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Motion/Position Control Motors and Controls

NEMA

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NEMA MG 7-1987

MG 7

MOTION/POSITION CONTROL MOTORS AND CONTROLS

Published by

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Foreword

Standards Publication No. MG7-1987 covers servo and stepper motors and their controls for use in a motion/position control system. Its primary purpose is to assist users in the proper selection and application of servo and stepper motors and to eliminate misunderstandings between manufacturers and users.

This Standards Publication provides technical information concerning performance, safety, tests, construction and manufacture of servo and stepper motors and their control systems within the product scope defined in the Scope section of this publication. It is based upon sound engineering principles, research, and records of test and field experience. Also involved is an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, and others having specialized experience.

The standards are regularly reviewed by the Motion/Position Control Motors Group of the Motor and Generator Section of NEMA for any revisions necessary to keep it up to date with advancing technology and are subject to such revision as further experience or investigation may show is necessary or desirable.

Comments or recommended revisions are welcomed and should be submitted to:

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Scope

This Standards Publication covers all rotational and linear electric servo and stepper motors and their power requirements, feedback devices, and controls intended for use in a motion/position control system that provides precise positioning, or speed control, or torque control, or in any combination.

Examples of components falling within this product scope are drives/amplifiers and the necessary intelligence to direct the application of this power in a controlled manner.

Excluded from the scope of this Standards Publication are general purpose industrial controls, systems, devices, and power supplies.

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MOTION/POSITION CONTROL MOTORS AND CONTROLS

Section 1

MOTORS

1.1 REFERENCED STANDARDS

In this Standards Publication, reference is made to the following publications. Copies are available from the sources indicated.

National Electrical Manufacturers Association
2101 L Street N.W., Suite 300
Washington, D.C. 20037

MG1-1987 *Motors and Generators*

American National Standards Institute, Inc.
1430 Broadway
New York, NY 10018

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street
New York, NY 10017

ANSI/IEEE 113-1985 *Standard Test Procedures for Direct Current Machines*

1.2 DEFINITIONS

1.2.1 Common

The following definitions are common to both servo and stepper motors. All items relating to measured values are defined with the understanding that in most cases a test procedure will describe the specified conditions of measurement.

Authorized Engineering Information 11-19-1987.

Acceleration/Deceleration

Acceleration/deceleration is the time rate of change of velocity. Angular acceleration is the time rate of change of angular velocity. This is expressed as:

$$\alpha = \frac{d\omega}{dt}$$

Axial Endplay

Axial endplay is the variation in shaft end surface position with reference to the motor mounting surface when a specified axial load is applied in each direction.

Axial Load

Axial load is the force applied to a shaft end surface directed along the axis of rotation.

Commutation

Commutation is the process of sequentially exciting the windings of a motor such that the relative angle between the magnetic fields of the stator and rotor is maintained within specified limits. Commutation is accomplished either mechanically or electronically.

Counter EMF (Back EMF, E_R)

Counter EMF is the generated voltage produced by the relative movement between the magnetic field and the coils of wire in an electromagnetic machine. It shall be measured in an open circuit condition and shall be stated as a peak or average or RMS value.

Counter EMF Constant (Back EMF Constant K_E)

Counter electromotive force EMF constant (back EMF constant, K_E) is the voltage generated by an electro-magnetic machine per unit speed at a specific motor temperature. The voltage must be specified either as a peak or average or RMS value.

Current Form Factor

Current form factor is the ratio of root mean square (RMS) current to the absolute value of average current. The RMS current is the heat producing value of the cur-

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rent, and the average current is the torque producing value of the current for these applications.

$$FF = \frac{\left\{\frac{1}{t_i}\int_0^{t_i} i^2 dt\right\}^{1/2}}{\left|\frac{1}{ti}\int_0^{t_i} idt\right|}$$

Demagnetization Current

Demagnetization current is the winding current that creates a magnetic flux opposing the main field flux which irreversibly decreases the field strength of the motor magnets under specified conditions.

Duty Cycle

Duty cycle is the variation of torque or speed or both with time during a specified operating cycle.

Duty Cycle Rating

Duty cycle rating is the torque or speed or both versus time capacity of a motor during a specified time interval.

Electrical Time Constant (τ_e)

Electrical time constant is the time required for the winding current to reach 63.2% of its final value under specified conditions when a step voltage input is applied.

Friction Torque (T_f), See Figure 1-1

1. *Breakaway or Static Friction Torque*

   Breakaway or static friction torque is the mechanical resistance which the motor must overcome before motion can occur.

2. *Coulomb Friction Torque*

   Coulomb friction torque is the resistance to motion which is independent of velocity.

3. *Viscous or Dynamic Friction Torque*

   Viscous or dynamic friction is the resistance to motion which is velocity dependent. It is the slope of the curve.

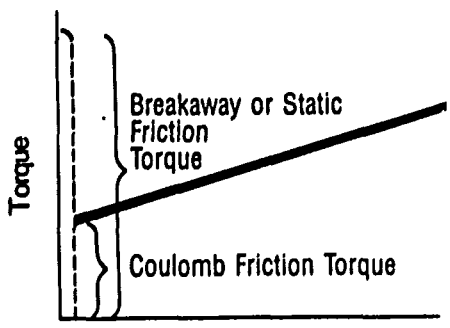


Figure 1-1
FRICTION TORQUE

High-Potential Test

High-potential tests are tests which consist of the application of a voltage higher than the rated voltage for a specified time for the purpose of determining the adequacy against breakdown of insulation materials and spacings under normal conditions (see MG 1, Part 3).

Input Impedance

Input impedance is a complex quantity including the capacitive reactance and inductive reactance as well as resistance expressed in ohms measured at a specified frequency and level at the input terminals of the device.

Inductance (Winding)

Inductance is that property of a coil or other electric circuit which opposes any change in current. In a stepper motor or servo motor, the inductance varies with rotor position, excitation current amplitude, and rate of change of current. Thus, when a figure for inductance is given, the conditions under which the measurements are taken shall be specified.

1. *Inductance Bridge Method*
   This method uses a bridge with a test frequency of 1000 Hz or less, and with current injected into the windings when inductance at a specified current level is required.
2. *Current Change Method*
   With this method, the inductance is determined by measuring the time for current decay or rise to a specified level.

Magnetic Pole

A magnetic pole is a concentrated area of magnetic flux which is the source/sink of a magnetic field. Magnetic poles are produced by permanent magnets or the current in a conductor.

Maximum Allowable Winding Temperature

The maximum allowable winding temperature is the maximum temperature of the winding permitted by the temperature class of the insulation system used.

Mounting Surface Perpendicularity

Mounting surface perpendicularity is the relationship between the shaft centerline about the axis of rotation and the mounting surface of the motor.

Peak Current (I_{pk})

Peak current is the maximum intermittent current which under specified conditions does not cause motor damage, or irreversible degradation of motor performance.

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Radial Load

Radial load is the force applied to the motor shaft perpendicular to the axis of rotation.

Radial Play

Radial play is the variation in position of the axis of rotation with respect to the datum axis of rotation under specified radial loading conditions.

Resistance, Motor Terminal

Motor terminal resistance is the total resistance measured at the motor terminals under specified conditions. For brush-type motors, it is the sum of the brush and armature resistances plus motor lead resistance. For brushless and stepper motors, the motor terminal resistance is equal to the winding resistance plus motor lead resistance.

Rotor

The rotor is the rotating component of an electro-magnetic machine.

Rotor Inertia (J_r)

Rotor inertia is the mass moment of inertia with respect to the rotational axis of the rotor.

Shaft Run-Out (TIR)

Shaft run-out is the difference between the maximum reading and the minimum reading of an indicator when probing the shaft surface at a specified point when the shaft is rotated 360°. In the case of double ended shaft motors, the shaft run-out for each end shall be specified separately.

Stator

A stator is the portion of a machine which includes the stationary magnetic parts with any associated windings.

Thermal Resistance (R_{th})

Thermal resistance is the opposition to the flow of heat in the materials of which the motor is constructed, expressed as degrees Celsius per watt. All measurements shall be taken under specified conditions.

Thermal Time Constant (τ_{th})

Thermal time constant is the time required for a motor winding to reach 63.2% of continuous (steady state) temperature rise with constant power dissipation under specified conditions.

