TRITEX II™ SERIES

FULLY INTEGRATED SERVO DRIVE/MOTOR

Rotary configuration

AC powered model

Multiple networking options

Tritex™ Series

Fully Integrated Drive/Motor/Actuator

By combining the latest electronic power technology with advanced thermal management modeling technology, Exlar® has set a new benchmark for electric actuator performance versus size. Tritex II actuators now integrate an AC or DC powered servo drive, digital position controller, brushless motor and linear or rotary actuator in one elegant, compact, sealed package. Now you can distribute motion control and resolve your application challenges with one integrated device. Simply connect power, I/O, communications and go!

Dramatically Reduce Space Requirements

Tritex II actuators are the highest power density, smallest footprint servo drive devices on the market. Finally, you can incorporate a fully electronic solution in the space of your existing hydraulic or pneumatic cylinder. You can also eliminate troublesome ball screw actuators or bulky servo gear reducers. And the space previously consumed by panel mount servo drives and motion controllers is no longer needed. Tritex II actuators may also reduce the size of your machine design while significantly improving reliability.

Reduce Costs

Now you can eliminate the labor costs for mounting and wiring panels because the Tritex II houses the servo drive, digital positioner, and actuator in one convenient package. Cable costs are also significantly reduced by eliminating the need for expensive, high-maintenance specialty servo cables. All that is required is an economical standard AC or DC power cord, and standard communication cable for digital and analog I/O.

These actuators also eliminate the issues associated with power signals and feedback signals traveling long distances from servo drive to servo motor. With the Tritex II, the servo drive and motor are always integrated in the same housing.

Flexible Communications

Multiple feedback types, including absolute feedback, allow you to select the system that is best-suited for your application. Digital and analog I/O, plus popular communication networks, such as Modbus TCP, Ethernet/IP, PROFINET IO, and CANopen, allow the Tritex II to become an integral part of your control architecture or machine control processes.

Improves Power, Performance, and Reliability

Tritex II actuators give you unrivaled power, performance, and reliability. No longer are you limited to trivial amounts of force or speeds so slow that many motion applications are not possible.

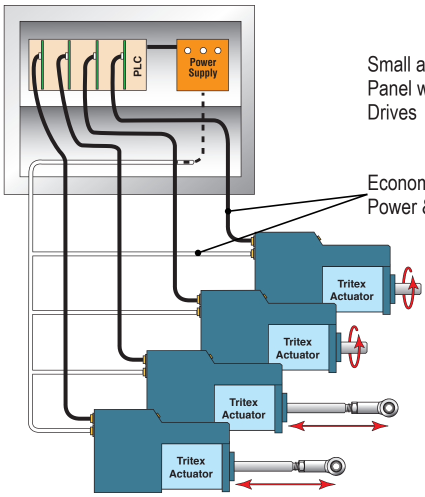
Tritex II AC Actuator

- Continuous force to 3225 lbf (14kN)
- Peak force to 5400 lbf (24kN)
- Speed to 33 in/sec (800 mm/sec)
- 1.5 kW servo amplifier
- Temperature operation range -40˚C to +65˚C
- AC power 100V – 240V, +/-10%

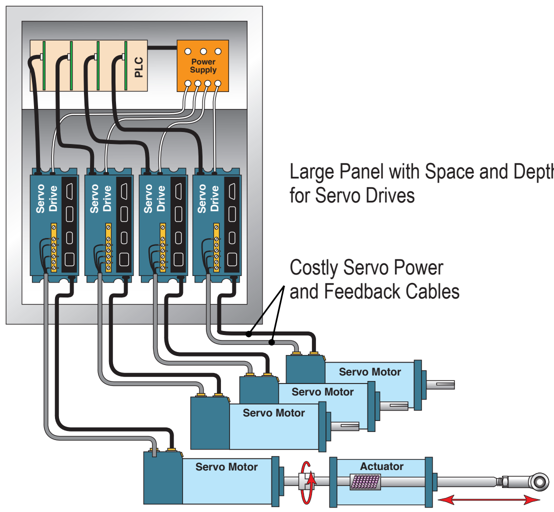
Tritex II DC Actuator

- Continuous force to 872 lbf (4kN)
- Peak force to 1190 lbf (5kN)
- Speed to 33 in/sec (800 mm/sec)
- 750W servo amplifier
- Temperature operation range -40˚C to +65˚C
- DC power 12-48 VDC nominal

Tritex II System



Alternative Systems



Linear Applications

Tritex II linear actuators employ a superior inverted roller screw mechanism for converting rotary motion to highly robust and long-life linear motion. These characteristics enable the Tritex actuator to solve applications that previously required pneumatic or hydraulic cylinders. No additional mechanisms (such as acme or ball screws) are necessary to convert the actuator's rotary power into linear motion in order to move the load.

