to decrease the stop distance during ordinary deceleration.

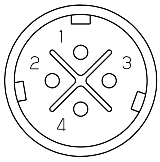
2 Match the timing of brake release (axis release) to the timing of servo on (motor energization) as much as possible.
Similarly, match the timing of brake start (axis fix) to the timing of servo off as much as possible.

3 Do not keep using the brake as assistant to the stop axis during energization of the motor. This causes an abnormal heat of the motor.

4 The total length of the models with a built-in brake is much longer than that of the model with no built-in brake. Be careful not to apply excessive force to the opposite side of the mounting flange or to apply excessive acceleration to the entire motor.

7.3 CONNECTOR SHAPES

The following shows the shape and pin arrangement of the brake connectors.



Connections: 1=BK, 2=BK, 3=NC(Not Connected), 4=GND(Note)

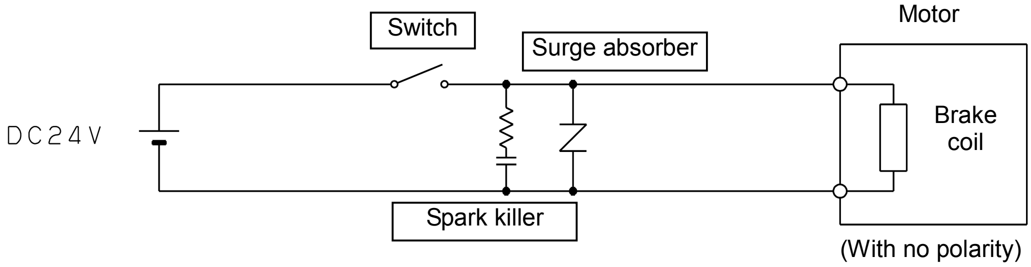
* BK indicates a power supply (24 VDC, 0 VDC) for the brake. You can use either pin to connect the brake because the brake is nonpolarized.

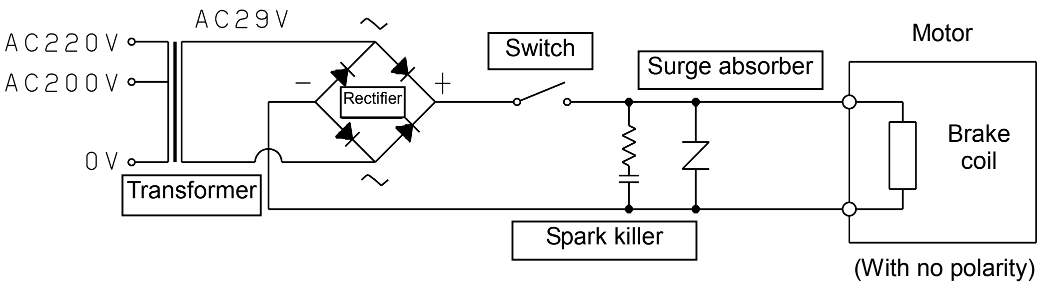
NOTE

Since pin 4 is connected to the brake cabinet, it can be used when the shield wire of a brake cable needs to be connected.

7.4 CONNECTION OF THE BRAKES

Configure a brake circuit by referencing the following brake connection diagrams and the recommended parts shown in the following section.





1. Use a 24-V regulated DC power supply or power (equivalent to 24 Vrms) produced by full-wave rectification after transforming commercial power (50 Hz/60 Hz) as the power supply for the α*i* series servo motor brake.
2. Use a power supply separate from the 24-V power supply for the NC and amplifier as the power supply for the brake. If the control power supply is also used for the brake, an NC or amplifier malfunction or another danger may occur. The power supply for a relay, solenoid, or another peripheral device can be used for the brake. Be careful of the power capacity and changes in voltage due to changes in load.
3. For full-wave rectification, transform the secondary side voltage obtained during energization of the brake into approximately 29 VAC by taking voltage drop in the rectifier or cable into account. In addition, check the power capacity and power voltage fluctuations sufficiently and then make sure the fluctuations of the voltage applied to the brake during energization falls within 24 Vrms ±10%. Switch the transformer's primary side input to a desired position such as 100-110 VAC or 200-220 VAC.
4. If the contact is installed on the DC side (at the position shown in the figure), the life of the contact is generally shortened due to the surge voltage at brake off. Provide an adequate contact capacity and always use a surge absorber and spark killer for protecting the contact.
5. You can use either positive or negative power pin to connect the brake because the brake coil is nonpolarized.

7.5 RECOMMENDED PARTS IN BRAKE CIRCUITS

The following table lists the recommended parts to be used as components of a brake circuit and their specifications.

Name	Model No.	Name of Manufacturer	Specifications	FANUC Procurement Dwg. No.
Rectifier	D3SB60 (Note)	SHINDENGEN ELECTRIC MFG. CO., LTD.	Withstand voltage 400 V min. Maximum output current: 2.3 A (with no fin)	A06B-6050-K112
Switch	-	-	Rated load capacity (resistance load) 250VAC 10A / 30VDC 10A or more	-
Spark killer	XEB0471	OKAYA ELECTRIC IND. CO., LTD.	47Ω / 0.1μF Withstand voltage 400 V min.	-
Surge absorber	ERZV10D820	Matsusihita Electric Industrial Co., Ltd.	Varister voltage 82V Max. allowable voltage 50VAC	-

NOTE

At an ambient temperature of 20°C, the temperature of the rectifier rises to about 60°C when one brake axis is used or to about 90°C when two brake axes are used. Use a radiator fin as required.

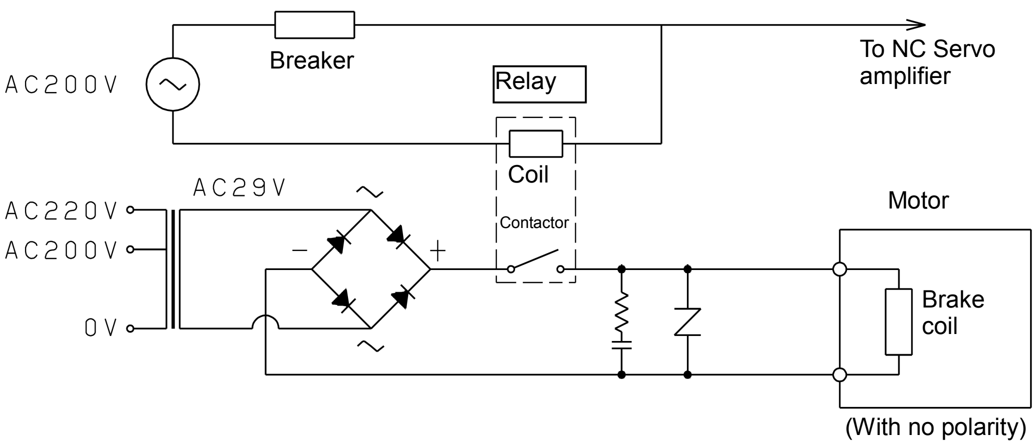
7.6 REDUCING THE BRAKE SHAFT FALL AMOUNT

During use of a motor with a brake, the amount of falling along an axis at a power failure or emergency stop, or when the CNC power supply is turned off during excitation of the motor may become an issue. To operate the brake immediately and reduce the amount of falling along an axis to a minimum, note the following points:

(1) To operate the brake immediately, the switch and relay for controlling on and off must be installed on the DC side (at the position shown in the following figure) of the break circuit.
If the contact is installed on the AC side (between the transformer's secondary side and rectifier), it takes time until braking starts because of the current returned to the rectifier diodes.

(2) To reduce the amount of falling along a vertical axis, the switch or relay must be turned off at a power failure as soon as possible. To turn the relay off immediately at a power failure, it is effective to supply the relay driving power from the main power supply whenever possible as shown in the following figure.

(3) To prevent the shaft from falling during an emergency stop, it is sometimes effective to use the "brake control function" in the servo software. This function enables continuous excitation of the motor until the motor built-in brake operates.
For details, see Parameter Manual (B-65270EN).



8 CONNECTORS

8.1 CONNECTOR ON THE MOTOR SIDE

For the FANUC AC servo motor αC*i* series, a TUV-approved connector is used as the power line connector to meet the IEC60034 standard. For this power line connector, a receptacle connector having a dripproof property by itself (when it is not engaged) is used as standard. Strictly speaking, this power line connector does not meet the MS standard, but it is compatible with the MS-standard round connector for use.

The signal line connectors are dripproof when engaged with a cable connector. (When the motor is left singly, these connectors are dripproof when the caps mounted at shipment are fit in them.)

8.1.1 Specifications of Connectors on the Motor Side

Motor Type	For Power	For Signal	For 24-V brake
αC4/3000*i* αC8/2000*i*	H/MS3102A18-10P-D-T(10) (Hirose Electric)	JN2AS10UL1 (Japan Aviation Electronics Industry)	JN2AS04MK2 (Japan Aviation Electronics Industry)
αC12/2000*i* αC22/2000*i* αC30/1500*i*	JL04HV-2E22-22PE-BT (Japan Aviation Electronics Industry)		

⚠ **CAUTION**

1 The motors should be installed with their connector facing downward as long as possible. When it is impossible to install a motor in this position, allow slack in the cable to keep liquids such as a dielectric fluid from going along the cable into the cable or motor. If there is a possibility that the motors and connectors get wet, provide a cover to protect them.

