Superior Electric

SLO-SYN® DC Step Motors

INTRO

Superior Electric and DC Step Motors

Superior Electric is recognized worldwide as the leading manufacturer of step motor positioning systems. Over 40 years ago, Superior Electric developed and patented their SLO-SYN® Step Motor products. Today, SLO-SYN® step motors and drives are the industry standard providing reliable, accurate positioning for a wide range of applications.

- Available in standard NEMA frame sizes: 23, 34, 42, 66
- Standard and High Torque
- Hazardous Duty models
- Washdown Models

Your partner in Motion Control

Superior Electric has extensive experience in customizing motors to meet our customer's specific design requirements. Our engineering staff will work with you to achieve your product performance goals. We provide motion control solutions for a wide variety markets and applications including:

- Semiconductor manufacturing
- Packaging
- Printing
- Industrial Automation
- Testing and measurement

Superior Electric's flexible manufacturing capabilities enable us to deliver specialized product quickly – helping you meet your development cycle objectives.

To complement these precision devices, Superior Electric offers a comprehensive line of Drives and Controls designed to optimize the output performance of a motion control system. Theses electronics address a wide array of requirements, ranging from simple repetitive moves to complex multi-axis motion. On-going motion controller product development enables Superior to provide innovative, leading edge solutions to our customers.

One of the best reasons to select a Superior Electric product is our "superior" service and support. Our SLO-SYN® products are available globally through the industry's most extensive and experienced distributor network. These trained distributors provide valuable technical assistance, in addition to fast delivery and service. A team of SLO-SYN® application engineers backs our distributor network. The combined experience of this support system ensures that our customers receive prompt, quality attention to their needs, no matter where they are located.

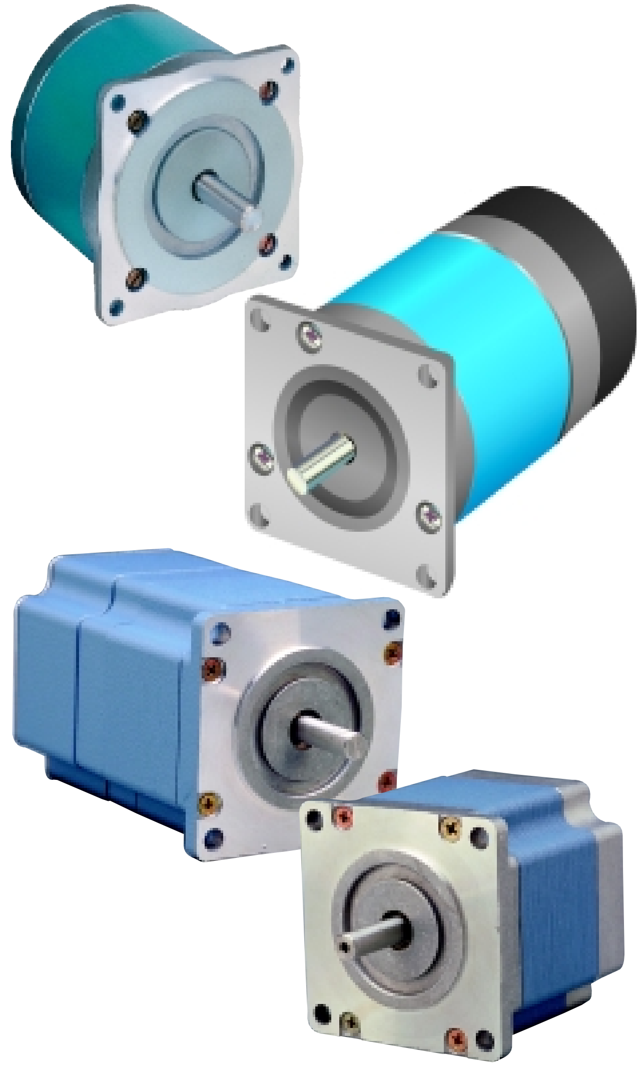
Further assistance and support is provided via Superior Electric's web site (superiorelectric.com). Visitors to this site will find product information, technical specifications, and information on our Distribution Network. In addition, CAMAS Motor Selection Software is available as a free download. This Windows based program helps determine the torque and speed requirements of an application.

The SLO-SYN® family of automation products also includes AC Synchronous Motors, AC Gearmotors and Servo Motors and Amplifiers.

Superior Electric is a member of the Danaher Motion Control Group, a global leader in Motion Control solutions.

INTRO TO MOTORS

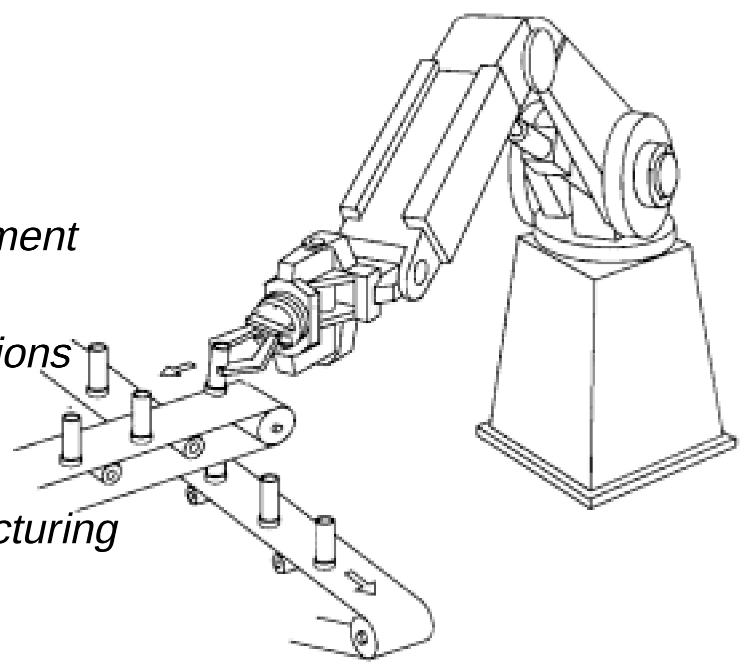
Introduction to Step Motors



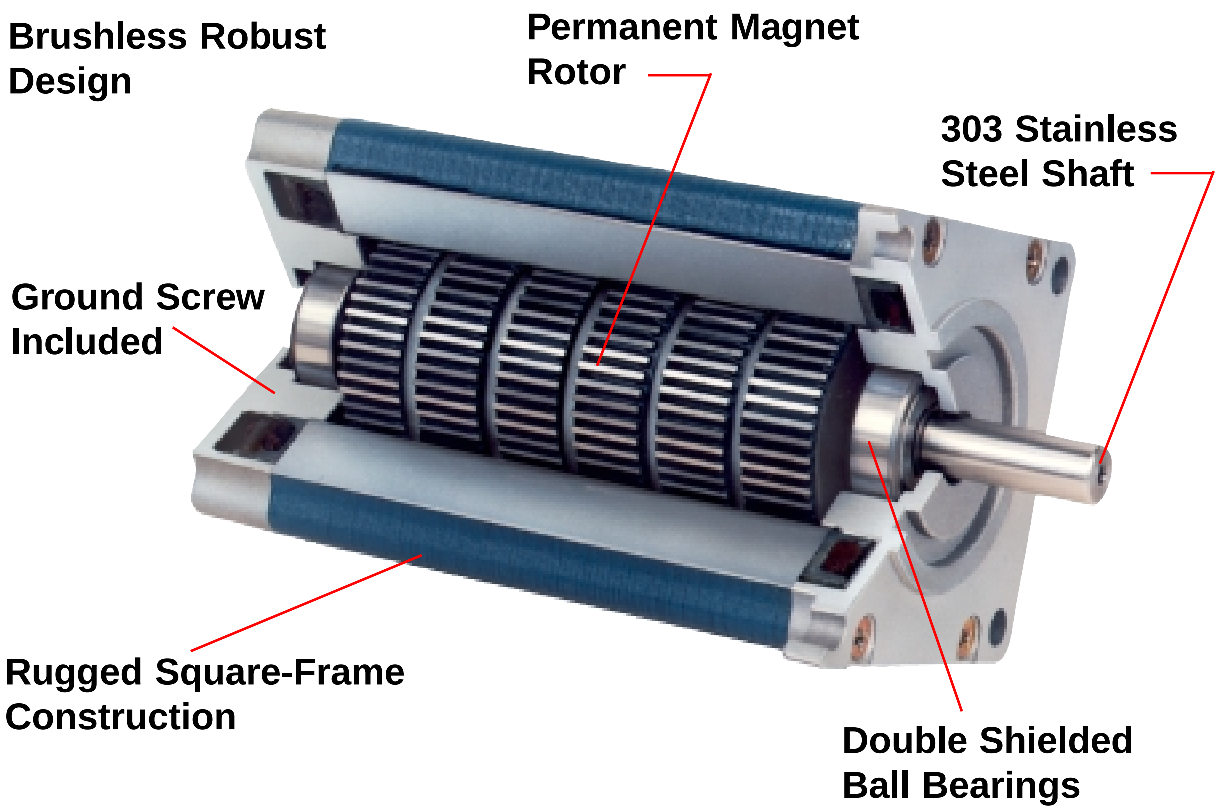
Step motors are capable of very precise positioning without the use of complicated and expensive feedback devices, although feedback systems may be incorporated into step motor systems if position comparison is desired. Because of the simplified control needs and the freedom from expensive feedback requirements, step motors are viable alternatives to pneumatic, hydraulic and servo motor systems. Step position loads by operating in discrete increments, or steps, unlike other devices that operate at constant speeds. The stepping action is accomplished by switching the power to the motor windings so that the motor phases are energized in a specific sequence.

Typical Applications

- *Automation and inspection*
- *Conveyor Transfer*
- *Cut-to-length metal, plastic, fabric, etc.*
- *Industrial HVAC*
- *Material Handling*
- *Medical equipment*
- *Office peripheral equipment*
- *Packaging systems*
- *Pick-and-place applications*
- *Printing systems*
- *Robotics*
- *Semiconductor manufacturing*
- *XYZ Applications*



Features of a High Torque Step Motor



Sizing and Selection Software for Superior Electric SLO-SYN® Products

How to Select a Stepper Motor

Successful application of a step motor requires careful selection of the proper step motor drive and control as well as the correct step motor. Since step motor systems are often used as ultra high performance positioning systems or motion controls, selection of the optimum motor/drive combination is of prime importance. The first step in the selection process is to decide the kind of system to use. Examples include Cylinder/Rod (solid or hollow), Lead Screw, Rack and Pinion, Disc/Pulley, Conveyer or Nip Rollers. A complete load analysis will be required to determine the correct motor size and the amount of torque needed to drive the load. Then it is necessary to determine which motor will best suit the application: Stepper Motor or Servo Motor. CAMAS software for Windows is a menu driven program which will make all these calculations for you. CAMAS is free software which is available upon request.

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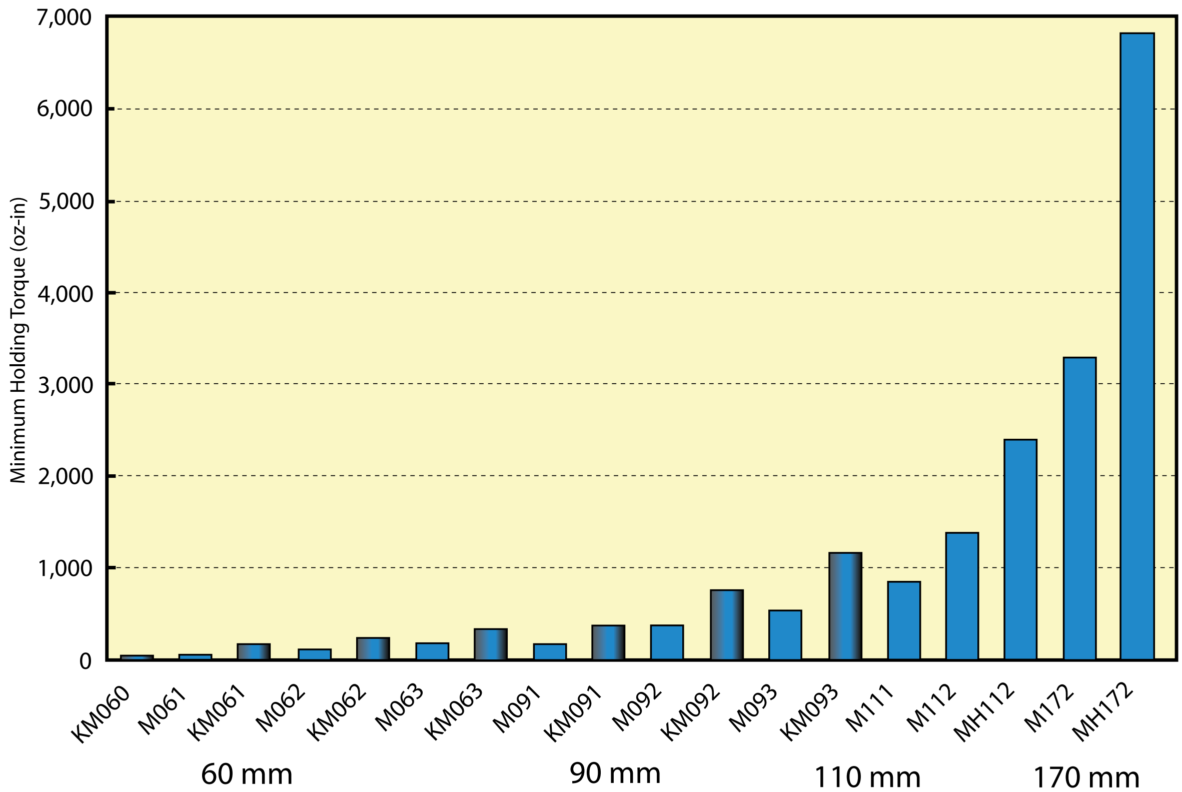
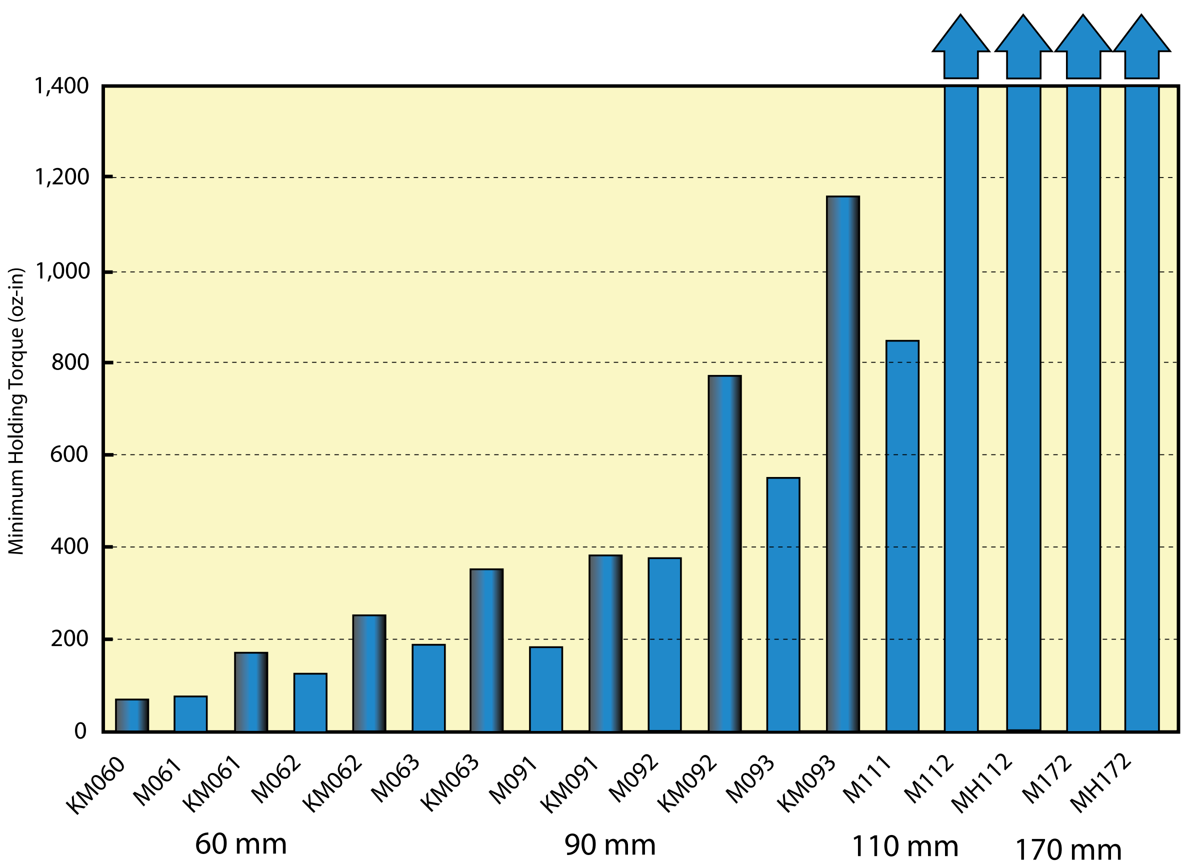
QUICK SELECT GUIDE

NEMA Frame	Product Line	Model	Holding Torque oz-in (Ncm)	Rotor Inertia oz-in-s^2 (kg-cm^2)
23	Standard SLO-SYN	M061	75 (53)	0.0017 (0.12)
		M062	125 (88)	0.0034 (0.24)
	KM Series High Torque	KM060	68 (48)	0.00154 (0.108)
		KM061	170 (120)	0.0034 (0.24)
		KM062	250 (177)	0.0056 (0.395)
		KM063	350 (247)	0.0084 (0.593)
34	Standard SLO-SYN	M091	180 (127)	0.0095 (0.67)
		M092	370 (261)	0.0174 (1.23)
		M093	550 (388)	0.0265 (1.87)
	KM Series High Torque	KM091	385 (272)	.016 (1.13)
		KM092	770 (544)	.031 (2.19)
		KM093	1155 (816)	.047 (3.32)
42	Standard SLO-SYN	M111	850 (600)	0.055 (3.93)
		M112	1390 (981)	0.114 (8.06)
	MH Series High Torque	MH112	2400 (1690)	0.133 (9.42)
66		MH172	4200 (2970)	0.870 (61.4)

MOTORS BY FRAME



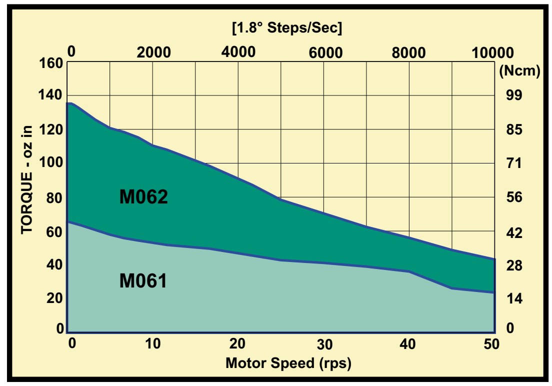


M06

Standard 60mm Frame Size (NEMA Size 23)

Performance Envelope

(see page DC11 for detailed torque-speed curves)



- Up to 150% rated torque reserve capacity
- ± 3% typical step accuracy
- Standard terminal box, encoders, and precision gearheads available
- Available with four, six or eight leads
- Customized configurations available

Motor Frame	Minimum Holding Torque		Rotor Inertia	Weight		Maximum Shaft Load		Minimum Residual Torque
	Unipolar 2Ø on	Bipolar 2Ø on		Net*	Ship*	Overhang	Thrust	
	oz-in (Ncm)	oz-in (Ncm)	oz-in-s² (kg-cm²)	lb (kg)	lb (kg)	lb (kg)	lb (kg)	oz-in (Ncm)
M061	60 (42)	75 (53)	0.0017 (0.12)	1.3 (0.57)	1.5 (0.68)	15 (6.8)	25 (11)	1.0 (0.71)
M062	100 (71)	125 (88)	0.0034 (0.24)	2.0 (0.91)	2.5 (1.1)	15 (6.8)	25 (11)	1.4 (0.99)

** Weight for motor with leads*

M06

M **06** ☐ ☐ ☐ ☐ ☐ **to add encoder see next page**

Stack Length
1 single stack
2 double stack

L leads
T terminal box

Connections
F 4
S 6
E 8

XX total current

E **double ended shaft**
(not available with terminal box or encoder)

See next page for detailed model number information

4-CONNECTION STEP MOTORS					
Model Number◊		Winding Specifications			
New	Old (Leads)	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH
See next page for options					
M061-¨F01	M061-LF-408	8.0	0.50	16	61
M061-¨F02	M061-FF-206	6.3	1.0	6.3	25
M062-¨F02	M062-LF-402	6.6	1.0	6.6	33
M062-¨F03	M062-FF-206	4.8	1.7	2.8	13

6-CONNECTION STEP MOTORS								
Model Number	Winding Specifications							
	Unipolar				Bipolar Series			
See next page for options	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH
M061-☐S01	11	0.44	23	38	16	0.30	45	150
M061-☐S02	5.0	1.0	5.0	9.6	7.0	0.70	10	38
M061-☐S08	1.3	3.8	0.33	0.64	1.8	2.7	0.66	2.5
M062-☐S03	5.3	1.6	3.3	8.3	7.5	1.1	6.6	33
M062-☐S04	4.2	1.9	2.2	5.9	5.9	1.3	4.4	24
M062-☐S06	2.6	3.1	0.88	2.0	3.9	2.2	1.8	8.0
M062-☐S09	1.7	4.7	0.35	0.80	2.3	3.3	0.7	3.2

*Old Model # is: M061-☐S-301

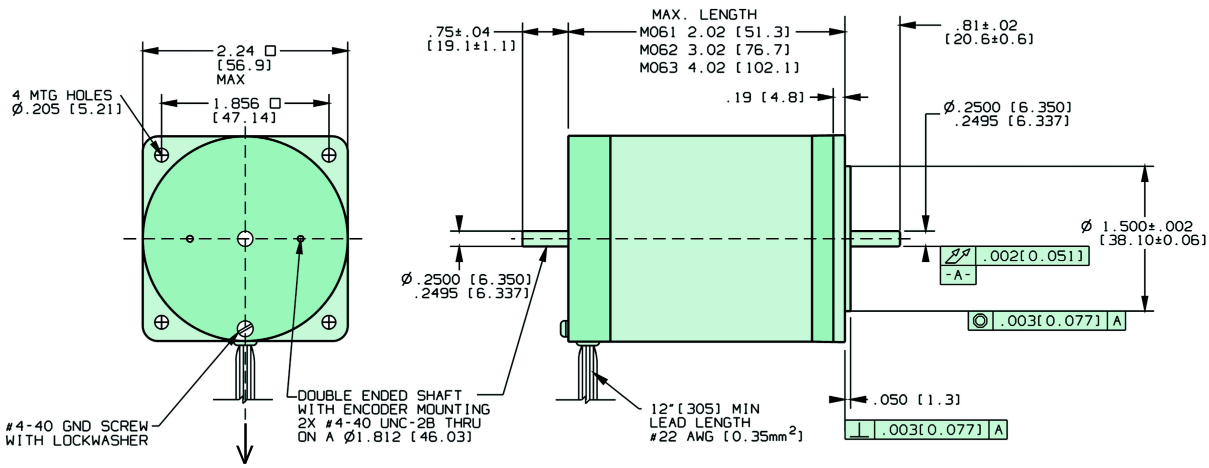
8-CONNECTION STEP MOTORS								
Model Number	Winding Specifications							
	Unipolar				Bipolar Parallel♦			
See next page for options	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH
M061-☐E02	5.0	1.0	5.0	9.6	3.5	1.4	2.5	9.6
M061-☐E08	1.3	3.8	0.33	0.64	0.89	5.4	0.16	0.64
M061-☐E04	4.2	1.9	2.2	5.9	3.0	2.7	1.1	5.9
M062-☐E06	2.6	3.1	0.88	2.0	1.9	4.4	0.44	2.0
M062-☐E09	1.7	4.7	0.35	0.80	1.2	6.7	0.18	0.80

◊ *nameplate may reference old model number*

♦ *see 6-lead table for 8-lead bipolar series ratings*

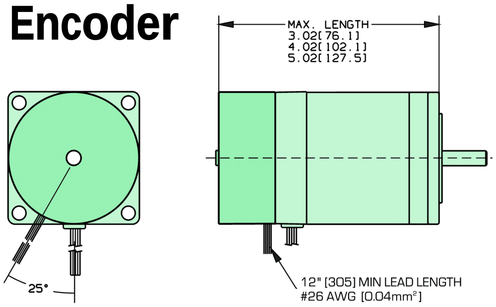
M06

Motor Dimensions

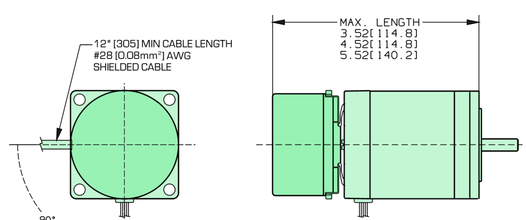


Add "E" to model number for double ended shaft. Example: M062-LS03E

Encoder



200, 400, 500 Pulse/Rev Encoders



1250 Pulse/Rev Encoder

Add to Model Number:

C 500 6

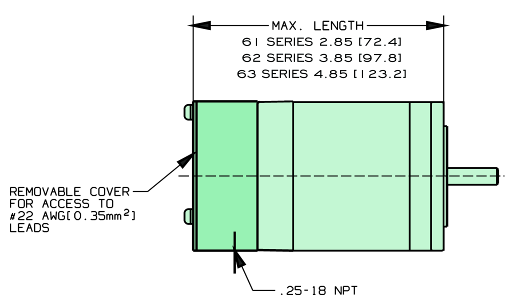
Pulses per Revolution
200, 400, 500, or 1250

Number of Outputs		
2	A, B	*(not available with 1250)*
3	A, B, Index	*(not available with 1250)*
6	A, B, Index, A, B, Index	
Differential Line Drivers supplied with 6 outputs		

M061-LE08C2003	single stack, eight leads, 8 amps, 200 pulse encoder with A , B outputs
M062-LS09C12506	double stack, six leads, 9 amps, 1250 pulse encoder with 6 ouputs.

(consult factory for encoder with terminal box)

Terminal Box



Change Model Number:

Example: M062-TE09 (double stack, terminal box, eight leads, 9 amp winding)

(consult factory for encoder with terminal box)

M06

24 V Bipolar - Full Step

- 24 volt data measured with SD200 Modular Drive Module or the SS2000MD4 Modular Drive.

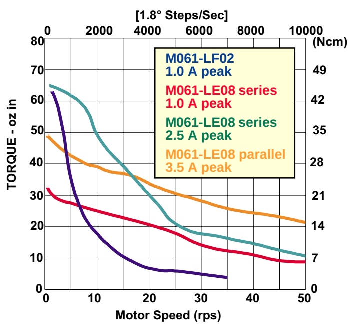
36 V Bipolar - Full Step

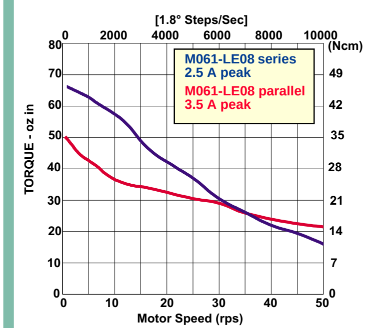
- 36 volt data measured with SD200 Modular Drive Module or the SS2000MD4 Modular Drive.