Torsional Resonance

Torsional resonance is the rotational oscillation which occurs in a rotating system when the frequency of a system rotational stimulus is equal to or close to any of the torsional natural frequencies of the system.

Velocity

Velocity is the time rate of change of position. Angular velocity is the time rate of change of angular displacement and is expressed mathematically as:

$$\omega = \frac{d\phi}{dt}$$

Winding

The winding is the electrical coil structure that is used in a motor to develop electro-magnetic fields.

Winding Resistance

Winding resistance is the ohmic resistance measured with the windings at 25°C.

NEMA Standard 11-19-1987.

1.2.2 Servo Motors

The following definitions pertain to servo motors. All items relating to measured values are defined with the understanding that in most cases a test procedure will describe the specified conditions of measurement.

Authorized Engineering Information 11-19-1987.

Armature

An armature is the component of an electro-magnetic machine which contains the windings that conduct the power producing component of current.

Armature Reaction

Armature reaction is a magnetic field produced by the current in the armature coils of an electro-magnetic machine which alters the main magnetic field.

Armature Resistance

Armature resistance is the resistance of the armature winding, and where applicable, the connections measured at the brush contact points.

Brushes

Brushes are the spring-loaded elements which are in contact with the commutator bars, or slip rings of the rotor. They provide the electrical path between the power source and the windings of the rotor.

Brushless DC Motor

A brushless dc motor is a rotating self-synchronous machine with a permanent magnet rotor and with known rotor shaft positions for electronic commutation. A motor meets this definition whether the drive electronics are in-

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tegral with the motor or separate from it.

Cogging Torque

Cogging torque is a periodic torque in an open-circuited motor resulting from the tendency of the rotor and stator to align themselves to positions of minimum magnetic reluctance.

Commutator

A commutator is a set of mechanical contacts arranged angularly or linearly, contacted by the brushes to provide the electrical path from the power source to the armature. Its purpose is to control the relative electrical phase angle between the fields of the stationary element and the moving element of a motor.

Continuous Stall Current

Continuous stall current is the maximum root mean square (RMS) current which can be continuously applied to a stalled motor under specified conditions.

Continuous Stall Torque

Continuous stall torque is the maximum continuous output torque which the stalled motor can develop under specified conditions.

Damping Coefficient (K_D)

A damping coefficient is a coefficient that describes the damping effect in a motor as defined by the mathematical expression:

$$K_D = \frac{K_E \times K_T}{\text{Motor Terminal Resistance}}$$

It is sometimes known as zero source impedance. It is calculated at a specified temperature. (This sentence has been approved as Authorized Engineering Information.)

Full Load Operation

Full load operation is continuous operation at the limits of the continuous safe area.

Maximum Theoretical Acceleration

Maximum theoretical acceleration is the peak motor torque divided by the rotor inertia. It is mathematically expressed as:

$$\alpha = \frac{T_{pk}}{J_m}$$

Mechanical Time Constant (τ_m)

Mechanical time constant is the time required for an unloaded motor to reach 63.2% of its final velocity after a zero source impedance step voltage input is applied. This constant is mathematically derived from the following formula at a specified temperature:

$$\tau_m = \frac{J_m \times R}{K_T \times K_E} = \frac{\text{Rotor inertia} \times \text{motor terminal resistance}}{\text{Torque constant} \times \text{counter emf constant}}$$

Motor Constant (K_M)

Motor constant is a figure of merit which defines the ability of a motor to convert I^2R power into torque. It is mathematically defined as:

$$K_M = \frac{\text{Torque}}{\sqrt{I^2R \text{ Loss}}}$$

It shall be measured at stall under specific conditions.

Peak Torque (T_{pk})

Peak torque is the maximum torque developed by a motor under specified conditions when the maximum allowable peak current is applied.

Root Mean Square Torque (RMS Torque)

Root mean square torque is expressed mathematically by taking the square root of the summation of the products of the torque squared, multiplied by the specific time periods of torque application, divided by the summation of the time periods expressed mathematically as:

$$\text{RMS Torque} = \sqrt{\frac{\sum T_i^2 t_i}{\sum t_i}}$$

Safe Operating Area

Safe operating area is the area defined by speed and torque conditions at which the motor will operate within its thermal limitations, centrifugal force limitations and within its commutation capability, where applicable.

Servo Mechanism

A servo mechanism is a control system which employs feedback in order to control a desired output such as speed or position. A servo mechanism will detect and attempt to correct detected errors.

Stalled Motor (Locked Rotor or Stall)

Stall is the condition where the rotor is held stationary while power is applied to the motor terminals.

Temperature Coefficient of Torque

Temperature coefficient of torque is a coefficient that defines the change in torque constant of the motor per unit change in motor average winding temperature.

Torque Constant (K_T)

Torque constant is the torque developed by a motor per ampere of input current. This constant is temperature dependent and can be mathematically derived from the

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counter EMF constant (K_E). The available shaft output torque is the developed torque reduced by frictional and rotational losses.

Torque Ripple

Torque ripple is the variation of torque within one shaft revolution under specified test conditions. It is expressed as the ratio of peak-to-peak torque amplitude to average torque. This does not include cogging torque.

Viscous Damping Factor (at Infinite Impedance Source), D

Viscous damping factor is a measure of rotational losses in torque that are approximately directly proportional to speed.

$$D = \frac{\Delta T}{\Delta \omega}$$

NEMA Standard 11-19-1987.

1.2.3 Stepper Motors

The following definitions pertain to stepper motors. All terms relating to measured values are defined with the understanding that in most cases a test procedure will describe the specified conditions of measurement.

Authorized Engineering Information 11-19-1987.

Detent Torque

Detent torque is that value of applied torque required to cause rotation between subsequent equilibrium positions over one complete revolution of an open-circuited motor.

1. *Minimum Detent Torque* is the lowest value of torque, as above.
2. *Maximum Detent Torque* is the highest value of torque, as above.

Dynamic Load Angle

Dynamic load angle is the angle between the loaded and unloaded position (theoretical zero) of the rotor at a given instant under otherwise identical conditions at a specified command pulse rate, mode of winding excitation, and phase current.

Holding Torque

Holding torque is the peak resistance to rotation of a gradually rotated shaft of an energized stepper motor. The mode of winding excitation and applied current shall be specified. The torque shall be considered "positive" when the rotor resists rotation of the shaft by an externally applied torque, and "negative" when it requires the external torque to retard the shaft.

Mechanical Hysteresis

Mechanical hysteresis is the angle between the unloaded stable equilibrium point when approached from one direction and the unloaded stable equilibrium point (of the same step position or minimum reluctance position) when approached from the opposite direction.

Overshoot (Transient)

Overshoot (transient) is the peak angular distance the shaft of the motor rotates beyond the actual final position (see Figure 1-2).

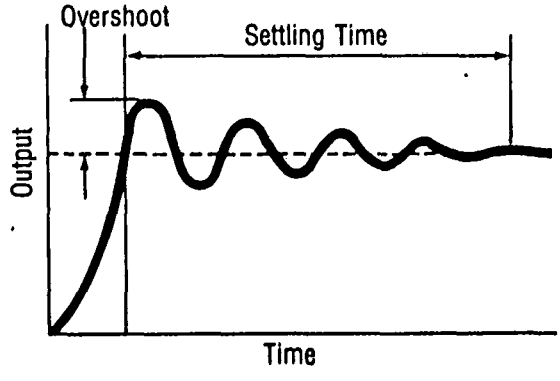


Figure 1-2
OVERSHOOT

Phase, Motor

(Motor) Phase is a set of electrically excited stator poles, consisting of one or more pairs of oppositely polarized poles.

A bifilar wound set of poles constitutes one motor phase, not two, in which the windings are linked magnetically, as one set of poles. (This sentence has been approved as Authorized Engineering Information.)

Phase Resistance

Phase resistance is the internal winding resistance which is equal to the motor terminal resistance less the lead resistance.

Positional Error—(Sometimes designated "Absolute Accuracy")

Positional error is the deviation from the theoretically correct angular position of any step position in a complete revolution. The zero position used in determining the theoretically correct angular position shall be the midpoint between the two extremes of position error. It is expressed as an angular measurement or a percentage of the nominal full step. It is measured under specified conditions.