2 If a motor is not connected to the earth ground through the machine (frame), connect the motor grounding point and the amplifier grounding point to absorb noise using a 1.25 mm^2 or larger conductor other than the grounding conductor in the power cable. Keep the grounding conductor as far from the power cable as possible.

8.2 CONNECTORS ON THE CABLE SIDE (FOR SIGNAL CABLE)

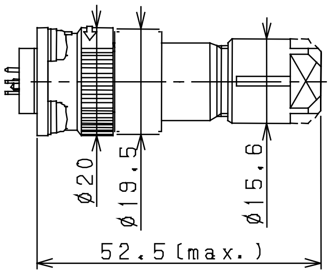
A small dedicated connector common to all servo motors is used. The connector is dripproof when engaged with the motor connector. To connect the cable, a dedicated crimping tool must be used. Consider crimping, cable clamp, and voltage drop. Also note that there are restrictions.

8.2.1 Connector Specifications

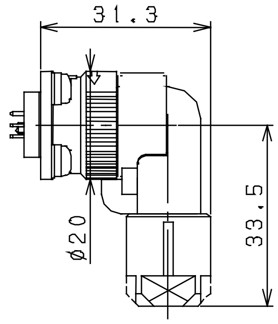
		For signal	
Connector specifications	Straight type	JN2DS10SL1 or JN2DS10SL2 : Connector, JN1-22-22S : Contact (Japan Aviation Electronics Industry) A06B-6114-K204#S (FANUC specification) * Including the contact	
	Elbow type	JN2FS10SL1 or JN2FS10SL2 : Connector, JN1-22-22S : Contact (Japan Aviation Electronics Industry) A06B-6114-K204#E (FANUC specification) * Including the contact	
Insulation external diameter		φ1.5 or less	
Compatible cable O.D.		φ5.7 to φ7.3 : JN2DS10SL1 or JN2FS10SL1 φ6.5 to φ8.0 : JN2DS10SL2 or JN2FS10SL2 * With the FANUC specifications, two types of bushings: for φ5.7 to φ7.3 and for φ6.5 to φ8.0 are included.	
Used wire		Cable length : 28 m or less	Cable length : 50 m or less
	5V,0V	0.3 $mm^2 \times 2$	0.5 $mm^2 \times 2$ (Strand configuration: 20/0.18 or 104/0.08)
	6V	0.3 mm^2	0.5 mm^2 (Strand configuration: 20/0.18 or 104/0.08)
	RD,*RD	Twisted pair of at least 0.18 mm^2	
Crimping tool		AWG#22(0.33mm^2) to AWG#24(0.2mm^2) AWG#26(0.13mm^2) to AWG#28(0.08mm^2)	CT150-2-JN1-B (Japan Aviation Electronics Industry) (conventional specification) A06B-6114-K201#JN1S (FANUC specification)
		AWG#21(0.5mm^2) AWG#25(0.18mm^2)	CT150-2-JN1-F (Japan Aviation Electronics Industry) (conventional specification) A06B-6114-K201#JN1L (FANUC specification)
		AWG#22(0.33mm^2) to AWG#24(0.2mm^2) AWG#25(0.18mm^2)	CT150-2-JN1-C (Japan Aviation Electronics Industry) (new specification)
Extractor		ET-JN1(Japan Aviation Electronics Industry) A06B-6114-K201#JN1R (FANUC specification)	

The outside dimensions of each type of connector when engaged are shown below:

Straight type



Elbow type

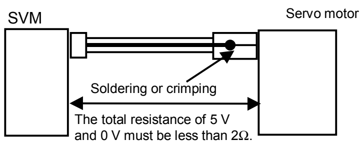


⚠ CAUTION

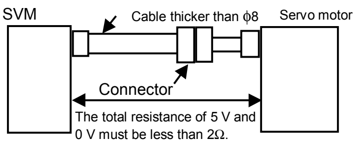
1 In case that the cable is prepared by MTB, total resistance of 5V and 0V must be less than 2Ω.

2 Pulsecoder side connector can accept maximum $0.5mm^2$ (wire construction 20/0.18 or 104/0.08, diameter φ1.5 or less) wire and sheath diameter is φ5.7 to φ8.0. In case of using thicker wire or cable, take measures described below.

[Case 1] Cable conductor exceeds $0.5mm^2$.



[Case 2] Sheath diameter of exceeds φ8.

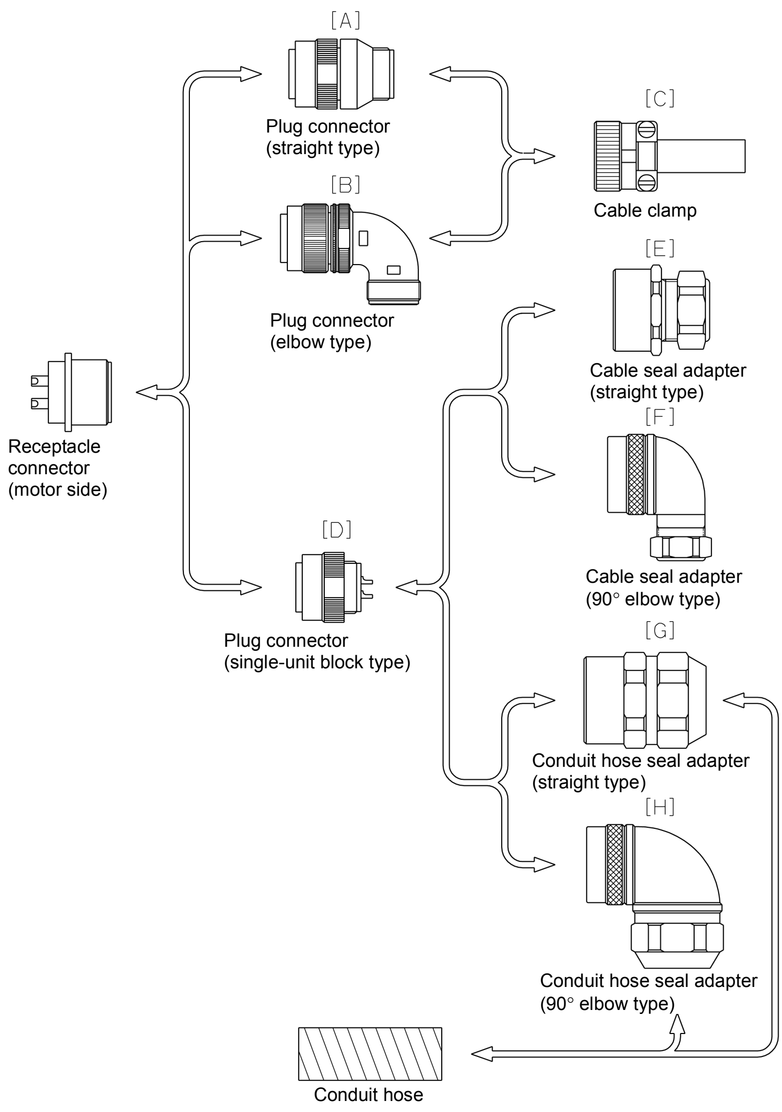


3 In case of incremental Pulsecoder, 6V is not necessary to be connected.

8.3 SPECIFICATIONS OF THE CONNECTORS ON THE CABLE SIDE (FOR POWER CABLE)

To meet the IEC60034 standard, TUV-approved plug connectors and cable clamps should be used in connecting the power cable. To meet the IEC60034 standard by using a cable or conduit hose seal adaptor, contact the manufacturer for details. FANUC can provide TUV-approved types (waterproof) and waterproof types as plug connectors on the cable side for the FANUC αC*i* series AC servo motors; all these connectors are black. Of course, conventional plug connectors may be used, because they are MS-compatible. The specifications of each connector are explained based on the examples shown below.

Example of connector connection



8.3.1 Specifications of Plug Connectors on the Cable Side (Support for Waterproof IP67, TUV-approved Type)

Specifications of Plug Connectors on the Cable Side (Waterproof TUV-approved Type)

Model Name	[A] Straight Type Plug Connector	[B] Elbow Type Plug Connector	[C] Cable Clamp	[D] Single Block Type Plug Connector
For Power				
αC4/3000*i* αC8/2000*i*	H/MS3106A18-10S-D-T(10) (Hirose Electric)	H/MS3108A18-10S-D-T(10) (Hirose Electric)	H/MS3057-10A(10) (Hirose Electric)	H/MS3106A18-10S-D-T(13) (Hirose Electric)
	Solder pot diameter ϕ2.6	Solder pot diameter ϕ2.6	Compatible cable O.D. ϕ10.3 to ϕ14.3	Solder pot diameter ϕ2.6
αC12/2000*i* αC22/2000*i* αC30/1500*i*	<1> JL04V-6A22-22SE-EB <2> JL04V-6A22-22SE-EB1 (Japan Aviation Electronics Industry)	<1> JL04V-8A22-22SE-EB <2> JL04V-8A22-22SE-EB1 (Japan Aviation Electronics Industry)	<1> JL04-2022CK-(14) <2> JL04-2428CK-(20) (Japan Aviation Electronics Industry)	JL04V-6A22-22SE (Japan Aviation Electronics Industry)
	Solder pot diameter ϕ5.3	Solder pot diameter ϕ5.3	Compatible cable O.D. <1> ϕ12.9 to ϕ16.0 <2> ϕ18 to ϕ21	Solder pot diameter ϕ5.3

* For the connectors of size 22-22, the part number of the plug connector differs depending on the type of cable clamp.