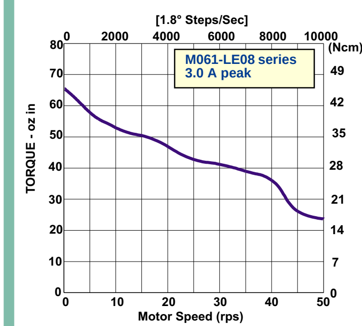
72 V Bipolar - Full Step

- 72 volt data measured with MD808 Modular Drive

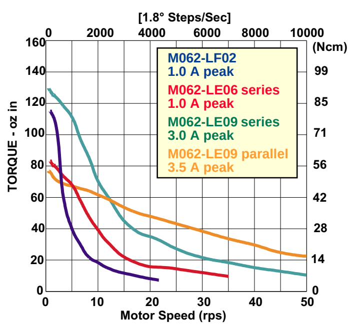
M061

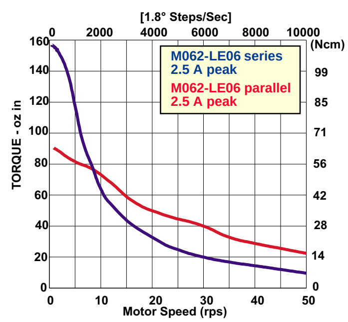


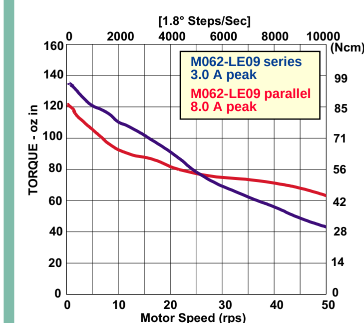




M062



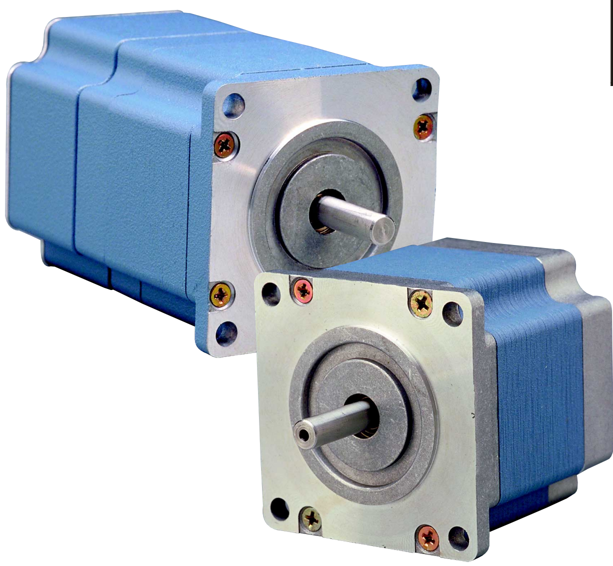




- The curves do not show system resonances which will vary with system mechanical parameters.
- Duty cycle is dependent on torque, speed, Drive parameters, and heat sink conditions. Maximum case temperature is 100°C.

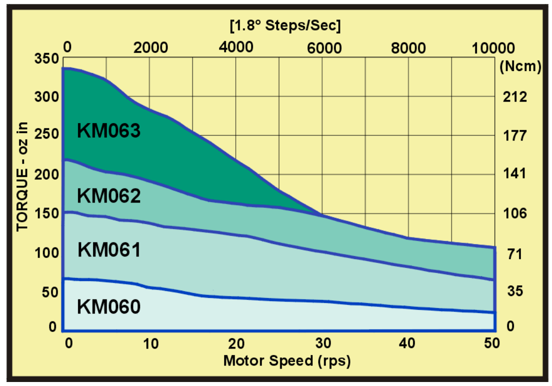
KM06

High Torque 60mm Frame Size (NEMA Size 23)



Performance Envelope

(see page DC15 for detailed torque-speed curves)

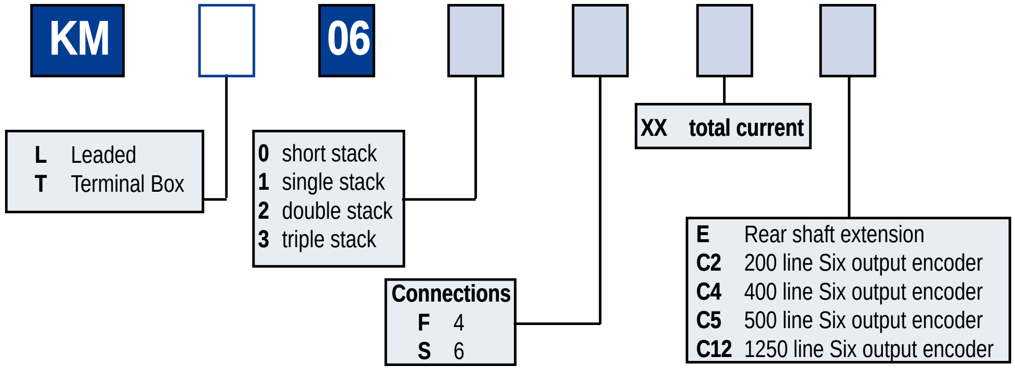


- Up to 200% rated torque reserve capacity
- ± 2% typical step accuracy
- Terminal box, encoders, precision gearheads and rear shafts available
- Available with four or six leads
- Customized configurations available

Washdown Motors Available see page DC 16

Motor Frame	Minimum Holding Torque		Rotor Inertia	Weight		Maximum Shaft Load		Minimum Residual Torque
	Unipolar 2Ø on	Bipolar 2Ø on		Net*	Ship*	Overhang	Thrust	
	oz-in (Ncm)	oz-in (Ncm)	oz-in-s² (kg-cm²)	lb (kg)	lb (kg)	lb (kg)	lb (kg)	oz-in (Ncm)
KM060	54 (38)	68 (48)	0.00154 (0.108)	1.03 (0.47)	1.1 (0.050)	15 (6.8)	25 (11)	2.0 (1.4)
KM061	128 (90.4)	170 (120)	0.0034 (0.24)	1.6 (0.73)	1.7 (0.77)	15 (6.8)	25 (11)	3.0 (2.1)
KM062	188 (133)	250 (177)	0.0056 (0.395)	2.3 (1.04)	2.5 (1.1)	15 (6.8)	25 (11)	6.0 (4.2)
KM063	263 (186)	350 (247)	0.0084 (0.593)	3.2 (1.45)	3.4 (1.5)	15 (6.8)	25 (11)	7.0 (4.9)

* *Weight for motor with leads (add approx. 0.2 lbs. for terminal box)*



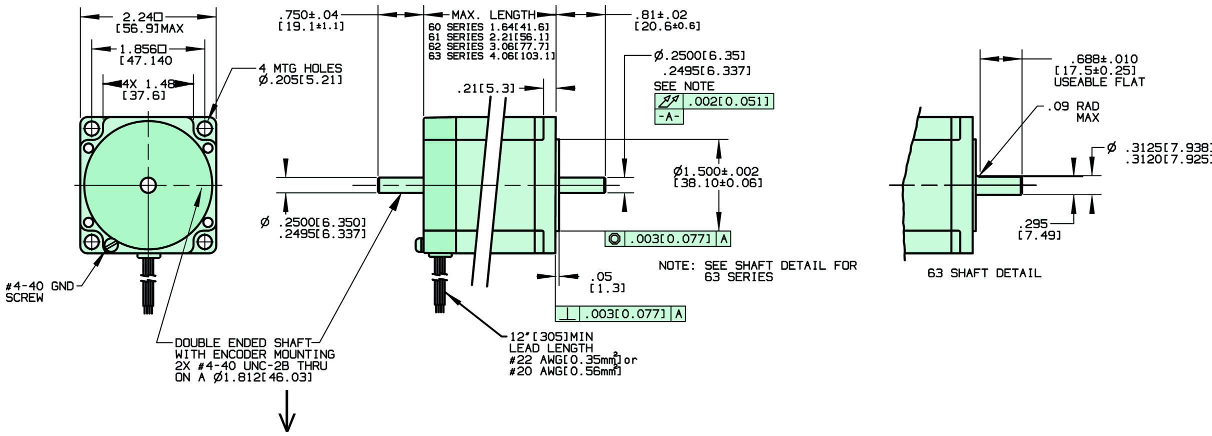
KM06

See next page for detailed model number information

4-CONNECTION STEP MOTORS				
Model Number	Winding Specifications			
See next page for options	Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)
KM□060F02	3.8	1.1	3.6	16
KM□060F05	1.7	2.7	0.64	2.5
KM□060F08	1.1	4.0	0.28	1.0
KM□060F11	1.0	5.3	0.19	0.63
KM□061F02	5.2	1.1	4.9	30
KM□061F03	4.2	1.4	3.0	16
KM□061F05	2.3	2.7	0.85	4.6
KM□061F08	1.4	4.1	0.33	1.8
KM□061F11	1.2	5.4	0.23	1.1
KM□062F03	4.4	1.5	2.9	17
KM□062F05	3.1	2.5	1.3	7.1
KM□062F07	2.5	3.3	0.75	3.4
KM□062F08	2.0	4.1	0.49	2.5
KM□062F13	1.3	6.6	0.20	0.85
KM□063F03	6.1	1.5	4.1	24
KM□063F04	5.0	1.8	2.8	17
KM□063F07	3.4	3.3	1.0	6.2
KM□063F08	2.6	4.1	0.64	3.9
KM□063F13	1.9	6.6	0.28	1.5

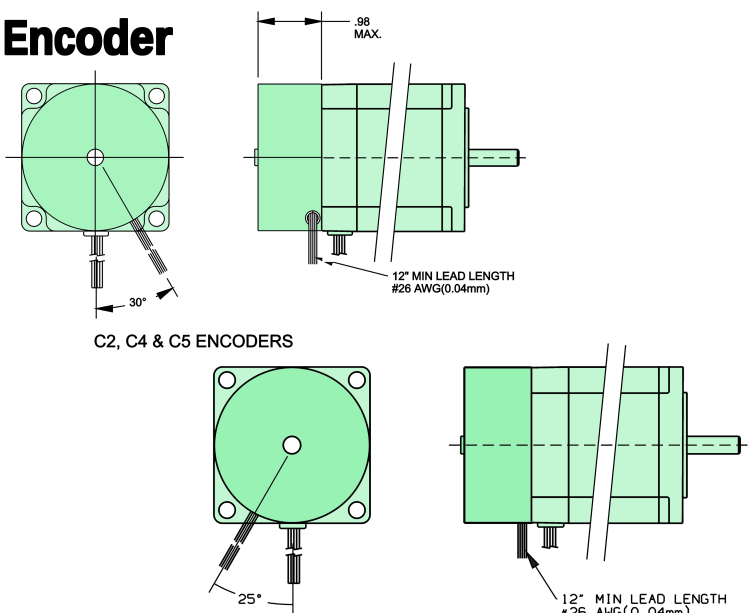
6-CONNECTION STEP MOTORS								
Model Number	Winding Specifications							
	Unipolar				Bipolar Series			
See next page for options	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH
KMo060S03	2.9	1.5	1.9	4.0	4.0	1.0	3.9	16
KMo060S08	1.3	3.8	0.34	0.63	1.8	2.7	0.67	2.5
KMo061S02	6.4	1.0	6.4	18	9.0	0.70	13	70
KMo061S04	3.0	2.1	1.5	3.5	4.2	1.4	2.9	14
KMo061S08	1.7	3.8	0.46	1.1	2.4	2.7	0.92	4.4
KMo062S04	3.1	2.1	1.5	4.2	4.4	1.5	2.9	17
KMo062S06	2.8	3.0	0.94	2.5	3.9	2.1	1.9	10
KMo062S09	1.8	4.7	0.38	0.85	2.5	3.3	0.75	3.4
KMo063S04	4.3	2.1	2.0	6.0	6.0	1.5	4.0	24
KMo063S09	2.5	4.7	0.54	1.6	3.5	3.3	1.1	6.3

Motor Dimensions



Add "E" to model number for double ended shaft. Example: KML062F07E

Encoder



C2, C4 & C5 ENCODERS

C12 ENCODERS

Add to Model Number:

C2	200 lines per rev.
C4	400 lines per rev.
C5	500 lines per rev.
C12	1250 lines per rev.

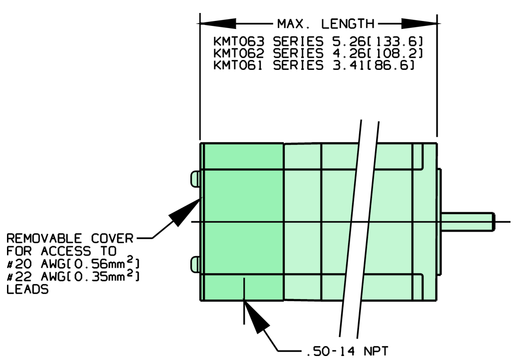
Outputs: A, B, Index,
$\overline{A}$, $\overline{B}$, $\overline{\text{Index}}$,

Differential Line Drivers supplied

Example: KML063S09C5

(consult factory for encoder with terminal box)

Terminal Box



Change Model Number:

Example: KMT063S09 (triple stack, terminal box, six leads, 9 amp winding)

KMCT062F05 (double stack, CE conform terminal box, four leads, 5 amp winding)

(consult factory for encoder with terminal box)

SLO-SYN® DC STEP MOTORS

KM06

24 V Bipolar - Full Step	36 V Bipolar - Full Step	72 V Bipolar - Full Step

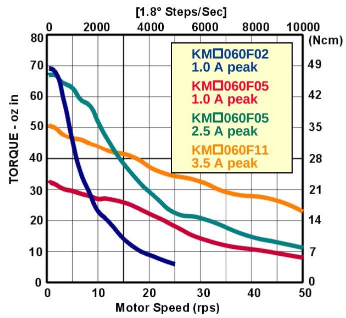
◆ 24 and 36 volt data measured with SD200 Modular Drive Module or the SS2000MD4 Modular Drive.

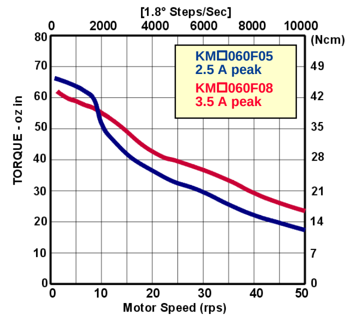
◆ 72 volt data measured with MD808 Modular Drive

◆ The curves do not show system resonances which will vary with system mechanical parameters.

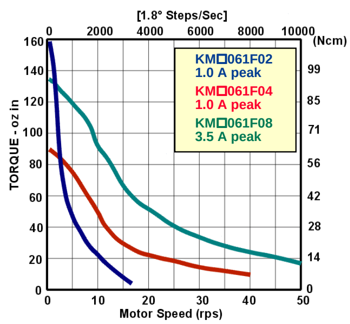
◆ Duty cycle is dependent on torque, speed, Drive parameters, and heat sink conditions. Maximum case temperature is 100°C.

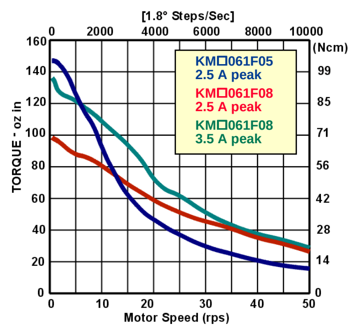
KM□060

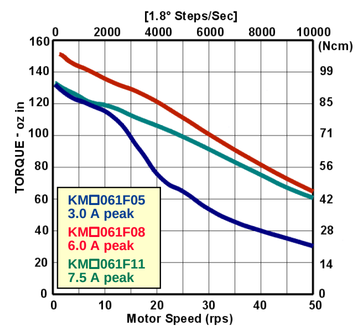




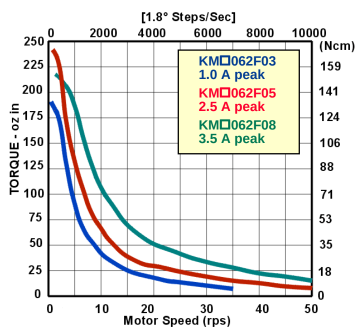
KM□061

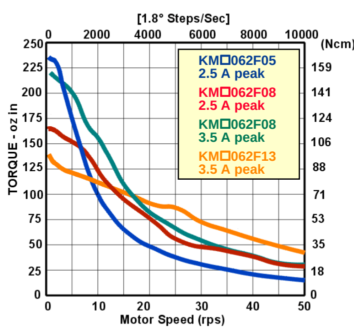


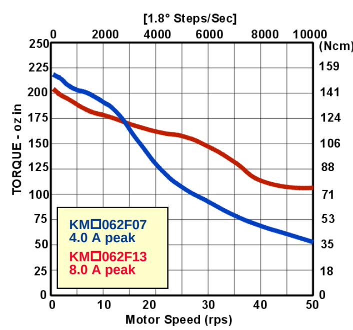




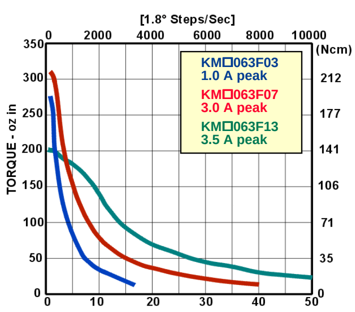
KM□062

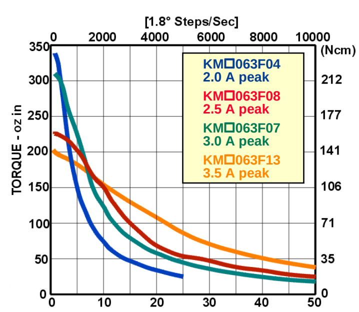


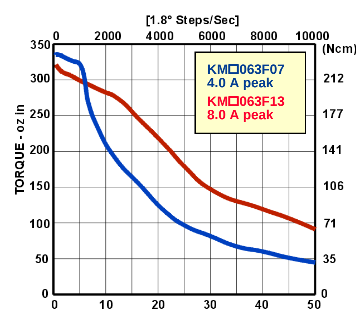




KM□063







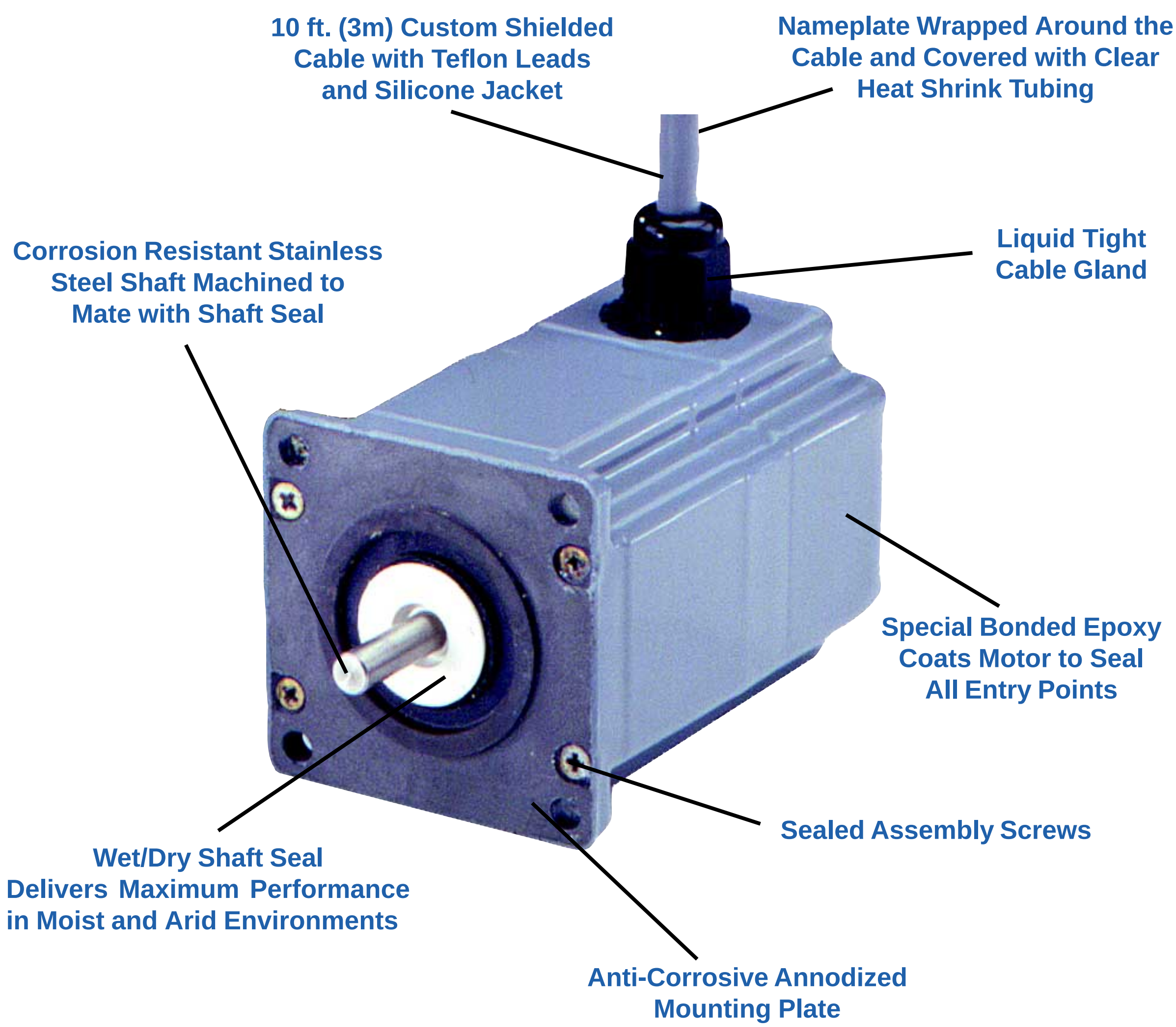
KMWS06

High Torque 60mm Washdown Motors

SLO-SYN® washdown motors are designed to deliver flawless motion control in both wet and arid conditions. They are dust protected and withstand powerful jets of fluid.

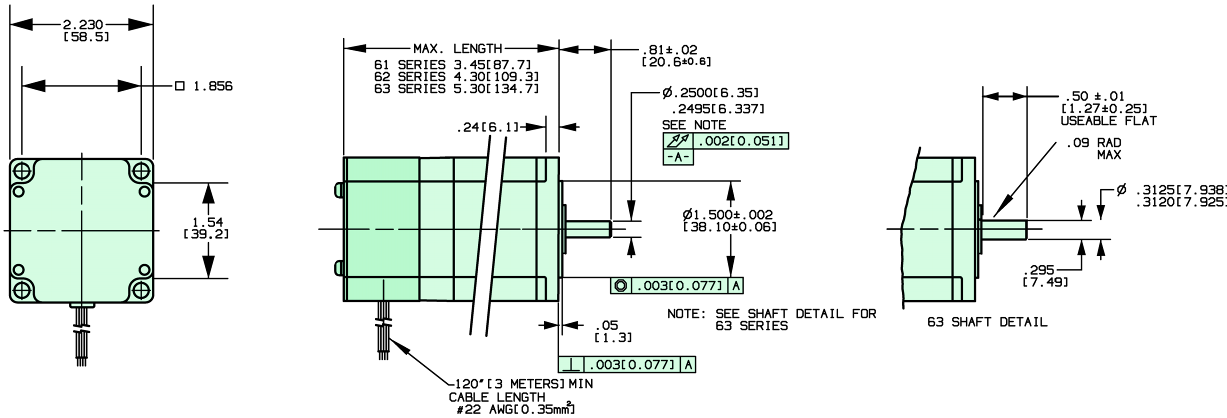
SLO-SYN® Washdown Motors Withstand IP 56 Conditions:

- Water & Salt Water
- Oil
- Grease
- Common Solvents
- Weak Acids
- Alcohol
- Dust
- Lint
- Fibers



KMWS06

Dimensions



Dimensions are shown in inches(mm)

KM **WS** **06** [ ] **F** [ ]

0 short stack	**2** double stack
1 single stack	**3** triple stack

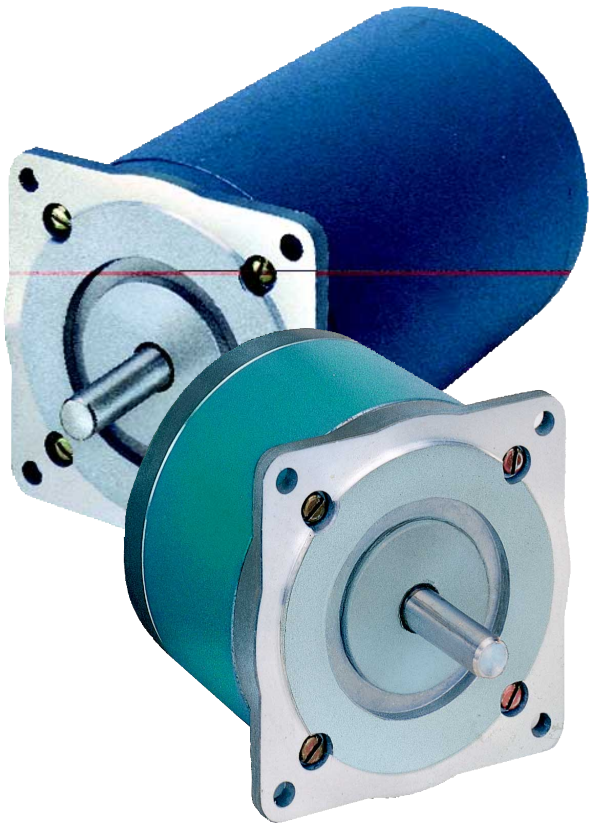
XX **total current**

(Refer to chart below to select winding)

4-CONNECTION STEP MOTORS				
Model Number	**Winding Specifications**			
	Voltage (VDC)	**Current (Amperes)**	**Resistance (ohms)**	**Inductance (mH)**
KMWS060F02	3.8	1.1	3.6	16
KMWS060F05	1.7	2.7	0.64	2.5
KMWS060F08	1.1	4.0	0.28	1.0
KMWS060F11	1.0	5.3	0.19	0.63
KMWS061F02	5.2	1.1	4.9	30
KMWS061F03	4.2	1.4	3.0	16
KMWS061F05	2.3	2.7	0.85	4.6
KMWS061F08	1.4	4.1	0.33	1.8
KMWS061F11	1.2	5.4	0.23	1.1
KMWS062F03	4.4	1.5	2.9	17
KMWS062F05	3.1	2.5	1.3	7.1
KMWS062F07	2.5	3.3	0.75	3.4
KMWS062F08	2.0	4.1	0.49	2.5
KMWS062F13	1.3	6.6	0.20	0.85
KMWS063F03	6.1	1.5	4.1	24
KMWS063F04	5.0	1.8	2.8	17
KMWS063F07	3.4	3.3	1.0	6.2
KMWS063F08	2.6	4.1	0.64	3.9
KMWS063F13	1.9	6.6	0.28	1.5

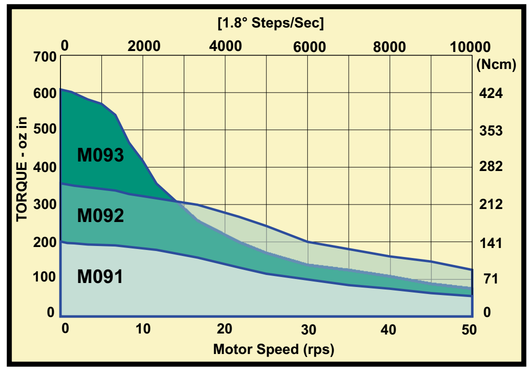
M09

Standard 90mm Frame Size (NEMA Size 34)



Performance Envelope

(see page DC21 for detailed torque-speed curves)



- Up to 150% rated torque reserve capacity
- ± 3% typical step accuracy
- CE conforming motors available
- Standard terminal box, encoders, and precision gearheads available
- Available with four or six leads
- Customized configurations available

