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DESIGN ENGINEER'S GUIDE TO DC STEPPING MOTORS



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DESIGN ENGINEER'S GUIDE TO DC STEPPER MOTORS

1.0 PURPOSE

The purpose of this guide is to acquaint the designer with basic characteristics of DC stepper motors and associated drives. Their advantages and capabilities as digital motion control devices are also discussed.

1.1 BASIC DESCRIPTION

The stepper motor is a device which translates electrical pulses into mechanical movements. The output shaft rotates or moves through a specific angular rotation for each incoming pulse or excitation. This angle or displacement per movement is repeated precisely with each succeeding pulse translated by appropriate drive circuitry. The result of this precise, fixed and repeatable movement is the ability to accurately position. Unlike a conventional motor, which has a free running shaft, the stepper motor shaft rotates in fixed, repeatable, known increments. The stepper motor therefore allows control of load velocity, distance and direction. Initial positioning accuracy of a load being driven by a stepper motor is excellent. The repeatability (the ability to position through the same pattern of movements a multiple number of times) is even better. The only system error introduced by the stepper motor is its single step error, which is generally less that 5% of one step. Most significantly, this error is noncumulative, regardless of distance positioned or number of times repositioning takes place. The stepper motor is generally controlled by a DC power supply and drive/logic circuitry which will be discussed in this guide.

1.2 STEPPER MOTOR TECHNOLOGY

As the use of stepper motor systems has increased in a broad base of applications, terminology has evolved which required definition.

A. Step Angle - This is the specific angular increment the motor shaft will move each time the winding polarity is changed. It is specified in degrees.

B. Steps Per Revolution - This term describes the total number of steps required for the motor shaft to rotate 360°, or one complete revolution. The number is calculated by dividing the step angle into 360°.

C. Steps Per Second - This is the number of steps accomplished by the motor in one second of time. This figure replaces the rpm value of a standard drive motor. See Section 7 for formulas used to calculate this value.

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D. Step Accuracy - Defined as positional accuracy tolerance. This value is generally expressed in percent and indicates the total error introduced by the stepper motors in a single step movement. The error is noncumulative, i.e., it does not increase as additional steps are taken. In a linear system with a resolution of 0.001 inch, a 3% accuracy motor would introduce a maximum of 0.00003 inch error into the system. This total error would not accumulate or increase with total distance moved or number of movements made.

E. Holding Torque - With the motor shaft at standstill (zero rpm condition), Holding Torque is the amount of torque, from an external source, required to break the shaft away from its holding position. It is measured with rated current and voltage applied to the motor. Holding torque is a basic characteristic of stepper motors and provides positioning integrity under standstill, or rest, conditions.

F. Residual Torque - This is the torque present at standstill under power off conditions and is a result of the permanent magnetic flux acting on the stator poles. Residual torque is present under power off conditions only with a motor of permanent magnet rotor design.

G. Step Response - When given a command to take a step, a stepper motor will respond within a specific time period. This time period, or "time for a single step", is a function of the torque-to-inertia ratio of the motor and of the characteristics of the electronic drive system. Ratings given are for no-load conditions and are generally expressed in milliseconds.

H. Torque-To-Inertial Ratio - This ratio is calculated by dividing the rated holding torque of the motor in ounce-inches by its rotor inertia in ounce-inch-seconds squared. The better the torque-to-inertia ratio, the better the step response. When dealing with step response problems, it is important to know the torque-to-inertia ratio of the motor.

I. Resonance - Stepper motors are a "spring response" system and, as such, have certain "natural" frequency characteristics. When a motor's natural frequency, or "resonance" is reached, an increase in the audible level of the motor's operation can be detected. In cases of server resonance, the motor may lose steps and/or oscillate about a point. The frequency at which this occurs depends on the motor and the load. In many applications, it may not occur to any perceptible degree. However, the designer should realize that this condition can exist and specific facts about the resonant characteristics of a particular motor should be obtained from the manufacturer.

J. Drives - This a broad term used to describe the circuitry which controls the stepper motor. It usually consists of a power supply, sequencing logic and power output switching components. These drives are generally categorized as Translators, Translator/Oscillators or Indexers.

K. Translator - An electronic control with circuitry to convert pulses into the switching sequence which will operate the motor one step for each pulse received. Translators usually have no counting capability.

L. Translator/Oscillator - Includes translator circuitry together with a built-in oscillator which can serve as a pulse source.

M. Indexer - An electronic control which includes the translator function plus additional circuitry to control the number of steps taken as well as direction and velocity.

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N. Pulse Rate - The rate at which windings are switched. Where one pulse equals one motor step, the pulse rate is also the motor stepping rate.

O. Ramping - This is the process of controlling the pulse frequency to accelerate the motor from base speed to running speed as well as to decelerate the motor from running speed to base speed. Ramping increases the ability to drive the motor and load to higher speeds, particularly with large inertial loads.

P. Slew Rate - An area of high speed where the motor can run unidirectionally in synchronism. However, it cannot start, stop or reverse at this rate. A stepper motor is brought to a slewing rate using acceleration and is then decelerated to stop under conditions where no step loss can be tolerated.

Q. Damping - Damping is defined as the reduction or elimination of step overshoot. It is used where settling down time is important,. Damping methods used include mechanical, electronic and viscous means.

1.3 STEP ANGLE

The step angle of a SLO-SYN Step Motor is 1.8°, equivalent to 200 steps per revolution.

2.0 BASIC CONSTRUCTION AND OPERATION

Operation of a stepper motor is related to basic permanent magnet theory, where "likes' repel and "opposites" attract. If the stator windings in Figure 1 are energized such that Stator A is the North Pole, Stator B is the South Pole and the permanent magnet rotor is positioned with its polarity as shown, it is impossible to determine the direction of rotation. However if, as shown in Figure 2, two additional Stator poles C and D are added and energized so that polarities appear as shown, we would then be able to dictate the direction of rotor rotation. In this case, the direction would be counterclockwise with the rotor aligning itself between the "average" South Pole and the "average" North Pole, as shown in Figure 3.

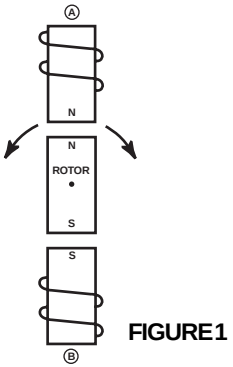


FIGURE 1

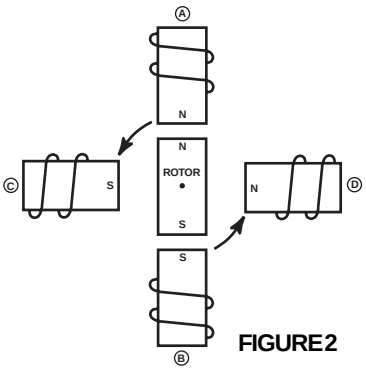


FIGURE 2

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To allow better single step resolution, four more stator poles are added and teeth are machined on each stator pole as well as on the rotor. In the final analysis, the number of teeth on the rotor determines the step angle that will be achieved each time the polarity of one winding is changed. The rotor/stator tooth configuration for a 1.8° stepper is shown in Figure 4.