* For the connectors of size 24-10, the part number of the plug connector differs depending on the type of cable clamp.

* The items preceded by the same number in < > correspond to each other.

> ⚠ **CAUTION**
>
> 1 TUV have certified that the plug connectors and cable clamps listed above, when combined with the FANUC AC servo motor αC*i* series, satisfy the VDE0627 safety standard.
> Several manufacturers offer other plug connectors. For information about whether the plug connectors satisfy the safety standard when combined with the FANUC α*i* series, contact the corresponding manufacturer. Also contact the manufacturers if you require details of their products.
> For details, see Chapter 5, "CONDITIONS FOR APPROVAL RELATED TO THE IEC60034 STANDARD."
> - Hirose Electric (HRS) : H/MS310 TUV-conforming series
> - Japan Aviation Electronics Industry (JAE) : JL04V series
> - DDK Ltd. (DDK) : CE05 series
>
> 2 The signal connectors and 24-V brake connectors are not subject to the IEC60034 standard.

8.3.2 Specifications of Plug Connectors on the Cable Side (Support for Waterproof IP67)

Specifications of Plug Connectors on the Cable Side (Waterproof Type)

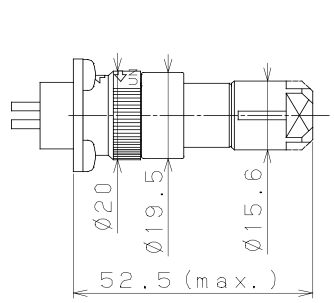
Model Name	[A] Straight Type Plug Connector	[B] Elbow Type Plug Connector	[C] Cable Clamp	[D] Single Block Type Plug Connector
For Power				
αC4/3000*i* αC8/2000*i*	JA06A-18-10S-J1-EB (Japan Aviation Electronics Industry) H/MS3106A18-10S(10) (Hirose Electric) MS3106A18-10S-B-BSS (DDK Ltd.)	JA08A-18-10S-J1-EB (Japan Aviation Electronics Industry) H/MS3108B18-10S(10) (Hirose Electric) MS3108A18-10S-B-BAS (DDK Ltd.)	JL04-18CK(13) (Japan Aviation Electronics Industry) H/MS3057-10A(10) (Hirose Electric) CE3057-10A-1(D265) (DDK Ltd.)	JA06A-18-10S-J1-(A72) (Japan Aviation Electronics Industry) H/MS3106A18-10S(13) (Hirose Electric) MS3106A18-10S-B (D190) (DDK Ltd.)
αC12/2000*i* αC22/2000*i* αC30/1500*i*	JA06A-22-22S-J1-EB (Japan Aviation Electronics Industry) H/MS3106A22-22S(10) (Hirose Electric) MS3106A22-22S-B-BSS (DDK Ltd.)	JA08A-22-22S-J1-EB (Japan Aviation Electronics Industry) H/MS3108B22-22S(10) (Hirose Electric) MS3108A22-22S-B-BAS (DDK Ltd.)	JL04-2022CK-(14) (Japan Aviation Electronics Industry) H/MS3057-12A(10) (Hirose Electric) CE3057-12A-1(D265) (DDK Ltd.)	JA06A-22-22S-J1-(A72) (Japan Aviation Electronics Industry) H/MS3106A22-22S(13) (Hirose Electric) MS3106A22-22S-B (D190) (DDK Ltd.)

8.4 CONNECTORS ON THE CABLE SIDE (FOR BRAKE OR FAN)

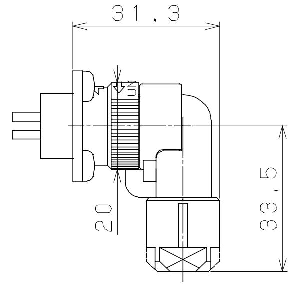
The αC*i* servo motors use a dedicated connector to connect the built-in brake and brake power supply.
This connector is dripproof. It is connected by soldering, so no special tool is required.
This connector differs from conventional connectors used for the α series. The following subsection explains this connector.
Consider soldering, cable clamp, and voltage drop. Also note that there are restrictions.

8.4.1 Specifications of Connectors

		For brake
Connector specifications	Straight type	JN2DS04FK2 (Japan Aviation Electronics Industry) A06B-6114-K213#S (FANUC specification)
	Elbow type	JN2FS04FK2 (Japan Aviation Electronics Industry) A06B-6114-K213#E (FANUC specification)
Applicable wire size		AWG#16 or less (1.25mm^2 or less) * Solder pot diameter φ1.9
Insulation external diameter		φ2.7 or less
Compatible cable O.D.		φ6.5 to 8.0
Example of applicable wire		300-V two-conductor vinyl heavy-duty power cord cable VCTF (JIS C 3306) or equivalent
Applicable wire size and cable length		0.75mm^2 (AWG#18) when cable length 30 m or less 1.25mm^2 (AWG#16) when cable length 50 m or less



Straight type



Elbow type

⚠ **CAUTION**
1 The same body is used for the brake and fan connectors. They differ in the key position to prevent an improper insertion.
2 If the cable length is longer than or equal to 50 m, take measures such as installation of repeaters so that the sum of wire resistance (for both ways) becomes 1.5Ω or less.
3 For details of brakes, see Chapter 7, "BUILT-IN BRAKE."

8.5 CONNECTION TO A CONDUIT HOSE

This section gives information on the specifications of several adapters to be connected that are made by conduit hose manufacturers for reference purposes.
Before using an adapter, contact the corresponding conduit hose manufacturer.

Specifications of plug connectors on the cable side (Waterproof type/seal adapter specifications)

Model Name	[E] Cable Seal adapter Straight type	[F] Cable Seal adapter Elbow type	[G] Conduit hose Seal adapter Straight type	[H] Conduit hose Seal adapter Elbow type
For power cable				
αC4/3000*i* αC8/2000*i*	CKD12-18 (SANKEI) YSO 18-12-14 (DAIWA DENGYOU) ACS-12RL-MS18F (NIPPON FLEX) CG12S-JL18 (NEOFLEX)	C90° KD12-18 (SANKEI) YLO 18-12-14 (DAIWA DENGYOU) ACA-12RL-MS18F (NIPPON FLEX) CG12A-JL18 (NEOFLEX)	KKD16-18 (SANKEI) MSA 16-18 (DAIWA DENGYOU) RCC-104RL-MS18F (NIPPON FLEX) MAS16S-JL18 (NEOFLEX)	K90° KD16-18 (SANKEI) MAA 16-18 (DAIWA DENGYOU) RCC-304RL-MS18F (NIPPON FLEX) MAS16A-JL18 (NEOFLEX)
αC12/2000*i* αC22/2000*i* αC30/1500*i*	CKD16-22 (SANKEI) YSO 22-12-14 (DAIWA DENGYOU) ACS-16RL-MS22F (NIPPON FLEX) CG16S-JL22 (NEOFLEX)	C90° KD16-22 (SANKEI) YLO 22-12-14 (DAIWA DENGYOU) ACA-16RL-MS22F (NIPPON FLEX) CG16A-JL22 (NEOFLEX)	KKD22-22 (SANKEI) MSA 22-22 (DAIWA DENGYOU) RCC-106RL-MS22F (NIPPON FLEX) MAS22S-JL22 (NEOFLEX)	K90° KD22-22 (SANKEI) MAA 22-22 (DAIWA DENGYOU) RCC-306RL-MS22F (NIPPON FLEX) MAS22A-JL22 (NEOFLEX)
For signal cable				
Common to all models			N2KY16-FN3 (SANKEI) PCJN-12-M13F (DAIWA DENGYOU) RQJN-M13-9 RQJN-M13-16 (NEOFLEX)	
For brake				
Common to all models			N2KY16-FN3 (SANKEI) PCJN-12-M13F (DAIWA DENGYOU) RQJN-M13-9 RQJN-M13-16 (NEOFLEX)	

(*) Manufacture
SANKEI : SANKEI MANUFACTURING CO.,LTD.
DAIWA DENGYOU : DAIWA DENGYOU CO.,LTD.
NIPPON FLEX : NIPPON FLEX CO.,LTD.
NEOFLEX

II. FANUC AC SERVO MOTOR αCi SERIES

1 TYPES OF MOTORS AND DESIGNATION

The types and specifications of αC*i* series servo motors are described as follows.

Models αC4/3000*i*, αC8/2000*i*, αC12/2000*i*, αC22/2000*i*, and αC30/1500*i*

A06B-02xx-By0z

xx

21	:	Model αC4/3000*i*
26	:	Model αC8/2000*i*
41	:	Model αC12/2000*i*
46	:	Model αC22/2000*i*
51	:	Model αC30/1500*i*

y

0	:	Taper shaft
1	:	Straight shaft
3	:	Taper shaft with the 24VDC brake
4	:	Straight shaft with the 24VDC brake

z

0	:	Pulsecoder αA1000*i*
1	:	Pulsecoder αI1000*i*

For these models, a tapered shaft is standard.