Motor Frame	Minimum Holding Torque		Rotor Inertia	Weight		Maximum Shaft Load		Minimum Residual Torque
	Unipolar 2Ø on	Bipolar 2Ø on		Net*	Ship*	Overhang	Thrust	
	oz-in (Ncm)	oz-in (Ncm)	oz-in-s² (kg-cm²)	lb (kg)	lb (kg)	lb (kg)	lb (kg)	oz-in (Ncm)
M091	150 (106)	180 (127)	0.0095 (0.67)	3.3 (1.5)	4.0 (1.8)	25 (11)	50 (23)	2.0 (1.4)
M092	300 (212)	370 (261)	0.0174 (1.23)	5.5 (2.5)	6.8 (3.1)	25 (11)	50 (23)	4.0 (2.8)
M093	450 (318)	550 (388)	0.0265 (1.87)	7.8 (3.5)	9.0 (4.1)	25 (11)	50 (23)	7.0 (4.9)

* *Weight for motor with leads*

M09

M | 09 | ☐ | ☐ | ☐ | ☐ | ☐ | to add encoder see next page

Stack Length
1 single stack
2 double stack
3 triple stack

L leads
T terminal box

Connections
F 4
S 6
E 8

XX total current

E double ended shaft
(not available with terminal box or encoder)

See next page for detailed model number information

4-CONNECTION STEP MOTORS					
Model Number◊		**Winding Specifications**			
New	**Old**	**Voltage VDC**	**Current Amperes**	**Resistance ohms**	**Inductance mH**
See next page for options					
M091-☐F02	M091-FF-401♦	6.8	1.0	6.8	52
M091-☐F06	M091-FF-206•	3.0	3.0	1.0	10
M092-☐F04	M092-FF-402♦	3.4	2.0	1.7	17
M092-☐F08	M092-FF-206•	4.0	4.0	1.0	11
M093-☐F06	M093-FF-402♦	4.5	3.0	1.5	17
M093-☐F08	M093-FF-206•	3.9	4.0	0.96	13

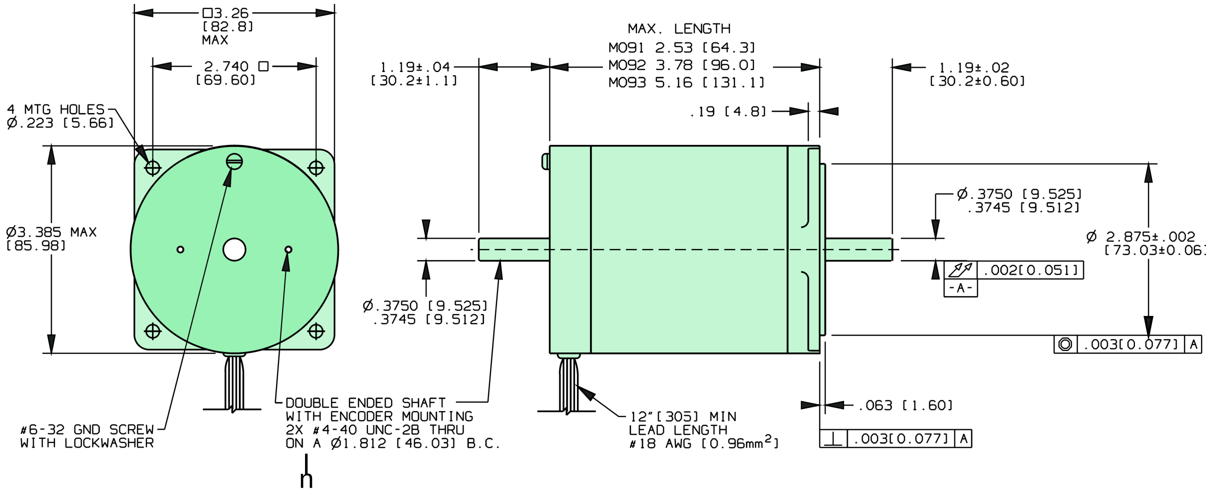
6-CONNECTION STEP MOTORS									
Model Number◊		**Winding Specifications**							
New	**Old (Leads)**	**Unipolar**				**Bipolar Series**			
See next page for options		**Voltage VDC**	**Current Amperes**	**Resistance ohms**	**Inductance mH**	**Voltage VDC**	**Current Amperes**	**Resistance ohms**	**Inductance mH**
M091-☐S03	M091-FD03	5.3	1.6	3.3	17	7.3	1.1	6.6	66
M091-☐S06	M091-FD06	2.6	3.1	0.85	4.1	4.8	2.2	1.7	17
M091-☐S09	M091-FD09	1.7	4.7	0.36	1.5	2.4	3.3	0.72	6.0
M092-☐S08	M092-FD08	3.0	4.0	0.75	3.6	4.2	2.8	1.5	14
M092-☐S09	M092-FD09	2.5	4.6	0.55	2.8	3.6	3.3	1.1	11
M093-☐S07	M093-FD07	4.3	3.5	1.2	7.9	6.1	2.5	2.4	31
M093-☐S11	M093-FD11	2.7	5.5	0.48	3.2	3.8	3.9	0.96	13
M093-☐S14	M093-FD14	2.3	7.0	0.33	2.0	3.2	5.0	0.65	8.0

8-CONNECTION STEP MOTORS									
Model Number◊		**Winding Specifications**							
New	**Old (Leads)**	**Unipolar**				**Bipolar Parallel***			
See next page for options		**Voltage VDC**	**Current Amperes**	**Resistance ohms**	**Inductance mH**	**Voltage VDC**	**Current Amperes**	**Resistance ohms**	**Inductance mH**
M091-☐E06	M091-FD-8106	2.6	3.1	0.85	4.1	1.9	4.4	0.43	4.1
M091-☐E09	M091-FD-8109	1.7	4.7	0.35	1.5	1.2	6.6	0.18	1.5
M092-☐E08	M092-FD-8108	3.0	4.0	0.75	3.6	2.1	5.7	0.38	3.6
M092-☐E09	M092-FD-8109	2.6	4.6	0.55	2.8	1.8	6.5	0.28	2.8
M093-☐E11	M093-FD-8111	2.6	5.5	0.48	3.2	1.9	7.8	0.24	3.2
M093-☐E14	M093-FD-8114	2.3	7.0	0.33	2.0	1.6	9.9	0.16	2.0

◊ *Nameplate may reference old model number*
♦ *Terminal box motor*
* *See 6-lead table for 8-lead bipolar ratings*
• *Leaded motor*

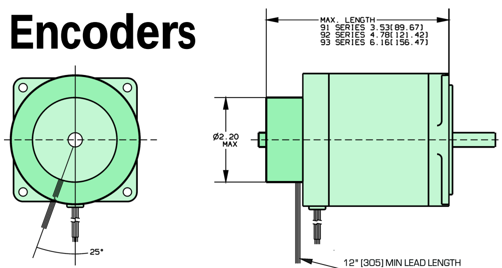
M09

Motor Dimensions

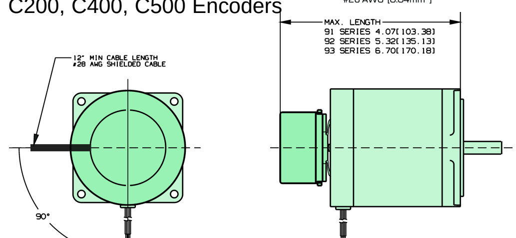


Add “E” to model number for double ended shaft. Example: M092-LS08E

Encoders



C200, C400, C500 Encoders



C1250 Encoder

Add to Model Number:

C	500	6

Pulses per Revolution

200, 400, 500, or 1250

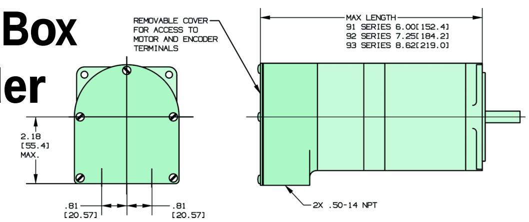
Number of Outputs

2 A, B *(not available with 1250)*
3 A, B, Index *(not available with 1250)*
6 A, B, Index, A, B, Index

Differential Line Drivers supplied with 6 outputs

M091-LE08C2003	single stack, eight leads, 8 amps, 200 pulse encoder with A , B outputs
M092-LS09C12506	double stack, six leads, 9 amps, 1250 pulse encoder with 6 ouputs.

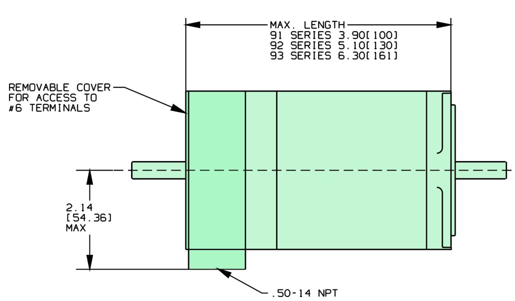
Terminal Box W/Encoder



Available on four(4) and six (6) connection motors.

Consult factory for order information

Terminal Box



Change Model Number:

Example: M092-TE09 (double stack, terminal box, eight leads, 9 amp winding)

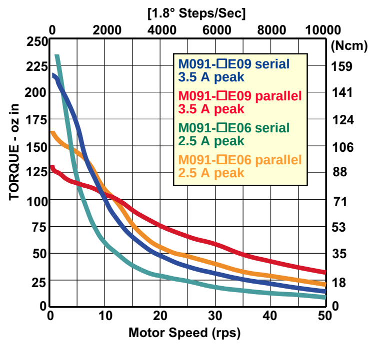
(consult factory for encoder with terminal box)

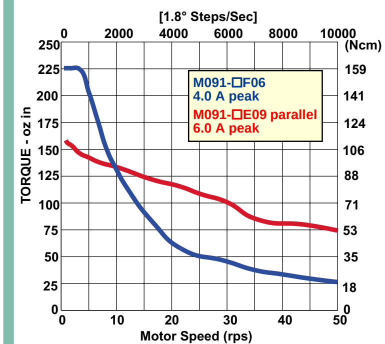
SLO-SYN® DC STEP MOTORS

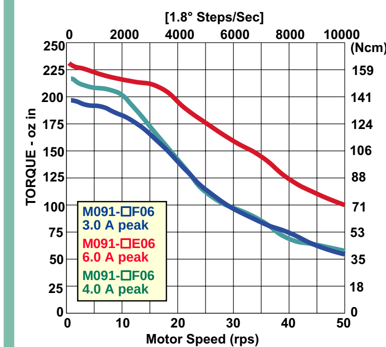
M09

36 V Bipolar - Full Step	72 V Bipolar - Microstep	170 V Bipolar - Microstep
◆ 36 volt data measured with SS2000MD4 Modular Drive.	◆ 72 volt data measured with MD808 Modular Drive.	◆ 170 volt data measured with SS2000D3 or D6 Packaged Drive

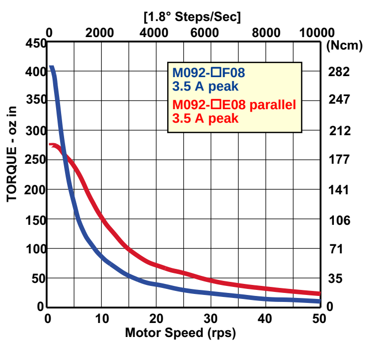
M091

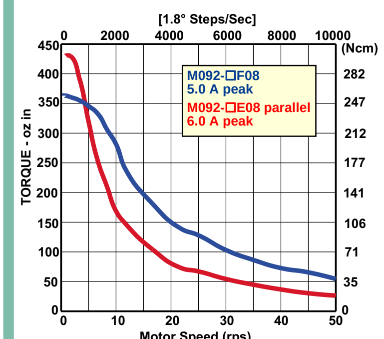


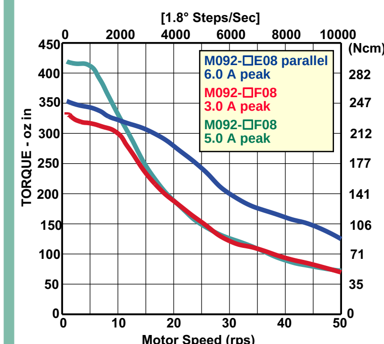




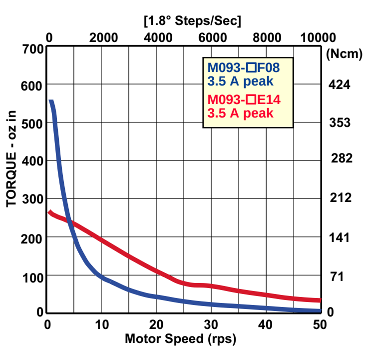
M092

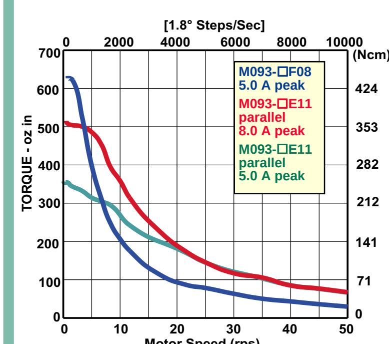


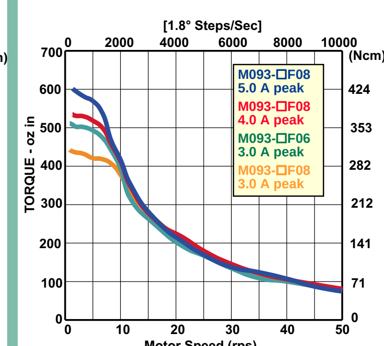




M093



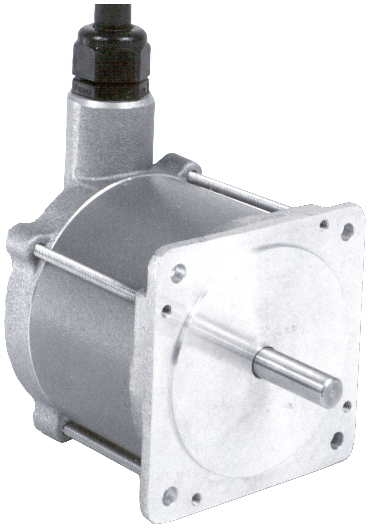




- ◆ The curves do not show system resonances which will vary with system mechanical parameters.
- ◆ Duty cycle is dependent on torque, speed, Drive parameters, and heat sink conditions. Maximum case temperature is 100°C.

MX09

Hazardous Duty 90mm Frame Size

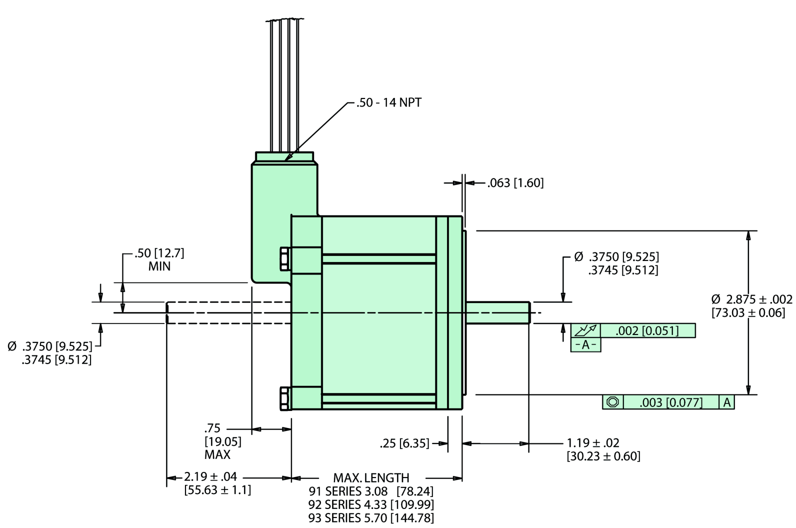


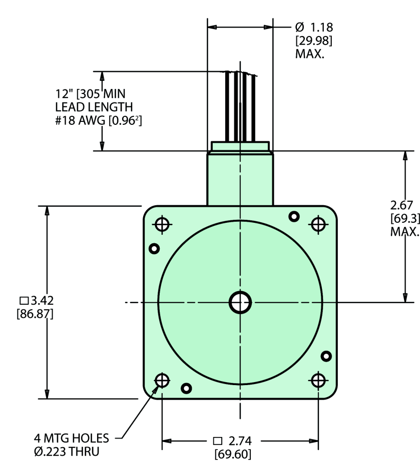
- Up to 150% rated torque reserve capacity
- ± 3% typical step accuracy
- Hazardous Duty
  UL Class 1, Division1, Group D

4-Connection Step Motors

Model #	Voltage VDC	Current Amps	R Ω	L mH
MX91-FF-206U	3.0	3.0	1.0	10
MX91-FF-402U	2.9	4.0	0.72	6.0
MX91-FF-403U	1.1	6.0	0.18	1.5
MX92-FF-206U	4.0	4.0	1.0	11
MX92-FF-401U	1.9	7.0	0.28	2.8
MX93-FF-206U	3.9	4.0	0.90	13
MX93-FF-401U	3.2	5.0	0.65	8.0
MX93-FF-402U	1.1	7.0	0.16	2.0

Change U to EU for double ended shaft.

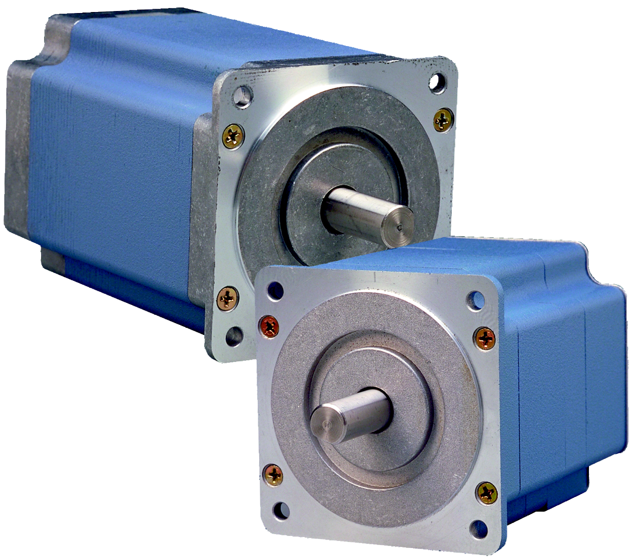




NOTES

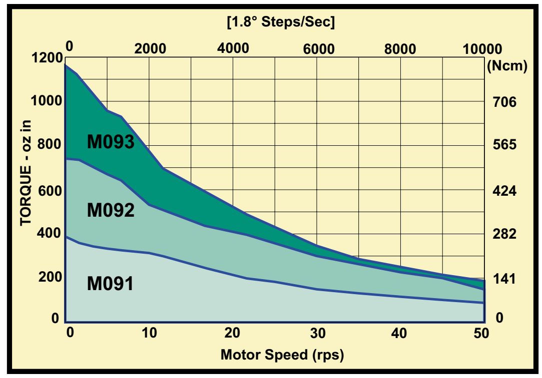
KM09

High Torque 90mm Frame Size (NEMA Size 34)



Performance Envelope

(see page DC27 for detailed torque-speed curves)



- Up to 200% rated torque reserve capacity
- ± 2% typical step accuracy
- Standard terminal box, encoders, and precision gearheads available
- Available with four or six leads
- Customized configurations available

Washdown Motors Available see page DC 28

Motor Frame	Minimum Holding Torque		Rotor Inertia	Weight		Maximum Shaft Load		Minimum Residual Torque
	Unipolar 2Ø on	Bipolar 2Ø on		Net	Ship	Overhang	Thrust	
	oz-in (Ncm)	oz-in (Ncm)	oz-in-s^2 (kg-cm^2)	lb (kg)	lb (kg)	lb (kg)	lb (kg)	oz-in (Ncm)
KM091	305 (215)	385 (272)	.016 (1.13)	3.8 (1.73)	4.0 (1.81)	25 (11)	50 (23)	10 (7.1)
KM092	610 (431)	770 (544)	.031 (2.19)	6.2 (2.82)	6.3 (2.82)	25 (11)	50 (23)	15 (11)
KM093	915 (646)	1155 (816)	.047 (3.32)	8.7 (3.95)	8.9 (3.95)	25 (11)	50 (23)	23 (16)

KM09

KM □ 09 □ □ □ □

- L Leaded
- T Terminal Box

- 1 single stack
- 2 double stack
- 3 triple stack

- F 4 leads
- S 6 leads

XX total current

- E Rear shaft extension
- C2 200 line Six output encoder
- C4 400 line Six output encoder
- C5 500 line Six output encoder
- C12 1250 line Six output encoder

See next page for detailed model number information

4-CONNECTION STEP MOTORS

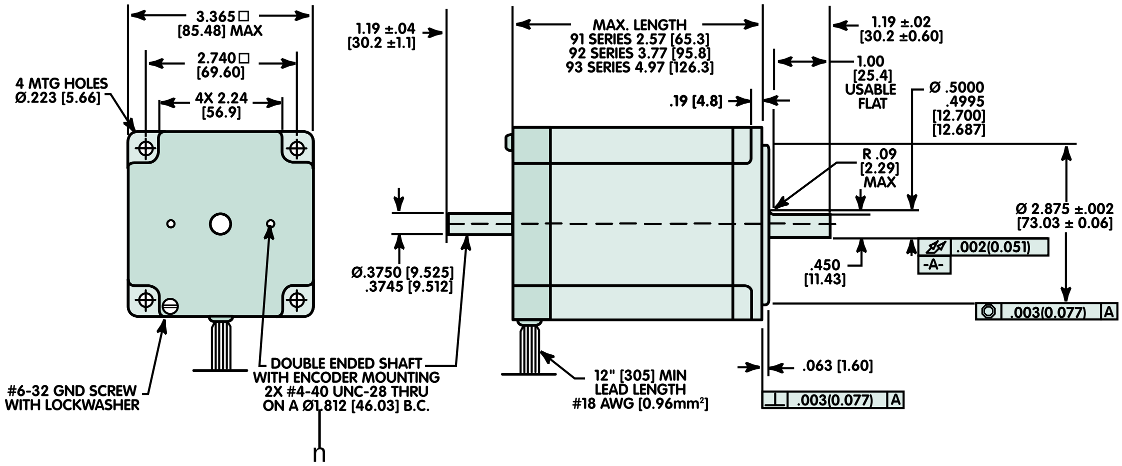
Model Number	Winding Specifications			
	Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)
KM□091F05	3.0	2.7	1.1	11
KM□091F07	2.5	3.3	0.76	7.5
KM□091F13	1.3	6.6	0.19	1.9
KM□092F07	3.5	3.3	1.1	11
KM□092F13	1.7	6.5	0.27	2.9
KM□093F07	4.9	3.4	1.4	18
KM□093F08	4.0	4.0	0.99	13
KM□093F10	3.2	5.1	0.63	8.3
KM□093F14	2.5	6.8	0.36	4.5

6-CONNECTION STEP MOTORS

Model Number	Winding Specifications							
	Unipolar				Bipolar Series			
See next page for options	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH
KMo091S02	9.3	1.0	9.3	47	13	0.70	19	190
KMo091S06	2.9	3.1	0.94	4.7	4.1	2.2	1.9	19
KMo091S08	2.1	3.8	0.55	2.9	2.9	2.7	1.1	11
KMo091S09	1.8	4.7	0.38	1.9	2.5	3.3	0.76	7.5
KMo092S09	2.5	4.6	0.54	2.8	3.4	3.2	1.1	11
KMo093S07	4.4	3.5	1.3	8.3	6.2	2.5	2.5	33
KMo093S10	3.5	4.8	0.72	4.5	4.8	3.4	1.4	18

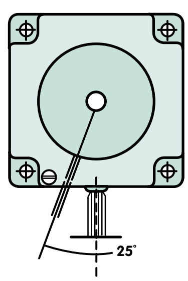
KM09

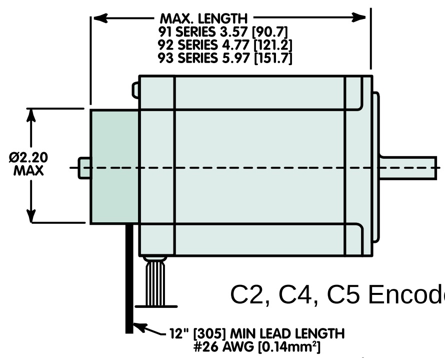
Motor Dimensions



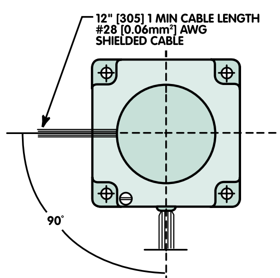
Add "E" to model number for double ended shaft. Example: KML092F07E

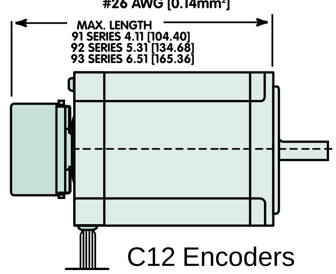
Encoder





C2, C4, C5 Encoders





C12 Encoders

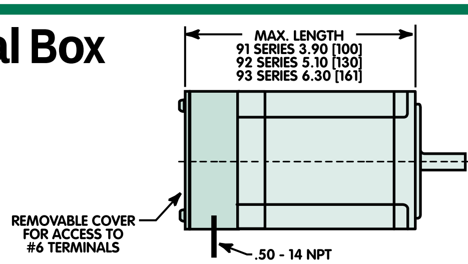
Add to Model Number:	
C2	200 lines per rev.
C4	400 lines per rev.
C5	500 lines per rev.
C12	1250 lines per rev.

