Tolomatic
EXCELLENCE IN MOTION®

ENGINEERING RESOURCES

CONTENTS

LINEAR SOLUTIONS MADE EASY

ACTUATOR SELECTION

BASIC SELECTION PROCESS AND SIZING EQUATIONS

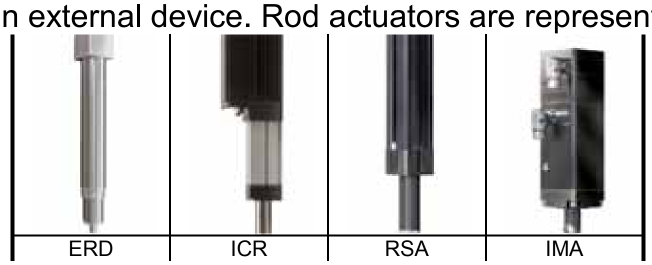
The process of selecting an sizing an electromechanical linear actuator can be complex. It is highly recommended that you contact Tolomatic or a Tolomatic distributor for assistance in selecting the best actuator for your application or use Tolomatic sizing and selection software. The following overview only considers a general case of loading and linear motion and should be used for reference only.

1. CHOOSE LINEAR ACTUATOR TYPE THAT IS BEST FOR YOUR APPLICATION

Tolomatic offers several families of rodless and rod-style electromechanical linear actuators.

Rodless actuators typically include a bearing system used for support and guidance of loads that are mounted on moving carriers. Choose from several **screw-driven** rodless actuators or timing **belt-driven** rodless actuators:

Rod actuators are suited for basic linear thrust applications. They don't have a bearing system and are typically used either to provide axial force or when the load being moved is guided by an external device. Rod actuators are represented by:

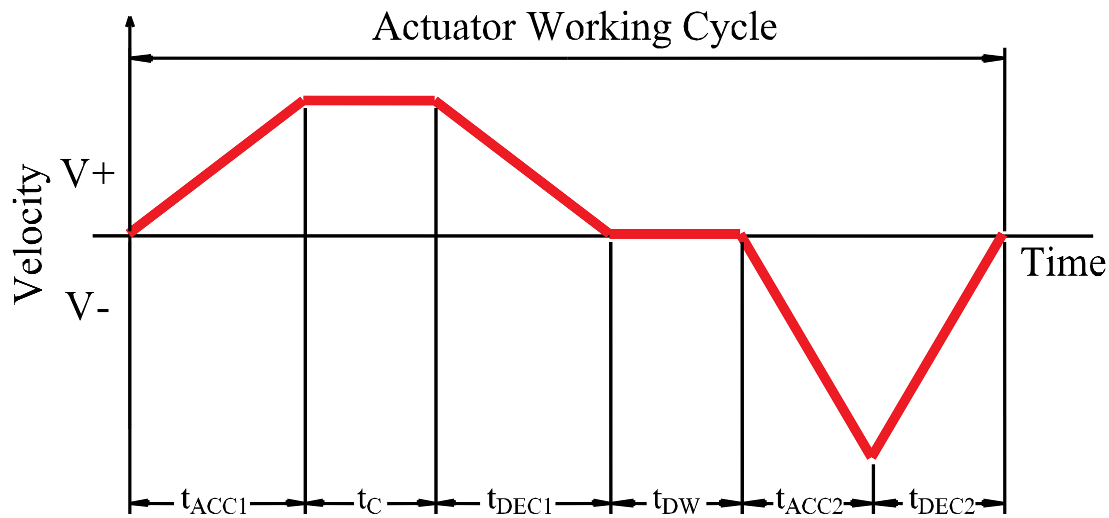


Guided **rod actuators** provide guidance/support for loads mounted on their tooling plates. The GSA is based on the RSA rod actuator, the ERD-GD2 is an option of the ERD rod actuator.

2. ESTABLISH YOUR MOTION PROFILE AND CALCULATE ACCELERATION/DECELERATION RATES

Actuator selection begins with the calculation of speed requirements. A move profile is a plot of velocity vs. time for one full actuator cycle.

Each actuator will have a maximum value of linear velocity that it can achieve for each specific load capacity. This maximum value will determine which type of motion profile can be used to complete the move. Two common types of move profiles are triangular and trapezoidal.

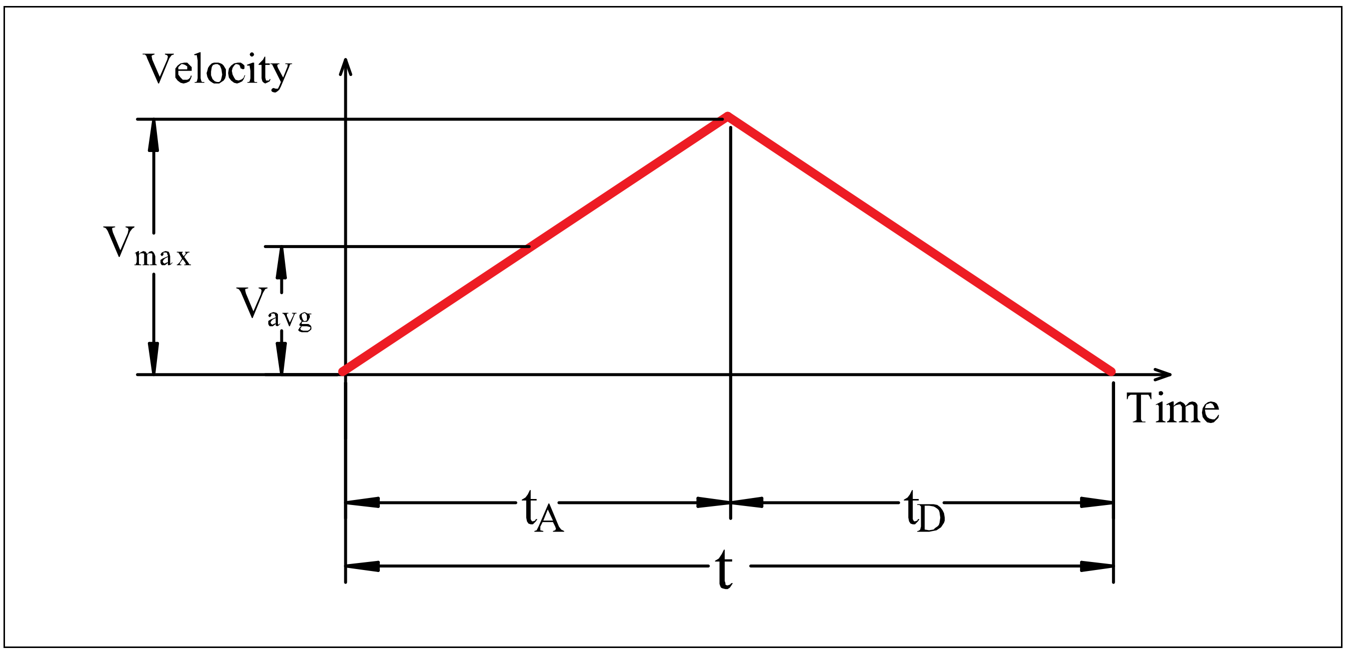


The figure above provides an example of an actuator working cycle. The first motion segment represents a trapezoidal move profile (acceleration to reach a required velocity level taking a time t_{ACC1}, constant velocity motion for a time t_C and deceleration at the end of the move distance or stroke taking a time t_{DEC1}). It is followed by a dwell for a time t_{DW}, that is followed by reversing direction, accelerating for a time t_{ACC2} and decelerating for a time t_{DEC2} as the actuator completes its working cycle.

TRIANGULAR PROFILE

In a typical triangular profile total time of a move is assumed to be equally divided between acceleration time and deceleration time.
If the average velocity of the profile is less than half of the maximum velocity of the actuator, triangular profile can be used. It results in the lowest possible acceleration and deceleration rate to complete the move with required velocity, consuming less motor torque. On the other hand since it results in a high maximum velocity, the motor speed capacity may become a limiting factor.