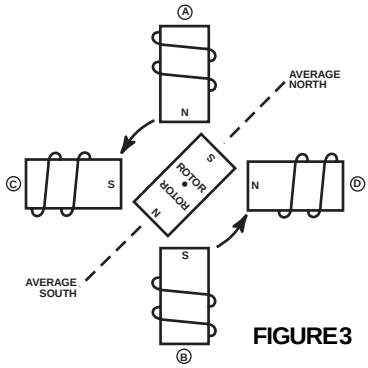


FIGURE 3

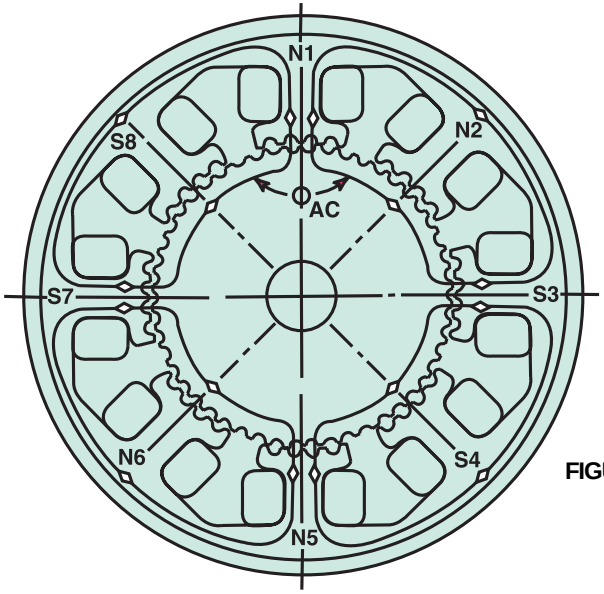


FIGURE 4

3.0 RATINGS

The chart lists typical ratings for SLO-SYN Stepper Motors as shown in our catalogs. While the voltage rating is straightforward, note that the current requirements are given in "amperes per winding." Using the typical four-step switching sequence, two windings are 'on' at any given time. Therefore, the total current requirement of the motor is twice the "amperes per winding" value given in the chart. Inductance and resistance values are also given "per winding."

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ELECTRICAL RATINGS

Motor Type			Typical Time For Single Stop (mS)	Nominal DC Volts	Rated Amperes for Winding	Nominal Resistance Per Winding (25°C) Ohms	Nominal Inductance Per Phase (Milli-Henrys)
2% Accuracy	3% Accuracy	5% Accuracy					
UNIPOLAR RATINGS (6-LEAD DRIVE)							
KM~060S03 KM~060S08	–	–	–	2.9 1.3	1.5 3.8	1.9 0.34	4.0 0.63
KM~061S02 KM~061S04 KM~061S08	–	–	–	6.4 3.0 1.7	1.0 2.1 3.8	6.4 1.5 0.46	18 3.5 1.1
KM~062S04 KM~062S06 KM~062S09	–	–	–	3.1 2.8 1.8	2.1 3.0 4.7	1.5 0.94 0.38	4.2 2.5 0.85
KM~063S04 KM~063S09	–	–	–	4.3 2.5	2.1 4.7	2.0 0.54	6.0 1.6
KM~091S02 KM~091S06 KM~091S08 KM~091S09	–	–	–	9.3 2.9 2.1 1.8	1.0 3.1 3.8 4.7	9.3 0.94 0.55 0.38	47 4.7 2.9 1.9
KM~092S09	–	–	–	2.5	4.6	0.54	2.8
KM~093S07 KM~093S10	–	–	–	4.4 3.5	3.5 4.8	1.3 0.72	8.3 4.5
–	M061~S02 M061~E02	–	2.5	5.0	1.0	5.0	9.57
–	M061~S08 M061~E08	–	2.0	1.25	3.8	0.33	0.635
–	M062~S04 M062~E04	–	2.8	4.2	1.9	2.2	5.89
–	M062~S06 M062~E06	–	–	2.6	3.1	0.88	2.0
–	M062~S09 M062~E09	–	2.2	1.65	4.7	0.35	0.8
–	M091-FC06	M091~S06	3.9	2.6	3.1	0.85	4.12
–	–	M091~E06	3.9	2.6	3.1	0.85	4.12
–	–	M091~E09	3.1	1.7	4.7	0.36	1.5
–	–	M092~E08	4.0	3.0	4.0	0.75	3.56
–	–	M092~E09	3.9	2.5	4.6	0.55	2.76
–	–	M093~E11	4.1	2.64	5.5	0.48	3.19
–	–	M093~E14	3.4	2.27	7.0	0.324	2.0
–	–	M111-FD12 M111-FD-8012	4.4	2.26	6.1	0.37	2.3
–	–	M112-FD12	5.5	3.66	6.1	0.80	5.3
–	–	M112-FJ-8012	5.5	3.66	6.1	0.60	5.3

~ = "L" for leads or "T" for terminal box

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ELECTRICAL RATINGS

Motor Type			Nominal DC Volts	Rated Amperes For Winding	Nominal Resistance Per Winding (25°C) Ohms	Nominal Inductance Per Phase (Milli-Henrys)
2% Accuracy	3% Accuracy	5% Accuracy				
4-CONNECTION STEP MOTORS						
KM~060F02 KM~060F05 KM~060F08 KM~060F11	–	–	3.8 1.7 1.1 1.0	1.1 2.7 4.0 5.3	3.6 0.64 0.28 0.19	16 2.5 1.0 0.63
KM~061F02 KM~061F03 KM~061F05 KM~061F08 KM~061F11	–	–	5.2 4.2 2.3 1.4 1.2	1.1 1.4 2.7 4.1 5.4	4.9 3.0 0.85 0.33 0.23	30 16 4.6 1.8 1.1
KM~062F03 KM~062F05 KM~062F07 KM~062F08 KM~062F13	–	–	4.4 3.1 2.5 2.0 1.3	1.5 2.5 3.3 4.1 6.6	2.9 1.3 0.75 0.49 0.20	17 7.1 3.4 2.5 0.85
KM~063F03 KM~063F04 KM~063F07 KM~063F08 KM~063F13	–	–	6.1 5.0 3.4 2.6 1.9	1.5 1.8 3.3 4.1 6.6	4.1 2.8 1.0 0.64 0.28	24 17 6.2 3.9 1.5
KM~091F05 KM~091F07 KM~091F13	–	–	3.0 2.5 1.3	2.7 3.3 6.6	1.1 0.76 0.19	11 7.5 1.9
KM~092F07 KM~092F13	–	–	3.5 1.7	3.3 6.5	1.1 0.27	11 2.9
KM~093F07 KM~093F08 KM~093F10 KM~093F14	–	–	4.9 4.0 3.2 2.5	3.4 4.0 5.1 6.8	1.4 0.99 0.63 0.36	18 13 8.3 4.5
– –	M061~F01 M061~F02	– –	8.0 6.3	0.5 1.0	15.9 6.3	61.0 25
	M062~F02 M062-~F03	–	6.6 4.2	1.0 1.5	6.8 2.8	33.0 13
–	M063~F03	–	5.4	1.5	3.6	18.0
–	–	M091~F02 M091~F06	6.8 3.0	1.0 3.0	6.8 1.0	52.0 10
–	–	M092~F04 M092-~F08	3.4 4.0	2.0 4.0	1.7 1.0	16.6 11
–	–	M093~F06 M093-~F08	4.5 3.9	3.0 4.0	1.5 0.96	16.9 13
–	–	M111-FF-401 M111-FF-206	4.0 3.5	3.4 5.0	1.14 0.70	17.7 9.2
–	–	MX111-FF-401U	4.0	3.4	1.14	17.7
–	–	M112-FF-401 M112-FF-206	1.95 3.0	4.0 6.0	0.49 0.49	8.80 8.80
–	–	MX112-FF-401	1.95	4.0	0.49	8.80
–	–	M113-FF-401	4.5	6.0	0.75	17

~ = "L" for leads or "T" for terminal box

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4.0 THE FOUR-STEP SWITCHING SEQUENCE

SLO-SYN Stepper Motors are normally operated using the four-step switching sequence. Each time one of the switches indicated in the chart is transferred, the motor takes a "step." After four steps, the same two windings will be "on" as when the sequence was started. The rotor moves one-fourth of a tooth pitch for every step taken; so for every four steps, the rotor moves one full tooth pitch. With 50 teeth on the rotor, four steps/full tooth pitch x 50 teeth/revolution = 200 steps per revolution. The step angle is, therefore, a function of the number of teeth on the rotor and the switching sequence.