Outputs: A, B, Index, $\overline{A}$, $\overline{B}$, $\overline{\text{Index}}$,

Differential Line Drivers supplied

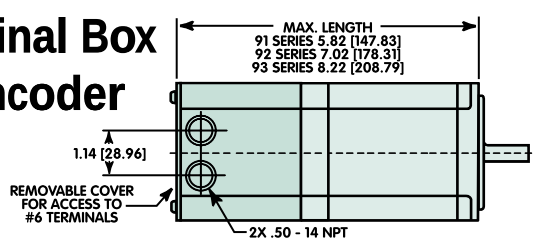
Example: KML093S07C5

Terminal Box



Change Model Number:	
Example:	KMT093S07 (triple stack, terminal box, six leads, 7 amp winding)

Terminal Box W/Encoder



Change Model Number:	
Example:	KMT092F07C12 (double stack, terminal box, four leads, 7 amp winding, C12 encoder)

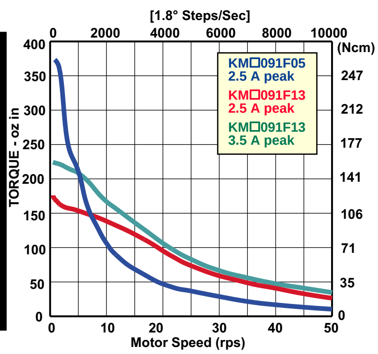
SLO-SYN® DC STEP MOTORS

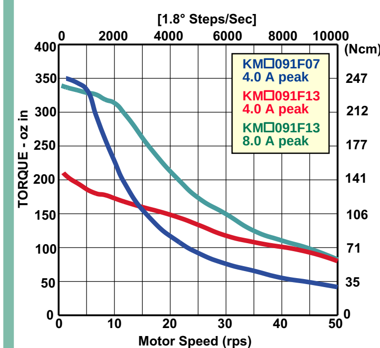
KM09

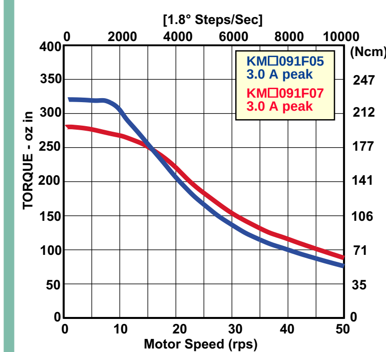
36 V Bipolar - Full Step	72 V Bipolar - Microstep	170 V Bipolar - Microstep

- 36 volt data measured with SS2000MD4 Modular Drive.
- 72 volt data measured with MD808 Modular Drive.
- 170 volt data measured with SS2000D3 or D6 Packaged Drive

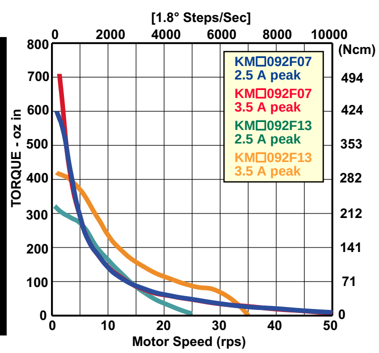
KM n 091

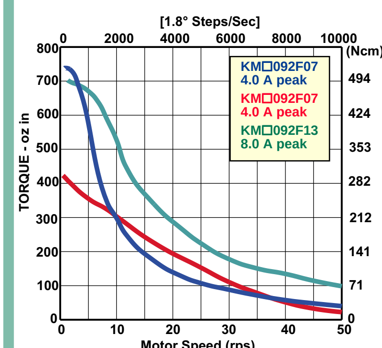


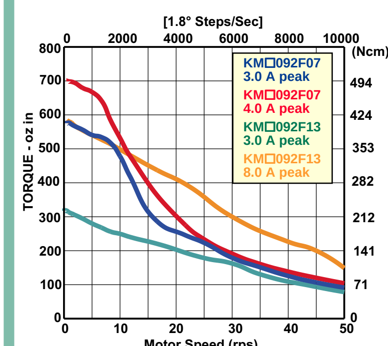




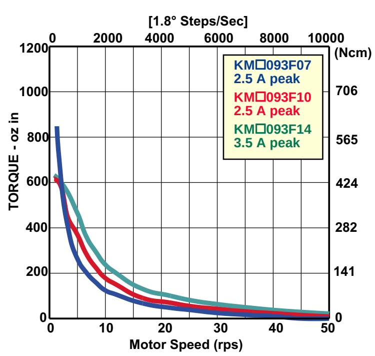
KM n 092

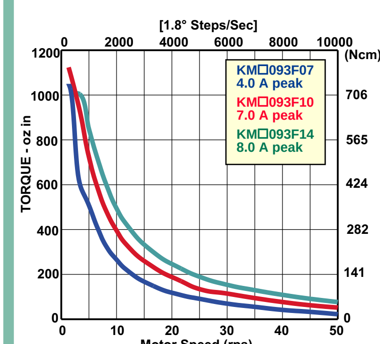


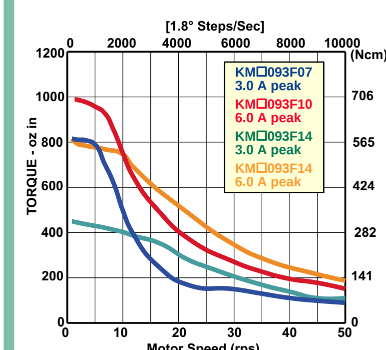




KM n 093







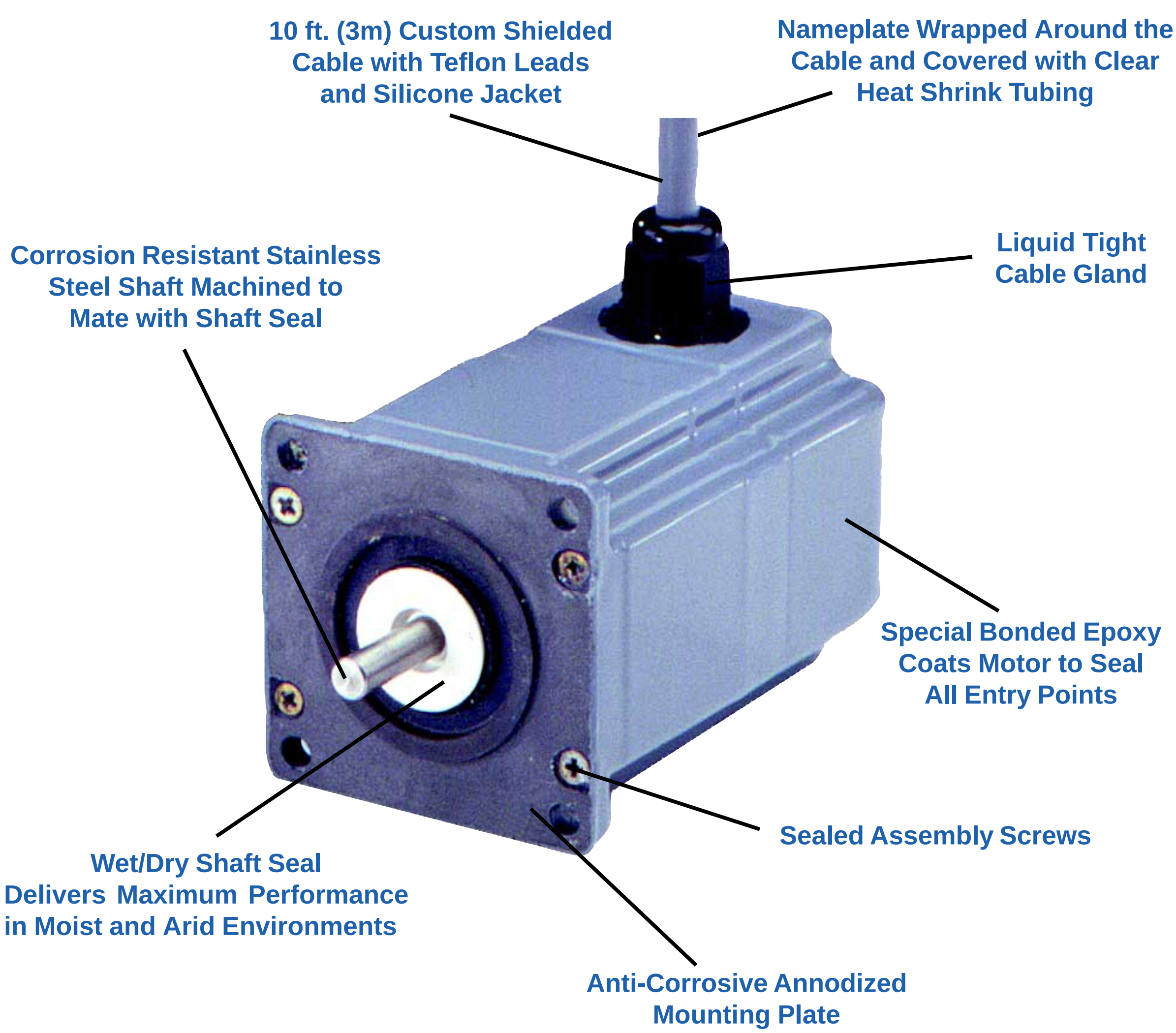
- The curves do not show system resonances which will vary with system mechanical parameters.
- Duty cycle is dependent on torque, speed, Drive parameters, and heat sink conditions. Maximum case temperature is 100°C.

High Torque 90mm Washdown Motors

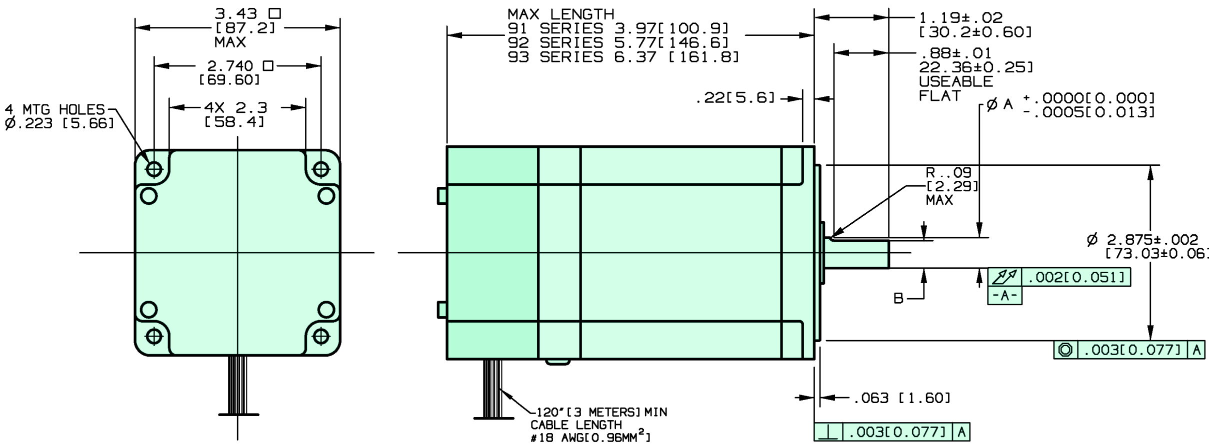
SLO-SYN® washdown motors are designed to deliver flawless motion control in both wet and arid conditions. They are dust protected and withstand powerful jets of fluid.

SLO-SYN® Washdown Motors Withstand IP 56 Conditions:

- Water & Salt Water
- Oil
- Grease
- Common Solvents
- Weak Acids
- Alcohol
- Dust
- Lint
- Fibers



Dimensions



Dimensions are shown in inches(mm)

Shaft Dimensions	"A"	"B"
KSWS091	.3750 (9.525)	.328 (8.33)
KSWS022	.3750 (9.525)	.328 (8.33)
KSWS093	.5000 (12.700)	.450 (11.43)
KMWS091	.5000 (12.700)	.450 (11.43)
KMWS092	.5000 (12.700)	.450 (11.43)
KMWS093	.5000 (12.700)	.450 (11.43)

KM **WS** **09** [ ] **F** [ ]

1 single stack **2** double stack **3** triple stack

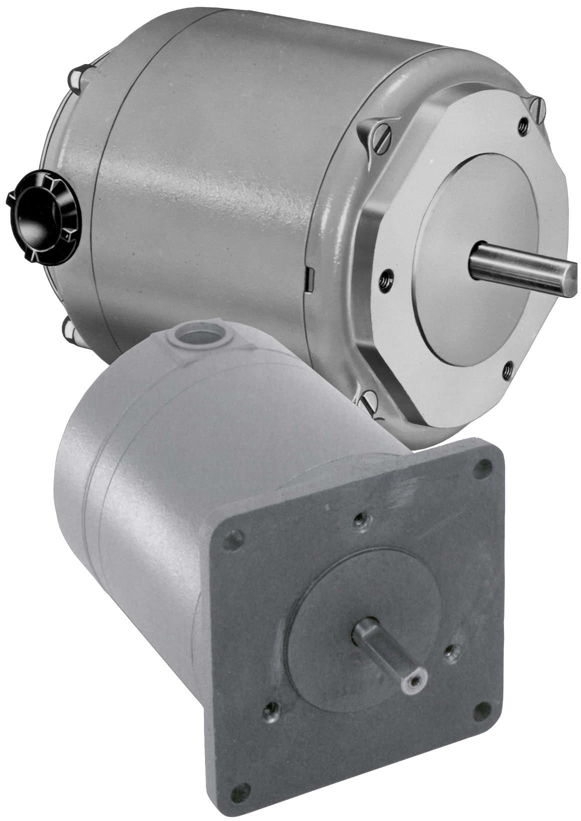
XX total current

(Refer to chart below to select winding)

4-CONNECTION STEP MOTORS				
Model Number	Winding Specifications			
	Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)
KMWS091F05	3.0	2.7	1.1	11
KMWS091F07	2.5	3.3	0.76	7.5
KMWS091F13	1.3	6.6	0.19	1.9
KMWS092F07	3.5	3.3	1.1	11
KMWS092F13	1.7	6.5	0.27	2.9
KMWS093F07	4.9	3.4	1.4	18
KMWS093F08	4.0	4.0	0.99	13
KMWS093F10	3.2	5.1	0.63	8.3
KMWS093F14	2.5	6.8	0.36	4.5

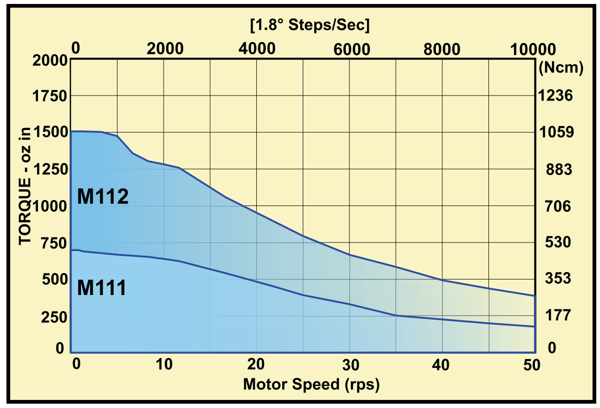
M11

Standard
110mm Frame Size
(NEMA Size 42)



Performance Envelope

(see page DC34 for detailed torque-speed curves)



- Up to 200% rated torque reserve capacity
- ± 5% typical step accuracy
- Standard terminal box, encoders, and `recision gearheads available
- Available with four, six or eight connections
- Customized configurations available

Motor Frame	Minimum Holding Torque		Rotor Inertia	Weight		Maximum Shaft Load		Minimum Residual Torque
	Unipolar 2Ø on	Bipolar 2Ø on		Net	Ship	Overhang	Thrust	
	oz-in (Ncm)	oz-in (Ncm)	oz-in-s^2 (kg-cm^2)	lb (kg)	lb (kg)	lb (kg)	lb (kg)	oz-in (Ncm)
M111	625 (441)	850 (600)	0.055 (3.93)	8.0 (3.63)	9.25 (4.2)	25 (11.3)	50 (22.7)	6 (4.24)
M112	1125 (794)	1390 (981)	0.114 (8.06)	16.7 (7.57)	16.5 (7.4)	25 (11.3)	50 (22.7)	12 (8.47)

M11

M 11 ☐ – F ☐ ☐

1 single stack
2 double stack
3 triple stack

D = 6 or 8 connections, round flange
F = 4 connections, square flange*
J = 6 or 8 connections, square flange, sealed against ingress or liquids or dust

* NOTE: Except the M111-FF401 which has a round flange

Identification Suffix (Coil Rating)

4-CONNECTION STEP MOTORS

Model Number (See Next Page for Options)	Flange	Winding Specifications: Voltage VDC	Current Amperes	Resistance ohms	Inductance mH
M111-FF-206	SQ	3.5	5.0	0.70	9.2
M111-FF-401	R	4.0	3.4	1.10	18.0
M112-FF-206	SQ	3.0	6.0	0.49	8.8
M112-FF-401	SQ	2.0	4.0	0.49	8.8

6-CONNECTION STEP MOTORS

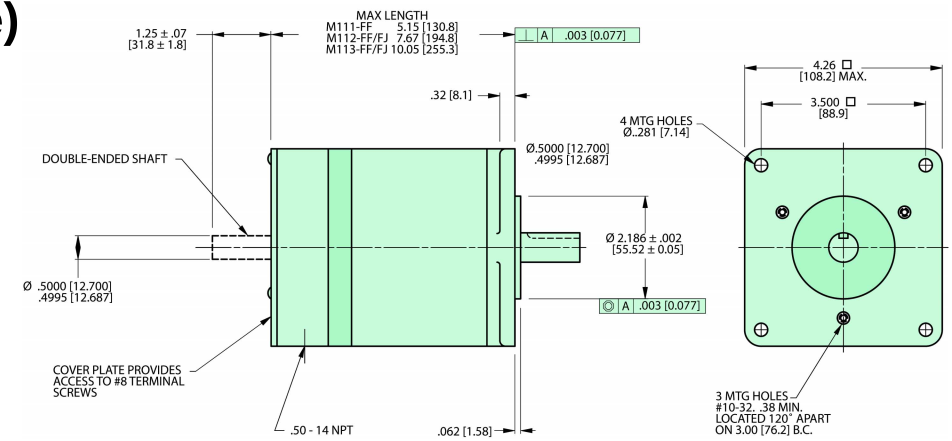
Model Number	Flange	Winding Specifications							
		Unipolar				Bipolar Series			
See next page for options		Voltage VDC	Current Amperes	Resistance ohms	Inductance mH	Voltage VDC	Current Amperes	Resistance ohms	Inductance mH
M111-FD12	R	2.26	6.1	0.37	2.3	3.2	4.3	0.74	9.2
M112-FD12	R	3.66	6.1	0.8	5.3	5.2	4.3	1.2	21.2

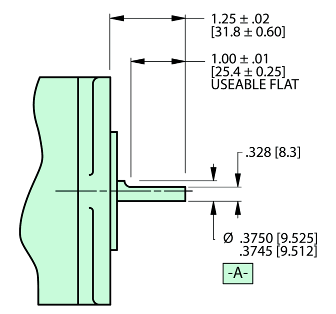
8-CONNECTION STEP MOTORS

Model Number	Flange	Winding Specifications											
		Unipolar				Bipolar Series				Bipolar Parallel			
See next page for options		Voltage VDC	Current Amps	Resistance ohms	Inductance mH	Voltage VDC	Current Amps	Resistance ohms	Inductance mH	Voltage VDC	Current Amps	Resistance ohms	Inductance mH
M111-FD-8012	R	2.3	6.1	0.37	2.3	3.2	4.3	0.73	9.2	1.6	8.6	0.19	2.3
M112-FJ-8012	SQ	3.7	6.1	0.60	5.3	5.2	4.3	1.2	21.0	2.6	8.6	0.30	5.3

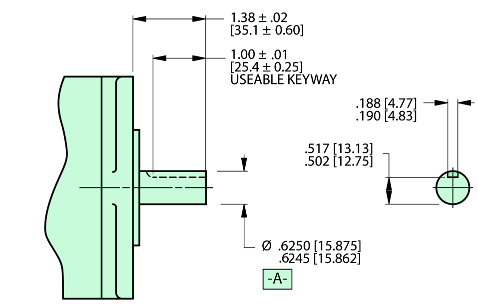
M11

Terminal Box Motor Dimensions (SQ Flange)



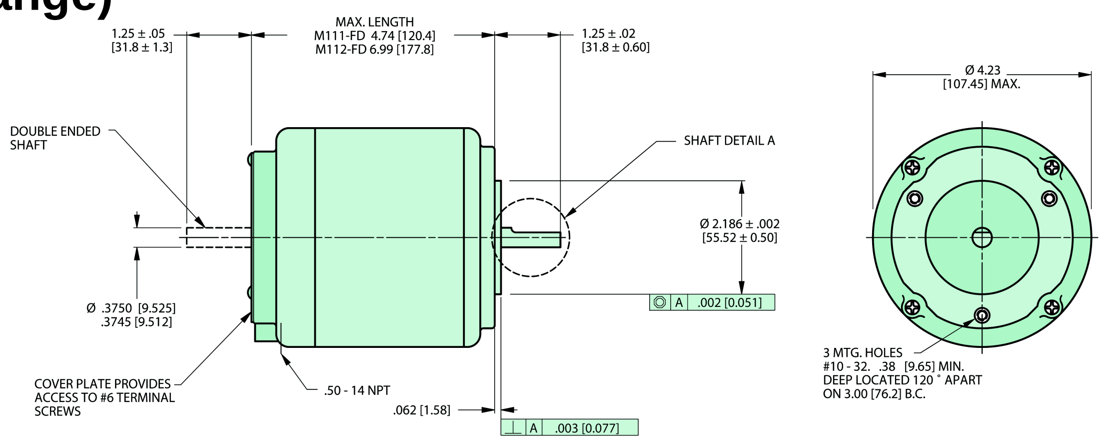


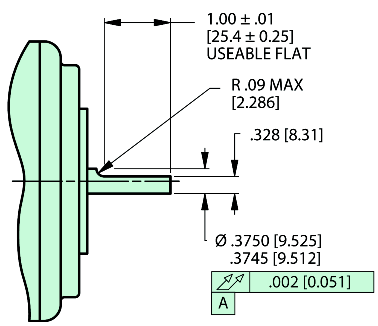
M111 SHAFT DETAIL



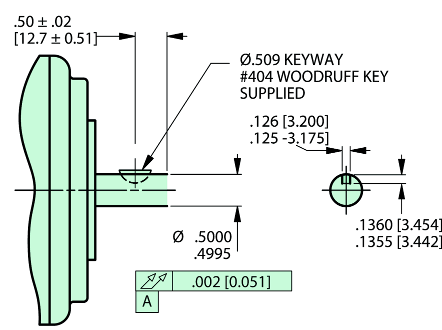
M112/M113 SHAFT DETAIL

(R Flange)



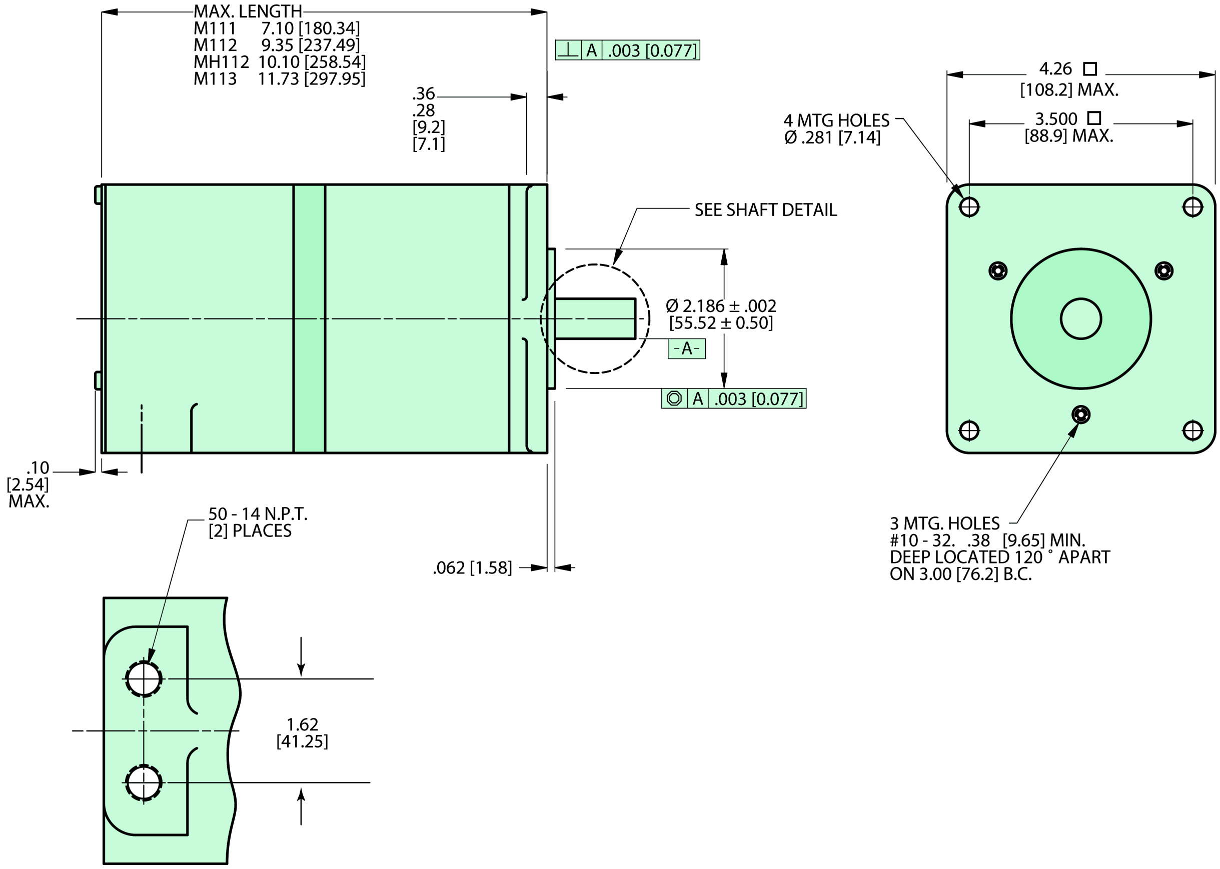


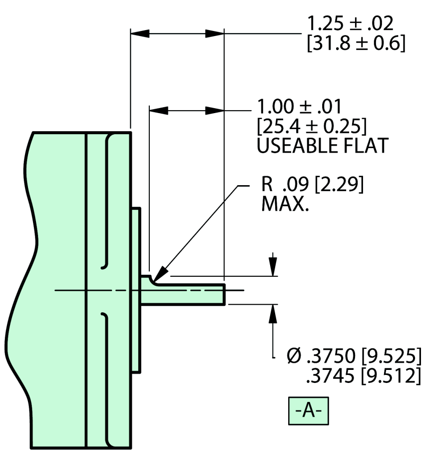
M111-FD/M111-FF SHAFT



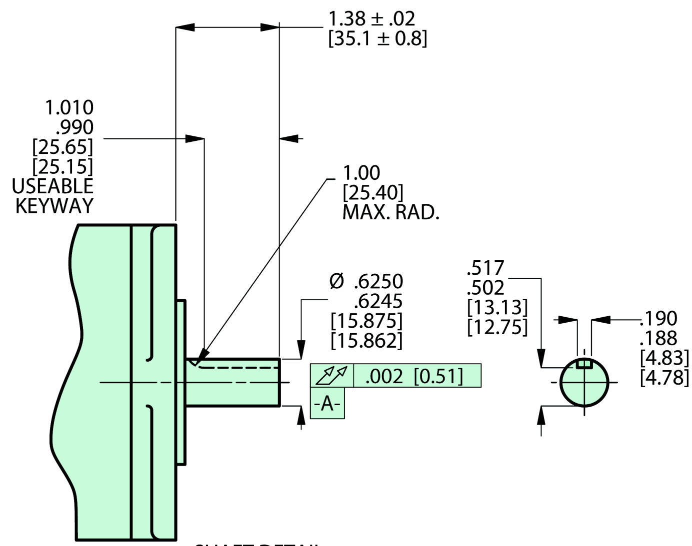
M112-FD SHAFT

Encoder





SHAFT DETAIL
FOR M111

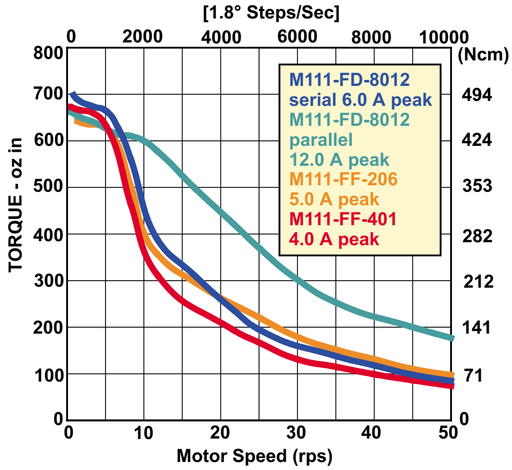


SHAFT DETAIL
FOR M112/MH112
M113

M11

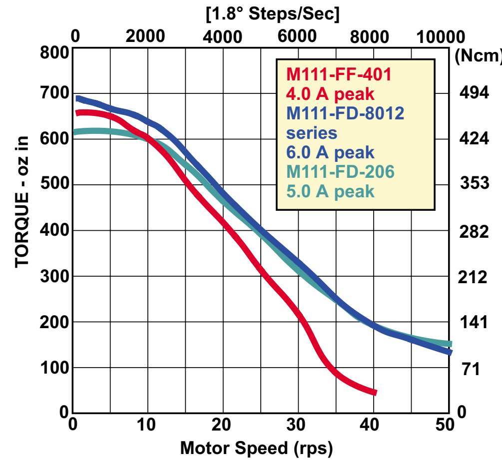
170 V Bipolar - Microstep

- Data measured with SS2000D3, D6, or D12 Packaged Drive

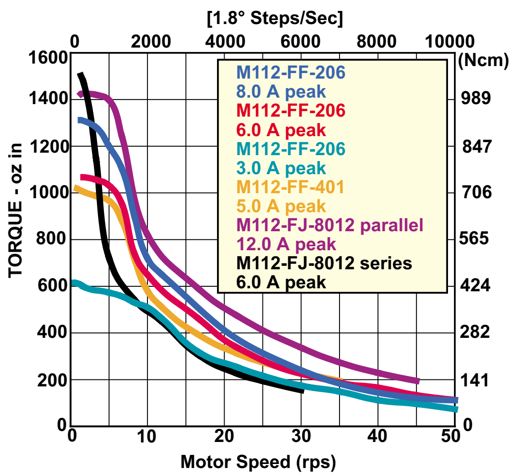


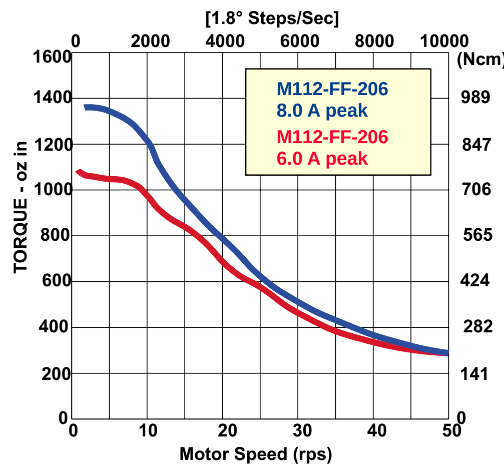
340 V Bipolar - Microstep

- Data measured with SS2000D12 Packaged Drive



M111

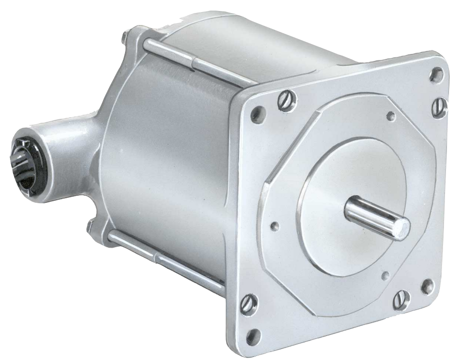




M112

- The curves do not show system resonances which will vary with system mechanical parameters.
- Duty cycle is dependent on torque, speed, Drive parameters, and heat sink conditions. Maximum case temperature is 100°C.