Figure 1. Triangular Move Profile and Equations



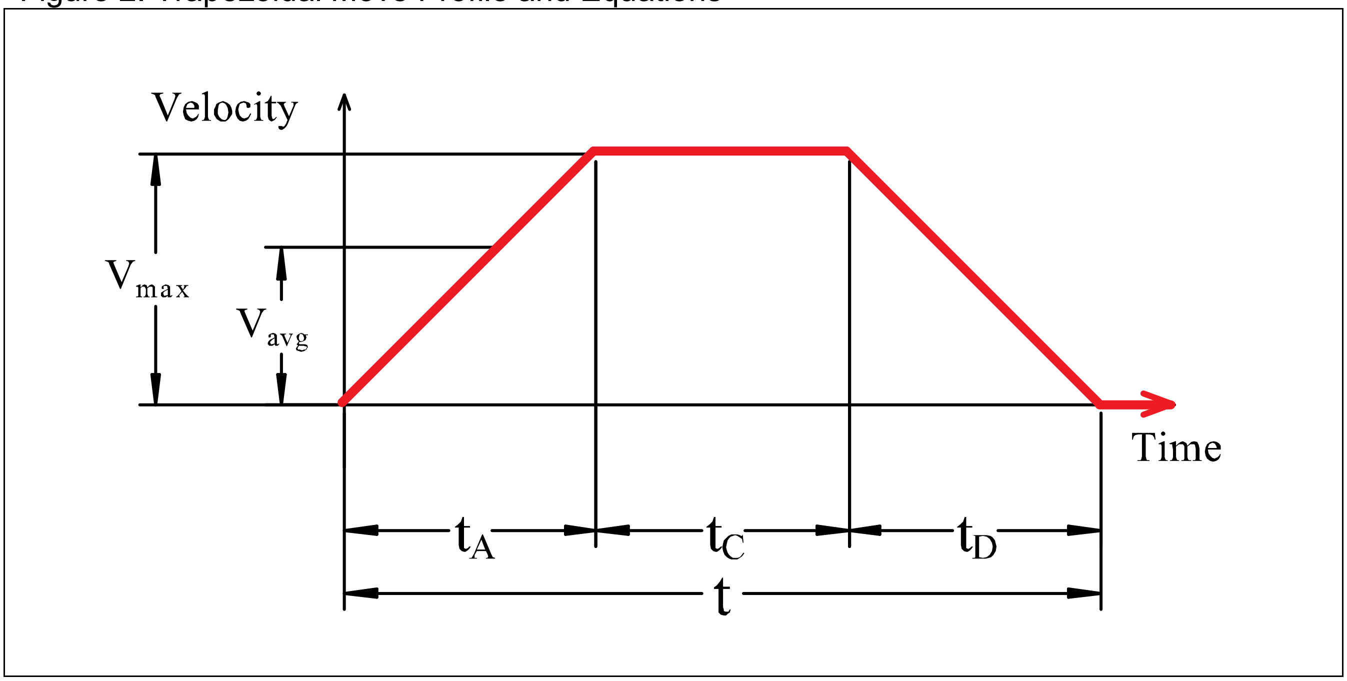
X – total move distance or stroke, in
t – total move time, s
V_{AVG} – average linear velocity, in/s

Maximum velocity	$V_{MAX} = 2 * X/t = 2 * V_{AVG}$
Acceleration/deceleration time	$t_A = t_D = t/2$
Acceleration/deceleration rate	$a = d = 4 * X/t^2 = 2 * V_{MAX}/t$

TRAPEZOIDAL PROFILE

In addition to acceleration and deceleration time, trapezoidal profile includes a constant speed time. If we assume that acceleration, deceleration and constant speed time are equal, the trapezoidal profile will result in 25% lower maximum linear velocity and 12.5% higher acceleration and deceleration rates, providing a good compromise between acceleration/deceleration rate and maximum velocity. Trapezoidal profile is usually a better choice and the recommended move profile.

Figure 2. Trapezoidal Move Profile and Equations



Maximum velocity	$V_{MAX} = 1.5 * X/t = 1.5 * V_{AVG}$
Acceleration/deceleration time	$t_A = t_D = t_C = t/3$
Acceleration/deceleration rate	$a = d = 4.5 * X/t^2 = 3 * V_{MAX}/t$

Using the application stroke length and either maximum required velocity or required time to comlete linear motion, establish the application motion profile by selecting a triangular or a trapezoidal move profile.

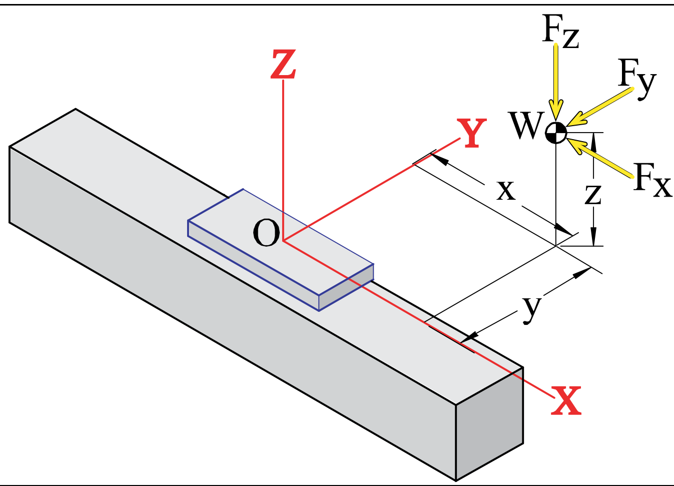
Next, calculate maximum acceleration/ deceleration rate of the move.

3. CALCULATE THE APPLICATION LOAD

In order to select an actuator with a proper bearing system capacity for a given application, all loads, forces and bending moments need to be carefully evaluated.

RODLESS ACTUATOR (B3S, B3W, BCS, MXE, MXB, TKS, TKB)
Three forces (F_X, F_Y, F_Z) and the load weight (W) are a general case load condition. The forces may be due to gravity, friction in bearings, external applied loads and acceleration/deceleration of masses. When the forces act at distances (x, y, z) from the carrier's center of symmetry they create bending moments M_X, M_Y, M_Z.

W – weight of load (lbf)
F_{EXTX} – external force along the x axis (lbf)
F_{EXTY} – external force along the y axis (lbf)
F_{EXTZ} – external force along the z axis (lbf)



x – distance from center of gravity of load to carrier's center of symmetry along x axis (in)
y – distance from center of gravity of load to carrier's center of symmetry along y axis (in)
z – distance from center of gravity of load to carrier's center of symmetry along z axis (in)
Ø – angle between horizontal plane and axis of linear motion.

Total force on the y axis (lbf)	$F_Y = F_{EXTY}$
Total force on the z axis (lbf)	$F_Z = F_{EXTZ} + W * \cos Ø$
Bending moment about the x axis (lbf-in)	$M_X = W * \cos Ø * y + F_Z * y - F_Y * z$
Bending moment about the y axis (lbf-in)	$M_Y = W * \cos Ø * x + F_Z * x - F_X * z$
Bending moment about the z axis (lbf-in)	$M_Z = F_x * y - F_Y * x$

Load combination factor.
For any loaded actuator the following condition must be satisfied:

$$Cf = (F_y/F_y\ max) + (F_z/F_z\ max) + (M_x/M_x\ max) + (M_y/M_y\ max) + (M_z/M_z\ max) \leq 1.5$$

GUIDED ROD-STYLE ACTUATOR (GSA)

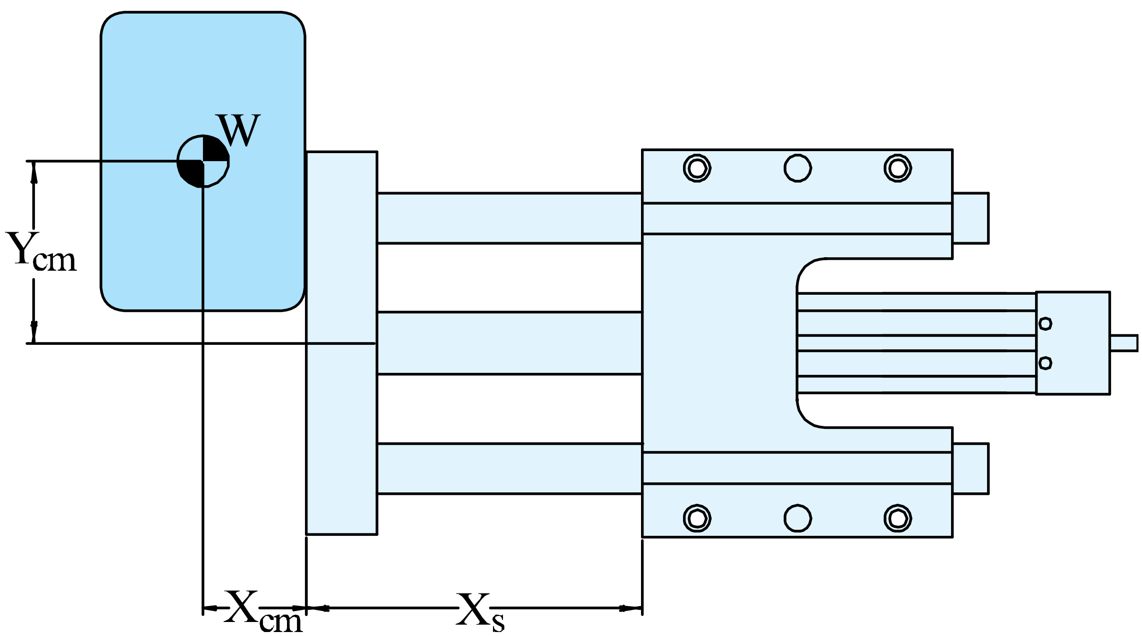
The sizing curves provided in the catalog assume the load mounted symmetrically to the tooling plate with load's center of gravity in close proximity to the surface of the tooling plate.