Pull-In Step Rate (Error Free Stop/Start)

Pull-in step rate is the maximum command pulse rate

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(constant) at which the energized stepper motor can accelerate an applied load from standstill to synchronism with the command pulse step rate without missing steps. Conditions shall be specified.

Pull-In Torque

Pull-in torque is the maximum coulomb friction torque at which an energized stepper motor will accelerate to command pulse step rate and run in synchronism with the command pulse rate without losing steps, under specified conditions.

Pull-Out Step Rate

Pull-out step rate is the maximum command pulse rate (constant) at which the energized stepper motor can run in synchronism with the command pulse rate and under specified conditions.

Pull-Out Torque

Pull-out torque is the maximum coulomb friction torque which the motor will overcome while running in synchronism with a command pulse rate without losing steps.

Resonant Step Rates (Including parametric instability)

Resonant step rates are those step rates at which the motor will miss steps when operating below the curve of pull-out torque versus step rate under specified conditions.

Settling Time

Settling time is the total time from the first arrival at the commanded position until the amplitude of the oscillatory motion of the rotor has diminished to a specified level under specified conditions (see Figure 1-2).

Static Load Angle

Static load angle is the angle through which the rotor is displaced from its energized stable equilibrium position by a given applied torque at a specified current.

Step

1. *Full-Step* (also called "Basic Step Angle") is the rated angular increment of rotor position, at no load, between any two adjacent stable equilibrium points when the phases are energized singly and in sequence. A full step is always associated with the same number of phases energized for each step in the sequence. The rated angular increment of rotor position of a hybrid stepper motor is given by

$$\phi = 360/(A \times B \times C)$$

Where:

A = Number of stator pole pairs per phase
B = Number of phases
C = Number of north/south pairs of rotor salients, but never less than "A"

2. *Half-Step* is the same as (1) except that alternate "1-on," "2-on" energization is used resulting in an angular increment of motion of one-half that of a full-step.
3. *Micro-Step* (Sometimes called Mini-Step) is the subdivision of a full-step into some finer increment than the half-step, by profiling the phase currents in accordance with a predetermined law.

Step Angle Error—(Sometimes designated "Incremental Step Accuracy")

The step angle error is the maximum plus or minus deviation from the rated incremental angular motion per step, for any adjacent steps in a complete revolution without reversing direction under specified conditions. It is expressed as a percent of the angle of the nominal step.

Step Position

Step position is the static angular position which the shaft of an unloaded stepper motor assumes when it is energized as specified.

Step Sequence

Step sequence is the sequence of excitation defined by the translator logic which is the repeatable cyclic pattern by which the windings are energized for unidirectional motion.

Stepper Motor

A stepper motor is a polyphase synchronous motor, the rotor of which rotates in discrete angular increments when the stator windings thereof are energized in a programmed manner either by appropriately timed direct current states or by a polyphase alternating current. Rotation occurs because of the magnetic interaction between the rotor poles and the poles of the sequentially energized stator phases.

1. *Permanent Magnet (PM)*
   A permanent magnet stepper motor utilizes a rotor which has permanently magnetized poles.
2. *Variable Reluctance (VR)*
   A variable reluctance stepper motor utilizes a rotor which has pole salients (soft iron) without magnetic bias in the de-energized state.
3. *Hybrid (HY)*
   A hybrid stepper motor utilizes a permanent magnet to polarize soft iron pole pieces.

Stepping Rate

The stepping rate is the number of step angles through which the stepper motor rotates in a specified time.

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Steps Per Revolution

The steps per revolution are the number of discrete steps for one motor revolution.

Stiffness—(Sometimes called Torque Gradient)

Stiffness is the derivative (slope) of the torque versus angle curve at the stable equilibrium point. The curve is the sum of the stiffness due to holding torque and detent torque.

Synchronism

Synchronism is the state that exists when the average speed of the rotor equals the command pulse rate multiplied by a constant determined by the number of full steps per revolution.

Torque Gradient

(See Stiffness for definition.)

Rated Current

Rated current is the direct current, the ripple content of which has no perceptible effect on heating, which when applied to the windings of a horizontally-mounted motor at a specified ambient temperature with specified heatsinking if used (with no auxiliary cooling), will result in maximum allowable winding temperature in accordance with 1.3.1.

Velocity Modulation

Velocity modulation is a periodic function superimposed on the average angular velocity. The peak-to-peak amplitude is expressed as a percent of the mean velocity.

NEMA Standard 11-19-1987.

1.2.4 Symbols for Quantities and their Units

The following symbols for quantities and their units pertain to servo and stepper motors, their controls, and their systems.

Quantity Symbol	Definition	Unit Symbols	
		SI	English
cw	clockwise rotation		
ccw	counter-clockwise-rotation		
D	viscous damping factor	Nm·s/rad	lb·in/krpm
E_g	internally generated voltage (counter EMF)	V	V
f	frequency	Hz	Hz
I	current	A	A
I_{pk}	peak current	A	A
J	moment of inertia	$kg \cdot m^2$	$lb \cdot in \cdot sec^2$
J_L	load moment of inertia	$kg \cdot m^2$	$lb \cdot in \cdot sec^2$
J_m	mass moment of inertia with respect to the rotational axis of the rotor	$kg \cdot m^2$	$lb \cdot in \cdot sec^2$
K_D	damping coefficient	Nm·s/rad, Nm·min/r	lb·in/krpm
K_E	voltage constant	V·min/r	Volts/krpm
K_M	motor constant	$Nm/\sqrt{W}$	$lb \cdot in/\sqrt{W}$
K_T	torque constant	Nm/A	lb·in/A
L	inductance	H	H
M	mass	kg	slug
n	rotational speed, shaft speed	r/min, kr/min	rpm, krpm
N	gear ratio	—	—
P	lead screw pitch	rev/mm	rev/inch
P_o	output power, watts	W	W
PM	permanent magnet	—	—
r	radius	m	inch
R	resistance	Ω	Ω
R_a	armature winding resistance	Ω	Ω

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Symbols for Quantities and Their Units

Quantity Symbol	Definition	Unit Symbols SI	Unit Symbols English
R_b	brush resistance	Ω	Ω
R_{th}	thermal resistance	°C/W	°C/W
SI	international system of units (metric system)	—	—
t	time	s	sec.
t_i	time interval	s	sec.
t_f	fall time	s	sec.
t_r	rise time	s	sec.
t_s	settling time	s	sec.
T	torque	Nm	lb·in
T_i	torque per time interval, t_i	Nm	lb·in
T_a	accelerating torque	Nm	lb·in
T_D	damping torque $T_D = D \cdot \omega$	Nm	lb·in
T_f	internal friction torque	Nm	lb·in
T_L	load torque	Nm	lb·in
T_{pk}	peak torque	Nm	lb·in
V	voltage	V	V
V_{pk}	peak voltage	V	V
V_S	supply voltage	V	V
W	power (watts)	W	W
α	angular acceleration $\alpha = \frac{d\omega}{dt}$	rad/s²	rad/sec.²
α_m	maximum theoretical acceleration from stall	rad/s²	rad/sec.²
ϕ	angular displacement	rad,°,r	rad,°, rev.
τ	time constant	s	sec.
τ_e	electrical time constant	s	sec.
τ_m	mechanical time constant	s	sec.
τ_{th}	thermal time constant	s	sec.
ω	angular velocity $\omega = \frac{d\phi}{dt}$	rad/s	rad/sec.
°	angular degree	—	—

CONVERSION FACTORS:

MULTIPLY:	BY:	TO OBTAIN:
lb·in	0.113	N·m
lb·in/krpm	1.079×10^{-3}	N·m·s/rad
lb·in·sec²	0.113	kg·m²
lb·in/krpm	113.0×10^{-3}	N·m·min/r
slug	14.6	Kg
inch	25.4	mm
inch	0.0254	metre

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1.3 RATINGS

The following performance ratings pertain to servo and stepper motors.

1.3.1 Maximum Allowable Winding Temperature for Stepper Motors

The maximum allowable winding temperature for stepper motors shall not exceed the values given in Table 1-1 when tested for rated current in accordance with 1.7.2.1, NEMA Standard 11-19-1987.