2 SPECIFICATIONS AND CHARACTERISTICS

2.1 TYPE OF MOTORS AND SPECIFICATIONS

Item	Unit	αC4/3000*i*	αC8/2000*i*	αC12/2000*i*
Output	kw	1.0	1.2	1.8
	HP	1.3	1.6	2.4
Rated torque at stall	Nm	4	8	12
	kgfcm	41	82	122
Rating rotation speed	min^{-1}	3000	2000	2000
Rotor inertia	kgm^2	0.0014	0.0026	0.0062
	$kgmcms^2$	0.014	0.026	0.063
Mass	kg	7.5	12	18

The above values are under the condition at 20°C.

Item	Unit	αC22/2000*i*	αC30/1500*i*
Output	kw	3.0	4.2
	HP	4.0	5.6
Rated torque at stall	Nm	22	30
	kgfcm	224	306
Rating rotation speed	min^{-1}	2000	1500
Rotor inertia	kgm^2	0.012	0.017
	$kgmcms^2$	0.12	0.17
Mass	kg	29	40

The above values are under the condition at 20°C.

2.2 CHARACTERISTIC CURVE AND DATA SHEET

Speed-torque characteristics

The intermittent operation zone is determined by the input voltage applied to the drive amplifier. The curve shown is the value for the rated input voltage (200V).

Overload duty characteristic

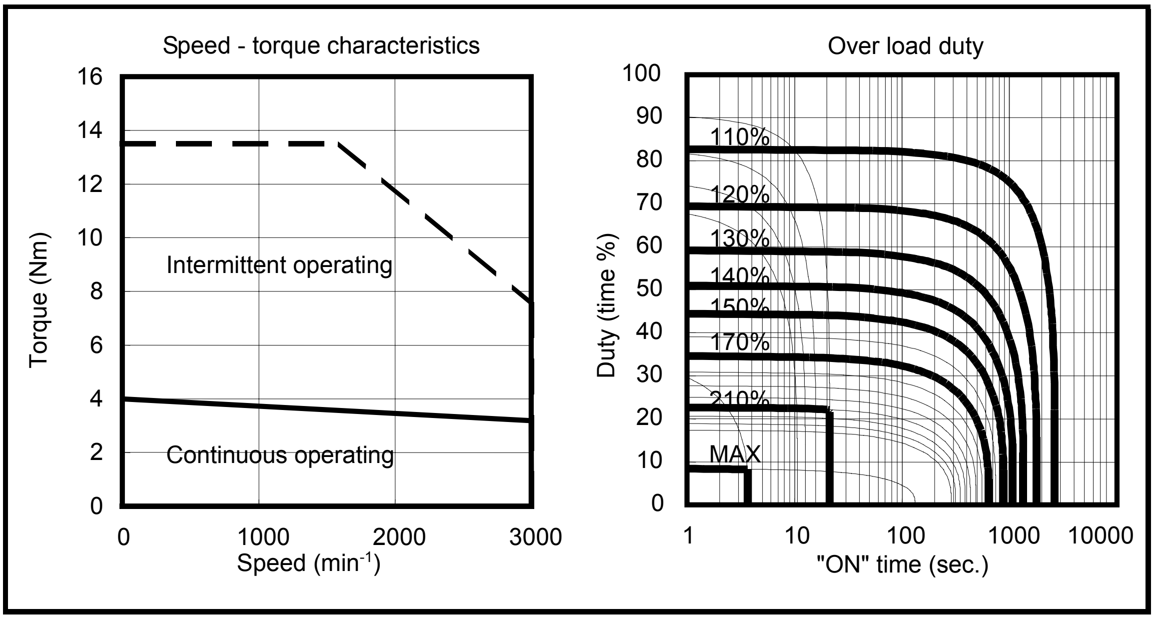
The motor operation is limited by the temperature limit on the motor itself (overheat alarm) and the soft thermal function (overcurrent alarm) of observing the current value using the servo software when the temperature suddenly rises. This curve indicates a range within which the motor can be controlled without these limitations by alarms.
Driving units (such as amplifiers) and built-in sensors contain their own overheating protection devices. Therefore, note that control may be imposed according to how the equipment is being used.

Data sheet

The parameters given in the data sheet are representative values for an ambient temperature of 20°C. They are subject to an error of ±10%.
The indicated logical values are threshold values for the single motor unit (when the motor is not restricted by the control system).
The maximum torque that can be produced during acceleration or deceleration in actual use is calculated as the approximate product of the motor torque constant and the current limit value of the amplifier.
This value is for reference only. The actual value will vary depending on changes in the power supply, as well as variations in motor parameters and amplifier limit values.
In some models, if the maximum current flows in the motor, the actual maximum torque is affected by, for example, magnetic saturation. As a result, the actual maximum torque will be lower than the calculated value. The intermittent operation area (maximum torque value) indicated in the speed to torque characteristics is the effective value, determined according to the combination with the amplifier.

Model αC4/3000*i*

Specification : A06B-0221-Bx0x



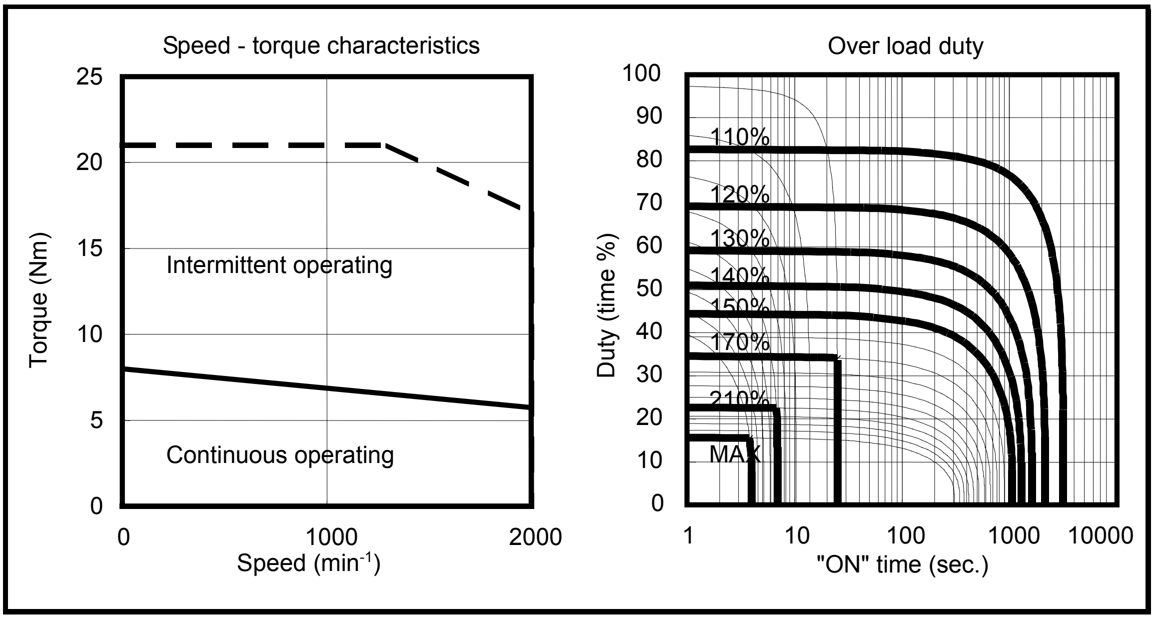
Data sheet

Parameter	Symbol	Value			Unit
Rating rotation speed	Nmax	3000			min^{-1}
Maximum rotation speed	Nlim	3000			min^{-1}
Rated torque at stall (*)	Ts	4 41			Nm kgfcm
Rotor inertia	Jm	0.0014 0.014			kgm^2 $kgfcms^2$
Continuous RMS current at stall (*)	Is	4.1			A(rms)
Torque constant (*)	Kt	0.98 10.0			Nm/A(rms) kgfcm/A(rms)
Back EMF constant (1-phase) (*)	Ke Kv	34 0.33			V(rms)/1000min^{-1} V(rms)sec/rad
Armature resistance (1-phase) (*)	Ra	1.5			Ω
Mechanical time constant	tm	0.006			s
Thermal time constant	tt	25			min
Static friction	Tf	0.3 3			Nm kgfcm
Mass		7.5			kg

(*) The values are the standard values at 20°C and the tolerance is ±10%.
The speed-torque characteristics very depending on the type of software, parameter setting, and input voltage of the digital servo motor. (The above figures show average values.)
These values may be changed without prior notice.