Ideal for mobile and remote applications using DC power sources, the Tritex II DC actuators have the power needed to perform. The simple to configure, yet robust interface software allows either the AC or DC Tritex II actuators to perform nearly any motion control application. The Tritex II linear actuator can be programmed to follow an analog command signal, making it ideal for controlling valves and dampers in process control applications or adjustment mechanisms on mobile equipment.

Longer Stroke Lengths

If your application requires a stroke length greater than the 18 inches available with Tritex II linear units, consider mounting a rotary Tritex II actuator to an Exlar universal actuator. This combination extends stroke length up to 40 inches. Please contact Exlar for more details.

Rotary Applications

Tritex II rotary motors and gearmotors provide high response and precise control of a rotatable shaft, similar to that found in any electric motor. The difference is that with Tritex II you can program (via your PC) the rotational speed and position of the output shaft in response to external commands. For example, the motor can be commanded to rotate at a controlled velocity and to precisely stop at a preprogrammed position. You can also program the unit to run at a preset velocity until a switch input is received or a preprogrammed torque level is produced against a load. Alternatively, the rotary Tritex II actuators can be set up to follow an analog signal—either voltage or current—representing your choice of torque, velocity, or position.

Signals for initiating the preprogram-med velocity and position commands come from optically isolated inputs or directly via network communications. Likewise, isolated output commands of the status and events enable precise coordination with your system controls or machine operator.

Optional Internal Gear Reducer

If your application requires greater torque and less speed than the base unit provides, the Tritex II is available with an integral servo grade planetary gear reducer. Gear ratios of 4:1 to 100:1 allow the power of Tritex II to be applied over a broad range of torque requirements.

Tritex II Models

Tritex II AC Models

- T2M standard mechanical capacity actuator, 75, 90, and 115 mm
- T2X high mechanical capacity actuator, 75, 90, and 115 mm
- R2M rotary motor, 75, 90, and 115 mm
- R2G rotary gearmotor, 75, 90, and 115 mm

Tritex II DC Models

- TDM standard mechanical capacity actuator, 60, and 75 mm
- TDX high mechanical capacity actuator, 60 and 75 mm
- RDM rotary motor, 60, 75, and 90 mm
- RDG rotary gearmotor, 60, 75, and 90 mm

Feedback Types (All Models)

- Analog Hall w/1000 count resolution
- Incremental encoder with 8192 count resolution
- Absolute Feedback (analog hall with multi-turn, battery backup)

Communications & I/O

The I/O count and type varies with each actuator model and option selected. Please see page 69 for Tritex II AC and page 96 for Tritex II DC models.

Standard Communications (All Models):

- 1 RS485 port, Modbus RTU, opto-isolated for programming, controlling and monitoring

Tritex II rotary motor with connectors

Tritex II linear actuator with customer-supplied cable glands ports

Tritex II Series Operation

The Tritex II Series actuators can operate in one of five different motion-producing modes. These modes solve an endless variety of applications in industrial automation, medical equipment, fastening and joining, blow molding, injection molding, testing, food processing, and more.

Programmed functions are stored in the Tritex II non-volatile memory. A standard RS485 serial interface allows control, programming, and monitoring of all aspects of the motor or actuator as it performs your application. Optional communications protocols are available.

Tritex Option Boards

- Option boards offer adding functionality to the base Tritex II actuators
  - Terminal board for customer I/O
  - Isolated 4-20mA analog input and output
  - Customer specific
- Communication buses
  - EtherNet/IP
  - Modbus TCP
  - PROFINET IO
  - CANopen
  - Ethercat

Connectivity

- Internal terminals accessible through removable cover (select models)
- Threaded ports for cable glands (select models)
- Optional connectors
  - M23 Power - M23/M16 I/O
- M8 connector for RS485
- M12 connector for EtherNet options
- Custom connection options
- Embedded leads (select models)

Operating Modes

1. *Move to a position (or switch)*
   The Tritex II Series actuators allow you to execute up to 16 programmed positions or distances. You may also use a limit switch or other input device as the end condition of a move. This combination of index flexibility provides a simple solution for point-to-point indexing.
2. *Move to a preset force or torque*
   The Tritex II Series allows you to terminate your move upon the achievement of a programmed torque or force. This is an ideal mode for pressing and clamping applications.
3. *Position proportional to an analog signal*
   Ideal for process control solutions, the Tritex II Series provides the functionality to position a control valve by following an analog input signal. Therefore, it delivers precise valve control — which cannot be achieved by other electric, hydraulic, or pneumatic actuators.
4. *Velocity proportional to an analog signal*
   Tritex II actuators offer you the capability to control velocity with an analog signal. This is particularly useful with Tritex II rotary motors which offer precise control of the speed of any process or operation.
5. *Force/torque proportional to analog signal*
   Perfect for pressing and torquing applications, you can control torque with an analog input while in torque mode.