If those two conditions are not satisfied, adjusted load weight and adjusted stroke need to be calculated and used for GSA bearing system sizing instead of their nominal values.

In a general case with the actuator mounted horizontally, adjusted load weight is:

$W_{adj} = W * \cos Ø * (1 + 0.53*Y_{cm})$, lbf,

where Y_{cm} (in) is the distance between load's center of gravity and tooling plate's center of symmetry in the y axis.



If the required stroke length is X_s, and the distance between load's center of gravity and tooling plate's center of symmetry in the x axis is X_{cm},
then adjusted load weight W_{adj} must not exceed the value from the GSA maximum load weight graph corresponding to the stroke length $X_{adj} = X_s + X_{cm}$

4. SELECT THE BEARING SYSTEM AND SIZE

RODLESS ACTUATORS (B3S, B3W, BCS, MXE, MXB, TKS, TKB)

Depending on the nature and type of loading conditions, the application may benefit from using one or the other type of bearing system.

B3S, B3W (3 sizes) – heavy duty recirculating ball bearings;
BCS (3 sizes) – self lubtricating composite bearings;
MXE, MXB (6 sizes) – self lubtricating composite bearings or LM guides providing high rigidity
TKS,TKB (4 sizes) – LM guides providing high straightness and flatness of motion

Calculated forces and moments must not exceed the values given in the specification sections of actuator brochures.

Load combination factor must not exceed 1.5 for B3S and B3W actuators and 1.0 for the rest of the actuators

GUIDED ROD-STYLE ACTUATORS (GSA)

GSA (4 sizes) are available with linear recirculating bushings or composite bearings. When composite bearings are used, each size also offers a choice of standard diameter or oversized guide rods to decrease load deflection.

5. SELECT THE SCREW TYPE AND LEAD

To make a proper nut selection for the application consider required axial force (thrust), linear velocity, duty cycle and expected life of actuator, as well as (if necessary) accuracy, repeatability and backlash. For a screw-driven actuator select between roller screw, ball screw or an Acme lead screw with a composite or bronze nut.

6. VERIFY THE CRITICAL SPEED OF THE SCREW

Verify that application's peak velocity does not reach the level of the screw's natural frequency excitation.

$RPM_{CR} = 4{,}760{,}000 * D_{ROOT} * f_0 / (L_B^2)$, where

D_{ROOT} – screw's root diameter, in
L_B – length of screw between bearing supports, in
f_0 - screw's end fixity factor (f_0 = 1 for rodless actuators (B3S, BCS, MXE, TKS), f_0 = 0.8 for rod actuators with nut, supported by internal bearings (RSA, ICR), f_0 = 0.36 for rod actuators with unsupported nut (GSA,ERD).

Tolomatic catalog graphs provide screw critical speed limits in a form of actuator linear speed V (critical value) as a function of actuator stroke length.

7. VERIFY THE PV LIMIT FOR A COMPOSITE NUT

Capacity of composite lead nuts under dynamic load is limited by heat buildup. PV_{SL} value is used to quantify the allowable heat generation in acetal lead nuts.

Application pressure on the nut P is calculated as

$P = (F/R) * 1250$, psi, where

F – application axial force (thrust), lbf,
R – manufacturer provided nut maximum force rating, lbf

Sliding velocity between the screw and nut should not be confused with the actuator's linear speed and is calculated as

$V_{SL} = D * \pi * RPM / 12$, ft/min, where

D – outside diameter of the screw, in

It is recommended that PV_{SL} is limited to 18,000.

Tolomatic catalog provides PV_{SL} limits in a form of application thrust F, lbf as a function of its linear speed V, in/s) graphs. To ensure proper performance Tolomatic recommends that the following condition is satisfied:

$(F/F_{MAX}) * (V/V_{MAX}) \leq 0.1$

Use the catalog PV graphs to make sure that the application's velocity and thrust do not exceed the PV limits for the size, type and lead of the selected Acme lead nut.

8. VERIFY AXIAL BUCKLING STRENGTH OF THE SCREW

Verify that the application's peak thrust does not exceed the critical buckling force (F_{CR}) for the size of the selected screw

You can calculate the critical axial force that if exceeded will lead to buckling of the screw using the classical Euler's formula:

$F_{CR} = \pi^2 * E * I / (f_1 * L_N)^2$, where

E = 29,000,000 psi – steel's modulus of elasticity,
$I = \pi * D_{ROOT}^4 / 64$,– moment of inertia of screw's crosssectional area, in^4,
f_1 – screw's end fixity factor ($f_1 = 1$ for rodless actuators and $f_1 = 2$ for rod actuators),
L_N – distance between the nut and load carrying bearing

Tolomatic catalog graphs provide buckling strength limits in a form of application thrust F, lbf as a function of actuator stroke length.

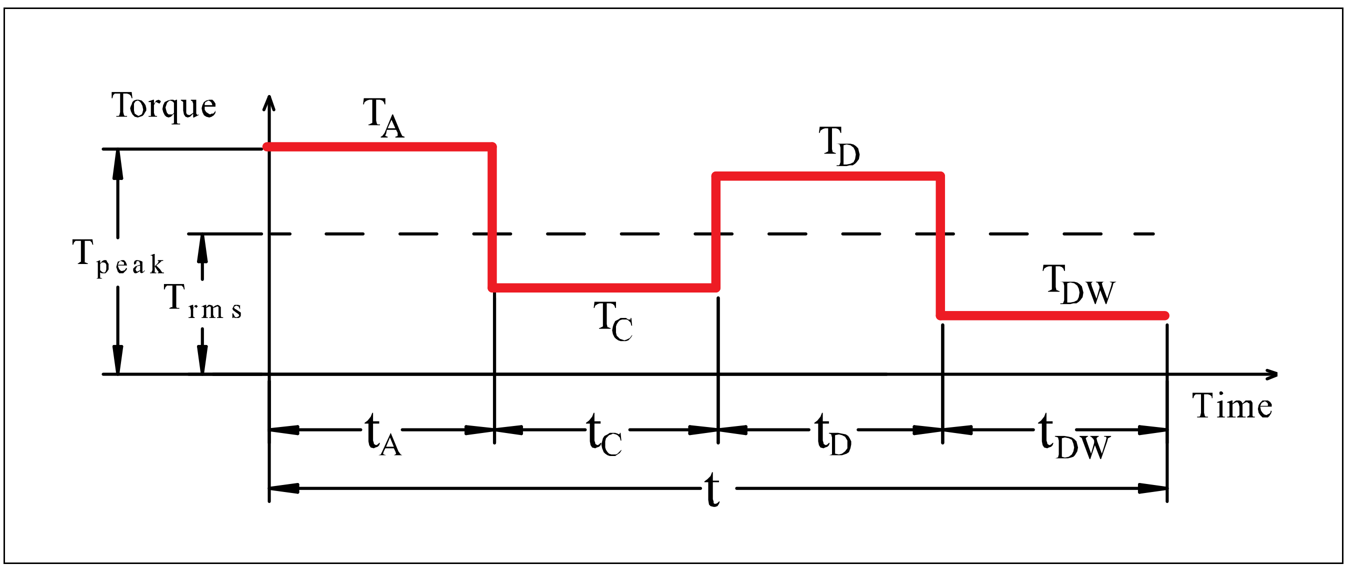
9. CALCULATE REQUIRED MOTOR TORQUE AND AVAILABLE THRUST

INTRODUCTION

To select the correct motor it is first necessary to calculate the motor torque required for a system. Start by setting the reduction ratio and efficiencies to 1.0 and inertia of motor and reduction device to zero. The calculation will produce the torque value required directly at the input of the actuator. Then a suitable motor/drive combination is selected. If no motor producing required torque is available, reduction must be considered. Recalculate the motor torque using the new reduction ratio and its efficiency. Once the motor has been selected recalculate it again including the motor's own inertia, as motors use some of the available torque to accelerate their rotors, reducing torque available to actuators.