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

See Figure 5 for switch wiring

5.0 THE EIGHT-STEP SWITCHING SEQUENCE (Half-Stepping)

The eight-step sequence is often called "electronic half-stepping." With this method, the rotor moves half its normal distance per step. For example, a 1.8° (200 step per revolution) motor would become a 0.9° (400 step per revolution) motor. The advantages of operating in this mode include finer resolution, the reduction of resonant amplitudes and greater speed capability.

EIGHT-STEP INPUT SEQUENCE (FULL-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

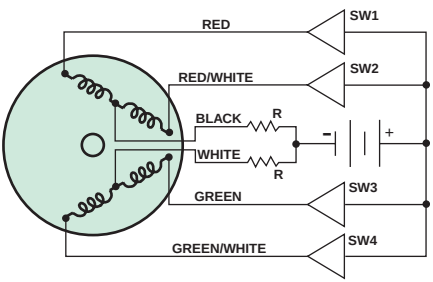


Figure 5

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6.0 TORQUE-SPEED RELATIONSHIP

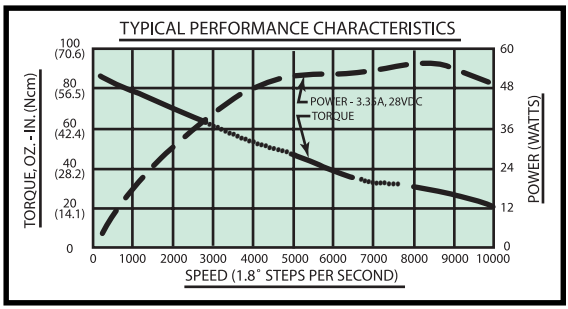
As the stepping rate increases, the back EMF (Electromotive Force) produced by the motor causes the current, and the motor torque, to decrease. Figure 6 shows a torque vs. speed curve for the M062-LE09 motor. Note that at standstill (zero steps per second) the torque output is 85 ounce-inches while at 2000 steps per second the torque has decreased to 70 ounce-inches.

A torque vs. speed curve must be used in the process of selecting a stepper motor. Note that the speed must be given in steps per second, not in rpm.

7.0 STEPS PER SECOND/RPM CONVERSIONS

As previously stated in part 1.2, paragraph B, it is necessary to convert information from "rpm" into "steps per second." The following formulas may be used:

1. Converting rpm into steps per second with a 1.8° step angle, 200 step per revolution motor:
   Steps Per Second = RPM x 3.34
2. For other step angles, use the following general formula:
   Steps Per Second = (rpm) (Steps per Revolution/60)
3. To find the rpm rate when the steps per second rate is known, use the following:
   For a 1.8°, 200 step per revolution motor
   rpm = Steps Per Second/3.34



M062-LE09 Motor With 3.5 Ampere, 28 Vdc Bipolar Chopper Drive
Figure 6

8.0 HANDLING INTERTIAL LOADS (Acceleration/Deceleration Time Allowed)

Stepper Motors are not limited to a specific "maximum moment of inertia" due to their ability to be accelerated to and decelerated from any given speed.

Moving an inertial load is a function of time and torque. The more time allowed to move a particular distance, the more inertia that can be moved.

The required torque can be calculated when the total value of inertia, the time allowed to accelerate and decelerate (acceleration rate) and the step angle of the motor are known.

The following formula applies:

Tj = (j) (α) (k) where:

Tj = Torque required to move the inertial (oz-in)

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j = Total system inertia including inertia of motor rotor (lb-in^2)
α = Acceleration rate (steps per second^2) (time element)
k = A constant. For 1.8° step motors, the constant is 1.31 x 10^{-3}

Further defining α:

$$\alpha = \frac{\Delta V \text{ (sps)}}{\Delta T \text{ (seconds)}} \quad \frac{\text{(change in velocity)}}{\text{(change in time)}}$$

Note that increasing the ΔT factor (time) will decrease α. Inserting α into the formula, then, will decrease the torque requirement. This example clearly illustrates that, if enough time is allowed, the required torque becomes very low.

IMPORTANT: The "Tj" value in the formula is the torque required to move the **inertia** only and **does not** include the **friction** torque requirement of the system. Friction torque must be added to get the total torque requirement. For example: assume that Tj equals 35 ounce-inches and frictional torque equals 50 ounce-inches. Total torque required would be 50 + 35, or 85 ounce-inches at the speed specified. The proper motor can now be determined by consulting a torque vs. speed curve and selecting the motor which produces 85 ounce-inches at the desired speed and acceleration rates.

8.1 HANDLING INERTIAL LOADS (No Acceleration/Deceleration Time Allowed)

At stepping rates above 50 steps per second where **no** acceleration/deceleration time is allowed, the following formula may be used:

Tj = (j) (α) (k) where
Tj = Torque required to move the inertial load (oz-in)
j = Total system inertia including rotor j of motor (lb-in^2)
$\alpha = \frac{V^2}{2} \quad \frac{(SPS)^2}{2}$
k = Constant (1.31 x 10^{-3} for a 1.8° stepper motor)

EXAMPLE: An application requires a 1.8° stepper motor to move 200 steps in one second with an inertial load of 1.5 lb-in^2. Friction torque is 25 oz-in. No acceleration/deceleration is allowed. An M092 frame size motor is desired.

Solution:

$$T = (j) \frac{(V^2)}{2} (k)$$

j = 1.5 lb-in^2 + M092 rotor j of 0.42 lb-in^2= 1.92 lb-in^2
k = 1.31 x 10^{-3} (constant)

Tj = (1.92) (200^2/2) (1.31 x 10^{-3})

Tj = (1.92) 20 x 10^3) (1.31 x 10^{-3})
Tj = 50.3 oz-in (torque required to move inertia)
+ TFriction of 25.0 oz-in

Total torque required: 75.3 oz-in @ 200 steps per second.

9.0 HOLDING TORQUE VS. TORQUE AT STANDSTILL

True holding, or "breakaway" torque is measured at **rated** voltage and current. For this reason, there is often confusion between holding torque and torque at zero steps per second with a given "drive." Typically at "standstill," a drive **does not** provide **rated** voltage and current to the motor due to a safety factor. Therefore, the standstill torque value at zero steps per second is generally less than **true** holding torque at **rated** voltage and current.