Model αC8/2000*i*

Specification : A06B-0226-Bx0x



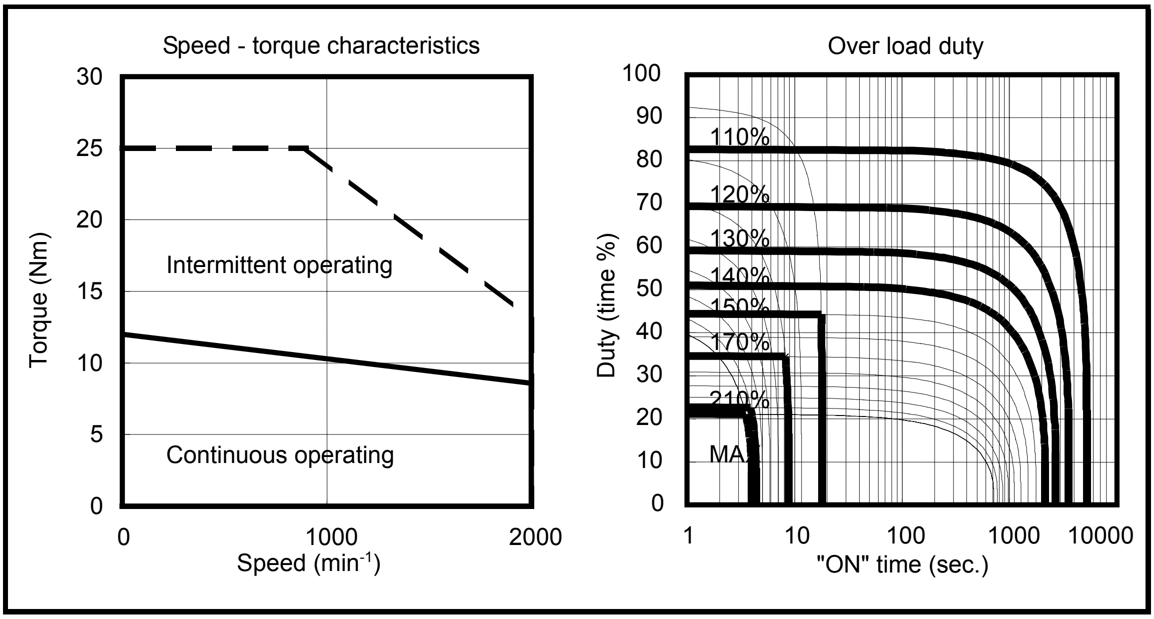
Data sheet

Parameter	Symbol	Value			Unit
Rating rotation speed	Nmax	2000			min^{-1}
Maximum rotation speed	Nlim	2000			min^{-1}
Rated torque at stall (*)	Ts	8 82			Nm kgfcm
Rotor inertia	Jm	0.0026 0.026			kgm^2 $kgfcms^2$
Continuous RMS current at stall (*)	Is	5.6			A(rms)
Torque constant (*)	Kt	1.43 14.6			Nm/A(rms) kgfcm/A(rms)
Back EMF constant (1-phase) (*)	Ke Kv	50 0.48			V(rms)/1000min^{-1} V(rms)sec/rad
Armature resistance (1-phase) (*)	Ra	1.2			Ω
Mechanical time constant	tm	0.004			s
Thermal time constant	tt	30			min
Static friction	Tf	0.3 3			Nm kgfcm
Mass		12			kg

(*) The values are the standard values at 20°C and the tolerance is ±10%.
The speed-torque characteristics very depending on the type of software, parameter setting, and input voltage of the digital servo motor. (The above figures show average values.)
These values may be changed without prior notice.

Model αC12/2000*i*

Specification : A06B-0241-Bx0x



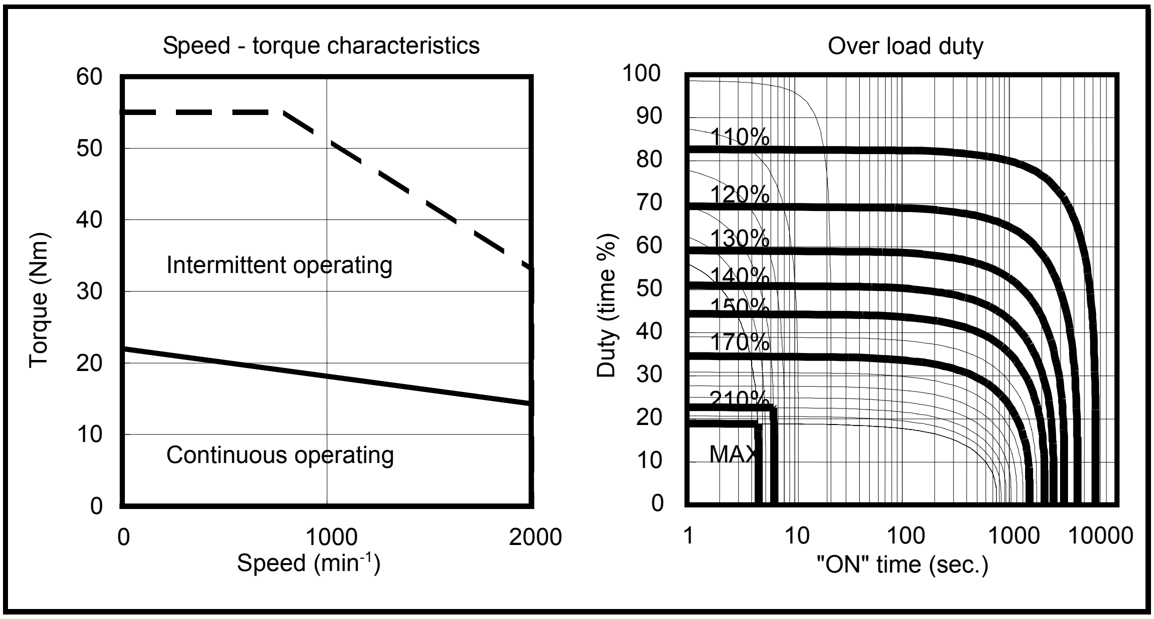
Data sheet

Parameter	Symbol	Value			Unit
Rating rotation speed	Nmax	2000			min^{-1}
Maximum rotation speed	Nlim	2000			min^{-1}
Rated torque at stall (*)	Ts	12 122			Nm kgfcm
Rotor inertia	Jm	0.0062 0.063			kgm^2 $kgfcms^2$
Continuous RMS current at stall (*)	Is	6.5			A(rms)
Torque constant (*)	Kt	1.85 18.9			Nm/A(rms) kgfcm/A(rms)
Back EMF constant (1-phase) (*)	Ke Kv	65 0.62			$V(rms)/1000min^{-1}$ V(rms)sec/rad
Armature resistance (1-phase) (*)	Ra	1.2			Ω
Mechanical time constant	tm	0.006			s
Thermal time constant	tt	50			min
Static friction	Tf	0.8 8			Nm kgfcm
Mass		18			kg

(*) The values are the standard values at 20°C and the tolerance is ±10%.
The speed-torque characteristics very depending on the type of software, parameter setting, and input voltage of the digital servo motor. (The above figures show average values.)
These values may be changed without prior notice.

Model αC22/2000*i*

Specification : A06B-0246-Bx0x



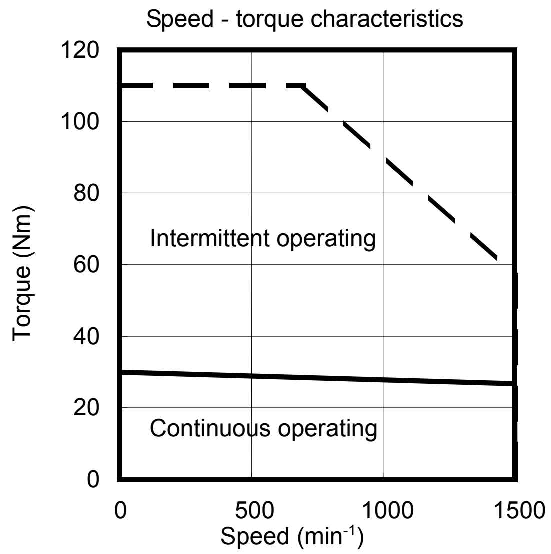
Data sheet

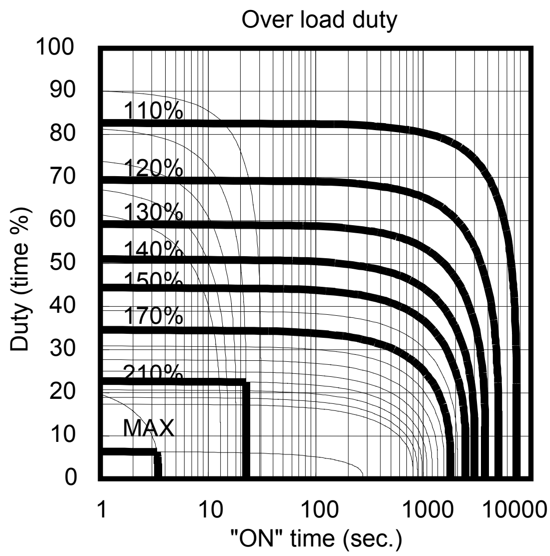
Parameter	Symbol	Value			Unit
Rating rotation speed	Nmax	2000			min^{-1}
Maximum rotation speed	Nlim	2000			min^{-1}
Rated torque at stall (*)	Ts	22 224			Nm kgfcm
Rotor inertia	Jm	0.012 0.12			kgm^2 $kgfcms^2$
Continuous RMS current at stall (*)	Is	12.3			A(rms)
Torque constant (*)	Kt	1.80 18.3			Nm/A(rms) kgfcm/A(rms)
Back EMF constant (1-phase) (*)	Ke Kv	63 0.60			V(rms)/1000min^{-1} V(rms)sec/rad
Armature resistance (1-phase) (*)	Ra	0.37			Ω
Mechanical time constant	tm	0.004			s
Thermal time constant	tt	60			min
Static friction	Tf	1.2 12			Nm kgfcm
Mass		29			kg

(*) The values are the standard values at 20°C and the tolerance is ±10%.
The speed-torque characteristics very depending on the type of software, parameter setting, and input voltage of the digital servo motor. (The above figures show average values.)
These values may be changed without prior notice.