Table 1-1
INSULATION SYSTEM CLASSIFICATION

Class	Maximum Allowable Winding Temperature
A	105° C
B	130° C
F	155° C
H	180° C

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1.3.2 Maximum Allowable Winding Temperature for Servo Motors *(under consideration)*

1.4 ENCLOSURES *(under consideration)*

1.5 DIMENSIONS, TOLERANCES AND MOUNTING

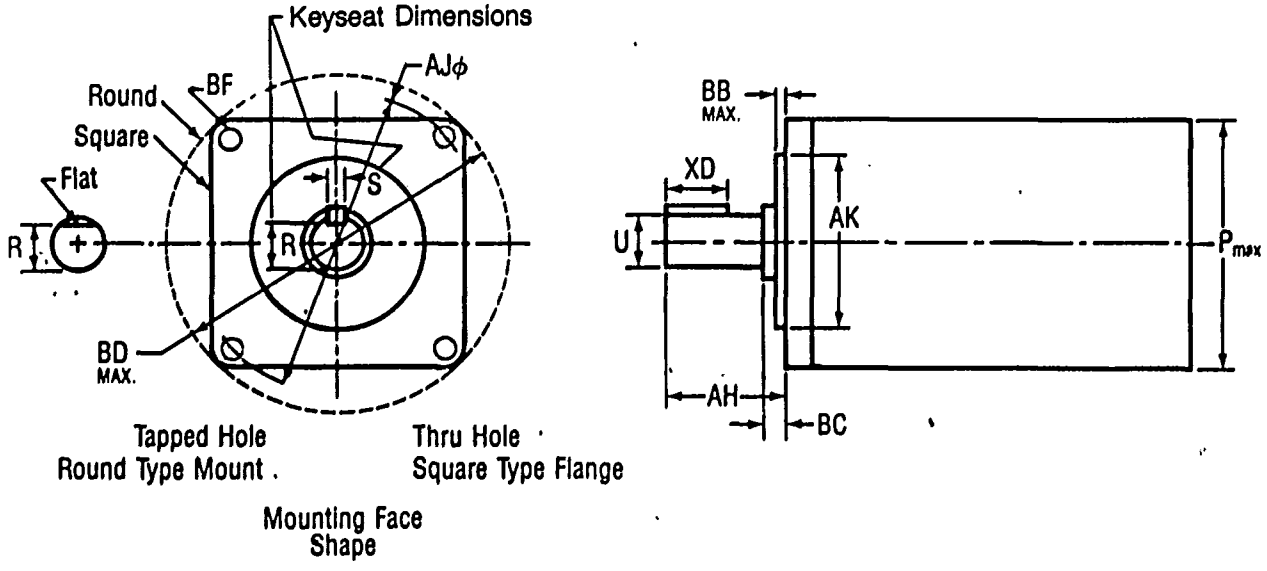
1.5.1 Dimensions for Servo Motors

1.5.1.1 ENGLISH DIMENSIONS *(under consideration)*

1.5.1.2 METRIC MOUNTING DIMENSIONS

Dimension sheets shall be lettered in accordance with Figure 1-3.

Suggested Standard for Future Design 11-19-1987.



AJ	Diameter of mounting bolt circle in face, flange, or base of machine.	BD_{max}	Maximum outside diameter of mounting face, flange, or base of machine.
AK	Diameter of male or female pilot on face, flange, or base of machine.	BB_{max}	Maximum depth of male or female pilot of mounting face, flange, or base of machine.
AH	Mounting surface of face, flange or base of machine to end of shaft.	BF	Threaded or clearance hole in mounting face, flange, or base of machine.
U	Diameter of shaft extension.	XD	Usable length of keyseat.
P_{max}	Maximum width of machine (end view) including pole bolts, fins, etc., but excluding terminal housing, lifting devices, feet and outside diameter of face or flange.	S	Width of keyseat.
		R	Bottom of keyseat or flat to opposite side of shaft or bore.
		BC	Distance between mounting surface of face, flange, or base of machine to shoulder on shaft.

Figure 1-3
LETTERING OF DIMENSION SHEETS FOR SERVO MOTORS

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1.5.1.3 METRIC MOUNTING DIMENSIONS FOR SERVO MOTORS

	AJ mm	AK mm	AK Tol mm	AH mm Pri	AH mm Sec	U mm Pri	U mm Sec	U Tol mm Pri	U Tol mm Sec	BC mm	Pmax/BDmax mm	BBmax mm	BF mm	BF Tol mm	Thread	XD mm Pri	XD mm Sec	S mm Pri	S mm Sec
55DM	55	40	+0.011 −0.005	20	30	9	14	+0.007 −0.002	+0.008 −0.003	0	70	2.5	5.8	+.300 −0	M5×O.8	15	20	3×3	5×5
65DM	65	50	+0.011 −0.005	20	30	9	14	+0.007 −0.002	+0.008 −0.003	0	80	2.5	5.8	+.300 −0	M5×0.8	15	20	3×3	5×5
75DM	75	60	+0.012 −0.007	23	40	11	16	+0.008 −0.003	+0.008 −0.003	0	90	2.5	5.8	+.300 −0	M5×0.8	18	30	4×4	5×5
85DM	85	70	+0.012 −0.007	30	40	14	19	+0.008 −0.003	+0.009 −0.004	0	105	2.5	7	+.360 −0	M6×1.0	20	30	5×5	6×6
100DM	100	80	+0.012 −0.007	30	40	14	19	+0.008 −0.003	+0.009 −0.004	0	120	3	7	+.360 −0	M6×1.0	20	30	5×5	6×6
115DM	115	95	+0.013 −0.009	40	50	19	24	+0.009 −0.004	+0.009 −0.004	0	140	3	10	+.360 −0	M8×1.25	30	40	6×6	8×7
130DM	130	110	+0.013 −0.009	40	50	19	24	+0.009 −0.004	+0.009 −0.004	0	160	3.5	10	+.360 −0	M8×1.25	30	40	6×6	8×7
145DM	145	110	+0.013 −0.009	40	50	19	28	+0.009 −0.004	+0.009 −0.004	0	165	3.5	10	+.360 −0	M8×1.25	30	40	6×6	8×7
165DM	165	130	+0.014 −0.011	50	50	24	28	+0.009 −0.004	+0.009 −0.004	0	200	3.5	12	+.430 −0	M10×1.5	40	40	8×7	8×7
200DM	200	114.3	+0.0 −0.025	79	—	35	—	+0.01 −0.00	—	0	235	4	13.5	+.430 −0	M12×1.75	70	—	10×8	—
215DM	215	180	+0.014 −0.011	60	—	32	—	+0.018 +0.002	—	0	250	4	15	+.430 −0	M12×1.75	50	—	10×8	—
265DM	265	230	+0.016 −0.013	85	—	48	—	+0.018 +0.002	—	0	300	4	15	+.430 −0	M12×1.75	60	—	14×9	—
300DM	300	250	+0.016 −0.013	85	—	48	—	+0.018 +0.002	—	0	350	5	19	+.520 −0	M16×2.0	60	—	14×9	—
350DM	350	300	+0.016 −0.016	110	—	55	—	+0.030 +0.011	—	0	400	5	19	+.520 −0	M16×2.0	90	—	16×10	—

Suggested Standard for Future Design 11-19-1987.

The suffix CM denotes C face-mounting motors with tapped mounting holes. The suffix DM denotes D flange-mounting motors with free-mounting holes. (This note is approved as Authorized Engineering Information.)

The reference for the tolerances is ISO Recommendation 286, S.I. Metric System of Limits and Fits. (This note is approved as Authorized Engineering Information.)

mensions refer to applications where it is clear a servo motor is required. They are not necessarily the same as the dimensions given in paragraph 1.5.3.

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1.5.2 Dimensions for Stepper Motors

1.5.2.1 ENGLISH DIMENSIONS

Dimension sheets shall be lettered in accordance with Figure 1-4.