Hazardous Duty
110mm Frame Size

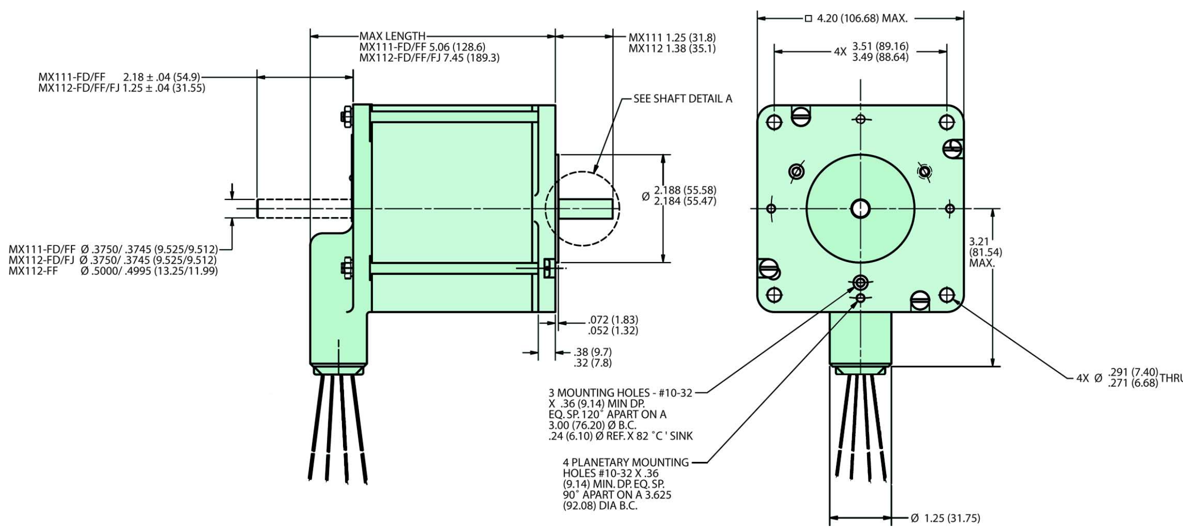


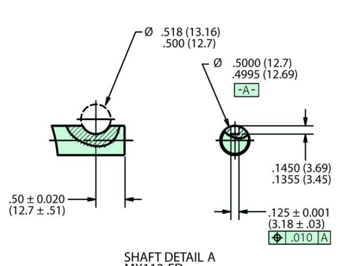
- Up to 200% rated torque reserve capacity
- ± 5% typical step accuracy
- Hazardous Duty
  UL Class 1, Division 1, Group D

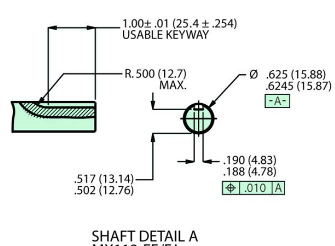
4-CONNECTION STEP MOTORS				
Model Number	Winding Specifications			
	Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)
MX111-FF-401U	3.8	1.1	3.6	16
MX112-FF-401U	1.7	2.7	0.64	2.5

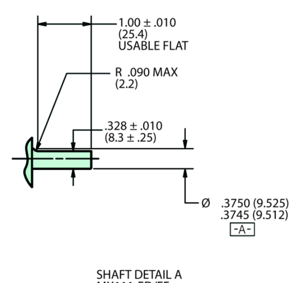
Change U to EU for double ended shaft

Dimensions



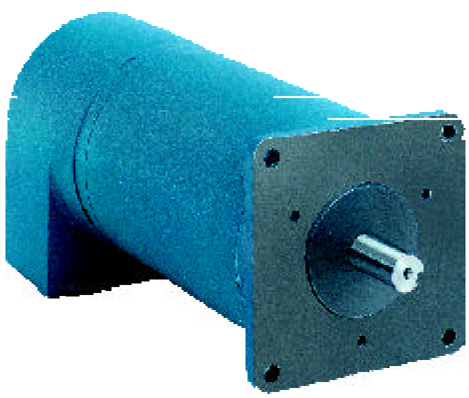






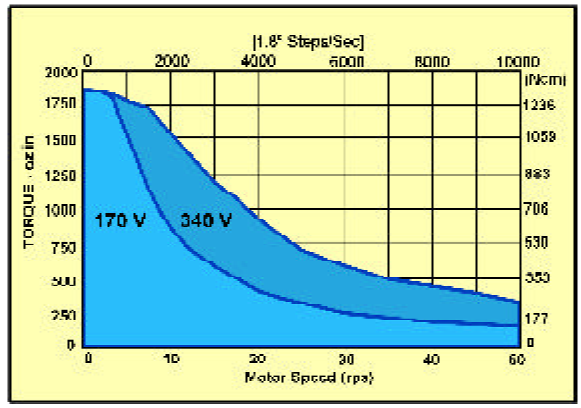
MH112

High Torque 110mm Frame Size (NEMA Size 42)



Performance Envelope

(see page DC39 for detailed torque-speed curves)



- Can withstand up to 2-1/2 times rated current (instantaneous) without demagetization
- ± 5% typical step accuracy
- Available with four or eight connections
- Class F insulation system
- Standard keyway

MH112 Specifications*

Rotor Inertia	0.133 oz-in-s^2 (9.42 kg-cm^2)
Weight (Net)	20.5 lbs. (9.3 kg)
Weight (Ship)	24 lbs. (11 kg)
Maximum Overhang Load	50 lbs. (23 kg)
Maximum Thrust Load	100 lbs. (45 kg)
Minimum Residual Torque	85 oz-in (60 Ncm)

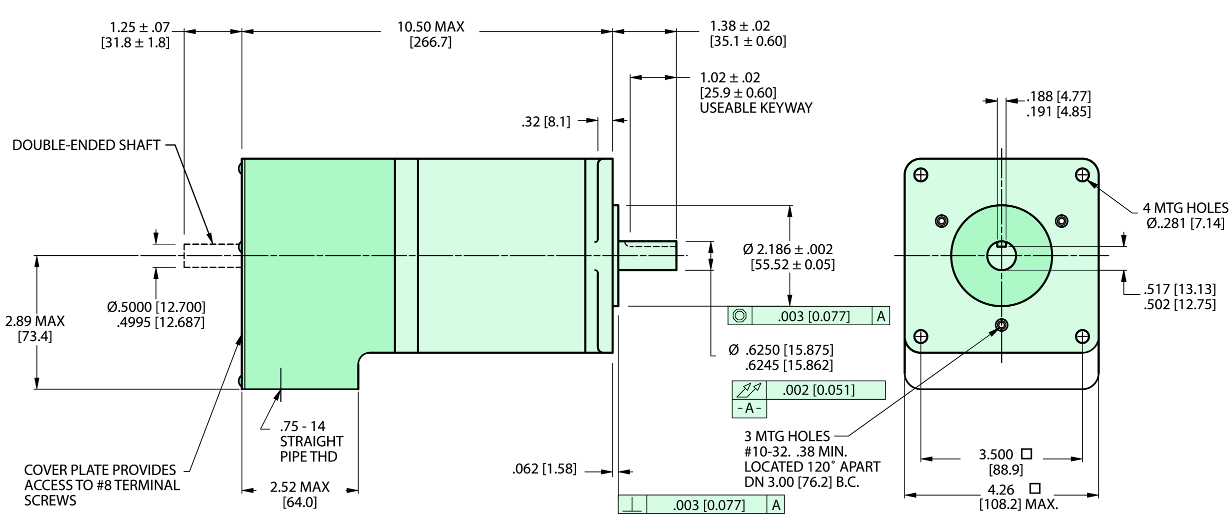
**Values shown are reference information. Parameters to be used as part of a specification should be verified with the factory.*

4-CONNECTION STEP MOTORS					
Model Number	Min. Holding Torque 2 On	Winding Specifications			
		Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)
MH112-FF-206*	2000	4.8	6	0.8	17
MH112-FJ-4201	1500	3.2	4	0.8	17

* Class B insulation system

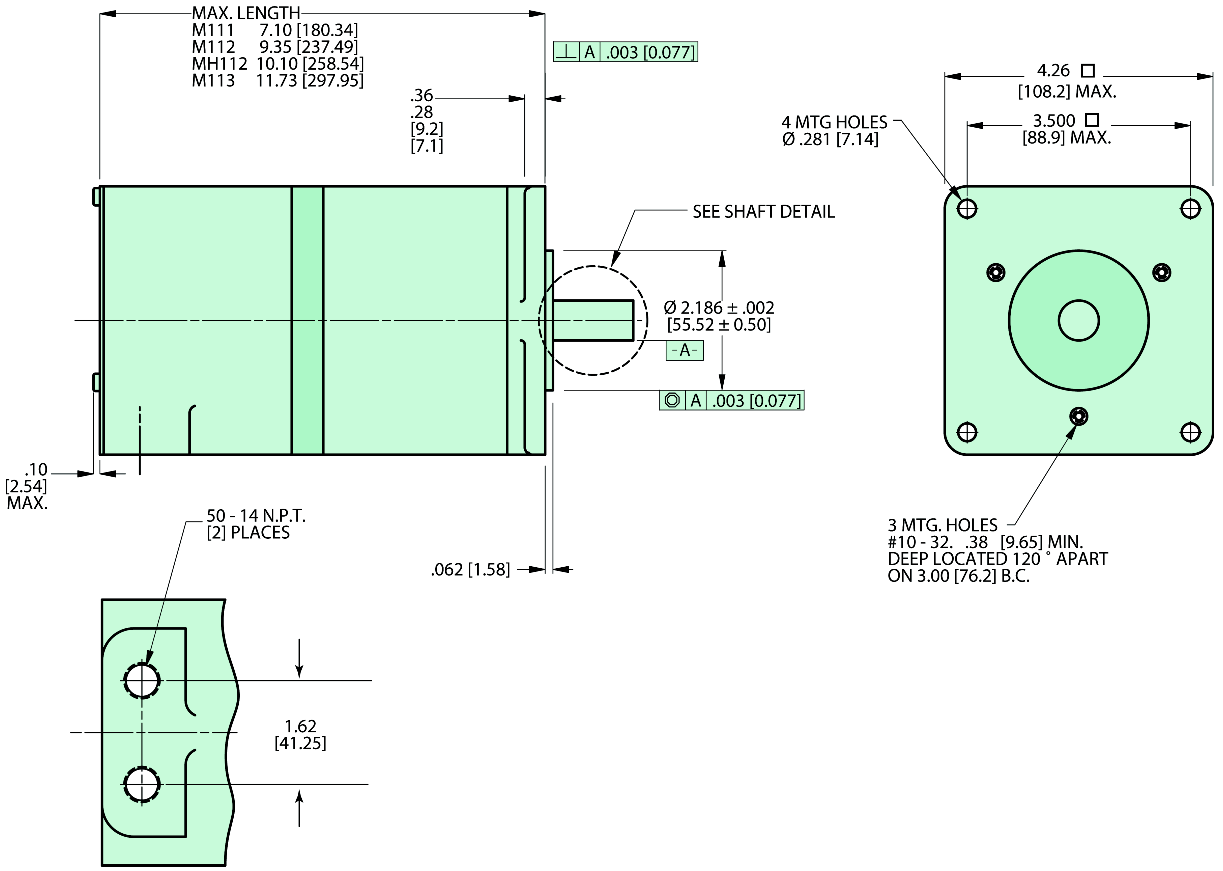
8-CONNECTION STEP MOTORS									
Model Number	Min. Holding Torque 2Ø On	Winding Specifications							
		Bipolar Series				Bipolar Parallel			
		Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)	Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)
MH112-FJ-8020	1760	3.8	7.1	0.53	12	1.9	14.1	0.13	3.0
MH112-FJ-8030	1760	2.5	10.6	0.23	4.1	1.3	21	0.058	1.0

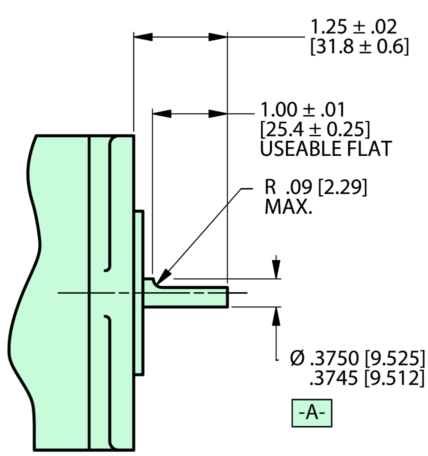
Motor Dimensions



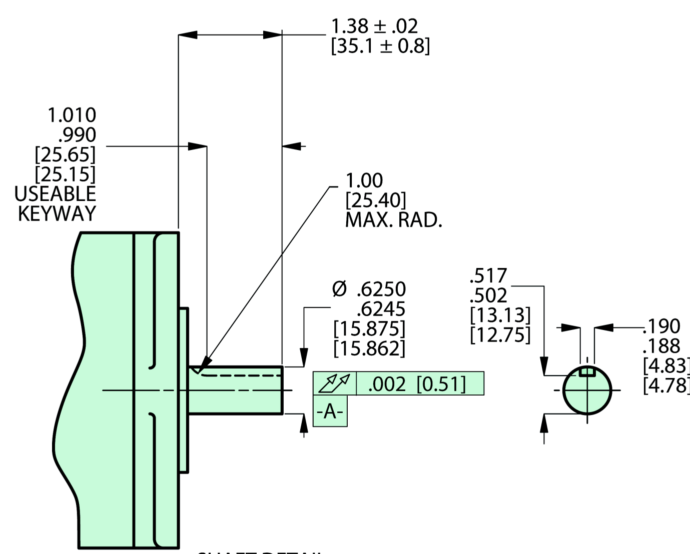
MH112

Encoder





SHAFT DETAIL
FOR M111

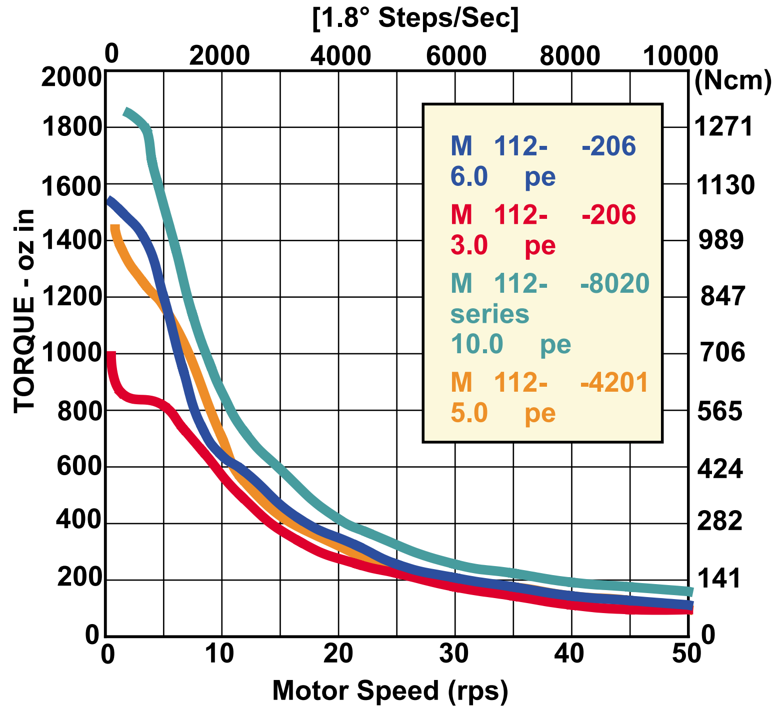


SHAFT DETAIL
FOR M112/MH112
M113

MH112

170 V Bipolar - Microstep

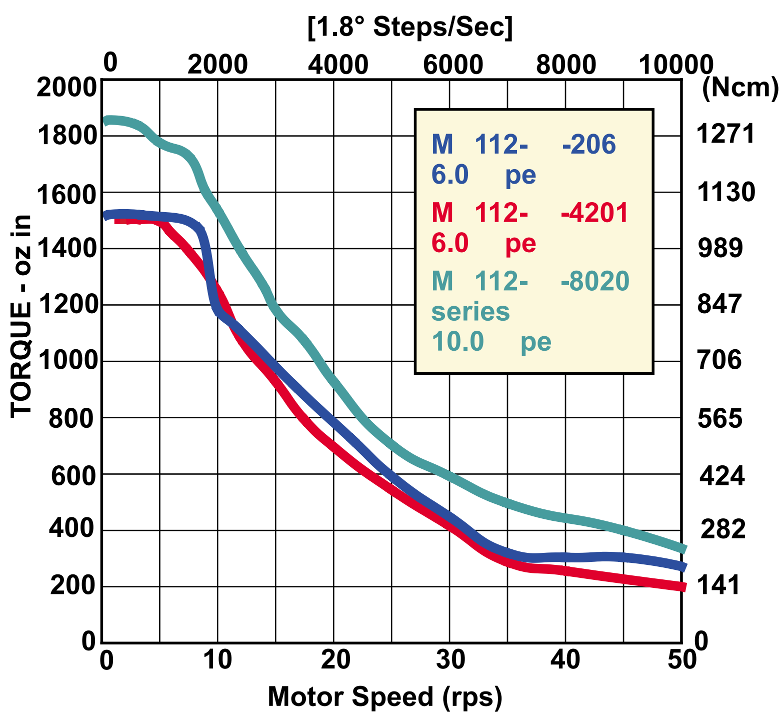
◆ Data measured with SS2000D3, D6, or D12 Packaged Drive



◆ The curves do not show system resonances which will vary with system mechanical parameters.

340 V Bipolar - Microstep

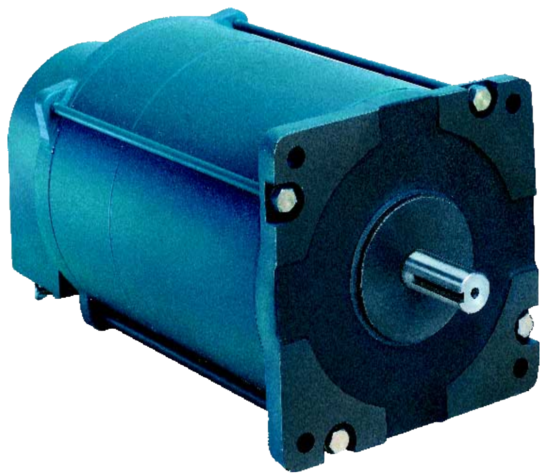
◆ Data measured with SS2000, or D12 Packaged Drive



◆ Duty cycle is dependent on torque, speed, Drive parameters, and heat sink conditions. Maximum case temperature is 100°C.

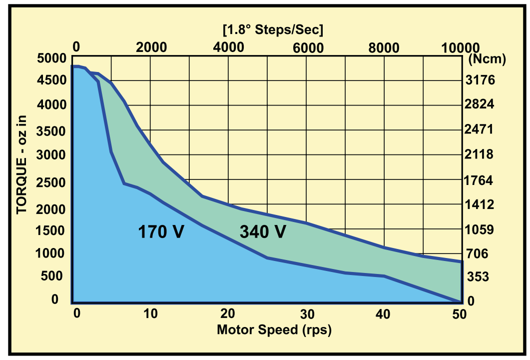
MH172

High Torque 170mm Frame Size (NEMA Size 66)



Performance Envelope

(see page DC41 for detailed torque-speed curves)



- Can withstand up to 2-1/2 time rated current (instantaneous)
- ± 5% typical step accuracy
- Available with eight connections
- Class F insulation system
- Standard keyway

MH172 Specifications*

Minimum Holding Torque (Bipolar 2Ø on)	5330 oz-in. (3764 Ncm)
Rotor Inertia	0.870 oz-in-s^2 (61.4 kg-cm^2)
Weight (Net)	53 lbs. (24 kg)
Weight (Ship)	62 lbs. (28 kg)
Maximum Overhang Load	100 lbs. (45.4 kg)
Maximum Thrust Load	150 lbs. (68.0 kg)
Minimum Residual Torque	50 oz-in (35 Ncm)

**Values shown are reference information. Parameters to be used as part of a specification should be verified with the factory.*

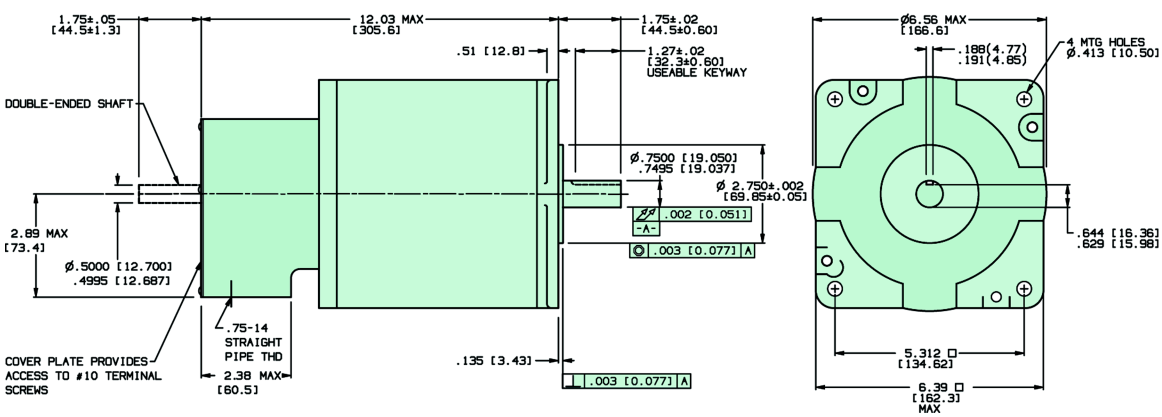
MH - 172 - FD - 8030 [ ]

E	=	Rear Shaft Extension
C2	=	200 line six output encoder
C4	=	400 line six output encoder
C5	=	500 line six output encoder

MH172

8-CONNECTION STEP MOTORS									
		Winding Specifications							
		Bipolar Series				Bipolar Parallel			
Model Number	Flange	Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)	Voltage (VDC)	Current (Amperes)	Resistance (ohms)	Inductance (mH)
MH172-FD8030	SQ	3.25	10.6	0.31	8.5	1.6	21	0.077	2.1

Motor Dimensions*



** Encoder if applicable, fits inside terminal box*

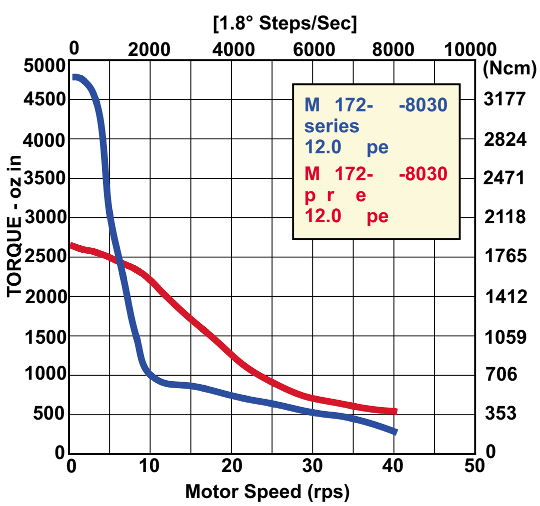
170 V Bipolar - Microstep

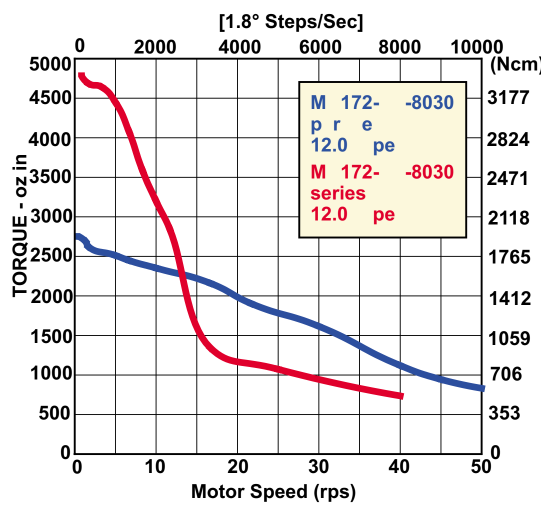
- Data measured with SS2000D3, D6, or D12 Packaged Drive

340 V Bipolar - Microstep

- Data measured with SS2000, or D12 Packaged Drive

MH172





- The curves do not show system resonances which will vary with system mechanical parameters.
- Duty cycle is dependent on torque, speed, Drive parameters, and heat sink conditions. **Maximum case temperature is 100°C.**