SERVO MOTORS

Servo motors have two torque/speed curves: for continuous duty and for intermittent duty. By calculating the root mean square (RMS) torque you may be able to take advantage of the higher peak torque available in the intermittent duty region. The RMS torque must fall within the continuous duty region of the motor/drive.



Total torque during the acceleration segment $T_A = T_{ACC\,ACT} + T_{ACC\,LOAD} + T_{FR} + T_{PR} + T_{EXT} + T_{GR}$, lbf-in,

SCREW-DRIVEN RODLESS ACTUATORS (B3S, BCS, MXE, TKS)

Calculate the inertia of actuator’s rotating parts (such as lead screw, coupling etc.)

$J_{ROT} = J_B + J_{SK}*X$ (lbf-in^2), where

J_B – “base” (zero stroke) inertia of actuator’s rotating parts (lbf-in^2) from the spec section of the actuator brochure,
J_{SK} – inertia of screw per inch of stroke (lbf-in^2/in) from the spec section of the actuator brochure,
X – total move distance or stroke, in

Calculate the load inertia

$J_{LOAD} = W * (l/2\pi)^2 * (1/m^2)$ (lbf-in^2), where

W – load weight (lbf)

Calculate the inertia of actuator’s parts in linear motion (such as carrier assembly)

$J_{MOV} = W_{MOV} * (l/2\pi)^2 * (1/m^2)$ (lbf-in^2), where

W_{MOV} – weight of actuator’s parts in linear motion (such as carrier assembly, nut bracket, etc. (lbf)

l - screw lead or linear travel of the screw for its every one full rotation around its axis, in
m –ratio of reduction device (if present)

Total inertia $J = J_{ROT} + J_{LOAD} + J_{MOV}$

Using the acceleration value established at stage 2, calculate the torque to accelerate/decelerate the actuator’s rotating parts, reduction device and motor shaft
$T_{ACC\ ACT} = T_{DEC\ ACT} = (2\pi*a)/(386*l) * [(J_{ROT})* (m/e_m) + J_{RD} + J_{MOTOR}]$ (lbf-in), where

e – screw efficiency,
e_m – efficiency of the reduction device,
J_{RD} and J_{MOTOR} – inertia of reduction device and motor respectively

Calculate the torque to accelerate/decelerate the load and actuator’s parts in linear motion

$T_{ACC\ LOAD} = T_{DEC\ LOAD} = (2\pi*a)/(386*l) * [(J_{LOAD} + J_{MOV}) /e] * (m/e_m)$ (lbf-in)

Calculate the torque to overcome friction in the bearing system

$T_{FR} = \mu * l * \cos Ø * (W + W_{MOV} + F_{EXTZ} + F_{EXTY})/(2\pi*e*m*e_m)$ (lbf-in), where

MOTOR SELECTION

W – load weight (lbf)

Calculate the inertia of actuator's parts in linear motion (such as carrier assembly and belt)

$J_{MOV} = W_{MOV} * r^2 * (1/m^2)$ (lbf-in^2) + $J_{SK} * X$, where

W_{MOV} – weight of actuator's parts in linear motion (lbf)
r – pitch radius of belt sprockets (in)
m – ratio of reduction device (if present)
J_{SK} – belt inertia per inch of stroke (lbf-in^2/in) from the spec section of the actuator brochure,
X (in) – total move distance or stroke

Using the acceleration value established at stage 2, calculate the torque to accelerate/decelerate the actuator's rotating parts, reduction device and motor shaft

$T_{ACC\ ACT} = T_{DEC\ ACT} = a/(386*r) * [(J_{ROT})* (m/e_m) + J_{RD} + J_{MOTOR}]$(lbf-in), where

e – timing belt efficiency,
e_m – efficiency of the reduction device,
J_{RD} and J_{MOTOR} – inertia of reduction device and motor respectively

Calculate the torque to accelerate/decelerate the load and actuator's parts in linear motion

$T_{ACC\ LOAD} = T_{DEC\ LOAD} = a / (386*r) * [(J_{LOAD} + J_{MOV}) /e]*(m/e_m)$ (lbf-in)

Calculate the torque to overcome friction in the bearing system

$T_{FR} = \mu * r * \cos Ø * (W + W_{MOV} + F_{EXTZ} + F_{EXTY})/(e*m*e_m)$ (lbf-in), where

W_{MOV} – weight of actuator's components that are in linear motion (carrier assembly) (lbf),
μ – bearing system's coefficient of friction
F_{EXTZ} – external force, acting perpendicular to the carrier plane and the axis of linear motion (lbf),
F_{EXTY} – external force, acting in the carrier plane perpendicular to the axis of linear motion (lbf)
Ø – angle between horizontal plane and axis of linear motion.

Calculate the torque to overcome friction in the mechanical system or "break away"

$T_{BR} = T_{MBR}/(m*e_m)$ (lbf-in), where

T_{MBR} – measured (experimentally obtained) value of breakaway torque from the spec section of the actuator brochure

Calculate the torque to overcome externally applied axial forces

MOTOR SELECTION

$T_{EXT} = F_{EXTX}*r/(e*m*e_m)$ (lbf-in), where

F_{EXTX} – axially applied external force (lbf)

Calculate the torque to overcome gravity

$T_{GR} = (W + W_{MOV})* \sin Ø *r/(e*m*e_m)$ (lbf-in), where

$RPM_{MAX} = 60 * V_{MAX} * m / (2\pi*r)$

Maximum axial force (thrust) delivered by actuator

$F = (1/r)* e*m*e_m* (T_{ACC\ LOAD} + T_{EXT} + T_{GR})$ (lbf)

SCREW-DRIVEN ROD-STYLE ACTUATORS (RSA, GSA, ERD, ICR)

Calculate the inertia of actuator's rotating components (such as lead screw, coupling etc.)IBG

$J_{ROT} = J_B + J_{SK}*X$ (lbf-in^2), where

J_B – "base" (zero stroke) inertia of actuator's rotating parts (lbf-in^2) from the spec section of the actuator brochure,
J_{SK} – inertia of rotating parts per inch of stroke (lbf-in^2/in) from the spec section of the actuator brochure,
X – total move distance or stroke, in

Calculate the load inertia

$J_{LOAD} = W * (l/2\pi)^2 * (1/m^2)$ (lbf-in^2), where

W – load weight (lbf)
L – screw lead (in)
m –ratio of reduction device (if present)

Calculate the inertia of actuator's parts in linear motion (such as carrier assembly and belt)

$J_{MOV} = (W_{MOV\ BASE} + W_{MOV\ SK}*X) * (l/2\pi)^2 * (1/m^2)$ (lbf-in^2), where

$W_{MOV\ BASE}$ – "base" (zero stroke) weight of actuator parts in linear motion (lbf)
$W_{MOV\ SK}$ - weight of actuator parts in linear motion per inch of stroke (thrust tube, GSA guide rods), lbf

MOTOR SELECTION

Using the acceleration value established at stage 2, calculate the torque to accelerate/decelerate the actuator's rotating parts, reduction device and motor shaft

$T_{ACC\ ACT} = T_{DEC\ ACT} = (2\pi*a)/(386*l) * [\ (J_{ROT})* (m/e_m) + J_{RD} + J_{MOTOR}]$ (lbf-in), where

e – screw efficiency,
e_m – efficiency of the reduction device,
J_{RD} and J_{MOTOR} – inertia of reduction device and motor respectively

Calculate the torque to accelerate/decelerate the load and actuator's parts in linear motion

$T_{ACC\ LOAD} = T_{DEC\ LOAD} = (2\pi*a)/(386*l) * [\ (J_{LOAD} + J_{MOV})/e] * (m/e_m)]$ (lbf-in)

Calculate the torque to overcome friction in the support/guidance bearing system (GSA, ERD with GD2 option)

$T_{FR} = \mu * l * \cos Ø * (W + W_{MOV} + F_{EXTZ} + F_{EXTY})/(2\pi*e*m*e_m)$ (lbf-in), where

μ – bearing system's coefficient of friction,
F_{EXTZ} – external force, acting perpendicular to the carrier plane and the axis of linear motion (lbf),
F_{EXTY} – external force, acting in the carrier plane perpendicular to the axis of linear motion (lbf)
Ø – angle between horizontal plane and axis of linear motion.