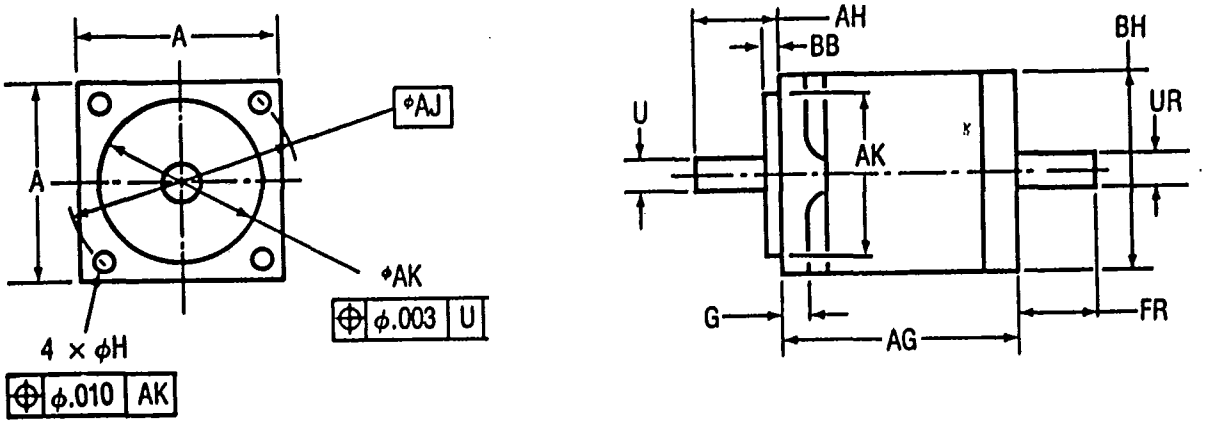


Figure 1-4
LETTERING OF DIMENSION SHEETS FOR HYBRID† STEPPER MOTORS

†These dimensions apply to hybrid stepper motors. Other stepper motors may have similar dimensions.

Authorized Engineering Information 11-19-1987.

NEMA Letter	IEC Letter		NEMA Letter	IEC Letter	
A	P	Outside diameter of mounting face, flange, or base of machine.	AK	N	Diameter of male or female pilot on face, flange, or base of machine.
G	LA	Thickness of mounting flange or base of machine.	BB	T	Depth of male or female pilot of mounting face, flange, or base of machine.
U	D	Diameter of shaft extension, drive end.	BH	. . .	Outside diameter of core or shell (side view). (Basic body diameter not including connection means.)
AG	LB	Mounting surface of face, flange, or base of machine to opposite end of housing (side view).	FR	. . .	Length of shaft from end of housing to end of shaft, end opposite the drive.
AH	. . .	Mounting surface of face, flange, or base of machine to end of shaft.	UR	. . .	Diameter of shaft extension, end opposite the drive.
AJ	M	Diameter of mounting bolt circle in face, flange, or base of machine.			

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1.5.2.2 ENGLISH MOUNTING DIMENSIONS FOR HYBRID STEPPER MOTORS

Nema Dia. & Length Code*	23C016 23D016	23C021 23D021	23C025 23D025	23C031 23D031	23C035 23D035	23C041 23D041	23C045 23D045
Industry Frame Size (Ref)	23	23	23	23	23	23	23
Dimension Symbol			Dimensions (Inches)				
A	<----------2.27---------->						
AG	1.6	2.1	2.5	3.1	3.5	4.1	4.5
AH	<----------0.85/0.78---------->						
AJ	<----------2.625---------->						
AK	<----------1.502/1.498---------->						
BB	<----------0.140/0.030---------->						
BH	<----------2.3---------->						
FR	<----------0.80/0.55---------->						
G	<----------0.232/0.156---------->						
H	<----------0.215/0.195---------->						
U	<----------0.2500/0.2495---------->						
UR	<----------0.2500/0.2494---------->						

*Length code is optional and may be deleted or used as deemed necessary by the manufacturers. (Sentence approved as Authorized Engineering Information.)

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NEMA Dia. & Length Code*	34C025 34ID025	34C032 34ID032	34C038 34ID038	34C046 34ID046	34C051 34ID051	34C059 34ID059
Industry Frame Size (Ref)	34	34	34	34	34	34
Dimensional Symbol			Dimensions (Inches)			
A	3.42					
AG	2.5	3.2	3.8	4.6	5.1	5.9
AH	1.31/1.16					
AJ	3.875					
AK	2.877/2.873					
BB	0.140/0.030					
BH	3.42					
FR	1.23/1.13					
G	0.25/0.18					
H	0.228/0.213					
U	0.3750/0.3745					
UR	0.3750/0.3745					

*Length code is optional and may be deleted or used as deemed necessary by the manufacturers. (Sentence approved as Authorized Engineering Information.)

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NEMA Dia. & Length Code	42C048 42D048	42C055 42D055	42C070 42D070	42C077 42D077	42C089 42D089	42C105 42D105	
Industry Frame Size (Ref)	42	42	42	42	42	42	
Dimensional Symbol	Dimensions (Inches)						
A	4.38						
AG	4.8	5.5	7.0	7.7	8.9	10.5	
AH	1.42/1.22						
AJ	4.950						
AK	2.188/2.184						
BB	0.140/0.050						
BH	4.27						
FR	1.35/1.15						
G	0.57/0.28						
H	0.330/0.210						
U	0.3750/0.3745		0.6250/0.6245 (Note 1)				
UR	0.5000/0.4995 (Note 2)						

Note 1: 0.5000/0.4995 inch diameter shafts are supplied by some manufacturers.

Note 2: 0.3750/0.3745 inch diameter shafts are supplied by some manufacturers.

*Length code is optional and may be deleted or used as deemed necessary by the manufacturer. (Sentence approved as Authorized Engineering Information.)

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NEMA Dia & Length Code*	66C110 66D110	66C122 66D122	66CX 66DX	66C 66D	66C 66D	66C 66D
Industry Frame Size (Ref)	66	66	66	66	66	66
Dimensional Symbol			Dimensions (Inches)			
A	6.39					
AG	11.0	12.2	Not Specified			
AH	1.77/1.73					
AJ	7.512					
AK	2.752/2.748					
BB	0.150/0.120					
BH	6.6					
FR	1.66/1.58					
G	0.52/0.46					
H	0.423/0.404					
U	0.6250/0.6245					
UR	0.6250/0.6245					

NEMA Standard 11-19-1987.

*Length code is optional and may be deleted or used as deemed necessary by the manufacturer. (Sentence approved as Authorized Engineering Information.)

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1.5.3 Metric Servo/Stepper Motor Mounting Dimensions

Refer to Figures 1-3 and 1-4 in conjunction with the following:

	Mounting Dimensions							Shaft Extensions					
Frame	AJ mm	AK mm	Tol.(AK) μm	Pmax, BDmax mm	BBmax mm	BF mm	Tol.(BF) μm	AH mm	U mm	Tol.(U) μm	XD mm	S mm	R mm
D70	70	36	+11 −5	82	3.5	5.8	+300 −0	20 20	6 9	+6,−2 +7,−2	15 15	— 3	−* 7.2†
D100	100	68	+12 −7	120	3.5	5.8	+300 −0	30 30	10 14	+7,−2 +8,−3	20 20	3 5	6.2* 11†
D125	125	52	+12 −7	155	3.5	7.0	+360 −0	35 40	16 19	+8,−3 +9,−4	25 30	5 6	13* 15.5†
D190	190	68	+12 −7	233	4.0	10	+360 −0	45 50	19 24	+9,−4 +9,−4	35 40	6 8	15.5* 20†
D215	215	180	+14 −11	250	4.0	15	+430 −0	50 60	24 32	+9,−4 +18,+2	40 50	8 10	20* 27†

Suggested Standard for Future Design 11-19-1987.

The table in paragraph 1.5.3 shows commonality between servo and stepper motor dimensions in applications when it is clear that either a servo or a stepper motor would suffice. These dimensions are not necessarily the same as the dimensions given in paragraph 1.5.1.3.

Authorized Engineering Information 11-19-1987.

Shaft Extensions:
*Preferred Series
†Secondary Series

1.5.4 Measurement and Tolerances

1.5.4.1 Method of Measurement of Shaft Runout and of (Concentricity) Eccentricity and Face Runout (Perpendicularity) of Mounting Surfaces

1. *Shaft Runout*
   The shaft runout shall be measured with the indicator stationary with respect to the motor and with its point at the end of the finished surface of the shaft (see Figures 1-5 and 1-6 for typical fixtures).

2. *Pilot Eccentricity and Face Runout of Mounting Surfaces*
   Pilot eccentricity and face runout of the mounting surfaces shall be measured with indicators mounted on the shaft extension. The point of the eccentricity indicator shall be at approximately the middle of the rabbet surface, and the point of the face runout indicator shall be at approximately the outer diameter of the mounting face. (See Figure 1-7 for typical fixture for "C" face or Figure 1-8 for "D" flange approximately at the included diameter.)