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MECHANICAL SPECIFICATIONS, 1.8° SLO-SYN STEPPER MOTORS

BASIC MOTOR SERIES	MINIMUM HOLDING TORQUE (1) OZ.-IN. (2) (Ncm) (3)	MINIMUM RESIDUAL TORQUE (2) OZ-IN. (Ncm)	NOMINAL ROTOR INERTIA OZ-IN-SEC^2 (kg-cm^2)	TYPICAL TORQUE TO INERTIA RATIO (RAD/SEC.^{2})	NUMBER OF LEADS OR TERMINALS	SHAFT DIAMETER INCHES (mm)	MAXIMUM OVERHANG LOAD LBS (kg)	MAXIMUM THRUST LOAD LBS (kg)
KM060	68 (48)	2.0 (1.4)	0.0015 (0.108)	4.41 X 10^4	4 or 6	0.250 (6.35)	15 (6.8)	25 (11.3)
KM061	170 (120)	3.0 (2.1)	0.0034 (0.24)	4.38 X 10^4	4 or 6	0.250 (6.35)	15 (6.8)	25 (11.3)
KM062	250 (177)	6.0 (4.2)	0.0056 (0.395)	5.05 X 10^4	4 or 6	0.250 (6.35)	15 (6.8)	25 (11.3)
KM063	350 (247)	7.0 (4.9)	0.0084 (0.593)	4.13 X 10^4	4 or 6	0.3125 (7.94)	15 (6.8)	25 (11.3)
M061	75 (53)	1 (0.71)	0.0017 (0.12)	4.53 X 10^4 (3)	4, 6 or 8	0.250 (6.35)	15 (6.8)	25 (11.3)
M062	125 (88)	1.4 (0.99)	0.0033 (0.23)	3.75 X 10^4 (3)	4, 6 or 8	0.250 (6.35)	15 (6.8)	25 (11.3)
KM091	385 (272)	10 (7.1)	0.0160 (1.13)	2.40 X 10^4	4 or 6	0.500 (12.70)	25 (11.3)	50 (22.7)
KM092	770 (544)	15 (11)	0.0310 (2.19)	2.52 X 10^4	4 or 6	0.500 (12.70)	25 (11.3)	50 (22.7)
KM093	1155 (816)	23 (16)		2.52 X 10^4	4 or 6	0.500 (12.700	25 (11.3)	50 (22.7)
M091	180 (127)	2 (1.41)	0.0095 (0.67)	1.87 X 10^4 (3)	4, 6 or 8	3.75 (9.53)	25 (11.3)	50 (22.7)
M092	370 (261)	3.9 (2.75)	0.0174 (1.23)	2.12 X 10^4 (3)	4, 6 or 8	0.375 (9.53)	25 (11.3)	50 (22.7)
M093	550 (388)	6.9 (4.87)	0.0265 (1.87)	2.05 X 10^4 (3)	4, 6 or 8	0.375 (9.53)	25 (11.3)	50 (22.7)
M111 MX111 (4)	850 (600)	6 (4.24)	0.0555 (3.93)	1.53 X 10^4 (3)	4, 6 or 8	0.375 (9.35)	25 (11.3)	50 (22.7)
M112-FD	1390 (981)	12 (8.47)	0.1140 (8.06)	1.21 X 10^4 (3)	4, 6 or 8	0.500 (12.7)	25 (11.3)	50 (22.7)
M112-FJ MX112 (4)	1390 (981)	12 (8.47)	0.1140 (8.06)	1.21 X 10^4 (3)	4, 6 or 8	0.625 (15.88)	25 (11.3)	50 (22.7)
MH112	1760 (1243)	85 (60)	0.1334 (9.42)	1.31 X 10^4 (3)	4 or 8	0.625 (15.88)	50 (22.7)	100 (45.4)
MH172	5330 (3764)	50 (35.3)	0.8702 (61.5)	6.1 X 10^3 (3)	4 or 8	0.75 (19.05)	100 (45.4)	150 (68)

(1) Both windings at rated current.
(2) Values shown are for reference information and are correct to the best of our knowledge at time of publication, but are subject to change without notice. Parameters to be used as part of a specification should be verified with the factory.
(3) Operation below rated current will reduce torque and may degrade step accuracy.
(4) Available only with 4 leads.

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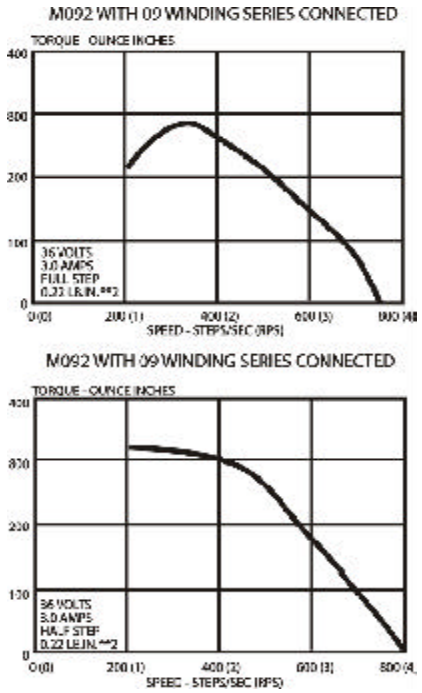
11.0 MICROSTEPPING

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. These increments have been chosen by Superior Electric to 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 positioning resolution of 0.001 inch when the motor is driving through a lead screw that has 0.2000 inch leads, resolutions of 0.000008 inch or less are theoretically possible using microstepping.

Another major benefit of microstepping is that it reduces the amplitude of 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. Figure 7 shows two typical Torque vs. Speed curves. The blank area at the beginning of each curve represents the area where resonance may occur.

Selection of a Superior Electric drive which provides microstepping operation allows the user to obtain the benefits of smoother step motor performance and finer step resolution.



Typical Torque Vs. Speed Curves Showing Area of Resonance
Figure 7

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12.0 RESONANCE

When a stepper motor is operated at its no load natural frequency, which is typically 90 to 160 steps per second depending on the motor model, an increase in the audible noise and vibration levels of the motor may occur. In actual use, the frequency at which the resonance will occur can vary widely, depending on the characteristics of the load.

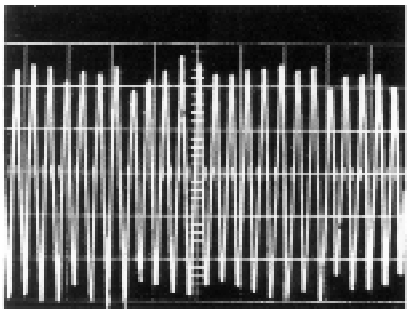
In applications where the motor must be operated at its "natural frequency," **inertial loading** (a flywheel) can be added to reduce resonance and allow satisfactory performance.

The natural frequency is **lowered** as inertia is increased. Another method is to operate at a higher stepping rate whenever possible. Also, the characteristics of the electronic drive can be changed to permit a "softer" step. However, this will result in a trade-off of torque-speed performance. Resonance can also occur at some higher harmonic of the "primary" resonant region (90 to 160 steps per second), but it is normally much less severe in these regions.

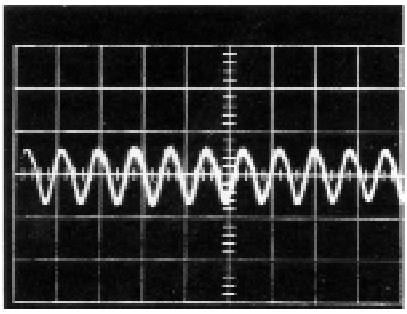
13.0 LANCHESTER DAMPERS

As discussed in Section 12.0, the effects of resonance can be reduced or eliminated by adding inertia (a flywheel) to the system. Adding inertia, however, can cause a reduction in overall system performance, especially where the friction load component is substantial.

SLO-SYN Step Motors are available with a viscous coupled inertial damper, called a Lanchester Damper. This device incorporates a light-weight aluminum outer shell which is driven by the motor shaft. A heavier flywheel located within the light-weight housing is caused to rotate by the "shear" effect of a fluid located between the outer rotating shell and the internal inertial flywheel. The results are good damping characteristics with little loss of overall performance. Figure 8 shows typical instantaneous velocity variations of an undamped motor operating in the primary resonance region while Figure 9 shows the dramatic reduction of these velocity variations when the Lanchester Damper is applied.



UNDAMPED MOTOR
FIGURE 8



DAMPED MOTOR
FIGURE 9

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14.0 ENCODER MOTORS

For those desiring an indication of true shaft position, a complete line of Encoder Motors is available. The encoder outputs produce one pulse for each step taken by the motor. Theses signals are in "phase quadrature" (two-channel output, 90° phase shift between the two channels) with one of those signals used as a reference for up and down counting. A third channel is also available as a "zero reference" or revolution counter whereby one output pulse per revolution is provided. Figure 10 shows a typical configuration and pulse output.