Calculate the torque to overcome friction in the mechanical system or "break away"

$T_{BR} = T_{MBR}/(m*e_m)$ (lbf-in), where

T_{MBR} – measured (experimentally obtained) value of breakaway torque from the spec section of the actuator brochure

Calculate the torque to overcome externally applied axial forces

$T_{EXT} = F_{EXTX} * l / (2\pi*e*m*e_m)$ (lbf-in), where

F_{EXTX} – axially applied external force (lbf)

Calculate the torque to overcome gravity

$T_{GR} = (W + W_{MOV})* \sin Ø * l / (2\pi*e*m*e_m)$ (lbf-in), where

Calculate maximum required RPM of the motor

MOTOR SELECTION

$RPM_{MAX} = 60 * V_{MAX} * m / l$

Maximum axial force (thrust) delivered by actuator

$F = (2\pi / l) * e * m * e_m * (T_{ACC\ LOAD} + T_{EXT} + T_{GR})$ (lbf)

REQUIRED MOTOR TORQUE

As stated above a minimum torque margin of 15% is recommended for brushless servo motors, and 50% - for stepper motors.

Peak torque required of a brushless servo motor:
$T_{MOTOR\ PEAK} = 1.15 * T_{MAX}$ (lbf-in)

Continuous torque required of a brushless servo motor:
$T_{MOTOR\ CONT} = 1.15 * T_{RMS}$ (lbf-in)

To avoid load instability and achieve best dynamic performance the ratio of summary inertia of the load and moving components to the inertia of the motor should be between 0.1 and 10.0

$J_{TOTAL} / J_{MOTOR} = 0.1 – 10.0$

10.SELECT MOTOR CONFIGURATION, SENSORS AND ACCESSORIES, DETERMINE MOUNTING REQUIREMENTS

After the linear actuator/motor/drive have been defined, select an inline or a reverse-parallel motor configuration. Select mounting options, accessories, rod end options (for rod actuators) and position sensors (if required).

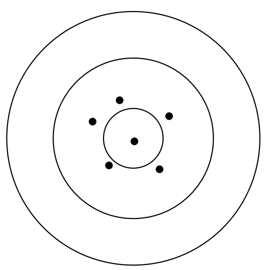
Glossary

A

ABSOLUTE MOVE
A move with reference to a fixed absolute zero location.

AC SERVO
Motor/Drive that generates sinusoidal motor currents and sinusoidal back EMF in a brushless motor.

ACCURACY
The degree to which an actuator is able to move to a specific commanded point. On the bullseye below, notice that all the holes are centered around the middle of the target, but the grouping is not very close together. Good accuracy does not require good repeatability. *(see repeatability & accuracy)*



ACME SCREW/NUT
Threaded screw and nut design which utilizes sliding surfaces between the two. Typical efficiencies are between 60-70%.

AUTO-PHASING
The drive function that determines the motor's angular rotor position for commutation without the need for Hall Effect switches.

AXIAL LOADING
Load where the force is acting along the axis of actuator (bearing) in any direction.

B

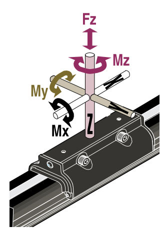
BACK EMF
Voltage produced across a motor winding due to the winding turns being cut by a magnetic field. This voltage is directly proportional to rotor velocity and is opposite in polarity to the applied voltage.

BACKLASH
Linear distance which is lost in positioning the nut or carrier when the screw direction of rotation changes.

BALL SCREW/NUT
Screw and nut design utilizing a nut that contains one or more circuits of recirculating steel balls which roll between the screw and nut.

BAUD RATE
Number of binary bits transmitted per second in a serial communication system.

BENDING MOMENT
Equivalent torque produced by a force displaced by a known distance from the carriage. Ex. Mx, My, Mz, Fz *(See illustration below).*



BREAKAWAY TORQUE
Torque required to start an actuator in motion. In an electric actuator, this consists primarily of the torque to overcome the preload of the lead screw nut assembly and the static friction of the carrier bearings.

BRUSHLESS DC SERVO
Motor/drive that generates trapezoidal motor currents and trapezoidal back EMF in a brushless motor.

C

CARRIER
Moving part of a rodless actuator providing a mounting surface for a load.

CLOSED LOOP (FEED BACK)
System where the output is measured and compared to the input. If this system is capable of making corrections to minimize the difference it is classified as a servo.

COMMUTATION
Switching of drive voltage to the motor windings necessary to provide continuous rotation. A brush motor uses mechanical switching through a brush-bar contact. Brushless motors use separate devices such as Hall Sensors to sense the rotor position. This information is then processed by the drive to determine the switching sequence.

CONTINUOUS TORQUE
Another term for RMS torque. See RMS torque

CRITICAL SPEED
Rotational speed of a lead screw at which the screw begins to oscillate or whip. This speed is dependent on the screw length and diameter.

CYCLE
A complete motion of actuator's carrier or tooling plate from start to finish and back.

CYCLE RATE
Total number of complete cycles in a specific period of time.

CENTER OF GRAVITY (CENTER OF MASS)
The point a which the entire weight of a body may be considered as concentrated so that if supported at this point the body would remain in equilibrium in any position.

D

DEAD LENGTH
Result of subtraction of stroke length from overall length of an actuator.

DEFLECTION
Amount of displacement of a point on rodless actuator carrier or rod actuator tooling plate, under load by forces or bending moments, measured in the direction perpendicular to actuator axis.

DUTY CYCLE
Ratio of on time to total cycle time.

$$\text{Duty Cycle} = \frac{\text{On Time}}{(\text{On Time} + \text{Off Time})}$$

DWELL TIME
A pause of motion within a move cycle.

E

EFFICIENCY
Ratio of power output to power input.

ENCODER
Device used to provide relative position and velocity information to a drive or controller by sensing mechanical motion and providing a corresponding pulse rate as output.

F

FLATNESS
When traveling in a straight horizontal line, the vertical deviation above or below the horizontal plane of travel of the carrier.

G

GANTRY
A method of connecting two actuators together so one motor can operate both actuators.

H

HOLDING TORQUE
Maximum external torque that can be applied to a stopped, energized motor without causing the rotor to rotate.

I

INCREMENTAL MOVE
A positional move referenced from the current position.

INERTIA
Measure of an object's resistance to change in motion that is a function of the object's mass and shape.

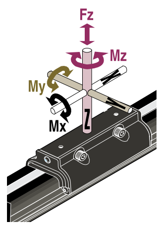
INERTIA MATCH
If the reflected inertia of the load is equal to the rotor inertia of the motor, the system will operate optimally for efficiency and dynamic performance.

Glossary

L

LEAD
Linear travel of a lead screw nut or carriage for every one full rotation of the lead screw expressed in inches per rev.

LOAD
A mass or weight supported by the carrier (rodless cylinders) or tooling plate (rod type cylinders). Ex. Fz
(See illustration below).



M

MAXIMUM DYNAMIC LOAD
Load of constant magnitude acting in one direction that results in a nominal life (travel) of a linear motion actuator (component).

MAXIMUM STATIC LOAD
Maximum load of constant magnitude acting in one direction that a static actuator (component) can withstand without permanent deformation.

MICROSTEPPING
Type of drive that proportions the current in a step motor's windings to provide intermediate positions between full steps. Advantages over full and half stepping include smoothness of rotation and higher position resolution.

MOMENT LOAD
Rotational forces applied to the carrier equal to the linear force applied (weight) multiplied by the distance between the location of the force (center of gravity) and the surface center of the carrier. Typically expressed as yaw (Mz), pitch (Mx) and Roll (My). (See illustration with "LOAD").

MOTION PROFILE
Definition of an object's position and velocity relationships in time during a move.

O

OPEN LOOP
Motion control system where no position or velocity signals are provided for correction. Typically, stepper systems run as open loop systems.

OPTICALLY ISOLATED
Transmission of a signal from one device to another with a light source (emitted) and sensor (received), in order to avoid direct electrical contact.

P

PITCH
Number of revolutions required by a leadscrew to move the nut or carrier one inch, expressed in revs/per inch

PLC
(Programmable logic controller) A digital electronic device that uses to store instructions and to implement functions such as logic sequencing, timing and counting in order to control machines and processes.

PWM
Pulse Width Modulation is a method of controlling current in the windings of a motor by on-off switching of transistors to vary the duty cycle.

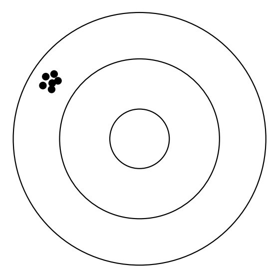
R

RADIAL LOAD
Load where the force is acting perpendicular to the axis of actuator (bearing) in the direction of actuator (bearing).