   Read the maximum and minimum values on the indicators as the shaft is rotated slowly through 360 degrees. The difference between the readings shall not exceed the specified value.

   NEMA Standard 11-19-1987.

On ball-bearing motors, it is recommended that the test be made with the shaft vertical to minimize the effect of bearing clearances.

Pilot eccentricity is sometimes called concentricity and face runout is sometimes called perpendicularity, although not strictly correct.

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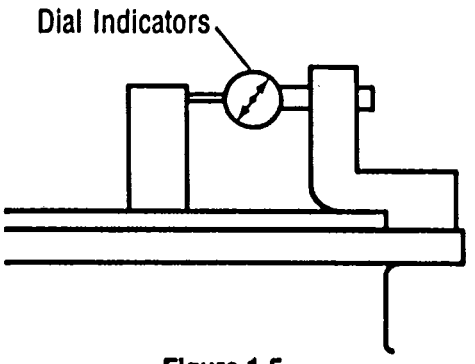


Figure 1-5

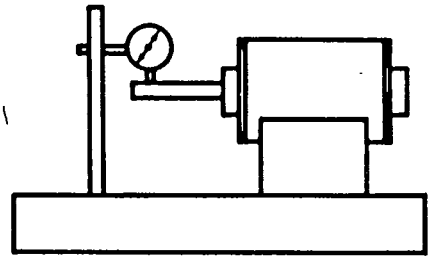


Figure 1-6

SHAFT RUNOUT TYPICAL MEASUREMENT TECHNIQUES

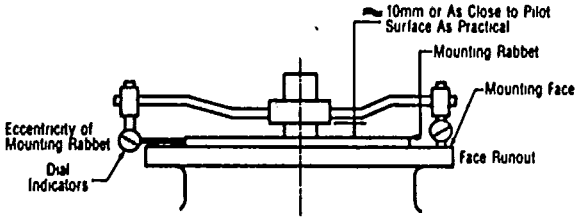


Figure 1-7
FACE RUNOUT MEASUREMENT FIXTURE FOR "C" FACE MOUNTING MOTORS

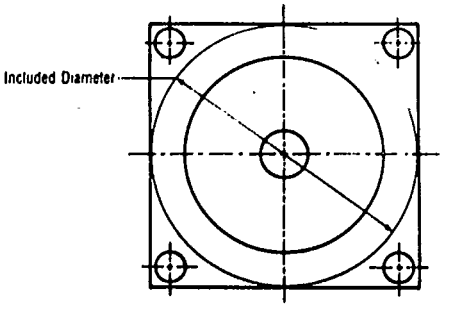


Figure 1-8
INCLUDED DIAMETER MEASUREMENT FOR "D" FLANGE MOUNTING MOTORS

1.5.4.2 Tolerances for Shaft Runout, Pilot Eccentricity and Face Runout (Servo and Stepper)

NEMA Metric Frame		Runout at Shaft End			
		Normal		Precision	
Servo	Stepper	Metric	English (Ref.)	Metric	English (Ref.)
55–100	D70–D100	0.035 mm*	0.0015 in.*	0.025 mm	0.001 in.
115–215	D70–D100 D125–D215	0.050 mm	0.002 in.	0.035 mm*	0.0015 in.*
265–350	—	0.075 mm	0.003 in.	0.050 mm	0.002 in.

*Not applicable to stepper motors.

NEMA Metric Flange		Pilot Eccentricity and Face Runout			
		Normal		Precision	
Servo	Stepper	Metric	English (Ref.)	Metric	English (Ref.)
55–115	D70–D100 D125**	0.080 mm	0.003 in.	0.025 mm	0.001 in.
130–265		0.100 mm	0.004 in.	0.050 mm	0.002 in.
300–350	D215**	0.125 mm	0.005 in.	0.063 mm	0.0025 in.

**No precision units available

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1.6 NAMEPLATE MARKINGS

1.6.1 Servo Motors

The minimum standard nameplate information for brush or brushless servo motors three inches in diameter or greater shall be as follows:

1. Manufacturer's name.
2. Manufacturer's model number (includes motor type identification such as ac, dc, and so forth).
3. Manufacturer's serial number or date code.
4. Maximum continuous stall torque at ____ degrees C ambient.
5. Maximum continuous RMS amperes at ____ degrees C ambient.
6. Maximum continuous output power (kW) at ____ degrees C ambient.
7. Maximum allowable intermittent volts (brush type only).
8. Maximum allowable speed.
9. Resistance, terminal at 25 degrees C.

NEMA Standard 11-19-1987.

1.6.2 Stepper Motors

The manufacturer's name and manufacturer's type number shall be marked on stepper motor nameplates. In addition, the following data shall be marked on stepper motor nameplates.

NEMA Code	Description	Example
To be coded:		
DD	Diameter, inches* × 10 (nominal)	34 = 3.4 in.
MM	Mounting Code	D-flange; C-face; etc.
LLL (optional)	Length in inches* × 10 (AG dimension)	016 = 1.6
To be coded or individually marked:		
CCC	Phase current in amps† × 1Ø, rated, for 2 phase-on operation.	016 = 1.6
I	Insulation class (NEMA definition)	B
VVV	Phase voltage rating* × 10	053 = 5.3
SSS	Steps per revolution	200
W (optional)	Winding code	See 1.6.3

*Quantities expressed with one place after the decimal point.
†A dash (−) is used to separate mounting characteristics from other data.

NEMA Standard 11-19-1987.

Examples:

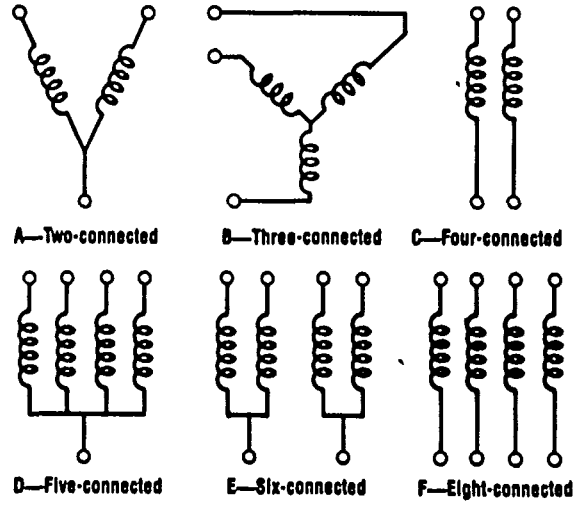
1) 3.4″ dia., D-flange — 34D
2) 4.2″ dia., D-flange w/C face tapped holes — 42CD
3) 2.3″ dia., D-flange, 1.6″ long — 23D016
4) 2.3″ dia., D-flange, 1.6″ long, 1.6A, Class B, 5.3V, 200 steps per revolution, winding connection A — 23D016-016B053200A
5) 2.3″ dia., D-flange, 1.6A, Class B, 5.3V, 200 steps per revolution, winding connection A — 23D-016B053200A

(Examples are Authorized Engineering Information 11-19-1987.)

1.6.3 Winding Codes for Stepper Motors

When stepper motors use a winding code on the nameplate marking to identify external connections, the letter symbol assignment shall be determined from the following diagramatic arrangements:

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NOTE: ○ indicates external connections.

Figure 1-9
WINDING CODES

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1.7 TESTS AND PERFORMANCE

1.7.1 Servo Motors

1.7.1.1 MOTOR TERMINAL RESISTANCE FOR BRUSH COMMUTATED MOTORS

The terminal resistance of brush commutated motors shall be measured as follows:

1. Lock the rotor shaft and apply a dc voltage sufficient to drive a current equal to 10% of rated current through the motor.
2. Measure voltage and current for at least five different equally spaced shaft angular positions. Take readings quickly to avoid heating effects.
3. Measure motor frame temperature, T, at the end of the test.
4. Average the values of resistance (R=V/I) to obtain R_T.
5. Calculate the resistance at 25°C using the following formula:

$$R_{25} = \left(\frac{K+25}{K+T} \right) R_T$$

Where R_{25} = Motor terminal resistance at 25°C (ohms).
R_T = Average resistance at temperature, T, (ohms).
K = 234.5
T = Motor frame temperature at time of test (°C).

NEMA Standard 11-19-1987.