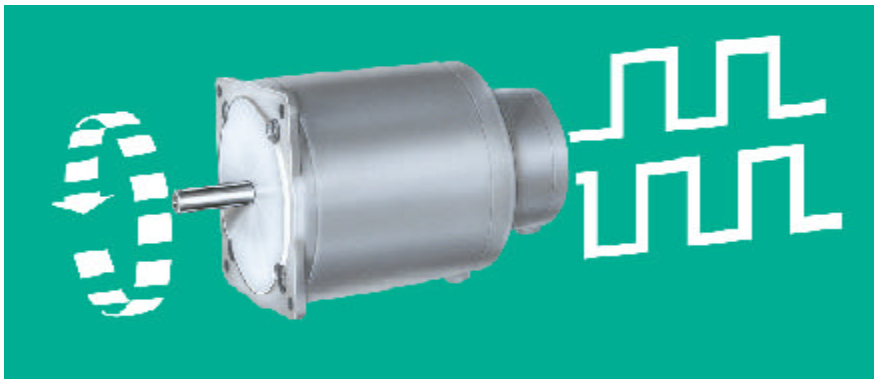


FIGURE 10

15.0 SPECIAL CAPABILITY STEPPER MOTORS

SLO-SYN Stepper Motors can be produced in a wide variety of special configurations, including:

A. **Double Ended Shaft -** Having a shaft that extends from both ends of the motor. Available in all models.

B. **Explosion-Proof -** Meet Underwriters Laboratories specifications for Class 1, Group D or Class 2, Groups E, F and G service.

C. **Special Environment -** Include High Temperature, Militarized, Limited Vacuum, Radiation Resistant and Splash-Proof models.

D. **Special Windings -** Electrical characteristics can be designed to perfectly match your drive for optimum performance.

E. **Special Shaft Configurations -** Flats, keyways, tapers, holes, knurls, threads, splines, etc. are available.

F. **Winding Configurations -** two-phase, three-phase or four-phase motors designed for single or dual winding excitation can be produced, depending on the model chosen.

For many years, Superior Electric has produced a wide variety of special motors to meet specific customer application needs. If you have a need for a "customized" stepper motor, contact us. Chances are, we've done it before!

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16.0 SELECTING A STEPPER MOTOR - INFORMATION REQUIRED

Sections 16.1, 16.2 and 16.3 which follow, provide formulas needed to calculate information required when selecting a stepper motor. Before these formulas can be used, however, it is necessary to obtain detailed information about the applications. The more complete the data, the more accurate the motor selection which will result.

The required data is as follows:

I. Clearly define the application

II. Determine the mechanical requirements

- A. Size and weight
- B. Mounting method
- C. Resolution - steps per revolution, linear increments
- D. Accuracy required - percent error
- E. Shaft Configuration - double-ended, keyway, etc.
- F. Runout
- G. Special environment capability
- H. Damper
- I. Encoder
- J. Leads or terminals
- K. Gearing, lead screws - define

III. Load Requirements

- A. Torque at standstill (power on)
- B. Torque at standstill (power off - detent)
- C. Torque at speed (running or "slew")
- D. Inertia (reflected)
- E. Distance versus time data
    1. Average speed
    2. Maximum speed

IV. Electronic drive description

- A. Type of drive
    1. Translator - pulse-to-step conversion
    2. Translator/Oscillator - Translator plus built in Oscillator
    3. Indexer - controls count, direction, etc.
- B. Source
    1. Customer built
    2. Purchased
- C. Drive design type
    1. Unipolar L/R
    2. Bipolar L/R
    3. Bi-level
    4. Constant current bipolar chopper
    5. Other - define
- D. Power supply capabilities
    1. AC input
    2. DC voltage
    3. DC current

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E. Drive Control logic
   1. Input pulse characteristics
   2. Ramping
   3. Damping
   4. Open- or closed-loop
   5. Full/half-step, microstep

16.1 SELECTING DC STEPPER MOTORS-FORMULAS

Before the correct SLO-SYN Stepper Motor for a particular application can be selected, the following information must be determined:

a) operating speed in steps per second
b) torque in ounce-inches
c) load inertia in lb-in²
d) required step angle
e) time to accelerate in milliseconds
f) time to decelerate in milliseconds
g) type of drive system to be used
h) size and weight considerations

Once this information is known, the best motor/drive combination can be determined using the torque vs. speed curves in the SLO-SYN Motors and Drives catalog and the formulas which follow.

1. Torque (oz-in) = Fr
where **F** = Force (in ounces) required to drive the load
r = Radius (in inches)

2. Moment of Inertia

$$I\ (\text{lb-in}^2) = \frac{Wr^2}{2} \quad \text{for a disk}$$

or

$$I\ (\text{lb-in}^2) = \frac{W}{2}\left(r_1^2 + r_2^2\right) \quad \text{for a cylinder}$$

Where **W** = Weight in pounds
r = Radius in inches

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3. Equivalent Inertia

A motor must be able to:

a. overcome any frictional load in the system
b. start and stop all inertial loads, including that of its own rotor

The basic rotary relationship is:

$$T = I\alpha/24$$

Where **T = torque in ounce-inches**
I = moment of inertia in lb-in^2
α = angular acceleration in radians per second^2

Angular acceleration (α) is a function of the change in velocity (ω) and the time required for the change.

$$\alpha = \frac{\omega 2 - \omega 1}{t}$$

or, if starting from zero

$$\alpha = \frac{\omega}{t}$$

where ω = angular velocity in radians per second
t = time in seconds

$$\text{since } \omega = \frac{\text{steps per second}}{\text{steps per revolution}} \times 2\pi$$

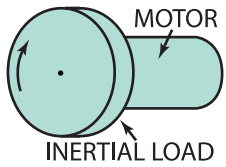
angluar velocity and angular acceleration can also be expressed in steps per second (ω^1) and steps per second^2 (α), respectively.

SAMPLE CALCULATIONS

A. Calculating torque required to rotationally accelerate an inertial load

$$T = 2 \times I_0 \frac{\alpha^1}{t} \times \frac{\pi Ø}{180} \times \frac{1}{24}$$

where **T** = torque required in oz-in
I_0 = inertial load in lb-in^2
π = 3.1416
Ø = step angle in degrees
α^1 = step rate in steps per second



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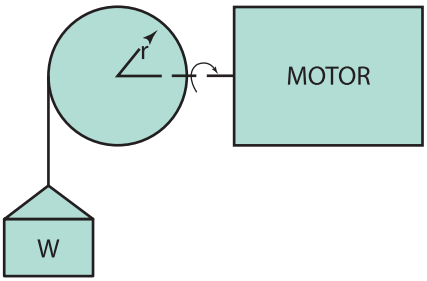
EXAMPLE: assume the following conditions:

Inertia = 9.2 lb-in2
step angle = 1.8°
acceleration = from 0 to 1000 steps per second in 0.5 seconds

$$\mathbf{T} = 2 \times 9.2 \times \frac{1000}{0.5} \times \frac{p \times 1.8}{180} \times \frac{1}{24}$$

T = 48.2 oz-in torque required to

B. Calculating torque required to accelerate and raise a weight using a drum and string.



The total torque which the motor must supply includes the torque required to:

- **a.** accelerate the weight
- **b.** accelerate the drum
- **c.** accelerate the motor rotor
- **d.** lift the weight