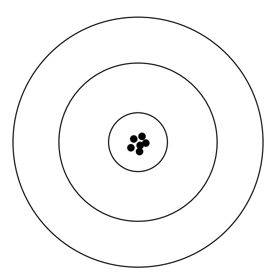
REGENERATION
Characteristic of a motor to act as a generator when the CEMF (counter electromotive force) is larger than the drive's applied voltage.

REGENERATIVE BRAKING
The technique of slowing or stopping a drive by regeneration.

REPEATABILITY
The degree to which an actuator can return to a reference location. Notice on the bullseye on the next page that the holes are close together, however the grouping is far from the bullseye. Repeatability can be thought of as how tight of a grouping can be made. Unidirectional repeatability, measured by approaching a position from a single direction, hides errors caused by backlash and hysteresis effects. Bidirectional repeatability, measured by approaching a position from opposing directions, includes these effects, and provides a more meaningful specification.



REPEATABILITY & ACCURACY
The measure of how close to a programmed point the actuator can come, and how close it gets to that same point again. The repeatability of industrial actuators is usually much better than the accuracy. Notice on the bullseye below that the points are centered around the middle of the target and are grouped close together. This is good accuracy and repeatability.



RESOLUTION
The smallest position increment that can be achieved.

RESOLVER
A feedback device consisting of a stator and rotor that provides position and velocity information to the drive for commutation.

REVERSE RADIAL LOAD
Load where the force is acting perpendicular to the axis of actuator (bearing) in the direction opposite from actuator (bearing).

RMS TORQUE
In an intermittent application, this is the torque provided to generate equivalent motor heating to one operating in a steady state.

$$Trms = \sqrt{\frac{\Sigma(Ti^2 \cdot ti)}{\Sigma ti}}$$

where Ti = Torque during interval i
ti = Time of interval i

ROCKWELL
Industry-accepted standard for definition of hardness.

ROD-STYLE ACTUATOR
An actuator using a rod attached to its drive mechanism to transmit force. Tolomatic models include: ERD, ICR, RSA, GSA and IMA.

RODLESS ACTUATOR
An actuator that contains the stroke within the actuator itself. Tolomatic models include: MXE-S, MXE-P, TKS, B3S,BCS, SLS, MXB-U, MXB-P, TKB, and B3W.

RS232
A standard for data communication that defines voltages and time requirements for information to be transferred on a single line in sequential format.

S

SCHEMATIC
A diagram of a circuit in which symbols illustrate circuit components.

Glossary

SERVO
System that compares the output of a device (by monitoring position, velocity, and/or torque) with the desired outcome and makes corrections to minimize the difference.

SERVO MOTOR
Motor used in closed loop systems where feedback is used to control motor position, velocity, and/or torque, usually expected to have high torque/inertia ratio.

SHIELDING
The practice of confining the electrical field around a conductor to the primary insulation of the cable by putting a conducting layer over and/or under the cable insulation. (External shielding is a conducting layer on the outside of the cable insulation. Strand or internal shielding is a conducting layer over the wire insulation.)

SIGNAL
The event, phenomenon, or electrical quantity that conveys information from one point to another.

SLEW
Constant non-zero velocity portion of a motion profile.

SOLID STATE DEVICES
Electronic components that control electron flow through solid materials (e.g., transistors, diodes, or integrated circuits).

STALL TORQUE
Maximum torque available at zero speed.

STIFFNESS
System ability to maintain accuracy when subject to disturbance.

STRAIGHTNESS
When traveling in a straight horizontal line, the side to side deviation within the horizontal plane of travel of the carrier.

STROKE LENGTH
The distance that the carrier and its load will move on the actuator.

SURGE
A transient variation in the current or potential at a point in the circuit.

SYSTEM
A collection of units combined to work as a larger integrated unit having the capabilities of all of the separate units.

T

TENSILE STRENGTH
The greatest longitudinal stress a substance can bear without permanent deformation.

THRUST
Measurement of linear force.

TORQUE
Measurement of force producing rotation.

TORQUE CONSTANT
Torque generated in a DC motor per ampere applied to the windings.

$$Kt = \frac{T\ (oz.\text{-}in.)}{A\ (amp)}$$

TRAPEZOIDAL PROFILE
A velocity vs time profile that is characterized by total move time spit evenly for acceleration, deceleration and velocity.

TRIANGULAR PROFILE
A velocity vs time profile that is characterized by equal time for acceleration and deceleration.

TRIAC AC REED SWITCH
These switches are designed for signaling end-of-stroke position to devices such as programmable controllers. They can be used to operate ac relays and solenoids if a protection circuit is used and if current and voltage limits are observed.

TUBE DEFLECTION
Due to the nature of loads and aluminum extrusions tube deflection will occur if actuator is supported only on the ends without tube supports at recommended intervals along length of cylinder.

TUBE SUPPORTS
Optional accessory for actuator to prevent tube deflection.

V

VALUE
A number that represents a computed or assigned quantity; or, a number contained in a data table or data file word.

VECTOR DRIVE
A class of drives that sense motor current in each individual motor phase and resolves these readings into two current vectors. One vector is the torque producing current and other is the waste current. The current control algorithm then works to drive the non-torque-producing component to zero. This results in a high bandwidth torque response over the full speed range without the phase lag and tolerance issues that occur in older drive technologies.

VOLT
Unit of electromotive force. It is the difference of potential required to make a current of one ampere flow through a resistance of one ohm.

VOLTAGE
The term most often used in place of electromotive force, potential, potential difference, or voltage drop. It describes the electric pressure that exists between two points and is capable of producing a flow or current when a closed circuit is connected between the two points.

VOLTAGE CONSTANT
Back EMF generated by a DC motor usually in units of volts per 1000 rpm.

$$KE = \frac{volts}{1000\ rpm}$$

VOLTAGE RATING
The maximum voltage at which a given device may be safely maintained during continuous use in a normal manner. It is also called working voltage.

W

WATT
A unit of power or a rate of doing work. The power dissipated by a one ohm resistor with one ampere of current is one watt.

Conversion Tables

To convert from A to B, multiply by entry in table

LENGTH (A \ B)	in	ft	yd	mm	cm	m
in	1	0.0833	0.028	25.4	2.54	0.0254
ft	12	1	0.333	304.8	30.48	0.3048
yd	36	3	1	914.4	91.44	0.914
mm	0.03937	0.00328	0.000109	1	0.1	0.001
cm	0.3937	0.03281	0.00109	10	1	0.01
m	39.37	3.281	1.09	1000	100	1

MASS (A \ B)	gm	kg	slug	lb(m)	oz(m)
gm	1	0.001	6.852×10^{-5}	2.205×10^{-3}	0.03527
kg	1000	1	6.852×10^{-2}	2.205	35.274
slug	14590	14.59	1	32.2	514.72
lb(m)	453.6	0.45359	0.0311	1	16
oz(m)	28.35	0.02835	1.94×10^{-3}	0.0625	1

PRESSURE (A \ B)	atm	bar	millibar	lbs/sqr ft (PSF)	lbs/sqr in (PSI)	N/sqr m (NSM)	N/sqr mm (NSMM)
atm	1	1.01325	1013.25	2,116.22	14.6454	101,325	0.101325
bar	0.986923	1	1000	2088.54	14.5037	100,000	0.1
millibar	0.000987	0.001	1	2.08854	0.014504	100	0.0001
PSF	0.000473	0.000479	0.478803	1	0.006944	47.88	0.000048
PSI	0.068046	0.068948	68.94757	143.99999	1	6,894.757	0.006895
NSM	0.00001	0.00001	0.01	0.020885	0.000145	1	0.000001
NSMM	98,692	10	10,000	20885.43	145.0377	1,000,000	1

FORCE (A \ B)	lb(f)	N	dyne	oz(f)	kg(f)	gm(f)
lb(f)	1	4.4482	4.448×10^{5}	16	0.45359	453.6
N	0.22481	1	100	3.5967	0.10197	---
dyne	2.248×10^{-6}	0.00001	1	3.59×10^{-5}	---	980.6
oz(f)	0.0625	0.27801	2.78×10^{4}	1	0.02835	28.35
kg(f)	2.205	9.80665	---	35.274	1	1000
gm(f)	2.205×10^{-3}	---	1.02×10^{-3}	0.03527	0.001	1