The resistance of brush commutated motors cannot be accurately measured with a conventional ohmmeter because the low voltage and current output of such devices will not break down the normal film which is present on the commutator surface. Where it is not in conflict, the ANSI/IEEE Std. 113 should be used (see 1.2, Referenced Standards).

Authorized Engineering Information 11-19-1987.

1.7.1.2 COGGING TORQUE

Cogging torque shall either be measured by the torque wrench or torque transducer method described below. The torque wrench method is typically used on motors whose cogging torque is much greater than the static friction. All measurements are made with no power applied to the motor under test, the motor leads open, and the motor at 25°C ± 5°C.

Torque Wrench Method—Rotate the motor shaft through one complete revolution with a torque wrench. Record the peak-to-peak value measured with the torque wrench. This is the cogging torque.

Torque Transducer Method—Rotate the motor shaft at 3 or less rpm with a torque transducer connected between the motor under the test and the driver. Record the peak-to-peak value measured with the torque transducer. The cogging torque is the measured peak to peak value.

1.7.1.3 FRICTION TORQUE AND VISCOUS DAMPING—SERVOMOTORS

Friction torque (T_F) and viscous damping factor (D) shall be determined by measuring the torque required to drive the motor under test at 30 rpm, half maximum continuous speed, and maximum continuous speed. The torque versus speed shall be plotted as a best fit straight line on a graph. The Y intercept is the friction torque and the slope is the viscous damping factor. (See Figure 1-10.)

NEMA Standard 11-19-1987.

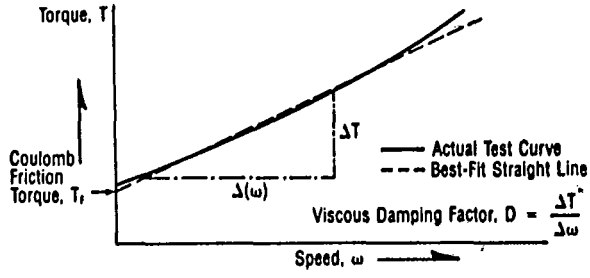


Figure 1-10
FRICTION TORQUE AND VISCOUS DAMPING

A preferred method is to drive the motor under test with an external motor and use a torque transducer to measure the required torque. (See Figure 1-11.)

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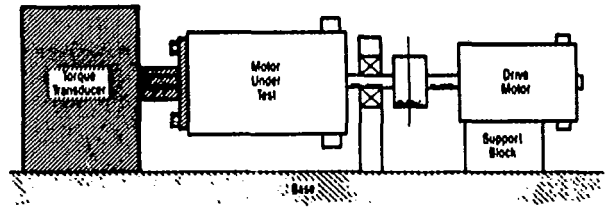


Figure 1-11
VISCOUS DAMPING TEST LAYOUT

1.7.2 Stepper Motors

1.7.2.1 RATED CURRENT

Rated current for stepper motors shall be determined by applying direct current from a suitable constant current

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supply, the ripple content of which has no perceptible effect on heating, that will maintain the output current with ± 1% to the specified winding and will result in a maximum winding temperature at thermal equilibrium in accordance with Table 1-1. If multiple windings are specified, they shall be connected in series for this test. The motor shall be suspended horizontally in a 25°C ambient without external heatsinking and no auxiliary cooling for this test.

NEMA Standard 11-19-1987.

1.7.2.2 WINDING TEMPERATURE

The winding temperature of stepper motors shall be determined by measurement of the winding resistance change under the specified test current and mounting conditions* according to the formula:

$$T_h = \frac{R_h}{R_c}(K + t_{ac}) - K$$

Where: T_h = Temperature of energized winding (final).

R_h = Resistance at final temperature T_h (ohms).

t_{ah} = Ambient temperature at the end of the heat run in the vicinity of the motor.

t_{ac} = Initial ambient temperature in the vicinity of the motor.

R_c = Cold resistance at temperature t_{ac} (ohms).
The temperature of the motor shall be allowed to stabilize at ambient (t_{ac}) prior to measurement of R_c.

K = Constant for copper, 234.5.

Also, Temperature Rise (T.R.) = $\frac{R_h}{R_c}(K + t_{ac}) - (K + t_{ah})$

Where T.R. = Winding temperature rise above ambient temperature, (t_{ah}).

All temperatures are in degrees Celsius. The measurement shall be made in accordance with the phase resistance procedure (under consideration). Rapid transfer from the power source to the resistance measuring device shall be made to avoid error due to motor cooling.

NEMA Standard 11-19-1987.

Errors due to rapid cooling may be avoided by plotting a cooling curve of resistance versus time and extrapolating to zero time. (Zero time is the time when power was removed from the motor.)

Authorized Engineering Information 11-19-1987.

1.7.2.3 HOLDING TORQUE

Holding torque for stepper motors shall be measured with rated current applied through two phases in series. The peak resistance to rotation is measured by slowly rotating a torque watch or other suitable torque transducer applied to the motor shaft. The holding torque is the minimum value observed through the full rotation of the shaft in either direction.

NEMA Standard 11-19-1987.

For rating purposes, the motor should be allowed to reach thermal equilibrium at the test current prior to measurement.

Authorized Engineering Information 11-19-1987.

1.7.2.4 DETENT TORQUE

Detent torque for stepper motors shall be measured in the same manner as holding torque except the phases are open-circuited.

NEMA Standard 11-19-1987.

For rating purposes, the motor temperature should be stabilized at 25 degrees C prior to measurement.

Authorized Engineering Information 11-19-1987.

1.8 APPLICATION DATA *(under consideration)*

*This test procedure is consistent with ANSI/IEEE Std. 113. (See 11. Referenced Standards.)

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Section 2

CONTROLS

2.1 DEFINITIONS

2.1.1 Common

The following definitions are common to controls for servo and stepper motors. All items relating to measured values are defined with the understanding that in most cases a test procedure will describe the specified conditions of measurement.

Authorized Engineering Information 11-19-1987.

Continuous Power Output

Continuous power output is the steady state power output capability of a device in watts.

Drift

Drift is an undesired, but relatively slow, change in output over a period of time with a fixed reference input.

Operating Ambient Temperature

Operating ambient temperature is the temperature of the air immediately surrounding a device.

Power Dissipation (heat generation)

Power dissipation (heat generation) is the amount of power dissipated in the controller due to its internal power losses.

Pulse Width Modulated Amplifier

A pulse width modulated amplifier is an amplifier which switches the supply voltage at a constant frequency but with a variable pulse width so that an adjustable average voltage or current to the load is established.

Pulse Width Frequency Modulated Amplifier

A pulse width frequency modulated amplifier is an amplifier which switches the supply voltage at a variable frequency or a variable pulse width or both so that an adjustable average voltage or current to the load is established.

Ripple Current

Ripple current is the peak-to-peak variation in current around the average value.

Step Response

Step response is the time domain response characteristic of the output of a device in response to a specified step level of input. (See Figure 1-2.)

Switching Frequency

Switching frequency is the fundamental frequency at which a power switching device controlling the motor current is turned on and off.

NEMA Standard 11-19-1987.

2.1.2 Servo

The following definitions pertain to controls for servo motors. All terms relating to measured values are defined with the understanding that in most cases a test procedure will describe the specified conditions of measurement.

Authorized Engineering Information 11-19-1987.

Deadband

Deadband is a range of input signals for which there is no system response.

Linearity

Linearity is a measure of the degree to which the output of a control device maintains a constant relationship to the input over a range of input values.

Scale factor, amplifier

The scale factor of the amplifier is the output change for a given input change.

Position Loop Bandwidth

Position loop bandwidth is the frequency range over which the magnitude of the closed position loop gains decreases by 3dB or less. (The position loop response time decreases as the bandwidth is increased.)

Regeneration

Regeneration is the process of returning energy to the source of the load.

Regenerative Capacity

Regenerative capacity is the amount of energy that the amplifier can accept during regeneration.

Scale factor, amplifier

The scale factor of the amplifier is the output change for a given input change.

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Six-step Brushless Motor Amplifier

A six-step brushless motor amplifier is an amplifier which provides polyphase outputs consisting of six discrete switching states occurring for each 360 degree electrical cycle.

Slewing

Slewing is the rapid transition of the output of a control device from one value to another value without requiring that the normal output versus input relationship be maintained through the intermediate values.