The rotational equivalent of the weight and the radius of the drum is:

$$\mathbf{I}_{(eq)} = wr^2$$

where $\mathbf{I}_{(eq)}$ = equivalent inertia in lb-in^2
w = weight in lbs
r = radius of drum in inches

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EXAMPLE: Assume the following conditions

Weight	5 lbs (80 oz)
Drum	3 inches O.D., 1.5 inches radius
Velocity	15 ft per second
Time To Reach Velocity	0.5 second
Motor Rotor Inertia	2.5 lb-in^2
Drum Inertia	(3" dia x 2" lg., steel) 4-5 lb-in^2

$$\begin{array}{lcll} \mathbf{I}_{(eq)} & = & 5 \times (1.5)2 & = & 11.25 \text{ lb-in}^2 \\ & & \text{I (drum)} & = & 4.50 \text{ lb-in} \\ & & \underline{\text{I (rotor)}} & = & \underline{2.50 \text{ lb-in}} \\ & & \text{I (total)} & = & 18.25 \text{ lb-in}^2 \end{array}$$

since the velocity is 15 ft per second using a 3" drum, the velocity in rev. per second can be calculated.

$$\text{speed} = \frac{15 \times 12}{3 \times \pi} = 19.1 \text{ rev per second}$$

The motor step angle is 1.8°, or 200 steps per revolution.

Therefore:

$$\omega' = 19.1 \times 200 = 3820 \text{ steps per second}$$

$$\mathbf{T} = 2 \times I_0 \times \frac{\omega'}{t} \times \frac{\pi \times \varnothing}{180} \times \frac{1}{24}$$

$$\mathbf{T} = 2 \times 18.25 \times \frac{3820}{0.5} \times \frac{3.1416 \times 1.8}{180} \times \frac{1}{24}$$

$$\mathbf{T} = 364 \text{ oz-in} = \text{torque required to accelerate the system}$$

Torque required to lift the weight equals

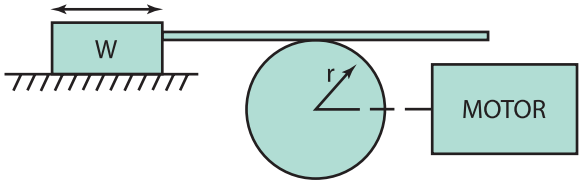
$$\begin{array}{lcl} \mathbf{T} & = & wr \\ & = & 80 \times 1.5 \\ & = & 120 \text{ oz-in} \end{array}$$

total torque required is, therefore:

364 oz-in (torque to accelerate)
120 oz-in (lifting torque)
484 oz-in (total torque)

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C Calculating the torque required to accelerate a mass moving horizontally and driven by a rack and pinion or similar device.



The total torque which the motor must provide includes the torque required to:

a. accelerate the weight, including that of the rack
b. accelerate the gear
c. accelerate the motor rotor
d. overcome the frictional losses

to calculate the rotational equivalent of the weight:

$$I_{(eq)} = w\,r^2$$

where w = weight in lbs
r = radius in inches

EXAMPLE

assume:

weight	=	5 lb
gear pitch diameter	=	3 inches
gear radius	=	1.5 inches
velocity	=	15 feet per second
time to reach velocity	=	0.5 second
pinion inertia	=	4.5 lb-in2
motor rotor inertia	=	2.5 lb-in2

$I_{(eq)}$	=	$w\,r^2$	=	$5 \times (1.5)^2$	=	11.25 lb-in^2
				I pinion	=	4.5 lb-in^2
				I rotor	=	2.5 lb-in^2
				I total	=	18.25 lb-in^2

Velocity is 15 feet per second with a 3" pitch diameter gear.

Therefore:

$$\text{Speed} = \frac{15 \times 12}{3 \times \pi} = 19.1 \text{ rev. per second}$$

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The motor step angle is 1.8° (200 steps per revolution). Therefore, the velocity in steps per second is:

$$w = 19.1 \times 200 = 3820 \text{ steps per second}$$

To calculate the torque needed to accelerate the system:

$$\mathbf{T} = 2 \times I_0 \times \frac{\omega'}{t} \times \frac{\pi Ø}{180} \times \frac{1}{24}$$

$$\mathbf{T} = 2 \times 18.25 \times \frac{3820}{0.5} \times \frac{3.1416 \times 1.8}{180} \times \frac{1}{24}$$

$$\mathbf{T} = 364 \text{ oz-in}$$

To calculate torque needed to slide the weight, assume a frictional force of 6 oz.

$$T \text{ friction} = 6 \times 1.5 = 9 \text{ oz-in}$$

Total torque required = 364 oz-in
+ 9 oz-in
= 373 oz-in

Lead Screw Formulas and Sample Calculations

1. Linear Speed

$$\text{Linear Speed (ipm)} = \frac{\text{steps/sec.}}{\text{steps/rev.}} \times 60 \times \frac{1}{p}$$

where **p** = lead screw pitch (threads per inch)

2. Axial Force

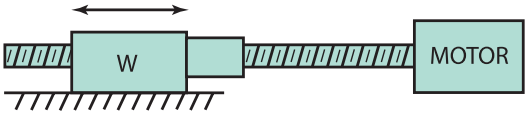
$$\text{Force (lb)} = \frac{2\pi}{16} \times T \times p \times \text{eff.}$$

Where **T** = torque in oz-in
p = lead screw pitch (threads per inch)
eff. = lead screw efficiency expressed as a decimal: 90% = 0.90

Note: Ball-nut lead screws are generally 85% to 95% efficient. Acme screws are generally 35% to 45% efficient, but can be as high as 85%.

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A. Calculating the torque required to accelerate a mass moving horizontally and driven by a ball bearing lead screw and nut.



The total torque the motor must provide includes the torque required to:

a. accelerate the weight
b. accelerate the lead screw
c. accelerate the motor rotor
d. overcome the frictional force

to calculate the rotational equivalent of weight **w:**

$$I_{(eq)} = w \times \frac{1}{p^2} \times (1/2\pi)^2$$

where **w** = weight
p = pitch in threads per inch
$\mathbf{I_{(eq)}}$ = equivalent polar inertial in lb-in^2

to calculate lead screw inertia (steel screw)

$$I\ screw = D^4 \times length \times 0.028$$

EXAMPLE

weight	=	100 lb
velocity	=	0.15 ft per second
time to reach velocity	=	0.1 second
ball screw diameter	=	1.5 inches
ball screw length	=	48 inches
ball screw pitch	=	5 threads per inch
motor rotor inertia	=	2.5 lb-in2
friction force to slide weight	=	6 oz.

$$I_{(eq)} = w \times \frac{1}{p^2} \times 0.025$$

$$I_{(eq)} = 1000 \times \frac{1}{25} \times 0.025$$

$I_{(eq)}$ = 1.0 lb-in2

I (screw)	=	D^4 x length x 0.028
I (screw)	=	5.06 x 48 x 0.028
I (screw)	=	6.8 lb-in2
I (screw)	=	6.8 lb-in2
$I_{(eq)}$	=	1.0
I rotor	=	2.5 lb-in2
I total	=	10.3 lb-in

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Velocity is 0.15 feet per second, which is equal to 1800 steps per second (the motor steps in 1.8° increments).