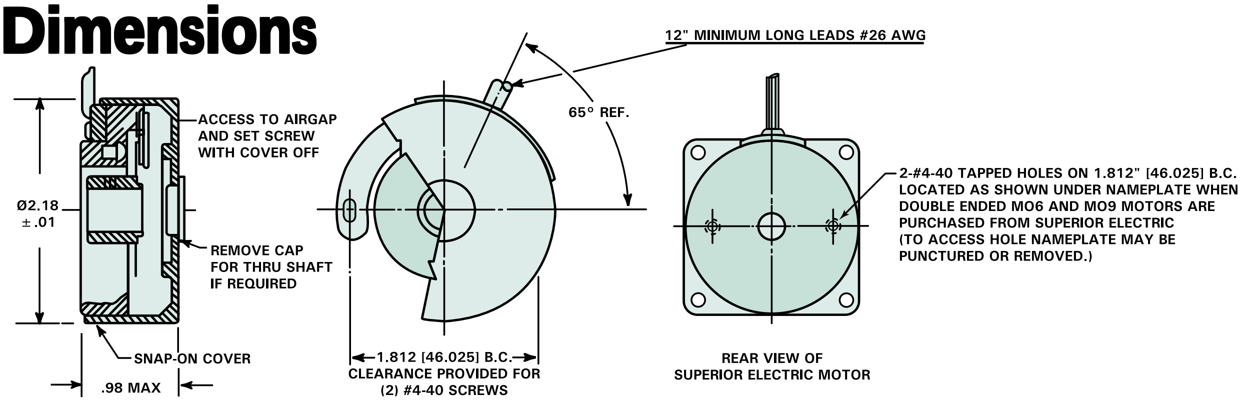
ENCODERS

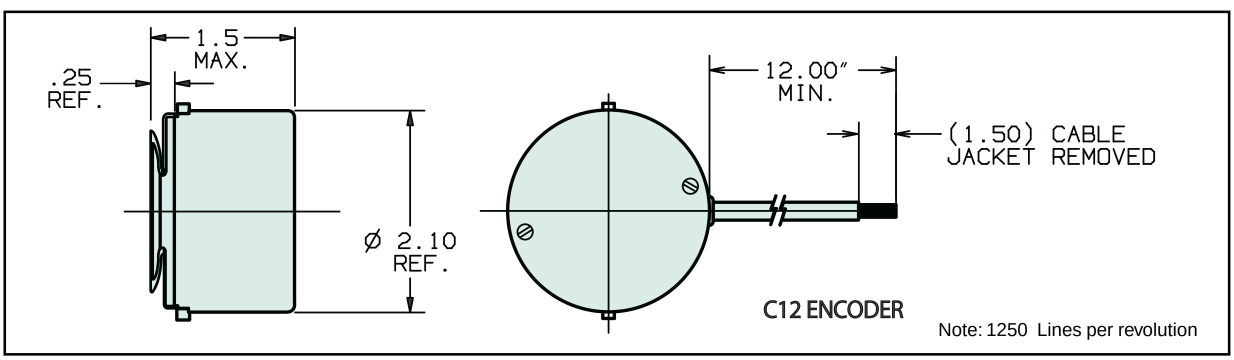
Incremental Rotary Optical Kit Encoders

200, 400, 500 lines per revolution

1250 lines per revolution

Dimensions





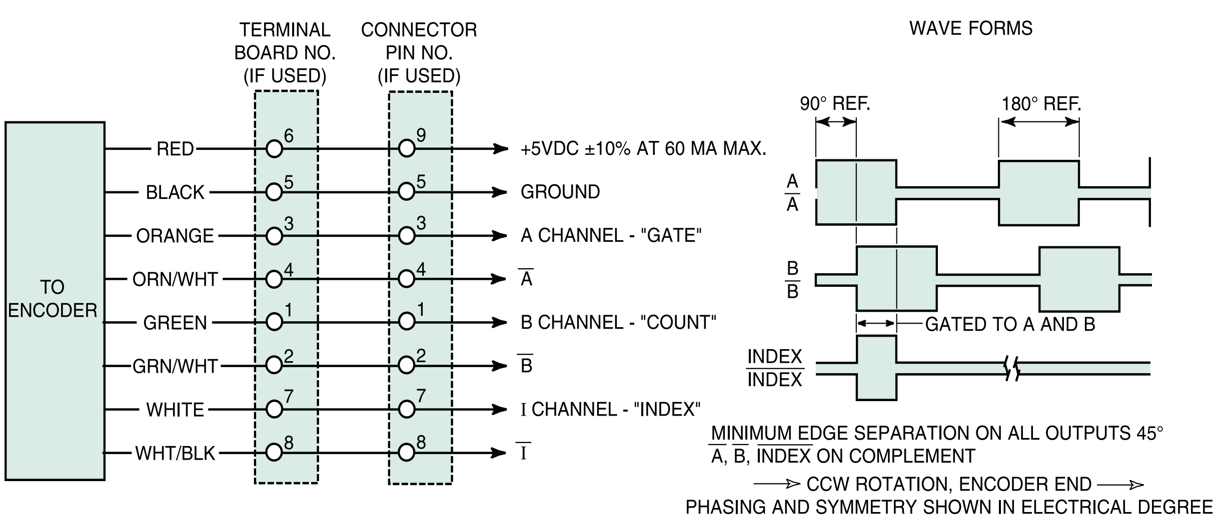
ORDERING INFORMATION

The following diagram explains the Encoder Kit number system:

EK 21 - 25 - 200 - 2

- EK — Encoder Kit
- 21 — Encoder Body Diameter (2.1 inches)
- 25 — Shaft Size
  - 25 = 1/4 Inch Diameter
  - 38 = 3/8 Inch Diameter
- 200 — Pulses Per Revolution: 200, 400, 500, 1250
- 2 — Number of Outputs
  - 2 = Single-Ended (A, B only)
  - 3 = A, B and Index
  - 6 = A, B, Index
    $\overline{A}$, $\overline{B}$, $\overline{\text{Index}}$
    (with Differential Line Drivers)

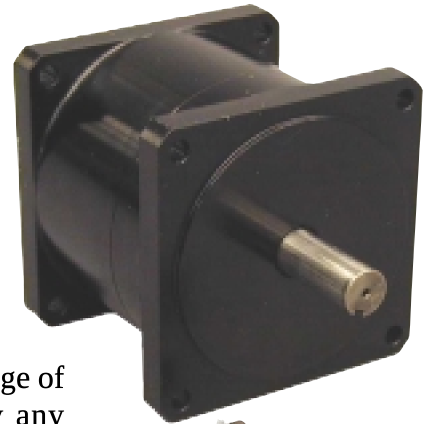
Specifcations	200, 400, 500 Lines per rev	1250 Lines per rev
Mechanical Specifications		
Weight	2.1 ounces	6 ounces
Moment of Inertia	2.6 x 10^{-4} oz-in-sec^2 max.	5.0 x 10^{-4} oz-in-sec^2
Bearing Life		L_{10} = 2 billion revolutions
Acceleration	100,000 rad/sec^2	
Bore Size	0.250 in. or 0.375 in.	
Slew Speed	15,000 rpm max.	7,000 rpm max.
Strain Relief	withstands 10 lb. pull on cable or wire bundle	
Motor Interface		
Mounting Holes	2 x #4-40 at 180 on a 1.812 dia. bolt circle	
Perpendicularity (Shaft-to Mount)	0.005 in. TIR	
Shaft Endplay	–0.010 in.	–0.060 in.
Shaft Diameter required	0.2495 / 0.2500 in. 0.3745 / 0.3750 in.	
Minimum useable shaft length	0.56 in.	Min. required 0.70 in.
Electrical Spciifications		
Code	Incremental	
Cycles per Revolution	200, 400, 500, as specified	1250
Supply Voltage	5 VDC	
Output Format	dual channel quadrature, 45 min. edge separation	
Output Format Options	index and complementary ouputs	
Output Type, Less Complements	square wave TTL compatible short-circuited protected capable of sinking 10mA	
Output Type, With Complements	differential line drivers (26LS31) capable of sinking 20mA	
Frequency Response	100 kHz	
Frequency Modulation	–0.5% max. @ 50 kHz	1% max.
Frequency Accuracy	3.0 arc min. max. (zero runout)	
Environmental Specifications		
Operation Temperature	-10 C to +80 C (less complements) -10 C to +100 C (with complements)	0 C to + 85 C
Storage Temperature	-20 C to +100 C (less complements) -40 C to +100 C (with complements)	-30 C to +110 C
Enclosure	Unsealed housing, (must be protected from harsh environments)	



ENCODER CONNECTION DIAGRAM AND OUTPUT WAVEFORM

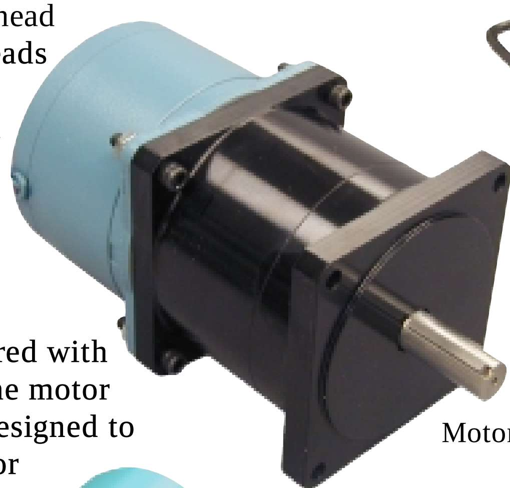
GEARHEADS

SLO-SYN® Gearheads

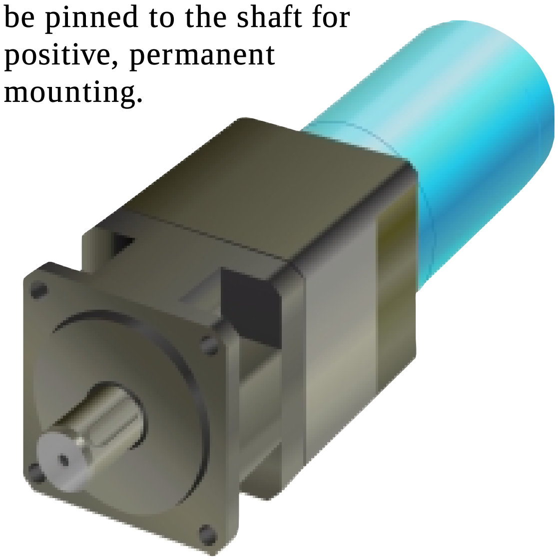


Many applications need a higher torque or a smaller step angle than is possible by directly driving the load from the motor shaft. An ideal way to satisfy these requirements is by using a motor that has an integrally mounted gearhead. SLO-SYN DCGearheads are available in precision NEMA and Planetary models to meet the need for speed reduction without the problems associated with belts or pulleys. The wide range of available ratios assures a design solution for virtually any Motor with NEMA Gearhead application. The Gearheads can be supplied as a complete assembly with the Gearhead already mounted to a SLO-SYN motor, or as a kit for mounting to an existing motor. Both NEMA and Planetary types are offered with a clamp-on pinion for the motor shaft or with a pinion designed to be pinned to the shaft for positive, permanent mounting.

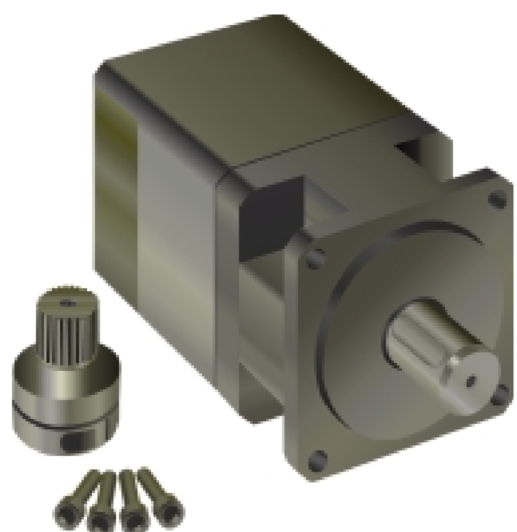
NEMA Gearhead Kit



Motor with NEMA Gearhead



Planetary Gearhead on DC Stepper Motor



Planetary Gearhead Kit

Gearhead Options and Ordering Information

60mm NEMA 23 Spur Gearheads

S ☐ 23 ☐ - ☐ - LB - M ☐

E - In Line
R - Right Angle

For Right Angle Only
S - Single Output Shaft
D - Double Output Shaft

Gear Ratio

003 - 3:1	020 - 20:1
005 - 5:1	050 - 50:1
010 - 10:1	100 - 100:1
015 - 15:1	

Insert to order Low Backlash Unit

000 - All motors with .250" shaft except KM063
108 - KM063 (.312" shaft)

60mm NEMA 23 Planetary Gearheads

P ☐ 23 ☐ - LB - M ☐ ☐

M - In Line
T - Right Angle

Gear Ratio
005 - 5:1
010 - 10:1
020 - 20:1
050 - 50:1
100 - 100:1

Insert to order Low Backlash Unit

X - In Line
Z - Right Angle

005 - All motors with .250" shaft except KM063
039 - *In Line* KM063 (.312" Shaft)
068 - *Right Angle* KM063 (.312" Shaft)

Gearhead Options and Ordering Information

90mm NEMA 34 Spur Gearheads

S [ ] 34 [ ] - [ ] - LB - M [ ]

E - In Line
R - Right Angle

For Right Angle Only
S - Single Output Shaft
D - Double Output Shaft

Gear Ratio

003 - 3:1	020 - 20:1
005 - 5:1	050 - 50:1
010 - 10:1	100 - 100:1
015 - 15:1	

Insert to order Low Backlash Unit

000 - All M09 Motors (.375” Shaft)

016 - All KM09 Motors (.500” Shaft)

90mm NEMA 34 Planetary Gearheads

P [ ] 34 [ ] - LB - M [ ] [ ]

M - In Line
T - Right Angle

Gear Ratio
005 - 5:1
010 - 10:1
020 - 20:1
050 - 50:1
100 - 100:1

Insert to order Low Backlash Unit

X - In Line
Z - Right Angle

006 - *In Line* M09 Series (.375” Shaft)

002 - *Right Angle* M09 Series (.375” Shaft)

005 - All KM09 motors (.500” Shaft)

Gearhead Options and Ordering Information

110mm NEMA 42 Spur Gearhead

S [ ] 42 [ ] - [ ] - LB - M [ ]

E - In Line
R - Right Angle

For Right Angle Only
S - Single Output Shaft
D - Double Output Shaft

Insert to order Low Backlash Unit

------- See Table Below------
000 - All Motors with 0.625" Shaft
016 - All Motors with 0.375" Shaft

Gear Ratio

003 - 3:1	020 - 20:1
005 - 5:1	050 - 50:1
010 - 10:1	100 - 100:1
015 - 15:1	

90mm NEMA 42 Planetary Gearheads

P [ ] 42 [ ] - LB - M [ ] [ ]

M - In Line
T - Right Angle

Insert to order Low Backlash Unit

X - In Line
Z - Right Angle

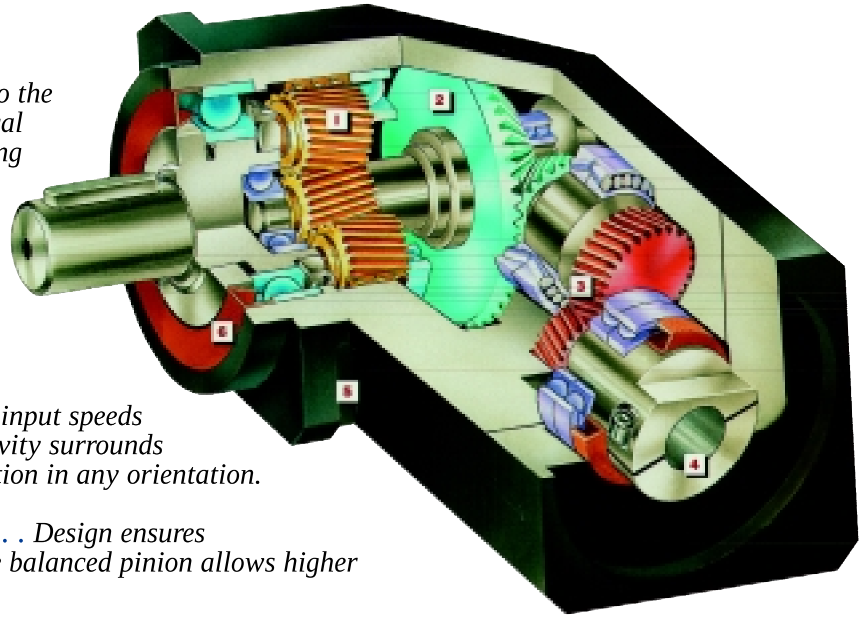
Gear Ratio
005 - 5:1
010 - 10:1
020 - 20:1
050 - 50:1
100 - 100:1

------- See Table Below------
001 - *In Line* Motors with 0.625" Shaft
251 - *In Line* Motors with 0.375" Shaft
183 - *Right Angle* Motors with 0.625" Shaft
186 - *Right Angle* Motors with 0.375" Shaft

Type Number	Shaft Diameter
M111-FF-206	0.375
M111-FF-401	0.375
M111-FD12	0.375
M111-FD8012	0.375
M112-FD12	No Gearbox Option
M112-FJ8012	0.625
M112-FF-206	0.625
M112-FF-401	0.625
M113-FF-401	0.625

GEARHEADS

New P Series Planetary Gearheads



1.Planetary Output . . .
Unique technology is built into the gearhead to deliver "The Helical Advantage" at the load-carrying output section.

2.Spiral Bevel Gears . . .
Deliver high efficiency and high torque in a compact, right angle package.

3.High Speed Input . . .
Helical gearing provides high input speeds with quiet operation. Input cavity surrounds the gears for constant lubrication in any orientation.

4.Patented Motor Mounting . . . *Design ensures error-free installation and the balanced pinion allows higher input speeds.*

5.Compact Design . . . *2 package lengths per frame size, 1 for ratios ≤ 10:1, 1 for > 10:1. Two lengths provides for a shorter packages for ratios ≤ 10:1.*

6. IP65 Sealed Unit . . . *Seals and O-Rings provide IP65 protection to prevent leaks and protect against harsh environments*

New P Series Planetary Gearheads are available as In-Line (PM Series) and Right Angle (PT Series) Models. They provide 30% more torque than their predecessors while operating faster, quieter, and with more accuracy.

Specifications:

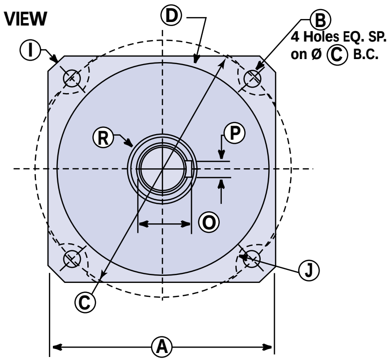
Efficiency: PM Series = 90% • PT Series = 92%
Noise: With 3000 RPM input speed, measured at 1 meter - 70dB
Ratios: 5:1, 10:1, 20:1, 50:1, 100:1

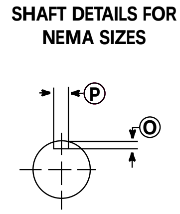
Model No.	Output Torque				Rated Input Torque		Rated Input Speed	Moment of Inertia		Backlash
	Rated(1)		Peak(1)(2)							Standard/Low
	in-lb	(Nm)	in-lb	(Nm)	in-lb	(Nm)		oz-in-sec^2	(kg-m^2)	arcminutes
Stealth PM Performance Specifications										
PM23	300	(34)	600	6(8)	Rated Output Torque + Applicable Ratio(3)		5,000	1.5 X 10^{-3}	(1.1 X 10^{-5})	15/10
PM34	800	(90)	1,600	(180)			4,000	3 X 10^{-3}	(2 X 10^{-5})	15/10
PM42	1,600	(180)	3,200	(360)			4,000	7 X 10^{-3}	(5 X 10^{-5})	15/10
Stealth PT Performance Specifications										
PT23	35.8	(41)	716	(82)	25	(2.8)	4,000	1.7 x 10^{-3}	(1.2 x 10^{-5})	10/6
PT34	916	(104)	1,832	(208)	75	(8.5)	4,000	3.3 x 10^{-3}	(2.2 x 10^{-5})	8/4
PT42	1,792	(203)	3,584	(406)	150	(17.0)	4,000	7.7 x 10^{-3}	(5.5 x 10^{-5})	8/4

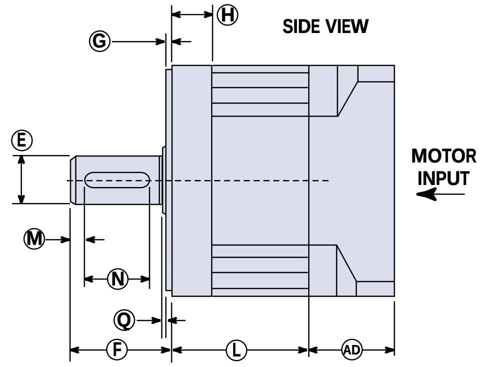
(1) Reduce ratings by 10% for 3:1, 10:1, 30:1, and 100:1 ratios
(2) Peak torques not to exceed 5% of duty cycle.
(3) Ex: Rated Input Torque For a PM34 Gearhead with 5:1 Ratio = 90 Nm/5 = 18Nm (800 in-lb/5 = 160 in-lb.)

GEARHEADS

Dimensions

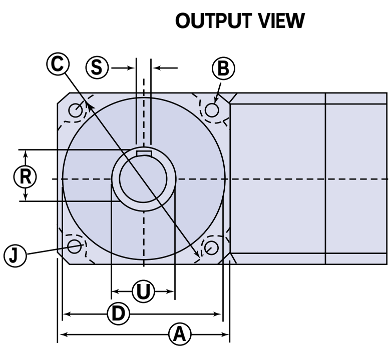


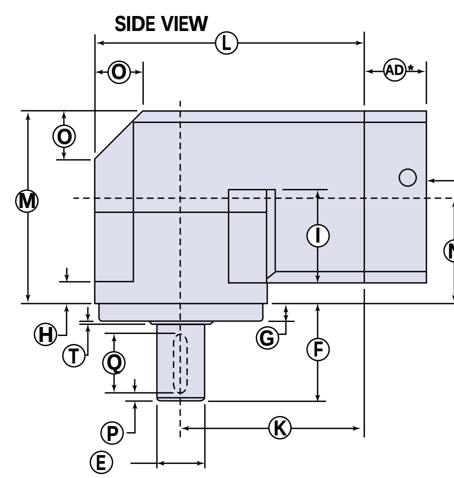




Model No.	A Square Flange in	(mm)	B Bolt Hole in	(mm)	C Bolt Circle in	(mm)	D Pilot Diameter in	(mm)	E Output Shaft Diameter in	(mm)	F Output Shaft Length in	(mm)	G Pilot Thickness in	(mm)	H Flange Thickness in	(mm)	I Housing Diameter in	(mm)	J Housing Recess in	(mm)
PM23	2.36	(60)	.217	(5.5)	2.756	(70)	1.969	(50)	.630	(16)	0.98	(25)	.098	(2.5)	.51	(13)	3.15	(80)	.197	(5.0)
PM34	3.54	(90)	.256	(6.5)	3.937	(100)	3.150	(80)	.787	(20)	1.57	(40)	.118	(3.0)	.67	(17)	4.57	(116)	.256	(6.5)
PM42	4.53	(115)	.335	(8.5)	(5.118	(130)	4.331	(110)	.945	(24)	1.97	(50)	.138	(3.5)	.79	(20)	5.98	(152)	.295	(7.5)

Model No.	AD Adapter in	(mm)	L1 Length (for Ratio ≤ 10:1) in	(mm)	L2 Length (for Ratio > 10:1) in)	(mm)	M Dist. From Shaft End in	(mm)	N Keyway Length in	(mm)	O Key Height in	(mm)	P Keyway Width in	(mm)	Q Shoulder Height in	(mm)	R Shoulder Diameter in	(mm)
)PM 23	1.299	(33)	1.69	(43.0)	2.874	(73.0)	.118	(3)	0.630	(3)	0.709	(18.0)	.20	(5)	.04	(1.0)	0.87	(22)
PM 34	1.399	(36)	2.224	(56.5)	3.780	(96.0)	1.97	(5)	1.102	(5)	0.886	(22.5)	.24	(6)	.04	(1.0)	1.38	(35)
PM 42	1.693	(43)	2.670	(67.8)	4.551	(115.6)	.276	(7)	1.260	(7)	1.063	(27.0)	.32	(8)	.06	(1.5)	1.38	(35)





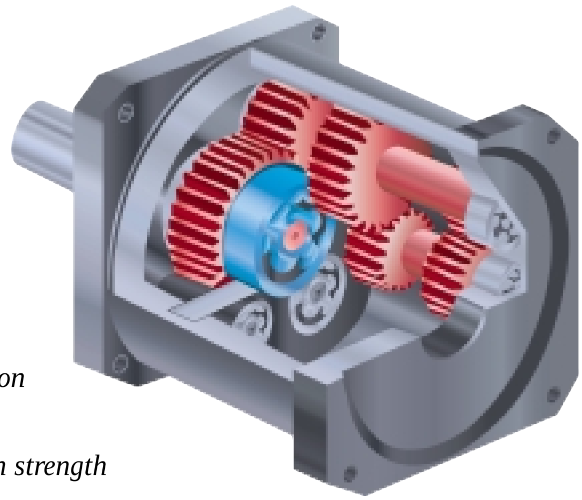
Model No.	A Square Flange in	(mm)	B Bolt Hole in	(mm)	C Bolt Circle in	(mm)	D Pilot Diameter in	(mm)	E Output Shaft Diameter in	(mm)	F Output Shaft Length in	(mm)	G Pilot Thickness in	(mm)	H Flange Thickness in	(mm)	I Recess Length in	(mm)	J Housing Recess in	(mm)
PT23	2.36	(60)	.217	(5.5)	2.756	(70)	1.969	(50)	.630	(16)	1.460	(37)	.276	(7)	.310	(8)	1.417	(36)	.197	(5.0)
PT34	3.54	(90)	.256	(6.5)	3.937	(100)	3.150	(80)	.866	(22)	1.890	(48)	.394	(10)	.394	(10)	1.969	(50)	.256	(6.5)
PT42	4.53	(115)	.335	(8.5)	5.118	(130)	4.331	(110)	1 260)	(32)	2.560	(65)	.472	(12)	.470	(12)	2.480	(63)	.295	(8.0)

Model No.	K Dist. to Output Centerline in	(mm)	L Housing Length in	(mm)	M Housing Width in	(mm)	N Dist. to Input Centerline in	(mm)	O Taper Dist. in	(mm)	P Dist. From Shaft End in	(mm)	Q Keyway Length in	(mm)	R Keyway Height in	(mm)	S Keyway Width in	(mm)	T Shoulder Height in	(mm)	U Shoulder Diameter in	(mm)
)PT23	2.598	(66.0)	3.78	(96)	2.87	(73)	1.693	(43.0)	.591	(15)	.079	(2)	.984	(25)	(709	(18.0)	(.197	(5)	.059	(1.5)	.866	(22)
PT34	4.055	(103.0)	5.827	(148)	4 05	(103)	2.283	(58.0)	.984	(25)	.118	(3)	1.260	(32)	.965	(24.5)	.236	(6)	.059	(1.5)	1.350	(35)
PT42	4.820	(122.5)	7.090	(180)	5 08	(129)	2.810	(71.5)	1.260	(32)	.197	(5)	1.575	(40)	1.378	(35.0)	(.390	(10)	.080	(2.0)	1.77	(45)

*** AD = Adapter Length:** PT23 - 25.4 (1.00); PT34 - 25.4 (1.00); PT42 - 38.1 (1.50)

GEARHEADS

S Series NEMA Spur Gearheads



1. Low Backlash . . .
   20 arcminutes standard (SE models)
   30 arcminutes standard (SR models)
2. Quick, Easy Mounting . . .
   Special Clamp-On Pinion for easy motor mounting
3. High Efficiency . . .
   Precision spur gears raise efficiency above 92%
4. Mounts in any Orientation . . . *Because they are grease-filled, the gearhead can be used in any orientation without messy oil leaks.*
5. Long Life . . . *Single piece construction gears and high strength aluminum alloy housing ensure long, reliable life.*

S Series NEMA spur gearheads are available as In-Line (SE series) and Right Angle (SR Series) models. They are designed to mount directly to the face of the motor. NEMA Gearheads are ideal for applications requiring smooth operation and low starting torque.