Model αC30/1500*i*

Specification : A06B-0251-Bx0x





Data sheet

Parameter	Symbol	Value			Unit
Rating rotation speed	Nmax	1500			min^{-1}
Maximum rotation speed	Nlim	1500			min^{-1}
Rated torque at stall (*)	Ts	30 306			Nm kgfcm
Rotor inertia	Jm	0.017 0.17			kgm^2 $kgfcms^2$
Continuous RMS current at stall (*)	Is	14.2			A(rms)
Torque constant (*)	Kt	2.11 21.6			Nm/A(rms) kgfcm/A(rms)
Back EMF constant (1-phase) (*)	Ke Kv	74 0.70			V(rms)/1000min^{-1} V(rms)sec/rad
Armature resistance (1-phase) (*)	Ra	0.31			Ω
Mechanical time constant	tm	0.004			s
Thermal time constant	tt	70			min
Static friction	Tf	1.8 18			Nm kgfcm
Mass		40			kg

(*) The values are the standard values at 20°C and the tolerance is ±10%.
The speed-torque characteristics very depending on the type of software, parameter setting, and input voltage of the digital servo motor. (The above figures show average values.)
These values may be changed without prior notice.

2.3 OUTLINE DRAWINGS

Model	Fig. No.
Models αC4*i* and αC8*i*	Fig.2.3(a)
Models αC4*i* and αC8*i* (with brake)	Fig.2.3(b)
Models αC4*i* and αC8*i* (shaft option)	Fig.2.3(c)
Models αC12*i*, αC22*i*, and αC30*i*	Fig.2.3(d)
Models αC12*i*, αC22*i*, and αC30*i* (with brake)	Fig.2.3(e)
Models αC12*i*, αC22*i*, and αC30*i* (shaft option)	Fig.2.3(f)

Fig.2.3(a) Models αC4*i* and αC8*i*

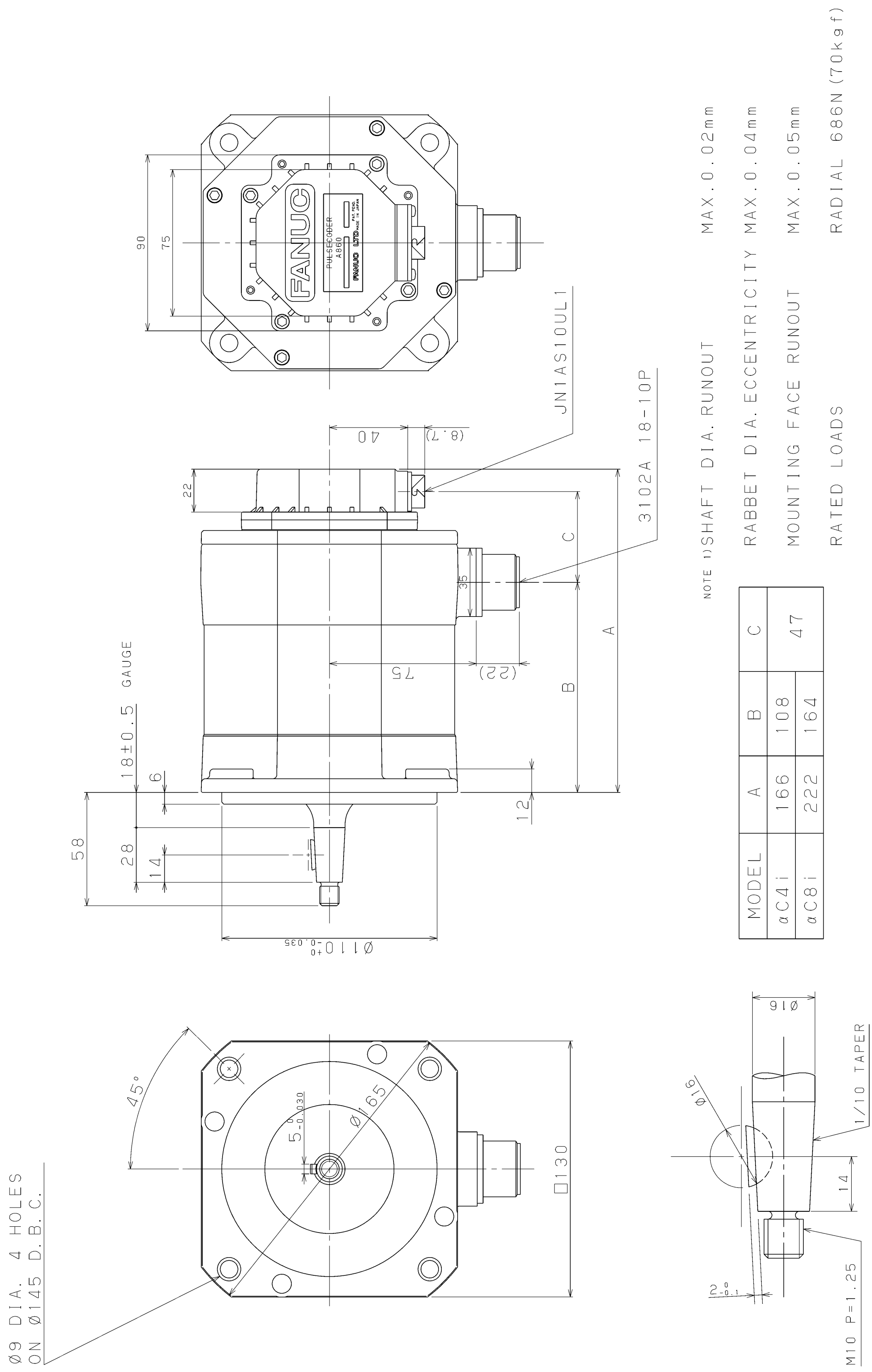
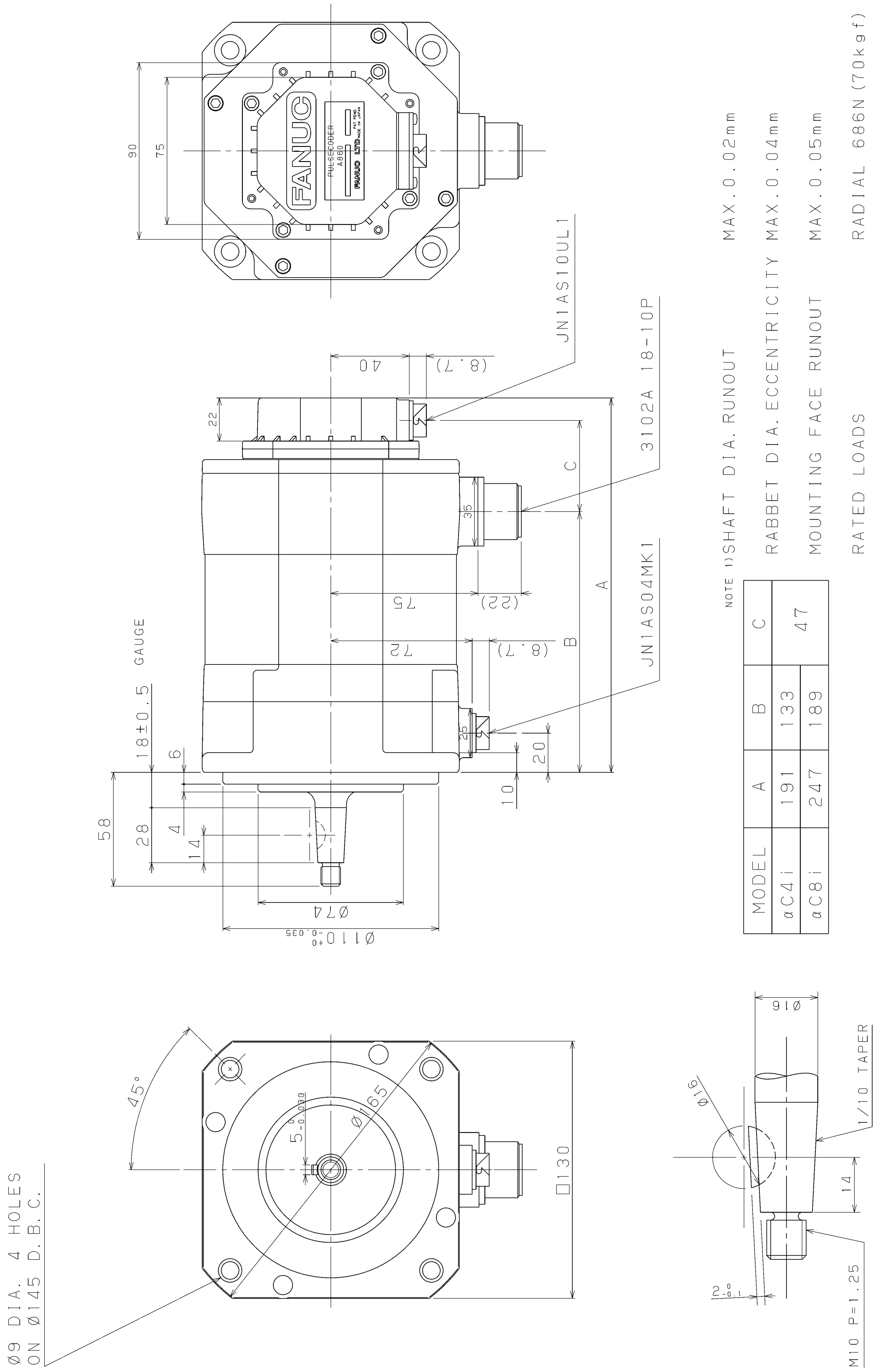