Torque to accelerate system

$$T = 2 \times I_0 \times \frac{\omega'}{t} \times \frac{3.14146 \times 1.8}{180} \times \frac{1}{24}$$

$$T = 2 \times 10.3 \times \frac{1800}{0.1} \times \frac{3.1416 \times 1.8}{180} \times \frac{1}{24}$$

$$T = 484 \text{ oz-in}$$

Torque to overcome friction

$$F = 0.393 \times T \times p \times \text{eff.}$$

$$6/16 = 0.393 \times T \times 0.90$$

where F = frictional force in lb-in
T = torque in oz-in
p = lead screw pitch in threads per inch
T = 0.22 oz-in

Total torque required = 0.22 oz-in
484.00 oz-in
484.22 oz-in

CONVERSION FACTORS

INERTIA

slug-ft^2 x 4600	=	lb-in^2
lb-ft^2 x 144	=	lb-in^2
oz-in^2 x 0.0625	=	lb-in^2
lb-ft-sec^2 x 4600	=	lb-in^2
lb-ft-sec^2 x 384	=	lb-in^2
oz-in-sec^2 x 24	=	lb-in^2
gm-cm^2 x 0.000342	=	lb-in^2
kp-m-sec^2 x 33,500	=	lb-in^2

METRIC - DECIMAL EQUIVALENTS

1 inch	=	2.54 cm
1 cm	=	0.3937 inch
1 pond (gm)	=	0.03527 oz.
1 oz	=	28.35 pond (gm)
1 kp (kg)	=	2.205 pound
1 gm-cm	=	0.0139 oz-in
1 kg-cm	=	1 kp-cm = 13.9 oz-in
1 hp	=	746 watts

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16.2 SELECTING DC STEPPER MOTORS-INCH UNITS

The following information will serve to amplify the application data given previously.

1) The torque required to accelerate a mass rotationally is found from the fundamental relationship that Torque = moment of inertia times angular acceleration $T = I_0 \alpha$.

This is a relation based on the rotational mass. Gravitational units, such as pound-inches squared, must be converted into mass units by applying the gravitational constant. This constant is 32.2 feet per second squared, which has been rounded to 32 feet per second squared for our use. As an illustration, assume an inertia of 9.2 lb-in^2.

$9.2 \times 16 = 147.2$ oz-in^2

Gravitational constant (g) = 32 ft per sec^2

$g = 32 \times 12 = 384$ in. per sec^2

The moment of inertia in **mass** units and in **compatible** units, therefore, is:

$$I_0 \text{ (oz-in sec}^2) = \frac{I_0 \text{ (lb-in}^2) \times 16}{g \text{ (in/sec}^2)}$$

$$= I_0 \text{ (lb-in}^2) \times \frac{16}{384}$$

$$= I_0 \text{ (lb-in}^2) \times \frac{1}{24}$$

$$9.2 \text{ lb-in}^2 = 9.2 \times \frac{1}{24} \text{ oz-in-sec}^2 = 0.383 \text{ oz-in-sec}^2$$

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2) Angular acceleration alpha (α) in the expression $T - I_0 \alpha$ is in units of radians per second squared, α = rad/sec^2. A circle (360°) contains 2 pi radians, 360° - 2π radians, or one radian = 57.3 degrees (approximately). Acceleration is the change of velocity per unit of time. In the rotational case being considered, velocity is expressed in radians per second and is denoted by ω (omega). The angular velocity for a stepper motor is therefore equal to the stepping rate (steps per second) times the step angle in radians.

$$\text{Step angle (radians)} = \text{step angle (degrees)} \times \frac{2\pi}{360}$$

Assume a 200 step per revolution (1.8° per step) motor running at 1000 steps per second.

$$w = 1000 \times 1.8 \times \frac{2\pi}{360}$$

$$= 31.42 \text{ radians per second}$$

The angular acceleration, α is the rate of change of angular velocity per unit of time (seconds). If the change is from zero speed, or velocity, the angular acceleration is the final angular velocity (ω_2) divided by the time taken to reach that velocity.

Assume the above motor reaches the speed of 1000 steps per second in 0.5 second. The angular velocity is:

$$\alpha = \frac{\omega_2}{t} = \frac{31.42}{0.5} = 62.84 \text{ rad. per sec}^2$$

If the change of velocity is from a first speed (ω_1) to a second speed (ω_2), the acceleration is:

$$\alpha = \frac{\omega_2 - \omega_1}{t}$$

To obtain the acceleration torque in oz-in, the inertia must be expressed in oz-in-sec^2 and the acceleration in radians/sec^2.

3) To accelerate an inertia of 9.2 lb-in^2 to 1000 steps per second in 0.5 second requires what torque?

$$T = I_0 \text{ (oz-in-sec2)} \times \text{(rad/sec}^2\text{)}$$
$$= 0.383 \times 62.84$$
$$= 24.1 \text{ oz-in}$$

4) For 1.8° per step (200 step per revolution) motors, this may be restated as:

$$T \text{ (oz-in)} = I_0 \text{(lb-in}^2\text{)} \times \frac{\text{change in speed (steps per second)}}{\text{time for change (seconds)}} \times \frac{1.8 \times \pi}{24 \times 360}$$

$$= I_0 \times \frac{\Delta s}{\Delta t} \times 1.31 \times 10^{-3}$$

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16.3 SELECTING DC STEPPER MOTORS - METRIC UNITS

1) The torque required to accelerate a mass rotationally is found from the fundamental relationship that Torque = moment of inertia times angular acceleration: $T = I_0 \ \alpha$

This is a relationship based on the rotational mass. Gravitational units, such as kg-cm squared, must be converted into mass units by applying the gravitational constant. This constant is 981 cm/sec squared, which has been rounded off to 980 cm/second squared for our use. As an example, assume an inertia of 26.9 kg-cm^2.

Gravitational constant is 980 cm/sec^2

The moment of inertia in **mass** units and in **compatible** units, therefore, is:

$$I_0 \text{ (kg-cm-sec}^2\text{)} = \frac{I_0 \text{ (kg-cm}^2\text{)}}{g \text{ (cm/sec}^2\text{)}}$$

$$= I \text{ (kg-cm}^2\text{)} \times \frac{1}{980}$$

$$26.9 \text{ kg-cm}^2 \times \frac{1}{980} = 0.027 \text{ kg-cm-sec}^2$$

2) Angular acceleration alpha (α) in the expression $T=I_0 \ \alpha$ is in units of radians per second squared.

A circle (360°) contains 2 pi radians: 360° = 2π radians, or one radian = 57.3 degrees (approximately). Acceleration is the change of velocity per unit of time. In the rotational case being considered, velocity is expressed in radians per second and is denoted by ω (omega). The angular velocity for a stepper motor is therefore equal to the stepping rate (in steps per second) times the step angle (in radians).

$$\text{Step Angle (radians)} = \text{step angle (degrees)} \times \frac{2\pi}{360}$$

Assume a 200 step per revolution (1.8° step angle) motor running at 1000 steps per second.

$$\omega = 1000 \times 1.8 \times \frac{2\pi}{360}$$

$$= 31.42 \text{ radians per second}$$

The angular acceleration (a) is the change of velocity per unit of time (seconds). If the change is from zero speed or velocity, the angular acceleration is the angular velocity (ω_2) divided by the time taken to reach that velocity.

Assume the above motor reaches the speed of 1000 steps per second in 0.5 second. The angular velocity is: ω_2 = 31.42 radians per second.

$$\alpha = \frac{\omega_2}{t} = \frac{31.42}{0.5} = 62.84 \text{ radians per second}^2$$

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If the change in velocity is from first speed (ω_1) to a second speed (ω_2), the acceleration is:

$$\alpha = \frac{\omega_2 - \omega_2}{t}$$

To obtain the acceleration torque in kg-cm, the inertia must be kb-cm-sec^2.