Specifications:

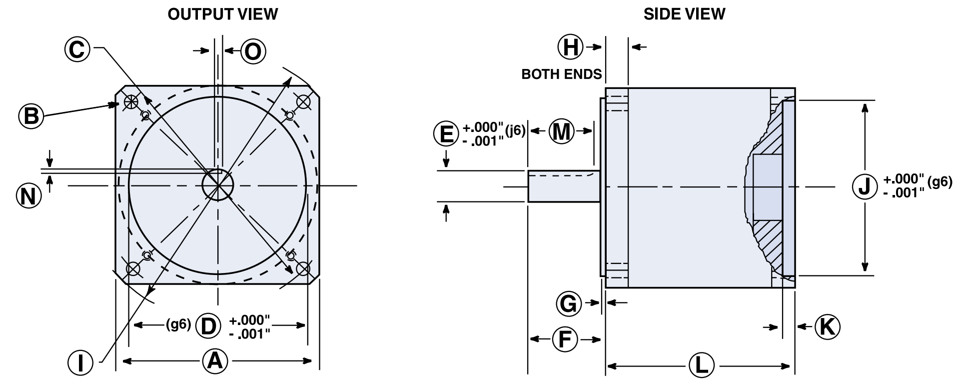
Efficiency: SE and SR Series = 92%
Ratios: 3:1, 5:1, 10:1, 15:1, 20:1, 50:1, 100:1

Model No.	Output Torque				Rated Input Torque		Rated Input Speed	Moment of Inertia		Backlash
	Rated		Peak[1]							Standard/Low
	in-lb	(Nm)	in-lb	(Nm)	in-lb	(Nm)		oz-in-sec²	(kg-m²)	arcminutes
NEMA SE Performance Specifications										
SE23	50	(6)	100	(11)	Rated Output Torque + Applicable Ratio[2]		4,000	7×10^{-5}	(5×10^{-7})	20/10
SE34	250	(28)	500	(56)			4,000	5×10^{-4}	(4×10^{-6})	20/10
SE42	500	(56)	1,000	(112)			4,000	4×10^{-3}	(3×10^{-5})	20/10
NEMA SR Performance Specifications										
SR23	50	(6)	100	(11)	Rated Output Torque + Applicable Ratio[2]		4,000	8×10^{-5}	(6×10^{-7})	30/15
SR34	250	(28)	500	(56)			4,000	6×10^{-4}	(4×10^{-6})	30/15
SR42	500	(56)	1,000	(112)			4,000	5×10^{-3}	(3×10^{-5})	30/15

(1) Peak torques not to exceed 5% of duty cycle.
(2) Ex: Rated Input Torque for an SE34 Gearhead with 5:1 Ratio = 28 Nm/5 = 5.6 Nm

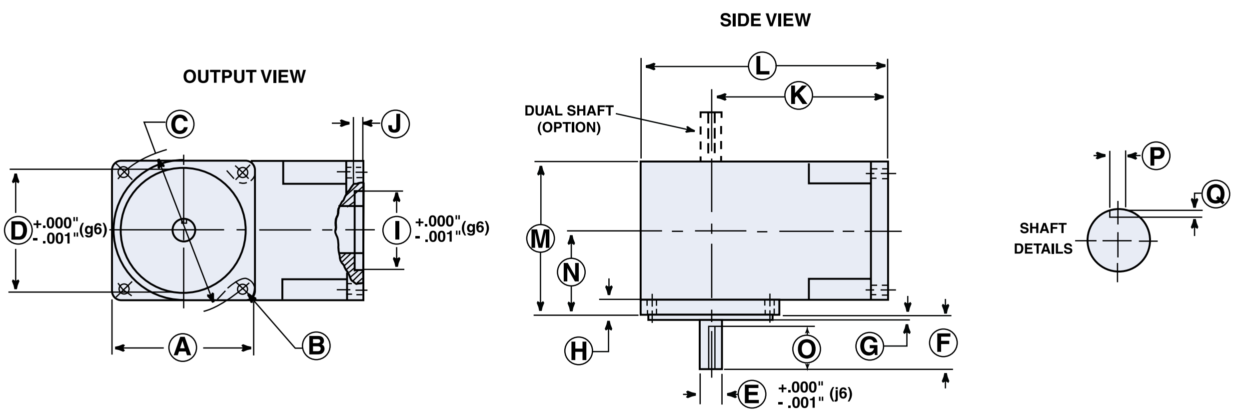
GEARHEADS

Dimensions



Model No.	A Square Flange in	(mm)	B Bolt Hole in	(mm)	C Bolt Circle in	(mm)	D Pilot Diameter in	(mm)	E Output Shaft Diameter in	(mm)	F Output Shaft Length in	(mm)	G Pilot Thickness in	(mm)	H Flange Thickness in	(mm)	I Housing Diameter in	(mm)
SE23	2.77	(58)	.195	(5.0)	2.625	(66.7)	1.500	(38.1)	.375	(9.5)	1.00	(25.4)	.062	(1.6)	.19	(5)	3.00	(76)
SE34	3.25	(83)	.218	(5.5)	3.875	(98.4)	2.875	(73.0)	.500	(12.7)	1.25	(31.8)	.065	(1.7)	.38	(10)	4.38	(111)
SE42	4.20	(107)	.281	(7.1)	4.950	(125.7)	2.187	(55.5)	.625	(15.9)	1.50	(38.1)	.093	(2.4)	.50	(13)	5.63	(143)

Model No.	J Input Pilot Diameter in	(mm)	K Input Pilot Depth in	(mm)	L Housing Length in	(mm)	M Keyway Length in	(mm)	N Keyway Depth in	(mm)	O Keyway Width in	(mm)
SE23	1.501	(38.1)	.125	(3.2)	2.30	(56)	0.75 flat	(19)	.015 flat	(0.4)	–	–
SE34	2.876	(73.1)	.200	(5.1)	2.99	(76)	1.06	(27)	.072	(1.8)	.125	(3.2)
SE42	2.188	(55.6)	.187	(4.7)	3.73	(95)	1.13	(29)	.108	(2.7)	.188	(4.8)



Model No.	A Square Flange in	(mm)	B Bolt Hole in	(mm)	C Bolt Circle in	(mm)	D Output Pilot Diameter in	(mm)	E Output Shaft Diameter in	(mm)	F Output Shaft Length in	(mm)	G Output Pilot Thickness in	(mm)	H Flange Thickness in	(mm)	I Input Pilot Diameter in	(mm)
SR23	2.27	(58)	.195	(5.0)	2.625	(66.7)	1.500	(38.1)	.375	(.95)	1.00	(25.4)	.062	(1.6)	.22	(6)	1.501	(38.1)
SR34	3.25	(83)	.218	(5.5)	3.875	(98.4)	2.875	(73.0)	.500	(12.7)	1.25	(31.8)	.065	(1.7)	.38	(10)	2.875	(73.1)
SR42	4.25	(108)	.281	(7.1)	4.950	(125.7)	2.187	(55.5)	.625	(15.9)	1.50	(38.1)	.093	(2.4)	.50	(13)	2.188	(55.6)

Model No.	J Input Pilot Depth in	(mm)	K Dist. to Output Centerline in	(mm)	L Housing Length in	(mm)	M Housing Width in	(mm)	N Dist. to Input Centerline in	(mm)	O Keyway Length in	(mm)	P Keyway Width in	(mm)	Q Keyway Depth in	(mm)
SR23	.080	(2.0)	3.09	(78)	4.22	(107)	2.49	(63)	1.36	(35)	0.75 flat	(19)	--	--	.015 flat	(0.4)
SR34	.200	(5.1)	4.33	(110)	5.96	(151)	3.63	(92)	2.00	(51)	1.13	(29)	.125	(3.2)	.072	(1.8)
SR42	.187	(4.7)	5.38	(137)	7.50	(191)	4.75	(121)	2.63	(67)	1.13	(29)	.188	(4.8)	.108	(2.7)

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Sizing and Selection Software for Superior Electric SLO-SYN® Products

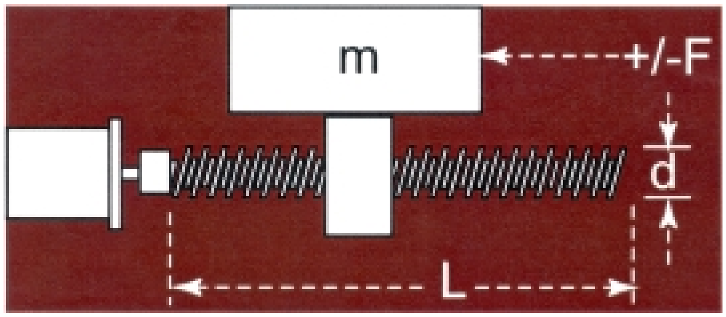
How to Select a Stepper Motor

Successful application of a step motor requires careful selection of the proper step motor drive and control as well as the correct step motor. Since step motor systems are often used as ultra high performance positioning systems or motion controls, selection of the optimum motor/drive combination is of prime importance.

The first step in the selection process is to decide the kind of system to use. Examples include Cylinder/Rod (solid or hollow), Lead Screw, Rack and Pinion, Disc/Pulley, Conveyer or Nip Rollers. A complete load analysis will be required to determine the correct motor size and the amount of torque needed to drive the load. Then it is necessary to determine which motor will best suit the application: Stepper Motor or Servo Motor. CAMAS software for Windows is a menu driven program which will make all these calculations for you. CAMAS is free software which is available upon request.

LEADSCREWS

A. Leadscrew System:



Variable Definitions:

L = length (in)
F = Force (lb)
r = Screw lead (in/rev)
g = 386 in/sec^2
J = inertia (lb in^2)
w = weight of load (lb)
d = diameter (in)
E = Efficiency (as a decimal)

Step 1: Calculate Load Inertia ($J_{total\ load}$):

$J_{load} = w * \rho^2 * (\frac{1}{2}\pi)^2$

$J_{screw} = \pi / 32 * d^4 * L * r$ or $\frac{1}{2} * w * r^2$

$J_{total\ load} = J_{load} + J_{screw}$

Step 2: Calculate Total Inertia (J_{total}):

$J_{total} = J_{total\ load} + J_{motor}$

J_{motor} is found in the Rotor Inertia table at the end of this section.

Note: If $J_{total\ load} > 10 * J_{motor}$, then this motor will not be applicable.

Step 3: Calculate the Torque in the System (T_L):

For a Horizontal leadscrew application, the formula for the system torque is:

$T_L = (F * \rho) / (E * 2\pi)$

For a Vertical leadscrew application, the formula for the system torque is:

$T_L = (((g * w) +/- F) * \rho) / (E * 2\pi)$

where E is the efficiency of the system and F any force that opposes the movement of the load with the exception of friction or gravity.

Step 4: Calculate the Torque Required to Obtain Base Speed (T_b):

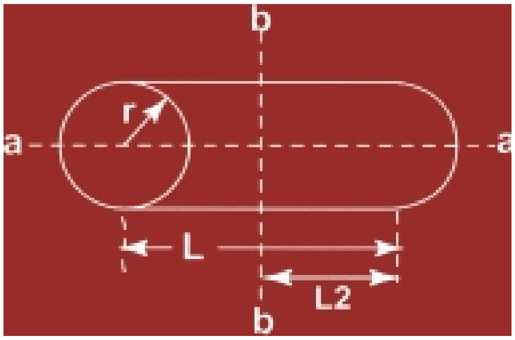
$T_b = J_{total} * V_b^2 * .00032$

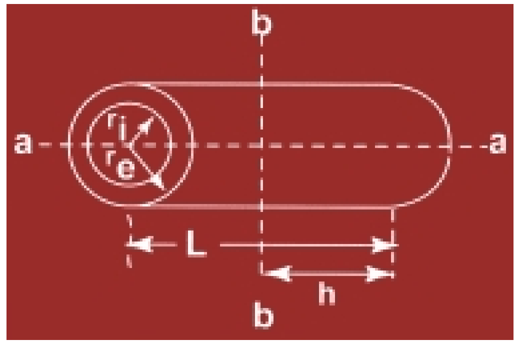
Step 5: Calculate Torque Required to Accelerate the System (T_a):

$T_a = J_{total} ((V_f - V_b) / t_{acc})* .00064$

t_{acc} **is the rate of acceleration.**

B. Cylinder/Rod System:





Variable Definitions:

r = radius (in)

L = length (in)
w = weight of cyl (lb)
J = inertia (lb in^2)
V_b = Base speed (steps/sec)
V_f = Final speed (steps/sec)

r_i = inner radius (in)
r_o = outer radius (in)
L = length (in)
w = weight of cyl (lb)
J = inertia (lb in^2)
V_b = Base speed (steps/sec)
V_f = Final speed (steps/sec)

Step 1: Calculate Load Inertia (J_{load}):

Solid Cylinder: Inertia at Axis A: $J_{load} = 1/2 * w * r^2$

Inertia at Axis B: $J_{load} = 1/12 * w(3r^2 + L_2)$

Hollow Cylinder: Inertia at Axis A: $J_{load} = ½ * w(r_o^2 + r_i^2)$

Inertia at Axis B: $J_{load} = ¼ * w(r_o^2 + r_i^2 + h / 3)$

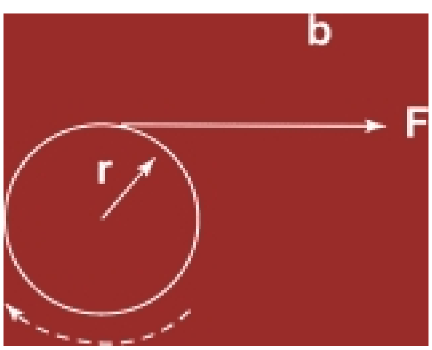
Step 2: Calculate Total Inertia (J_{total})

Very simply: $J_{total} = J_{load} + J_{motor}$

J_{motor} **is found in the Rotor Inertia table at the end of this section.**

Note: If $J_{load} > 10 * J_{motor}$, then this motor will not be applicable.

Step 3: Calculate the Torque in System (T_L):



$T_L = F * r$

where F **is the Force in Pounds.**

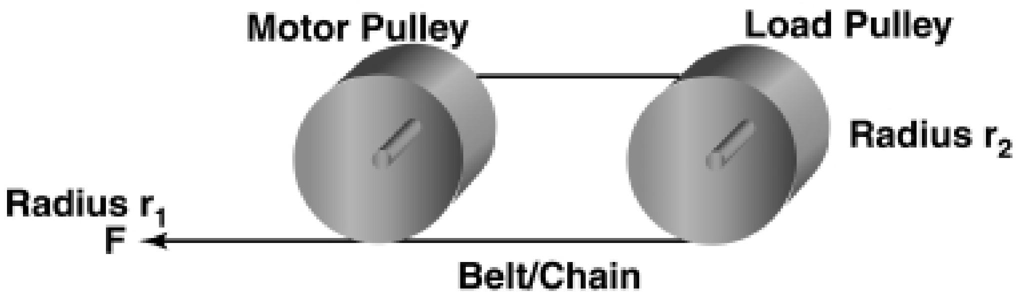
Step 4: Calculate Torque Required to reach Base Speed (T_b):

$T_b = J_{total} * V_b^2 * .00032$

Step 5: Calculate Torque Required to Accelerate the System (T_a):

$T_a = J_{total} ((V_f – V_b) / t_{acc})* .00064$

C. Disc/Pulley System:



Variable Definitions:

r_1 = radius motor pulley (in)
w_1 = weight motor pulley (lb)
F = Force required to rotate system (lb)
V_b = Base speed (steps/sec)
r_2 = radius load pulley (in)
w_2 = weight load pulley (lb)
J = inertia (lb in²)
V_f = Final speed (steps/sec)

Step 1: Calculate Load Inertia ($J_{total\ load}$):

$J_{motor\ pulley} = 1/2 * w * r_1^2$
$J_{load\ pulley} = 1/2 * w * r_2^2$
$J_{total\ load} = J_{motor\ pulley} + J_{load\ pulley}$

Step 2: Calculate Total Inertia (J_{total})

$J_{total} = J_{total\ load} + J_{motor}$

J_{motor} **is found in the Rotor Inertia table at the end of this section.**

Note: If $J_{total\ load} > 10 * J_{motor}$, then this motor will not be applicable.

Step 3: Calculate the Torque in System (T_L):

$T_L = F * r_1$

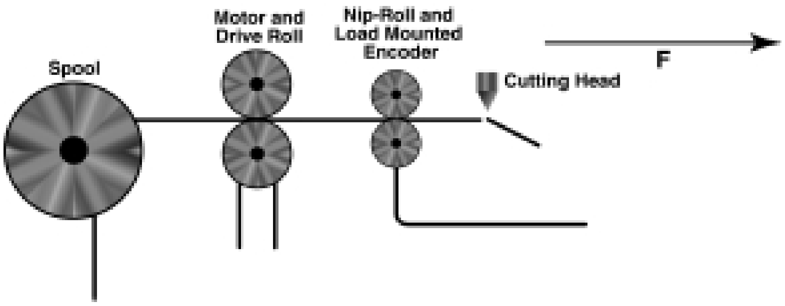
Step 4: Calculate Torque Required to reach Base Speed (T_b):

$T_b = J_{total} * V_b^2 * .00032$

Step 5: Calculate Torque Required to Accelerate the System (T_a):

$T_a = J_{total} ((V_f – V_b) / t_{acc})* .00064$

D. Nip Roller System:



Variable Definitions:

F = Force (lb)
r = radius (in)
F = Force required to rotate system (lb)
V_b = Base speed (steps/sec)
J = inertia (lb in^2)
w = weight (lb)
V_f = Final speed (steps/sec)

Step 1: Calculate Load Inertia ($J_{total\ load}$):

Inertia of a roller or disc is calculated as:

$J_{roll} = ½ * w * r^2$

Repeat the above formula for each roller or disc that must be rotated as the load progresses.

$J_{total\ load} = J_{spool} + J_{roll\ 1} + J_{roll\ 2} + J_{roll\ 3} + J_{roll\ 4}$ etc

Step 2: Calculate Total Inertia (J_{total})

$J_{total} = J_{total\ load} + J_{motor}$

J_{motor} **is found in the Rotor Inertia table at the end of this section.**

Note: If $J_{total\ load} > 10 * J_{motor}$, then this motor will not be applicable.

Step 3: Calculate the Torque in System (T_L):

$T_L = F * r$

Where r represents the radius of the roller or disc driven directly by the motor.

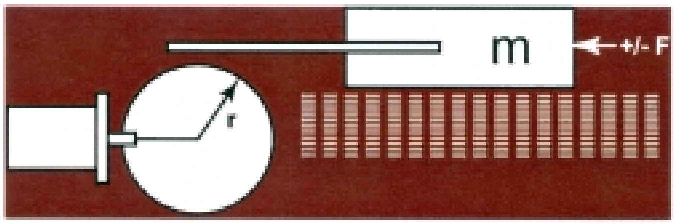
Step 4: Calculate Torque Required to reach Base Speed (T_b):

$T_b = J_{total} * V_b^{\ 2} * .00032$

Step 5: Calculate Torque Required to Accelerate the System (T_a):

$T_a = J_{total} ((V_f – V_b) / t_{acc})* .00064$

E. Rack and Pinion:



Variable Definitions:

w = weight of load (lb)
F = Force (lb)
J = inertia (lb in^2)
V_f = Final speed (steps/sec)
r = radius of pinion gear (in)
g = 386 in/sec^2
V_b = Base speed (steps/sec)
μ = Coefficient of friction between 2 surfaces.

Step 1: Calculate Load Inertia ($J_{total\ load}$):

$J_{pinion} = 1/2 * w * r^2$
$J_{rack} = w * r^2$
$J_{total\ load} = J_{pinion} + J_{rack}$

Step 2: Calculate Total Inertia (J_{total})

$J_{total} = J_{total\ load} + J_{motor}$

J_{motor} **is found in the Rotor Inertia table at the end of this section.**

Note: If $J_{total\ load} > 10 * J_{motor}$, then this motor will not be applicable.

Step 3: Calculate the Torque in System (T_L):

For horizontally positioned Rack and Pinion applications, Torque for the system is calculated as:

$T_L = w * \mu * r$

The value for μ can be found on the Coefficient of Friction table at the end of this section.

For vertically positioned Rack and Pinion applications, Torque for the system is calculated as:

$T_L = ((g * w) + (w * \mu)) * r$

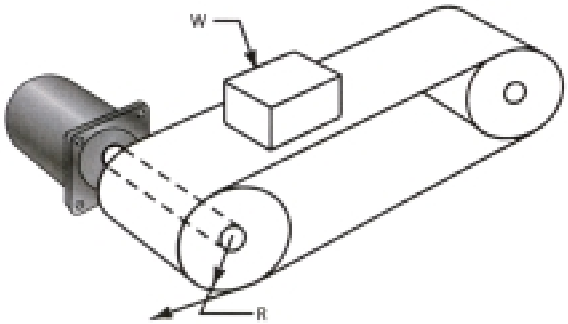
Step 4: Calculate Torque Required to reach Base Speed (T_b):

$T_b = J_{total} * V_b^2 * .00032$

Step 5: Calculate Torque Required to Accelerate the System (T_a):

$T_a = J_{total} ((V_f - V_b) / t_{acc}) * .00064$

F. Convever Svstem:



Variable Definitions:

w = weight (lb)
J = inertia (lb in^2)
V_f = Final speed (steps/sec)
r = radius (in)
V_b = Base speed (steps/sec)
F = Force required to move the system (lb)

Step 1: Calculate Load Inertia ($J_{total\ load}$):

$J_{motor\ roll} = ½ * w_{motor\ roll} * r_{motor\ roll}^2$
$J_{driven\ roll} = (½ * w_{driven\ roll} * r_{driven\ roll}^2) / (r_{driven\ roll} / r_{motor\ roll})^2$
$J_{belt} = w_{belt} * r_{motor\ roll}^2$
$J_{load} = w_{load} * r_{motor\ roll}^2$

Additional driven roll inertias must be added to the calculation as required.

$J_{total\ load} = J_{motor\ roll} + J_{driven\ roll} + J_{belt} + J_{load}$

Step 2: Calculate Total Inertia (J_{total})

$J_{total} = J_{total\ load} + J_{motor}$

J_{motor} **is found in the Rotor Inertia table at the end of this section.**

Note: If $J_{total\ load} > 10 * J_{motor}$, then this motor will not be applicable.

Step 3: Calculate the Torque in System (T_L):

$T_L = F * r$

Where r represents the radius of the roller or disc driven directly by the motor.

Step 4: Calculate Torque Required to reach Base Speed (T_b):

$T_b = J_{total} * V_b^2 * .00032$

Step 5: Calculate Torque Required to Accelerate the System (T_a):

$T_a = J_{total} ((V_f – V_b) / t_{acc})* .00064$

Motion Calculations (applicable to all configurations):

Enter Required Torque:
Enter value from Step 5 for your particular system. __________oz in

Determine available torque at required Velocity
by referring to Speed/Torque Curve of the motor. __________oz in

If Available Torque is greater than Required Torque, then the motor is acceptable.
Duty cycle considerations must be evaluated for proper motor selection.

Required Tables:

Rotor Inertia (for M series)

Model:	Inertia (lb in^2)	Model:	Inertia (lb in^2)
M061	.04	M093	.64
M062	.08	M111	1.34
M063	.11	M112	2.75
M091	.23	M113	4.1
M092	42	MH112	3.22
M172	21.0	MH172	21.0

Rotor Inertia (for KM series)

Model:	Inertia (lb in^2)	Model:	Inertia (lb in^2)
KM060	.0369	KM091	.3858
KM061	.0819	KM092	.7477
KM062	.1349	KM093	1.133
KM063	.2025		

Density Table for Material:

Material	Density (lb/in^3)	Material	Density (lb/in^3)
Acryl	.0433	Iron (cast)	.2635
Aluminum	.0975	Magnesium	.0614
Bakelite	.0469	Nickel	.3177
Brass	.3069	Nylon	.0412
Bronze	.3213	Rubber	.0433
Copper	.3213	Steel	.2816
Glass	.0939	Teflon	.0794
Iron	.2852		

Coefficients of Static Friction Materials:

(Dry contact unless noted)

Steel on Steel	.58
Steel on Steel (lubricated)	.15
Aluminum on Steel	.45
Copper on Steel	.22
Brass on Steel	.19
Teflon on Steel	.04

Leadscrew Efficiencies:

Type	High	Median	Low
Ball – Nut	95	90	85
Acme with metal nut **	55	40	35
Acme with plastic nut	85	65	50

**Since metallic nuts usually require a viscous lubricant, the coefficient of friction is both speed and temperature dependant.

Conversion Table

To convert from A to B multiply by conversion factor. Divide to convert from B to A

	A	B
INERTIA	oz-in^2	70.62 kg-cm^2
	oz-in^2	24.13 lb-in^2
	lb-in^2	2.926 kg-cm^2
TORQUE	oz-in	0.0625 lb-in
	oz-in	0.7062 N-cm
	lb-in	11.3 N-cm
WEIGHT	lb	0.4536 kgf
ROTATIONAL SPEED	rpm	3.333 steps/sec[1]
	rps	200 steps/sec[1]
	rad/sec	31.83 steps/sec[1]

[1] for 200 steps per revolution

Application notes

NOTES

TECHNICAL

Characteristics of SLO-SYN DC Step Motors

- *Brushless, permanent magnet motors*
- *Operate in full-step (1.8°) or half-step (0.9°) increments*
- *Can be microstepped to achieve increments as small as 0.0072°*
- *Accuracies typically ±2% or ±3% for size 23 and 34 motors. (For larger motors it is ±5%)* (1)
- *Can be operated at rates to 20,000 steps per second (6000 rpm)*
- *Holding torque ratings from 54 to 5330 oz-in (38 to 3764 Ncm)*
- *Wide range of torque ratings, shaft configurations and frame sizes*
- *Easily adapted to different control types, including microprocessor based systems*
- *Class B insulation, operate at ambient temperatures from -40°C to +65°C (-40°F to +149°F)*
- *No brushes, ratchets or detents to wear out*
- *Lubricated-for-life ball bearings*

(1) Maximum positive or negative deviation from the rated angular motion per step, for any step in a complete revolution. Expressed as a percentage of the angle of a single step. Measured at no load with rated current applied to both motor windings (balanced to within 1%) and motor operated in the "two windings on" mode.

Underwriters Laboratories Recognition & Canadian Standards Association Certification and CENELEC Certification

- *All M06, KM06 and M09, KM09 Series motors are recognized by UL, UL#E31544*
- *KM06 and KM09 Series motors carry the CE mark*
- *Most standard motors are listed by Canadian Standards Association, including all M06 and M09 Series Motors*
- *Motors in other series which meet UL requirements are identified with letter U suffix or are provided with a UL logo. Most standard motors, as well as double end motors, are eligible*

Comparison of Servomotors versus DC Step Motors

Too often, when a motion control system is being specified, the designer automatically assumes that a servomotor system must be used. The truth is that, in many cases, a well designed step motor system will perform the same function as well, and at lower cost. The following comparison of the outstanding characteristics of the two types of motors outlines some of the advantages of step motors for motion control.