Fig.2.3(b) Models αC4*i* and αC8*i* (with brake)



NOTE 1) SHAFT DIA. RUNOUT MAX. 0.02mm
RABBET DIA. ECCENTRICITY MAX. 0.04mm
MOUNTING FACE RUNOUT MAX. 0.05mm
RATED LOADS RADIAL 686N(70kgf)

MODEL	A	B	C
αC4i	191	133	47
αC8i	247	189	

Fig.2.3(c) Models αC4*i* and αC8*i* (shaft option)

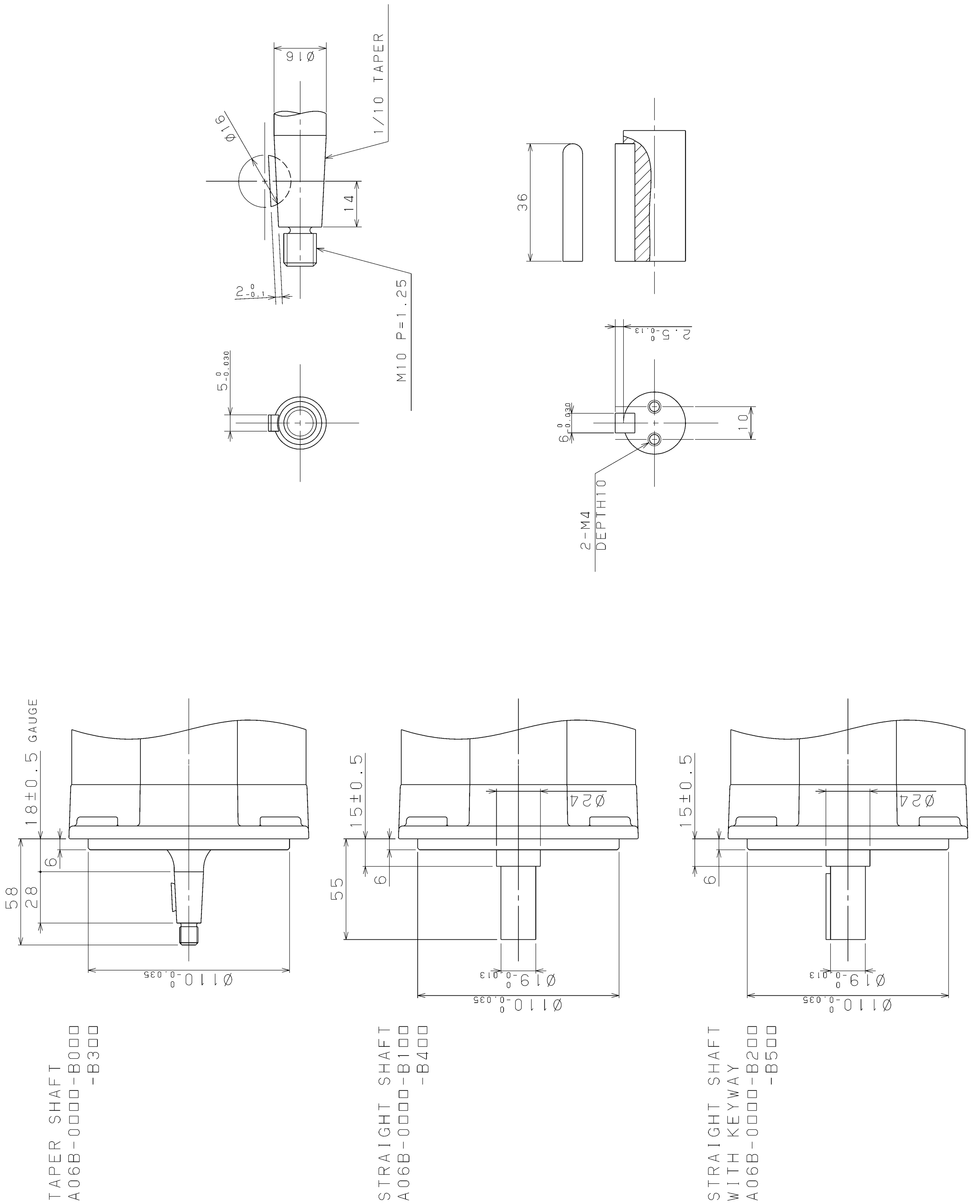
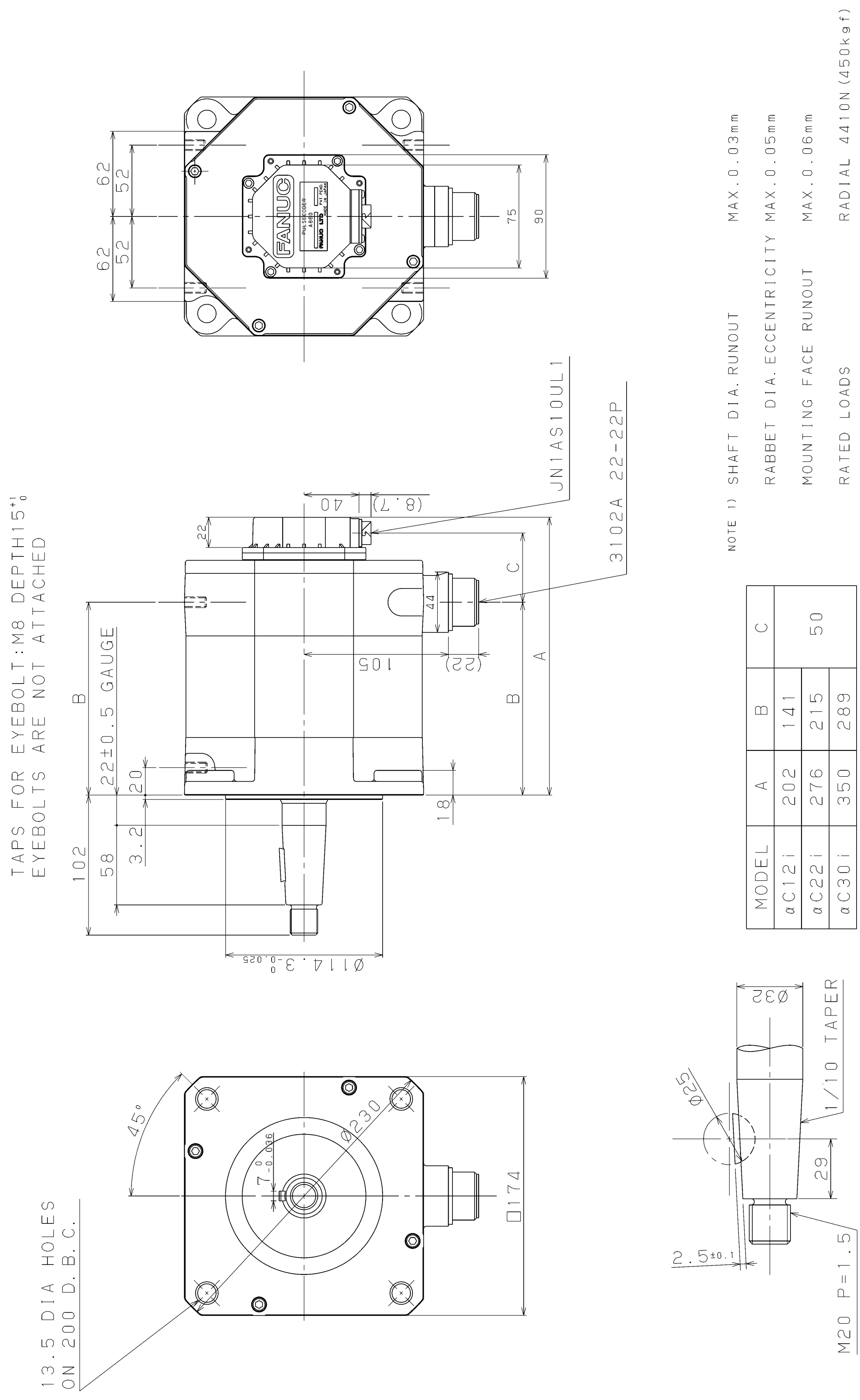


Fig.2.3(d) Models αC12*i*, αC22*i*, and αC30*i*



MODEL	A	B	C
αC12i	202	141	50
αC22i	276	215	
αC30i	350	289	

Fig.2.3(e) Models αC12*i*, αC22*i*, and αC30*i* (with brake)