POWER (A \ B)	Watts	KW	hp (US customary)	hp (Metric)	ft-lb/s	in-lb/s
Watts	1	1×10^{-3}	1.34×10^{-3}	1.36×10^{-3}	0.74	8.88
kw	1000	1	1.34	1.36	738	8880
hp (US customary)	746	0.746	1	1.01	550	6600
hp (Metric)	736	0.736	0.986	1	543	6516
ft-lb/s	1.35	1.36×10^{-3}	1.82×10^{-3}	1.84×10^{-3}	1	12
in-lb/s	0.113	1.13×10^{-4}	1.52×10^{-4}	1.53×10^{-4}	8.3×10^{-2}	1

ABBREVIATED TERMS

atm	= atmosphere (STD)
C	= Celsius
cm	= centimeter
F	= Fahrenheit
ft	= foot
g	= gravity
gm	= gram
gm(f)	= gram force
hp	= horse power
in	= inch
kg	= kilogram
kg(f)	= kilogram force
kw	= Kilowatt
lb(f)	= pound force
lb(m)	= pound mass
min	= minute
mm	= millimeter
m	= meter
N	= Newton
oz(f)	= ounce force
oz(m)	= ounce mass
rad	= radians
rpm	= revs per minute
rps	= revs per second
s	= seconds
sqr	= square

Conversion Tables

To convert from A to B, multiply by entry in table

TORQUE (A → B)	dyne-cm	gm-cm	oz-in	kg-cm	lb-in	N-m	lb/ft	kg/m
dyne-cm	1	1.019×10^{-2}	1.416×10^{-5}	1.0197×10^{-6}	8.850×10^{-7}	10^{-7}	7.375×10^{-6}	1.019×10^{-6}
gm-cm	980.665	1	1.388×10^{-2}	.001	8.679×10^{-4}	9.806×10^{-5}	7.233×10^{-5}	10-5
oz-in	7.061×10^{4}	72.007	1	7.200×10^{-2}	6.25×10^{-2}	7.061×10^{-3}	5.208×10^{-3}	7.200×10^{-4}
kg-cm	9.806×10^{5}	1000	13.877	1	0.8679	9.806×10^{-2}	7.233×10^{-2}	0.001
lb-in	1.129×10^{6}	1.152×10^{3}	16	1.152	1	0.112	8.333×10^{-2}	1.152×10^{-2}
N-m	10^{7}	1.019×10^{4}	141.612	10.197	8.85	1	0.737	0.102
lb-ft	1.355×10^{7}	1.382×10^{4}	192	13.825	12	1.355	1	0.138
kg-m	9.806×10^{7}	105	1.388×10^{3}	100	86.796	9.806	7.233	1

NOTE: Mass inertia = $\frac{\text{wt. inertia}}{g}$

INERTIA (ROTARY) (A → B)	gm-cm^2	oz-in^2	gm-cm-s^2	kg-cm^2	lb-in^2	oz-in-s^2	lb-ft^2	kg-cm-s^2	lb-in-s^2	lb-ft-s^2 or slug-ft-s^2
gm-cm^2	1	5.46×10^{-2}	1.01×10^{-3}	38,992	3.417×10^{-4}	1.41×10^{-5}	2.37×10^{-6}	1.01×10^{-4}	8.85×10^{-7}	7.37×10^{-4}
oz-in^2	182.9	1	0.186	0.182	0.0625	2.59×10^{-2}	4.34×10^{-4}	1.86×10^{-4}	1.61×10^{-4}	1.34×10^{-5}
gm-cm-s^2	980.6	5.36	1	0.9806	0.335	1.38×10^{-2}	2.32×10^{-3}	38,992	8.67×10^{-4}	7.23×10^{-5}
kg-cm^2	1,000	5.46	1.019	1	0.3417	1.41×10^{-2}	2.37×10^{-3}	1.019×10^{-3}	8.85×10^{-4}	7.37×10^{-5}
lb-in^2	2.92×10^{3}	16	2.984	2.925	1	4.14×10^{-2}	6.94×10^{-3}	2.96×10^{-3}	2.59×10^{-3}	2.15×10^{-4}
oz-in-s^2	7.06×10^{4}	386.08	72	70.615	24.13	1	0.1675	7.20×10^{-2}	6.25×10^{-2}	5.20×10^{-3}
lb-ft^2	4.21×10^{5}	2,304	429.71	421.4	144	5.967	1	0.4297	0.3729	3.10×10^{-2}
kg-cm-s^2	9.8×10^{5}	5.36×10^{3}	1,000	980.66	335.1	13.887	2.327	1	0.8679	7.23×10^{-2}
lb-in-s^2	1.129×10^{4}	6.177×10^{3}	1.152×10^{3}	1.129×10^{3}	386.08	16	2.681	1.152	1	8.33×10^{-2}
lb-ft-s^2	1.355×10^{7}	7.41×10^{4}	1.38×10^{4}	1.35×10^{4}	4.63×10^{3}	192	32.17	13.825	12	1

ANGULAR VELOCITY (A → B)	deg/s	rad/s	rpm	rps
deg/s	1	1.75×10^{-2}	0.167	2.78×10^{-3}
rad/s	57.3	1	9.55	0.159
rpm	6	0.105	1	1.67×10^{-2}
rps	360	6.28	60	1

TEMPERATURE
°F = (1.8 x °C) + 32
°C = .555 x (°F -32)

LINEAR VELOCITY (A → B)	in/min	ft/min	in/sec	ft/sec	mm/sec	m/sec
in/min	1	0.0833	0.0167	1.39×10^{-3}	0.42	4.2×10^{-4}
ft/min	12	1	0.2	0.0167	5.08	5.08×10^{-3}
in/sec	60	5	1	0.083	25.4	0.0254
ft/sec	720	60	12	1	304.8	0.3048
cm/sec	23.62	1.97	0.3937	0.0328	10	0.01
m/sec	2362.2	196.9	39.37	3.281	1000	1

GRAVITY
(Acceleration Constant)
g = 386 in/sec^2 = 32.2 ft/sec^2 = 9.8 m/sec^2

Terms / Conditions of Sale

1. **ORDER ACCEPTANCE.** All orders or services are subject to acceptance in Minnesota by the written approval of an authorized official of Tolomatic, Inc. Any such order shall be subject to these Terms and Conditions of Sale, and acceptance shall be conditioned on Purchaser's assent to such conditions. Purchaser's assent shall be deemed given unless Purchaser shall expressly notify Tolomatic, Inc. in writing to the contrary within five (5) days after receipt of acknowledgment to confirmation of an order.

2. **CANCELLATION AND CHANGES.** No order accepted by Tolomatic, Inc. may be modified in any manner by Purchaser unless agreed to in writing, by an authorized official of Tolomatic, Inc. Order cancellations, including reductions to order quantities, and changes shall be governed by the following:

   a. Any standard product order scheduled for shipment within five (5) working days of purchaser's request to cancel or modify will be shipped as previously acknowledged and purchaser agrees to accept shipment and payment responsibility, in full, at the price agreed upon.

   b. "Customer Special" orders scheduled for shipment within twenty (20) working days of purchaser's request to cancel or modify will be shipped as previously acknowledged and purchaser agrees to accept shipment and payment responsibility, in full, at the price agreed upon.

   c. All work in connection with "Customer Special" orders, not covered under Paragraph b, will be stopped immediately upon notification, and purchaser agrees to reimburse Tolomatic, Inc. for all work-in-process and any materials or supplies used, or for which commitments have been made by Tolomatic, Inc. in connection therewith.

3. **QUOTATIONS AND PRICES.** Written quotations automatically expire 30 calendar days from the date issued unless terminated sooner by written notice. (Verbal quotations expire, unless accepted in writing, the same day.)

   All published prices and discounts are subject to change without notice. In the event of a net price change, the price of product(s) on order will be the price in effect on the date of order acknowledgment. Any addition to an outstanding order will be accepted at prices in effect when the addition is made.

4. **MINIMUM BILLING.** Orders amounting to less than $35.00 net will be billed at $35.00

5. **TAXES.** Any Manufacturer's Tax, Retailers Occupation Tax, Use Tax, Sales Tax, Excise Tax, Duty, Customer, Inspection or Testing Fee, or any other tax, fee or charge of any nature whatsoever, imposed by any government authority, on or measured by any transactions between Tolomatic, Inc. and Purchaser shall be paid by the Purchaser in addition to the prices quoted or involved. In the event Tolomatic, Inc. shall be required to pay any such tax, fee or charge, Purchaser shall reimburse therefore.

6. **TERMS OF PAYMENT.** Net invoice amount is due within 30 days from date of invoice subject to credit approval. A 2% per month service charge shall apply to all invoices not paid within 30 days. All clerical errors are subject to correction. Any invoice in not paid within 60 days will subject that account to an immediate shipping hold.