Servomotor Characteristics

- *Require complex, expensive control systems*
- *Position sensing devices needed for feedback to control*
- *Relatively low torque for size*
- *Thermally inefficient*
- *Control system must be "tuned" to load; must be "retuned" if load is changed*
- *Brushes on DC servomotors subject to wear*

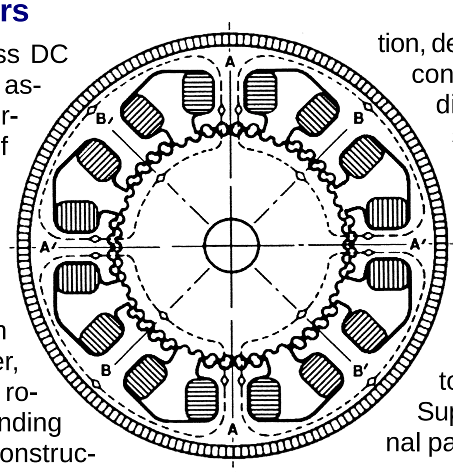
SLO-SYN DC Step Motor Characteristics

- *Relatively inexpensive*
- *Can be operated "open-loop" (no position feedback required)*
- *Noncumulative step error*
- *Simple control electronics can be used*
- *Brushless construction aids reliability*
- *Maintenance free*
- *Will not be damaged if stalled*
- *High torque for size*
- *Maintain position when at rest*

Call Superior Electric for a copy of "Superior Motion Control Application Solutions," a user's guide to applying step motors and controls.

Construction of DC Step Motors

A SLO-SYN® Step Motor is a brushless DC motor consisting of a rotor and a stator assembly. The illustration shows the internal construction and tooth alignment of the motor. A certain number of teeth, evenly spaced around the entire diameter, provide the incremental angular rotation that results in mechanical motion. SLO-SYN steps motors are constructed with a 48-50 or a 52-50 tooth pitch configuration. The second number, 50, refers to the number of teeth on the rotor. The 50 teeth, combined with the winding configuration and permanent magnet construction, deliver a 1.8° step angle. Both configurations have a slightly different tooth pitch on the stator (48 or 52) to provide smoother operation and softer step-to-step motion with less resonance or mechanical instability at low speed. The 52 tooth stator design is used in the new KM06 and KM09 motors to provide extra torque. Superior Electric held the original patent on the 48-50 design.



Stepping Techniques

The terms full-step, half-step and microstep are commonly used in the discussion of step motors.

A standard 1.8° step motor has 200 discrete positions in a full 360° revolution. Since 360° divided by 200 equals 1.8°, the motor shaft will advance 1.8° each time the motor is given a digital command to take one step. This is known as a full-step.

The term "half-step" implies a 0.9° step angle (half of a full 1.8° step), resulting from a different switching technique of the drive transistors that provide power to the motor windings.

The term "microstep" refers to a more sophisticated form of control which goes beyond the simple switching of power between phase A and phase B of the motor windings and takes control of the amount of current being sent to the individual windings. Microstepping permits the rotor and shaft to be positioned in places other than the natural 1.8° and 0.9° positions during motion.

SLO-SYN Step Motors, because of their basic nature as digital devices and reliable position and motion control actuator, have proven themselves for many years to be a very dependable source of motion control.

Microstepping

Microstepping is a method of step motor control that allows the rotor to be positioned at places other than the 1.8° or 0.9° locations provided by the full-step and half-step methods. Microstepping positions occur between these two angular points in the rotation of the rotor.

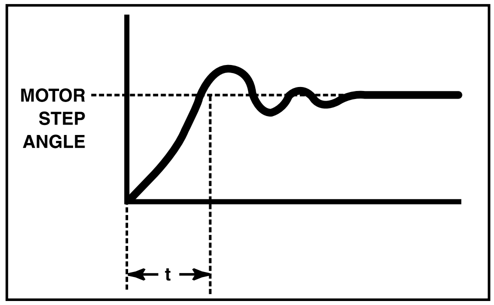
The most commonly used microstep increments are 1/5, 1/10,1/16,1/32, 1/125 and 1/250 of a full step. Microstep increments chosen by Superior Electric simplify control of both US and metric units of measurement, and also allow finer positioning resolution. While a full step of 1.8° will give a 0.001 inch resolution when the motor is driving through a lead screw which has a 0.2000 inch lead, resolutions of 0.000008 inch or less are theoretically possible using microstepping.

A major benefit of microstepping is that it reduces the amplitude of the resonance that occurs when the motor is operated at its natural frequency or at sub-harmonics of that frequency. The improved step response and reduced amplitude of the natural resonances result from the finer step angle.

Superior Electric drives offer microstepping, so the benefits of microstepping are available whenever smoother Step motor performance or finer positioning resolution are required.

Step Response

When a step signal is given to a step motor, the motor shaft will rotate the specified angular distance within a measurable period of time which is called the step response time. This time is a function of the motor and of the characteristics of the electronic drive circuits.



STEP RESPONSE

Torque vs. Speed Characteristics

Many factors determine the torque vs. speed characteristics of a SLO-SYN Step Motor. These include the design of the drive system and the voltage supplied to the motor, as well as the inductance rating of the motor used.

Switching Sequence For Operation From Bipolar Drives

FULL-STEP (TWO-PHASE ON) ENERGIZING SEQUENCE*

STEP	PHASE A	PHASE B
1	+1	+1
2	+1	-1
3	-1	-1
4	-1	+1
1	+1	+1

HALF STEP PHASE ENERGIZING SEQUENCE*

STEP	PHASE A	PHASE B
1	+1	+1
2	+1	—
3	+1	-1
4	—	-1
5	-1	-1
6	-1	—
7	-1	+1
8	—	+1
1	+1	+1

FULL-STEP (ONE PHASE ON) ENERGIZING SEQUENCE*

STEP	PHASE A	PHASE B
1	+1	—
2	—	-1
3	-1	—
4	—	+1
1	+1	—

Continued next page . . .

TECHNICAL

Switching Sequence For Operation From Unipolar Drives

FOUR STEP INPUT SEQUENCE (FULL-STEP MODE)*

STEP	SW1	SW2	SW3	SW4
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

EIGHT STEP INPUT SEQUENCE HALF-STEP MODE*

STEP	SW1	SW2	SW3	SW4
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	OFF
3	ON	OFF	OFF	ON
4	OFF	OFF	OFF	ON
5	OFF	ON	OFF	ON
6	OFF	ON	OFF	OFF
7	OFF	ON	ON	OFF
8	OFF	OFF	ON	OFF
1	ON	OFF	ON	OFF

*** Rotation is clockwise as viewed from label end of motor. For counter-clockwise rotation, sequence should go from bottom to top of chart.**

Effects of Drive Design

Design of the drive which operates the motor is an important factor in determining the performance which will be obtained. The types of drives offered, and their effects on motor performance, are as follows:

NOTE: MH112 and MH172 motors are designed to operate only from four-terminal bipolar drives.

L/R Drives - This design was the basis for most older drives and is still used on some existing drives. It allows half- or full-step motor operation, but does not permit variable control of current level. L/R drives also require dropping resistors, which reduce motor efficiency. L/R drives provide satisfactory performance at lower stepping rates, but do not have good high speed capabilities. This is the most basic drive design, and it is typically the lowest in cost.

Constant Current Chopper Drives - These drives maintain relatively constant current to the motor at all speeds, and therefore offer good stepping performance at rates up to approximately 10,000 steps per second. Although more costly and complex than L/R drives, they allow use of features such as closed-loop control, microstepping, current boost and stabilization in addition to improved motor performance.

Line Operated, High Voltage Chopper Drives - These drives deliver higher voltage to the motor for optimum high speed performance. They are also able to operate larger motors to provide high performance and excellent efficiency. Since they do not need bulky stepdown transformers, line operated drives are more compact than other chopper drives.

Effects of Motor Voltage

Motor performance at mid-range and high-range speeds can be unproved by increasing the voltage to the motor. However, the motor will operate at a high temperature when the voltage is increased, so some means of cooling may be necessary. In general, motor supply voltage does not affect operation at lower stepping rates.

Motor Inductance Effects

For a given supply voltage, a low inductance motor will give better performance at high speeds than a high inductance motor, but will operate at a high temperature.

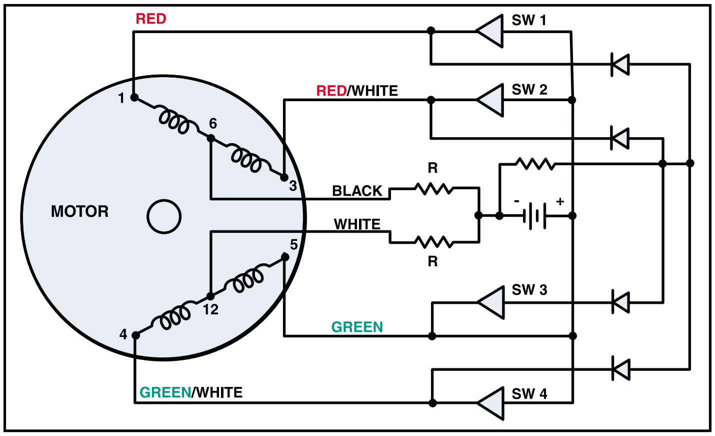
This is true because a lower inductance motor requires more current than does a high inductance model. High inductance motors yield higher maximum torque and operate cooler, but their top speed is limited and torque falls off more rapidly as speed rises than is the case with a lower inductance motor.

Transient Voltage Suppression

As current is switched through the motor windings during stepping, transient voltages are generated which can cause faulty operation and damage to the motor and drive components. To prevent these problems, some means of limiting or removing these transients must be provided. The most common means of accomplishing this employs shunting diodes as shown in the connection diagram.

Typical diodes for use in this circuit are 1N4002 and 1N4003 and similar types. Resistance may be varied between 0 and 50 ohms, as needed, to reduce transient voltages to an acceptable level. Capacitors can be used in place of the diodes. Capacitor ratings between 0.1 and 1.0 mfd. can be used, depending on the characteristics of the switches.

See picture on next page . . .



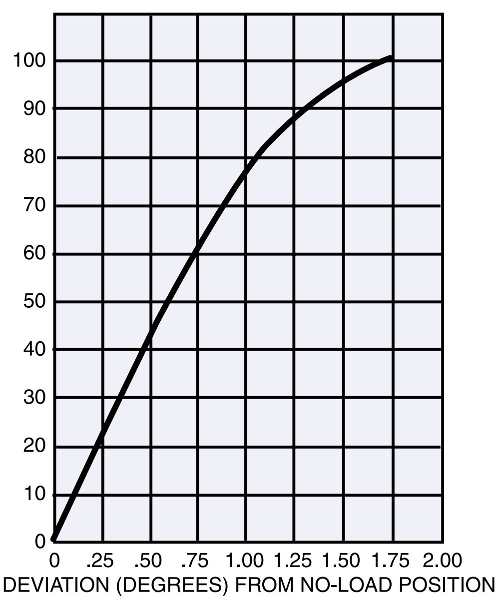
Note: Circuit shown is only for use with a unipolar drive
TYPICAL TRANSIENT VOLTAGE SUPPRESSION CIRCUIT

Holding and Residual Torque

The permanent magnet design of a SLO-SYN Step Motor provides a small residual torque which helps hold the motor shaft in position when the motor is not energized. If greater holding torque is required, one or both motor windings can be energized with dc voltage when the motor is not stepping. The sections for each motor list residual torque values, as well as holding torque values with both one and two motor windings energized at rated voltage and current.

Angular Position Deviation

When a load is applied to a motor shaft, the shaft will rotate angularly from the no load position. The Angular Position Deviation curve shows shaft deviation from the no load position vs. percent of rated holding torque. This curve is valid for all 1.8° step angle SLO-SYN Step Motors.



ANGULAR POSITION DEVIATION

NOTE: Proper construction of the mechanism of the driven load is essential in order to accurately achieve a true versus theoretical position.

Available Options

Double End Shafts - These motors have an output shaft at both ends. Motors with double end shafts are used to mount an encoder on the motor shaft or to mount a knob for turning the motor shaft manually. Double end shaft models of the size 23 and 34 Series are equipped with two drilled and tapped holes on the rear end bell for mounting encoders. Motors with shafts at both ends are identified with a letter E suffix added to the type number. See individual sections for detailed ordering information.

NOTE: Double-end shafts are not available on motors that have a shaft mounted encoder.

Shaft Modifications - A variety of motor output shaft modifications can be supplied. These include special flats and keyways, through holes and similar changes which may be needed to allow mounting of timing belts, pulleys or gears or to facilitate mounting the motor to the equipment being driven.

Electrical Modifications - Motors can be supplied with a number of electrical modifications, including nonstandard lead lengths, electrical connectors and special electrical windings.

Shaft Mounted Encoder - Superior Electric offers encoders which can be supplied as kits for mounting to existing double-end motors, or which can be supplied as an integral part of any standard M06 or M09 Series double-end motor. They can also be supplied on M111-FF and M112-FF (square flange) motors. The encoders are available with outputs of 200, 400, 500 or 1250 pulses-per-revolution with an optional zero reference pulse. Kits are offered for mounting on shafts 1/4 inch or 3/8 inch in diameter. Type numbers for ordering kits are shown in the encoder section. Consult the factory for information on ordering a motor with an integral encoder.

Optional Post Machining

Motors in the M090 and larger frame sizes are available with optional post machining to provide closer shaft runout and mounting surface tolerances. Call . . .

DEFINITIONS

Definition of Terms

1.1 **COMMAND PULSE RATE:** Command pulse rate is the rate at which successive command pulses are applied to the motor by the drive circuit.

1.2 **DETENT TORQUE**: Detent torque is the lowest value of torque (for a complete revolution) which can be applied to the motor's shaft which causes the rotor to advance to the next detent position with the stator winding de-energized and not connected to one another in any way electrically.

1.3 **DIELECTRIC WITHSTAND VOLTAGE:** Dielectric withstand voltage is the maximum RMS value of a 50 to 60 Hz voltage which may be applied to the motor (winding to winding, or winding to frame, as specified) without avalanche breakdown of the insulation occurring within 60 seconds from the time of the application of the test voltage. Reactive components of current are to be disregarded. Avalanche breakdown is defined as a sudden discontinuity in the rate of change of current with change in voltage (di/dv).

1.4 **DIRECTION OF ROTATION:** The direction of rotation of the shaft is determined by viewing the stepping motor facing the shaft extension associated with the mounting surface. The standard (positive) direction of shaft rotation is CW.

1.5 **DRIVE CIRCUITS:** A drive circuit is a combination of the translator logic and a power amplifier which switches the phases of the stepping motor in a predetermined mode sequence.

1.6 **GENERATED EMF:** Generated EMF is the counter-electromotive force (CWMF), also called "back EMF" (EMF), generated by the rotation of the rotor of a hybrid or P.M. motor when the phase windings are not energized and are open circuited. It is measured as the peak-to-peak value of the generated voltage of one winding when the rotor is driven at a constant angular velocity or 1000 RPM. It is reported as peak volts (half of the peak-to-peak value measured) per 1000 RPM.

Note: This does not apply to V.R. motors as they nave no rotor magnets.

1.7 **HOLDING TORQUE:** Holding torque is the peak resistance (at a specified current) to rotation of a gradually rotated shaft of an energized stepping motor. There are two 'n' such torque peaks (half positive, half negative) in a motor rated at n steps/revolution. The mode 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.

1.8 **LOAD:** Any external static or dynamic resistance to motion that is applied to the motor. The character of the load must be defined (e.g. Coulomb Friction, Viscous Friction, etc.)

1.9 **LOAD ANGLE**

1.9.1 **STATIC LOAD ANGLE:** Static Load Angle is the angle through which the rotor is displaced from its energized quiescent position by a given applied torque at a Command Pulse Rate of zero, at a specified current.

1.9.2 **DYNAMIC LOAD ANGLE:** The Dynamic Load Angle is the angle between the loaded and unloaded position of the rotor (at a given instant) under otherwise identical conditions at a specified command Pulse Rate & Phase Current.

1.10 **MAXIMUM REVERSING COMMAND PULSE RATE:** The maximum reversing pulse rate is the maximum pulse rate at which the unloaded step motor is able to reverse and remain in synchronism under the specified drive conditions.

1.11 **MAXIMUM SLEW PULSE RATE:** The maximum slew pulse rate is the maximum pulse rate at which the unloaded step motor can remain in synchronism under the specified drive conditions.

1.12 **MECHANICAL HYSTERESIS:** The angle (mechanical) between the unloaded quiescent point when moving CW and the unloaded quiescent point (of the same step position) when moving in the CCW direction.

1.13 **MOUNTING SURFACE PERPENDICULARITY:** Mounting surface perpendicularity is the difference between the maximum reading and the minimum reading of the dial indicator probing the surface of a flat ground parallel surface metal plate (a minimum of 6mm thick) mounted to the mounting surface of the motor. The motor shaft is held stationary and the motor with its test plate rotated about the shaft. The test plate shall have a surface finish of 1 micrometer (32 microinch) or better, and shall be parallel within 0.0025mm (0.0001 inch) TIR over the surface. The indicator probe shall be applied at a diameter equal to the body diameter of the motor.

1.14 OVERSHOOT (TRANSIENT): The overshoot (transient) is the amount the shaft of the step motor rotates beyond the final position.

1.15 (MOTOR) PHASE: A motor phase is a set of electrically excited stator poles, consisting of one or more pairs of oppositely polarized poles. The magnetic polarity of these poles is sequentially reversed when the number of phases are even integers, in which case the electrical angle between phases is 180°/number of phases. When the number of phases are odd integers, the polarity of the poles does not reverse and the electrical angle between phases is 300°/ number of phases.

NOTE: A bifilar wound set of poles constitutes one motor phase, not two, since the flux reverses in the pole albeit the pole has two windings and the current in each is unidirectional. The number of phases is not dependent on the number of windings, but rather on the electrical angle between poles.

1.16 POSITIONAL ERROR: Positional error (sometimes designated 'Absolute Accuracy') 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 a % of the angle of the rated incremental angular motion per step, measured at no load, with rated current applied to the winding(s), the step sequence specified, and measured at 25° Celsius. In the 2-on step sequence the phase currents shall be balanced to within 1% of each other.

1.17 PULL-IN STEP RATE: The pull-in step rate is the maximum command pulse rate (constant) at which the energized step motor can accelerate an applied load from standstill to command pulse step rate, synchronously without missing steps.

1.18 PULL-IN TORQUE: The pull-in torque is the maximum positive coulomb friction torque at which an energized step motor will accelerate to command pulse step rate, and run in synchronism with the command pulse rate without losing steps, on application of a fixed specified inertial load and drive circuit conditions.

1.19 PULL-OUT STEP RATE: The pull-out step rate is the maximum command pulse rate (constant) at which the energized step motor can run in synchronism with the command pulse rate at a specified position coulomb friction load. Conditions of measurement shall exclude viscous friction and any other form of speed-dependent torque.

1.20 PULL-OUT TORQUE: Pull-out torque is the maximum positive coulomb friction torque which can be applied to the rotating shaft of a step motor (already running in synchronism with the command pulse rate) at a given command pulse rate and conditions of drive circuit, without missing a step. Conditions of measurement shall exclude viscous friction and any other form of speed-dependent torque.

1.21 RESOLUTION: The resolution is the reciprocal of the number of (full) steps per revolution of the motor shaft.

1.22 RESONANT STEP RATES: Resonant step rates are those step rates at which there are definitive peaks on the curve of velocity modulation amplitude vs step rate. The severity of a given resonant range is dependent on: (a) the velocity modulation amplitude and (b) the bandwidth of the step-rates in the range.

1.23 RESPONSE RANGE: Response range is the command pulse range over which the unloaded motor can accelerate to command pulse rate from standstill, decelerate from command pulse rate to standstill, or reverse direction (on command) without missing steps.

1.24 SALIENT: A salient is a projection of magnetically permeable material on the pole of a rotor or stator.

1.25 SETTLING TIME: Settling time is the total time from the application of the command signal until the amplitude of the oscillatory motion of the rotor has diminished to 10% of the amplitude of the greatest oscillatory excursion in a given step.

1.26 SHAFT RUN-OUT: Shaft run-out is the difference between the maximum reading and the minimum reading of a dial indicator when located on the shaft surface. When the distance from the mounting surface is not specified, the extremity of the shaft shall be used by default. The motor frame is stationary during such measurement.

1.27 SLEW RANGE: Slew range is the range of command pulse rates over which the motor can remain unidirectinally in synchronism with the command pulse rate but cannot start, or reverse at a fixed command pulse rate without missing steps. The drive circuit conditions shall be specified.

1.28 **STEP:** A (full) “step” is the increment in angular position of the rotor between any tow adjacent quiescent states when the phases are energized singly and in sequence. A step is alwasy associated with two phases energized at all times or with one phase energized at all times. Alternate 1-on, 2-on energization is termed half-stepping.

1.29 **STEP ANGLE (BASIC):** Is the rated angular increment of rotor position, at no load between any two adjacent quiescent states when the phases are energized singly in sequence.

1.30 **STEP ANGLE ERROR:** (Sometimes designated “Incremental Step Accuracy”.) This is the maximum + or - deviation from the rated incremental angular motion per step, for any adjuacent steps in a complete revolution without reversing direction. It is expressed as a % of the angle of the rated incremental angular motion per step, measured at no load, with rated current applied to the winding(s), the step sequence specified, and measured at 25° Celsius. In the 2-on step sequence the phase currents shall be balanced to within 1% of each other.

1.31 **STEP POSITION:** A step position is the static angular position which the shaft of an unloaded step motor assumes when it is energized without causing continuous rotation. The step sequence shall be specified.

1.32 **STEP SEQUENCE:** The sequence of excitation defined by the drive curcuit, which when applied to the motor provides a repeatable cyclic pattern by which the windings are energized.

1.33 **STEPPING MOTOR:** A step motor is a polyphase synchronous inductor motor, the rotor of which rotates in descrete angular increments when the stator windings thereof are energized in a programmed manner either by appropriately timed d.c. pulses or by a polyphase alternating current. Rotation occurs because of the magnetic interaction between th erotor poles and the poles of the sequentially energized stator phases. The rotor has no electrical winding but rather salient or magnetized poles.

1.33.1 **PERMANENT MAGNET (PM):** A permanent magnet step motor utilizes a rotor which has permanently magnetized poles.

1.33.2 **VARIABLE RELEUCTANCE (VR) STEP MOTORS:** A variable reluctance step motor utilizes a rotor which has pole salients (soft iron) without magnetic bias in the de-energized state.

1.33.3 **HYBRID (HY):** A hybrid step motor utilizes a permanent magnet to polarize soft iron pole pieces.

1.34 **STEPPING RATE:** The stepping rate is the number of step angles through which the step motor shaft rotates in a specified time.

1.35 **SYNCHRONISM:** Synchronism exists when the stepping rate of the motor equals the command pulse rate.

1.36 **TERMINATION:** A terminal or wire (sometimes termed “leads” in an aggreagate) or the motor which connects the stator phase windings to the drive circuit, through which electric current to the windings is supplied.

1.37 **THERMAL RESISTANCE:** Thermal resistance is the opposition to the flow of heat in the materials of which the motor is constructed. It is expressed as degrees Celsius per watt. All measurements are taken after steady state conditions have been achieved.

1.37.1 **THERMAL RESISTANCE (WINDING TO FRAME):** This is the measured difference in temperature between the winding and the surface of the motor O.D. (midpoint) divided by the total electrical power (watts) input to the motor at the time and two temerpature readings are taken.

1.37.2 **THERMAL RESISTANCE (FRAME TO AIR):** This is the same as 1.37.1 except that the temperature difference between the winding and the surface of the O.D. midpoint and the air surrounding the motor. The air shall be still, the motor suspended in the air to prevent heat sink effect of bench surfaces, etc.

1.37.3 **THERMAL RESISTANCE (FRAME TO HEAT SINK):** This is the same as 1.37.1 except that the temperature differential is that which exists between motor frame and a heat sink. The heat sink shall be sufficiently large and sufficiently thick to be (effectively) an “infinite heat sink” to the motor in question.

1.38 **THERMAL TIME CONSTANT:** This is the time required for the winding temperature of a motor to reach 63% of its steady state temperature of a motor to reach 63% of its steady state temperature RISE with constant POWER applied to the motor. It is measured by allowing the motor to reach steady state temperature, and then disconnecting the electrical power input. The winding temperature is recorded as a function of time, zero time being the time at which the power source was disconnected. The time required to drop to 37% of the steady state temperature rise is the hermal time constant. It is usually expressed in seconds, but any uint of time may be used.

1.39 TORQUE GRADIENT: Torque gradient (sometimes called "stiffness torque") is the slope of the torque displacement curve at th eno-load quiescent point.

1.40 TRANSLATOR LOGIC: Translator logic translates the input pulse train into the selected mode pattern to be applied to a step motor.

1.41 WINDING: A winding is an aggregate of magnet wire turns all on the poles of a given phase. Where ther are two windings per phse, they may be connected in series or parallel. In the case of the series connection, the connection between the two windings of a phse (5-lead or 6-lead motors), the motor is referred to as a bifilar wound motor, but a "winding" consists of the magnet wire turns from the center tap to either end and not end to end.

1.42 WINDING INDUCTANCE: The winding inductance of a step motor winding varies both with rotor position and with excitation current. Measurements can also be affected by the rate of change of current; thus when a figure for inductance is given, the conditions under which the measurements were taken must be quoted. The following three types of inductance measurements each have their advantage and disadvantage. That of 1.42.1 is the simplest and fastest measurement to make, and requires the least equipment, but is least representative of actual operation conditions. The method of 1.42.3 on the other hand is the most representative of actual operating conditions, but is the most difficult and time-consuming of the methods and requires the most specialized equipment. The method of 1.42.2 is a compromise, perhaps leaning towards 1.42.3 as being representative of actual operating conditions.

1.42.1 INCREMENTAL UNENERGIZED WINDING INDUCTANCE: An inductance bridge having a test frequency of 1 KHz is used for this test. THe bridge voltage should be 1 v RMS applied to the motor. THe inductance measurement should be made with the rotor locked in the "aligned" or "unaligned" position, with no d.c. current applied to any of the windings. The figure reported should state whether the "aligned" or "unaligned" position is used.

1.42.2 INCREMENTAL ENERGIZED WINDING INDUCTANCE: This is the same as 1.42.1 except that the inductance measurement is made at some value of winding excitation. Unless otherwise stated, the winding excitation shall be that of rated current.

1.42.3 INCREMENTAL ENERGIZED WINDING INDUCTANCE BY CURRENT RISETIME METHOD: This measurement provides information from which incremental inductance can be calculated at any level of excitation up to the level of steady state energization. It is similar in nature to the inductance obtainable by paragraph 1.42.2 except that it does not suffer from the effects of the 1 KHz test frequency. Measurements are made with the rotor locked in the "aligned" and/or the "unaligned" position. As in 1.42.2 a constant d.c. voltage is applied to a phase winding. The voltage shall be of such magnitude that the steady state current is 10% higher than the highest value of current at which iinductance information is desired. The rise of current with time is recorded (storage oscilloscope, digitized data on floppy disk, oscilloscope photograph, etc) The derivative of the current vs. time curve (di/dt) is that used to compute the inductance at the value of excitaiton of interest from

$$L = \frac{V - I*R}{di/dt}$$

WHERE:

- V = Applied voltage
- I = Current in amperes at which di/dt is measured
- R = total circuit resistance (including current monitoring shunt if used) in ohms
- di/dt = rate of change of current with voltage in amps/sec
- L = inductance in Henries

1.43 WINDING RESISTANCE: Winding resistance is the lead-to-lead (terminal-to-terminal) ohmic resistance measured with the windings at 25° Celcius. A winding is defined in paragraph 1.41. The method used for measurement of resistance shall be accurate to four significant figures, and the value reported to three significant figures, the minimum value rounded down, and the maximum value rounded up.