Three-Phase Sinusoidal Brushless Motor Amplifier

A sinusoidal brushless motor amplifier is an amplifier which provides three sinusoidal current outputs, phase shifted 120 degrees electrical.

2.1.3 Stepper

The following definitions pertain to controls for stepper motors. All terms relating to measured values are defined with the understanding that in most cases a test procedure will describe the specified conditions of measurement.

Authorized Engineering Information 11-19-1987.

Acceleration/Deceleration

Acceleration/Deceleration is a change in velocity of a stepper motor by adjustment of pulse rate.

Base Speed

Base speed is a speed without ramping and with no position error with a specified load.

Bi-Level

A bi-level drive is a dual voltage motor drive circuit, which provides high voltage to initially build up the current in the windings, and then switches to a low voltage after the rated current or preset time is reached. This descreases the motor current build up time and improves motor performance.

Chopper

A chopper drive is a motor drive circuit in which the supply voltage is switched (chopped) by pulse width or frequency modulation or both to maintain an average current level to the motor windings. The chopping frequency can typically range from 1 kHz to 30 kHz. This permits the use of drive voltages several times the motor's rated value to cause the motor currents to build up rapidly for improved high-speed performance.

Command Pulse Rate

Command pulse rate is the rate at which successive command pulses are applied to the motor drive logic.

Constant Current

Constant current drive is a motor drive circuit which maintains the average motor currents relatively constant independent of motor speed (e.g., chopper or linear driver with current feedback loop) in order to provide improved high speed motor performance.

Controller, Stepper Motor

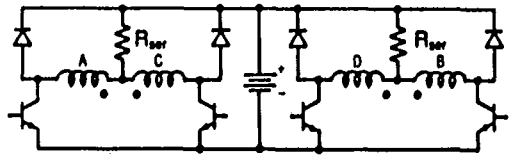
The stepper motor controller is the system that provides intelligence and power to the stepper motor controlled.

Drive Circuits

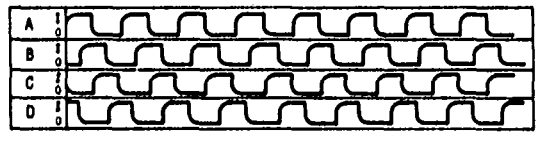
A drive circuit is a combination of a translator and a power amplifier which energizes the phases of the stepper motor.

Drive Configurations

Unipolar—A unipolar drive circuit maintains the winding current flow in only one direction. An example of a unipolar drive circuit is shown in Figure 2-1.



Unipolar Drive Circuit

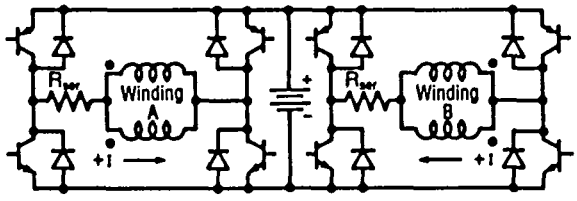


Winding Currents for Full Step Rotation (2Ø On, Unipolar)

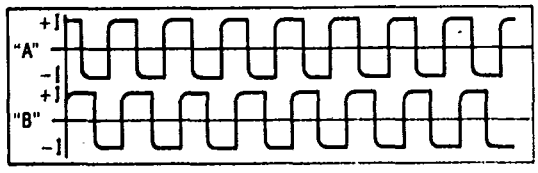
Figure 2-1

Bipolar—A bipolar drive circuit is a drive circuit in which the phase winding current is bi-directional. An example of a bipolar drive circuit is shown in Figure 2-2.

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Single Supply—Parallel Bipolar Drive Circuit



Full Step CW*

Winding Currents for Full-Step Rotation

*Winding "A" and Winding "B" notation refers to parallel not to the A & B windings shown in the unipolar schematic.

Figure 2-2

Driver, Stepper Motor

The stepper motor driver is that portion of the control that provides power to the stepper motor in a controlled manner to achieve the specified motor performance characteristics.

Maximum Reversing Command Pulse Rate

The maximum reversing command pulse rate is the maximum pulse rate at which the unloaded stepper motor is able to reverse and remain in synchronism under the specified drive conditions. The number of pulses must be enough to assure stability of the dynamic load angle before reversal.

Maximum Slew Pulse Rate

The maximum slew pulse rate is the maximum pulse rate at which the unloaded stepper motor can remain in synchronism with the command pulses under the specified drive conditions.

Pulse Stream Control

Clockwise/Counterclockwise is a direction control method where separate pulse stream inputs are provided for clockwise or counterclockwise rotation of the stepper motor.

Ramping

Ramping is the acceleration/deceleration of a stepper motor by means of controlled change in a pulse rate above base speed.

Response Range

Response range is the range of command pulse rates over which the unloaded motor can be operated in one of the following specified conditions without missing steps.

a. Start-stop without reversal.
b. Reverse during acceleration, deceleration or slew.
c. Acceleration *and* deceleration.
d. Acceleration *or* deceleration.

Rotation, Direction Control Types

Control Input/Output Pulse and Direction is a direction control method where a logic state (high or low) determines direction of rotation of the stepper motor, while a separate pulse stream determines rotor position.

Series R, (or L/R)

A series R drive (or L/R) is a motor drive circuit which uses extra resistors in series with the motor windings and drive transistors to reduce the current buildup time constant from L_m/R_m to $L_m/(R_m+R)$ and thus improve high speed performance; wherein,

L_m = Motor windings inductance
R_m = Motor windings resistance
R = Extra series resistance

Slew Range

(See Response Range for definition.)

Stepping

Stepping is the process of supplying a proper logic pattern of drive signals that cause the motor driver to supply required stepper motor winding currents at appropriate times to create incremental motion. (See Stepper Motor Terminology—Step.)

1. Full Step—A full step is a logic pattern that will produce a unit of incremental motion which results in step increments that are determined by the basic stepper motor structure. (See Motor Full Step.)
2. Half Step—A half step is the unit of incremental motion that is 1/2 of a basic motion increment (full step). (See Motor Half Step.)
3. Micro Step—A micro step is a logic pattern that will produce regular increments smaller than a half step. (See Motor Micro Step.)

Translator

A translator is the control section that converts the input commands to a suitable logic patterned waveform to properly drive the stepper motor.

Translator Logic

Translator logic converts the single channel pulse train into the multi-channel states to be applied to the power amplifier which energizes the stepper motor.

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2.1.4 Symbols for Servo and Stepper Motor Controls *(under consideration)*

2.2 RATINGS *(under consideration)*

2.3 ENCLOSURES *(under consideration)*

2.4 MANUFACTURING *(under consideration)*

2.4.1 Dimensions *(under consideration)*

2.5 NAMEPLATE MARKINGS *(under consideration)*

2.6 TESTS AND PERFORMANCE *(under consideration)*

2.7 APPLICATION DATA *(under consideration)*

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MEMBER COMPANIES
MOTION/POSITION CONTROL MOTORS GROUP
MOTOR AND GENERATOR SECTION

Allen Bradley Company
Milwaukee, WI 53201

BMD, Inc.
El Paso, TX 79936

Baldor Electric Company
Fort Smith, AR 72902

Bodine Electric Company
Chicago, IL 60618

CSR-Powertron Division
Contraves Goerz Corporation
Charlotte, NC 28217-1503

Delco Products
Division of General Motors
Dayton, OH 45401

EG&G Torque Systems
Watertown, MA 02172

Electro-Craft Corporation
Hopkins, MN 55343

GE
Fort Wayne, IN 46801-2205

Gould Electronics
Motion Control Operation (Gettys)
Racine, WI 53404

G&L Electronics
Fond du Lac, WI 54935

Micro Mo Electronics, Inc.
St. Petersburg, FL 33701

Moog, Inc.
East Aurora, NY 14052

Pacific Scientific
Rockford, IL 61105

Peerless-Winsmith, Inc.
Warren, OH 44485

PITTMAN, A Division of
Penn Engineering & Mfg.
Corporation
Harleysville, PA 19438

Reliance Electric Company
Cleveland, OH 44117

Rexroth Corporation
Indramat Division
Wood Dale, IL 60191

Siemens Energy &
Automation, Inc.
Atlanta, GA 30346-9000

The Superior Electric Company
Bristol, CT 06010

Toshiba International Corporation
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