7. **F.0.B. POINT.** All sales are F.0.B. Tolomatic, Inc.'s facility in Hamel, Minnesota, unless quoted otherwise.

8. **DELIVERY.** Delivery of product(s) by Tolomatic, Inc. to a carrier shall constitute delivery to Purchaser, and regardless of freight payment, title and all risk or loss or damage in transit shall pass to Purchaser at that time.

   Should shipment be held beyond scheduled date, upon request of Purchaser, product will be billed and Purchaser agrees to accept any charges for warehousing, trucking and other expenses as may be incident to such delay.

   Great care is taken by Tolomatic, Inc. in crating its product. Tolomatic, Inc. cannot be held responsible for breakage after having received "In Good Order" receipts from the transporting carrier. All claims for loss and damage must be made by Purchaser to the carrier within 14 days from receipt of goods. Tolomatic, Inc. will assist insofar as practical in securing satisfactory adjustment of such claims wherever possible.

   Claims for shortages or other errors must be made, in writing, within ten (10) days to Tolomatic, Inc. and any additional expense of the method or route of shipment specified by Purchaser shall be borne by the Purchaser.

9. **SHIPPING SCHEDULES.** All quoted shipping schedules are approximate and will depend upon prompt receipt from Purchaser of confirming copy of Purchase Order. Dimensional drawings and specifications submitted by Tolomatic, Inc. to Purchaser for approval must be returned to Tolomatic, Inc. within 10 working days, with approval granted, and any exceptions noted, in order to avoid delay in manufacturing schedules.

   Orders which include penalty clauses for failure to meet shipping schedules will not be acceptable, except in those cases specifically approved in writing by the General Manager of Tolomatic, Inc.

   Tolomatic, Inc. shall not be liable for damage as a result of any delay due to any cause beyond Tolomatic, Inc.'s reasonable control, including, without limitation, an Act of Nature; act of Purchaser; embargo, or other government act, regulation or request; fire; accident; strike; slow down; war; riot; flood; delay in transportation; and inability to obtain necessary labor, materials or manufacturing facilities. In the event of any such delay, the date of delivery shall be extended for a period equal to the time loss by reason of the delay. The acceptance of the product when delivered shall constitute a waiver of all claims for damages caused by any such delays.

10. **RETURN OF PRODUCT.** No product may be returned without first obtaining a Return Goods Authorization form and confirming memorandum from Tolomatic, Inc. Product, if accepted for credit, shall be subject to a minimum service charge of 35% of the invoice price and all transportation charges shall be prepaid by the Purchaser; however, assembled products classified as "special," such as Cable Cylinders and other products which have been modified or built as "Customer Specials," are not returnable to Tolomatic, Inc.

11. **WARRANTY.** Tolomatic, Inc., WARRANTS PRODUCT MANUFACTURED BY IT TO BE FREE FROM DEFECTS IN MATERIAL AND WORKMANSHIP FOR A PERIOD OF ONE YEAR FROM DATE OF SHIPMENT BY Tolomatic, Inc. IF WITHIN SUCH PERIOD ANY SUCH PRODUCT SHALL BE PROVED TO Tolomatic, Inc.'s SATISFACTION TO BE SO DEFECTIVE, SUCH PRODUCT SHALL EITHER BE REPAIRED OR REPLACED AT Tolomatic, Inc.'s OPTION.

THIS WARRANTY SHALL NOT APPLY:

   a. TO PRODUCT NOT MANUFACTURED BY Tolomatic, Inc. WITH RESPECT TO PRODUCT NOT MANUFACTURED BY Tolomatic, Inc. THE WARRANTY OBLIGATIONS OF Tolomatic, Inc. SHALL IN ALL RESPECTS CONFORM AND BE LIMITED TO THE WARRANTY ACTUALLY EXTENDED TO Tolomatic, Inc. BY ITS SUPPLIER.

   b. TO PRODUCT WHICH SHALL HAVE BEEN REPAIRED OR ALTERED BY PARTIES OTHER THAN Tolomatic, Inc. SO AS, IN Tolomatic, Inc.'s JUDGMENT, TO AFFECT THE SAME ADVERSELY, OR

   c. TO PRODUCT WHICH SHALL HAVE BEEN SUBJECT TO NEGLIGENCE, ACCIDENT, OR DAMAGE BY CIRCUMSTANCES BEYOND THE CONTROL OF Tolomatic, Inc. OR TO IMPROPER OPERATION MAINTENANCE OR STORAGE, OR TO OTHER THAN NORMAL USE AND SERVICE.

   THE FOREGOING WARRANTIES ARE EXCLUSIVE AND IN LIEU OF ALL OTHER EXPRESS AND IMPLIED WARRANTIES WHATSOEVER, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, Tolomatic, Inc. SHALL NOT BE SUBJECT TO ANY OTHER OBLIGATIONS OR LIABILITIES WHATSOEVER WITH RESPECT TO PRODUCT MANUFACTURED OR SUPPLIED BY Tolomatic, Inc. OR SERVICE RENDERED BY IT.

12. **CONSEQUENTIAL DAMAGE.** Tolomatic, Inc. shall not, under any circumstances, be liable for consequential damages.

13. **SERVICE CHARGES.** Should the Purchaser request the service of any erector, demonstrator or service man (except as specifically provided for and included in the price of the product) such service will be rendered at the rate outlined in the schedule of field service charges in effect at the date of request.

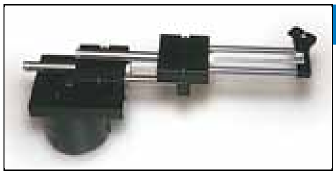
THE TOLOMATIC DIFFERENCE What you expect from the industry leader:

EXCELLENT CUSTOMER SERVICE & TECHNICAL SUPPORT

Our people make the difference! Expect prompt, courteous replies to all of your application and product questions.

INDUSTRY LEADING DELIVERIES

Standard catalog products are built to order and ready-to-ship in 5 days or less. Modified and custom products ship weeks ahead of the competition.

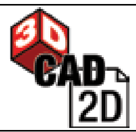


INNOVATIVE PRODUCTS

From standard catalog products... to modified products... to completely unique custom products, Tolomatic designs and builds the best solutions for your challenging applications.

ONLINE SIZING & SELECTION SOFTWARE

Online sizing that is easy to use, accurate and always up-to-date. Input your application data and the software will determine a Tolomatic electric actuator to meet your requirements.



3D MODELS & 2D DRAWINGS AVAILABLE ON THE WEB

Easy to access CAD files are available in many popular formats.

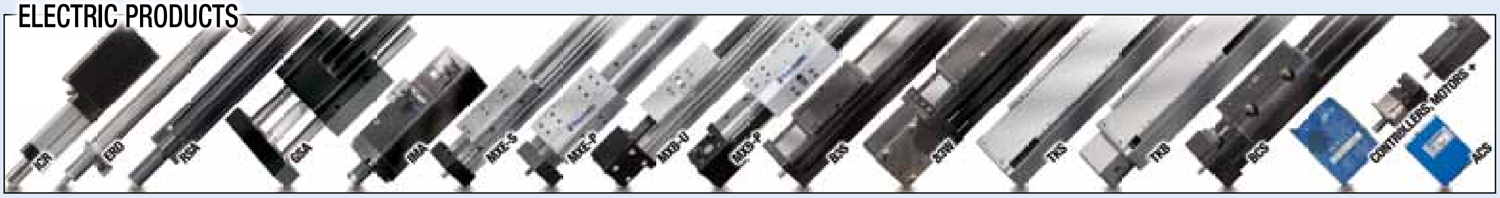
ALSO CONSIDER THESE OTHER TOLOMATIC PRODUCTS:

PNEUMATIC PRODUCTS

RODLESS CYLINDERS: Band Cylinders, Cable Cylinders, MAGNETICALLY COUPLED CYLINDERS/SLIDES; GUIDED ROD CYLINDER SLIDES

"FOLDOUT" BROCHURE #9900-9075
PRODUCTS BROCHURE #9900-4028

ELECTRIC PRODUCTS



ROD & GUIDED ROD STYLE ACTUATORS, HIGH THRUST ACTUATORS, SCREW & BELT DRIVE RODLESS ACTUATORS, MOTORS, DRIVES AND CONTROLLERS

"FOLDOUT" BROCHURE #9900-9074
PRODUCTS BROCHURE #9900-4016

POWER TRANSMISSION PRODUCTS

GEARBOXES: Float-A-Shaft®, Slide-Rite®; DISC CONE CLUTCH; CALIPER DISC BRAKES

"FOLDOUT" BROCHURE #9900-9076
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