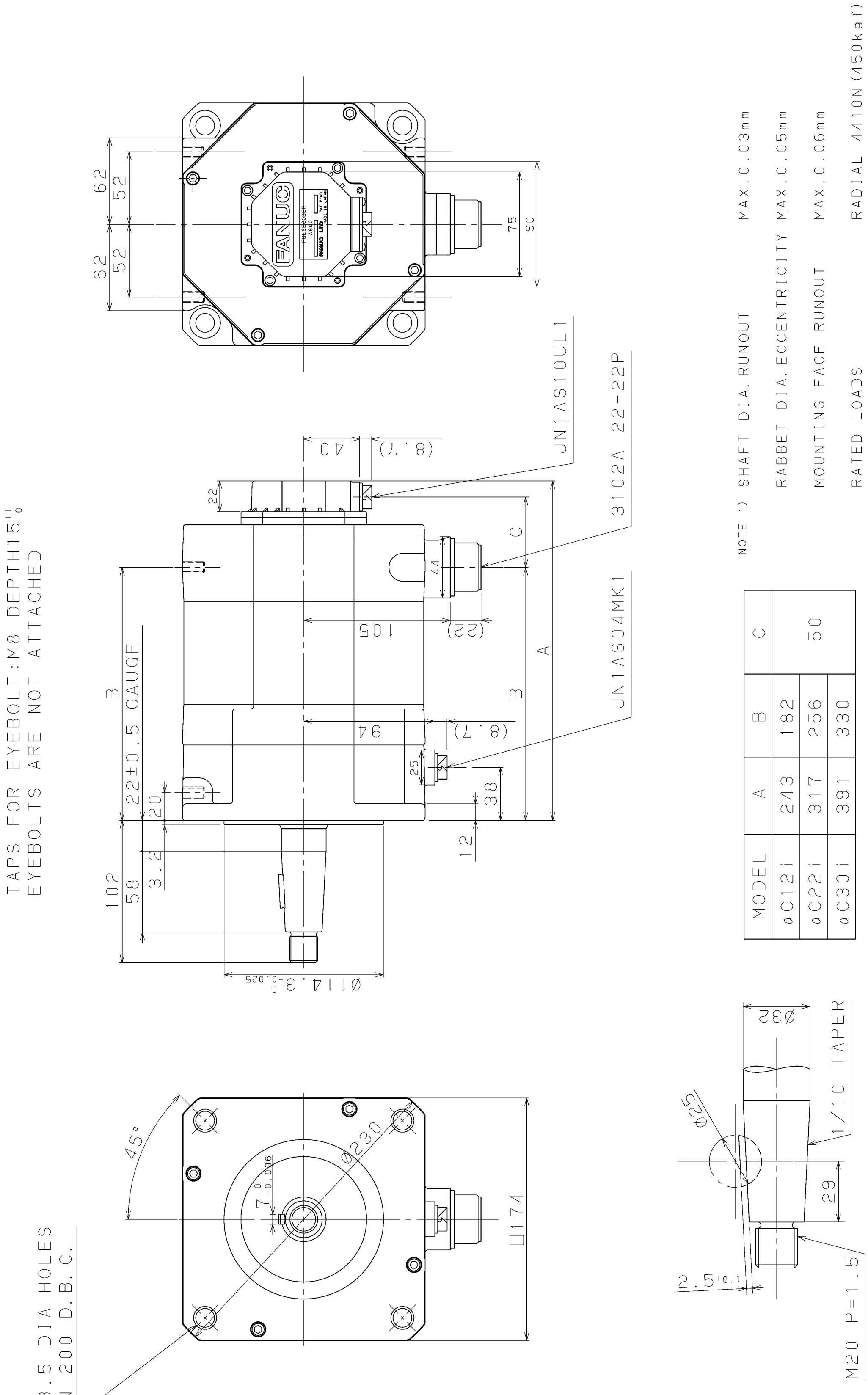
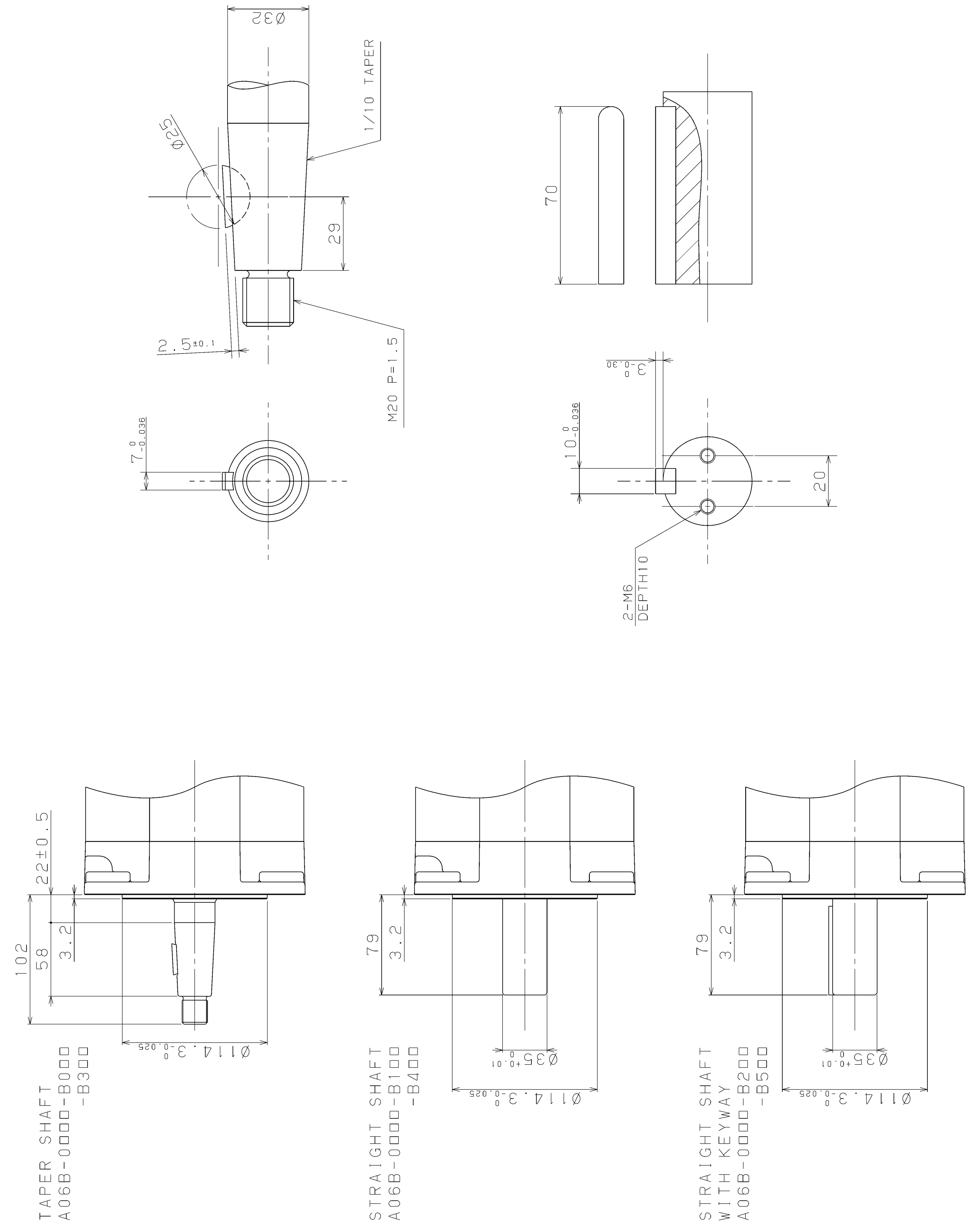
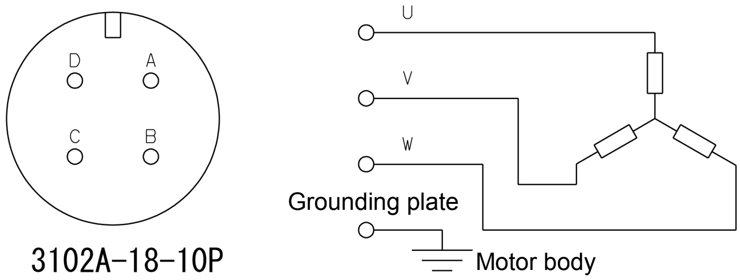


Fig.2.3(f) Models αC12*i*, αC22*i*, and αC30*i* (shaft option)

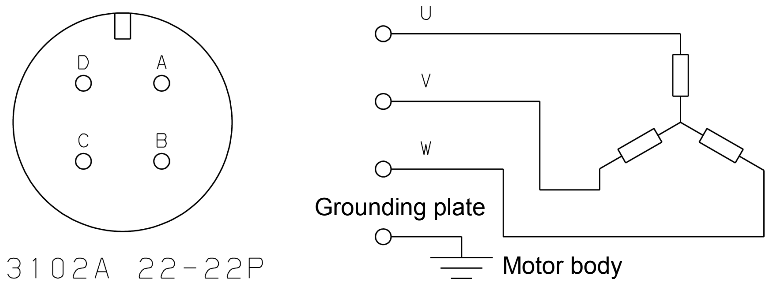


2.4 CONNECTION OF POWER LINE

Models αC4/3000*i* and αC8/2000*i*



Models αC12/2000*i*, αC22/2000*i*, and αC30/1500*i*



> ⚠ **CAUTION**
> The motors should be installed with their connector facing downward as long as possible. When it is impossible to install a motor in this position, allow slack in the cable to keep liquids such as a dielectric fluid from going along the cable into the cable or motor. If there is a possibility that the motors and connectors get wet, provide a cover to protect them.

INDEX

Revision Record

FANUC AC SERVO MOTOR αCi series DESCRIPTIONS (B-65362EN)

Edition	Date	Contents	Edition	Date	Contents
01	May, 2003	———			