3) What torque is required to accelerate an inertia of 26.9 kg-cm^2 to 1000 steps per second in 0.5 second?

$$T = I_0 \text{ (kg-cm-sec}^2\text{)} \times \text{rad/sec}^2$$

$$= 0.027 \times 62.84$$

$$= 1.7 \text{ kg-cm}$$

4) For 1.8° per step (200 steps per revolution) motors, this may be restated as:

$$T \text{ (kg-cm2)} = I_0 \times \frac{\text{change in speed (steps/sec}}{\text{time for change (seconds)}} \times \frac{1}{980} \times \frac{1.8 \times 2\pi}{360}$$

$$= I_0 \text{ (kg-cm}^2\text{)} \times \frac{\Delta s}{\Delta t} \times 3.2 \times 10^{-5}$$

$$T = 26.9 \times \frac{1000}{0.5} \times 3.2 \times 10^{-5}$$

$$= 1.72 \text{ kg-cm}$$

17.0 APPLICATIONS

The applications for SLO-SYN Stepper Motors are virtually unlimited. Listed are some typical applications where reliability, repeatability and controllability are most important.

APPLICATION	USE
Computer Peripherals	
Floppy Disc	position magnetic pickup
Printer	carriage drive
Printer	rotate character wheel
Printer	paper feed
Printer	ribbon wind/rewind
Printer	position matrix print head
Tape Reader	index tape
Plotter	X-Y-Z positioning
Plotter	paper feed

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APPLICATION	USE
Business Machines	
Card Reader	position cards
Copy Machine	paper feed
Banking Systems	credit card positioning
Banking Systems	paper feed
Typewriters (automatic)	head positioning
Typewriters (automatic)	paper feed
Copy Machine	lens positioning
Card Sorter	route card flow
Process Control	
Carburetor Adjusting	air-fuel mixture adjust
Valve Control	fluid gas metering
Conveyor	main drive
In-Process Gaging	parts positioning
Assembly Lines	parts positioning
Silicon Processing	I.C. wafer slicing
I.C. Bonding	chip positioning
Laser Trimming	X-Y positioning
Liquid Gasket Dispensing	valve cover positioning
Mail Handling System	feeding and positioning letters
Machine Tool	
Milling Machines	X-Y-Z table positioning
Drilling Machines	X-Y table positioning
Grinding Machines	downfeed grinding wheel
Grinding Machines	automatic wheel dressing
Electron Beam Welder	X-Y-Z positioning
Laser Cutting	X-Y-Z positioning
Lathes	X-Y positioning
Sewing	X-Y table positioning
Graphics	
Printing Presses	roller drive
Printing Presses	ink pump
Phototypesetting Equipment	rotate character wheel and paper feed
Film Processing	index film frame-by-frame
Animation Camera	control focus, fade, dissolve, etc.
Microfilm Systems	position film
Microfilm Systems	automatic focus
Medical	
I.V. Pump	control drip plate
X-Ray Equipment	scanning head positioning
X-Ray Equipment	position patient
Blood Analyzer	test tube positioning
Radiation Therapy	scanning head positioning

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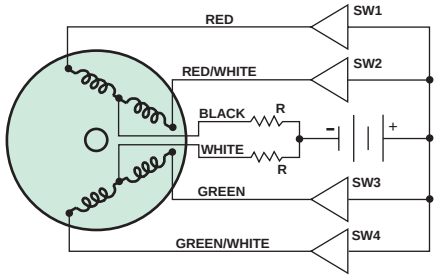
18.0 THE ELECTRONIC DRIVE

The most important element in any stepper motor system is the electronic drive which controls the motor.

The "drive" determines the performance characteristics of a given motor. Parameters such as speed, time for a single step, holding torque and setting time can be controlled by the electronic drive.

18.1 L/R UNIPOLAR DRIVES

This is the simplest form of stepper motor control. It has a single-ended power supply, winding sequence logic, and series resistance between drive and motor, and provides good performance to 2000 steps per second. Other advantages include high reliability and low cost.



L/R Unipolar Drive
FIGURE 11

18.2 L/R BIPOLAR DRIVES

This type of drive requires two power supplies of equal current capability. They provide good intermediate speed performance (2k to 5k sps). They energize all windings simultaneously to achieve a 30% to 40% increase over unipolar L/R drives in low speed torque. An L/R bipolar drive requires a four-lead or an eight-lead stepper motor.

18.3 TWO LEVEL DRIVES

These drives utilize two power supplies to achieve fast current rise to initiate the step and to sustain the current during the entire move. They are well suited for applications requiring short, fast moves and provide good intermediate speed performance.

18.4 REACTIVE DRIVES

A reactive drive uses a choke on the input of the power supply. This allows voltage to increase as the stepping rate is increased. No series resistor is required. This type of drive provides good overall performance. It is more expensive than an L/R drive, but is more efficient.

18.5 CHOPPER DRIVES

This is a more complex drive that "chops" the current to achieve current limiting. High voltage that can be many times the rated voltage of the motor can be applied. These drives provide good overall performance and fast response, but are expensive.

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19.0 TRANSLATORS

SLO-SYN Translators serve as the interface between a pulse source and the stepper motor. They contain the logic necessary to convert, or "translate" digital information into motor shaft rotation. The motor will move one step for each pulse received by the Translator.

The pulse source supplies the desired number of pulses at the specified or programmed rate, which provides the distance and speed information. Figure 12 shows this concept.



TRANSLATOR DRIVE SYSTEM
FIGURE 12

Some Translators can operate in an eight-step switching sequence (half-stepping). When this mode is used, one pulse input will cause the motor shaft to rotate one-half its normal distance. A 1.8° step angle motor will operate in steps of 0.9° in the half-step mode.

SLO-SYN Translators are available in both modular and packaged models in a wide range of power ratings. Modular models require an external power supply. Packaged versions are self-contained and have internal power supplies.

SLO-SYN Translator/Oscillators are also offered. Essentially, a Translator/Oscillator is a Translator with the addition of a built-in oscillator which may be used to provide the pulse and direction signals.

20.0 INDEXERS

A SLO-SYN Indexer is a complete stepper motor control package which provides control of:

- Speed (steps per second)
- Distance (number of steps per move)
- Direction (CW or CCW)

Both Preset Indexer and Programmable Indexer models are available. A SLO-SYN Preset Indexer is intended for control of simple, repetitive operations. It is used where an operation can be directed using a single line of data.

A SLO-SYN Programmable Indexer can store up to 400 lines of program information. They are designed for simplicity of programming and operation. Both modular and packaged models are offered.

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20.0 THE DRIVE SELECTION PROCESS

Follow the procedure below to select the correct motor and drive combination for your application.

A. Select the step angle which will provide the desired linear resolution.
B. Select the type of drive - Translator, Translator/Oscillator, Preset Indexer or Programmable Indexer.
C. Select the specific drive that provides the speed range required.
D. Consult the literature which gives torque vs. speed curves for the selected drive used with appropriate motors.
E. Select the motor which provides the necessary step angle and torque at the required step rate.

EXAMPLE

An X-Y table must be positioned at a rate of 255 inches per minute (4.25 inches per second). The table is positioned by a 5-pitch ball nut lead screw. Linear resolution of 0.001 inch per motor step is required. The required torque is 51 ounce-inches, including the torque needed to accelerate the inertia. It is desired to have the motor drive the table a pre-selected distance each time a "Start" command is given.

Solution

A. Select the required motor step angle needed to achieve the correct linear resolution. In this case, a 1.8°, 200 step per revolution stepper will provide the desired 0.001 inch linear motion per motor step when operating a 5-pitch (five revolutions = 1 inch linear motion) lead screw.
B. Counting capability with the ability to store a single line of program information is needed. Therefore, a Preset Indexer should be selected.
C. The required speed is 4250 steps per second (5-pitch lead screw, 1000 steps = 1" linear motion; 4.25 inches/sec required = 4250 steps per second).
D. Consult the torque vs. speed curves in the SLO-SYN Motion Control catalog and select a Motor/Indexer combination that drive the load at the required step rate.

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