Selectable Input Functions

• Enable • Execute Move (0-15) • Dedicated Position • Jog+
• Jog- • Jog Fast • Home • Extend Switch • Retract Switch
• Home Switch • Teach Enable • Teach Move (1-16)
• Select Move • Stop • Hold • Reset Faults
• Alternate Mode (allows you to switch between 2 operating modes)

Selectable Output Functions

• Enabled • Homed • Ready (Enabled and Homed)
• Fault • Warning • Fault or Warning Active
• Move (0-15) in Progress • Homing • Jogging
• Jogging+ • Jogging- • Motion • In Position
• At Home Position • At Move (0-15) • Position
• Stopped • Holding • In Current Limit • In Current Fold Back
• Above Rated Current • Home

Expert User Interface

Expert, the Tritex II user interface software, provides you with a simple way to select all aspects of configuration and control required to set up and operate a Tritex II actuator. Easy-to-use tabbed pages provide access to input all of the parameters necessary to successfully configure your motion application. ‘Application’ files give you a convenient way to store and redistribute configurations amongst multiple computers, and ‘Drive’ files allow the same configuration to be distributed to multiple Tritex II actuators. Motion setup, homing, teach mode, tuning parameters, jogging, I/O configurations, and local control are all accomplished with ease using Expert software.

Protocol Options

The standard communication protocol for Tritex is an RS485 connection using Modbus RTU. The Modbus protocol provides a simple and robust method to connect industrial electronic devices on the same network. The Expert software acts as a Modbus Master and the Tritex II acts as the Slave device, only responding to requests commanded through the software. The Expert software allows full access to commissioning, configuring, monitoring, and controlling the Tritex II.

In addition the following protocol options are available by selecting the communication option boards. Exlar requires initial commissioning of a Tritex II actuator to be performed with the Modbus protocol.

Modbus TCP

Modbus TCP couples Modbus communication structure from Modbus RTU with EtherNet connectivity. The Modbus TCP option is fully supported by the Expert software and offers seamless commissioning, configuring, monitoring and controlling the Tritex II. A Modbus mapping table allows you to map all Communication protocol DSP301 is supported as well as DSP 402 supporting Profile Torque, Profile Velocity, Profile Position and Homing. Setup on the system is most easily achieved with the Expert software using the RS485 port. of the parameters you wish to read and modify into a register bank of up to 100 registers. This allows a PLC program to perform a single read operation and a single write operation to all the parameters.

EtherNet/IP

EtherNet/IP allows you to change, monitor, and control the Tritex II through implicit or explicit messaging initiated from your Rockwell PLC. Tritex parameters are set up through the Expert software using a Tritex II parameter to EtherNet/IP parameter mapping table. Up to 100 input, and 100 output 16 bit registers can be mapped to Tritex II parameters.

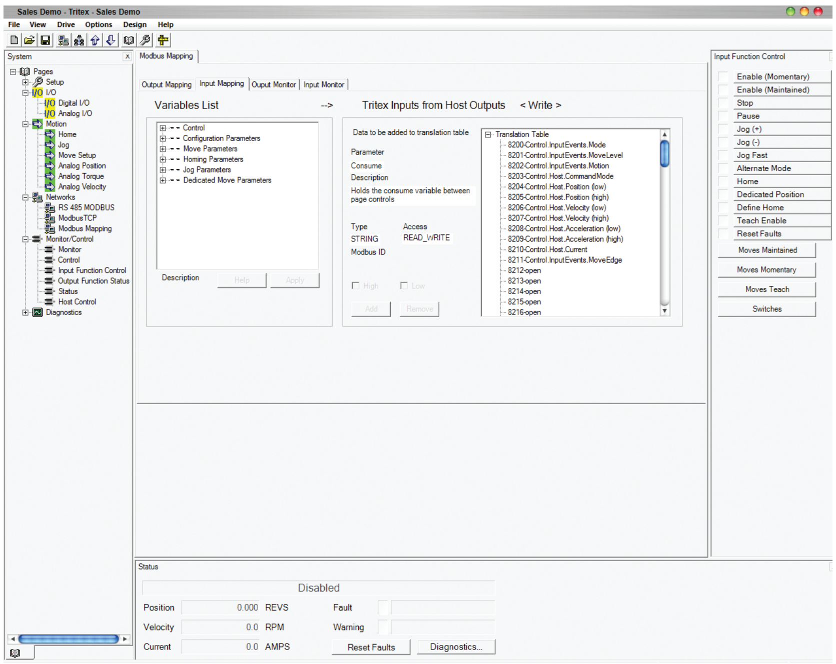
PROFINET IO

PROFINET IO allows you to change, monitor and control the Tritex II from your Siemens PLC. Tritex parameters are set up through the Expert software using a Tritex II parameter to PROFINET IO parameter mapping table. Up to 100 input and 100 output, 16 bit registers can be mapped to Tritex II parameters.

CANopen

The Tritex II with the CANopen network is intended to perform as a Slave, receiving commands from a CANopen Master. It does not have all the features of a stand-alone indexer, like other Tritex models. CANopen Communication protocol DSP 301 is supported as well as DSP 402 for Profile Torque, Profile Velocity, Profile Position, and Homing. Setup is most easily achieved with the Expert software using the RS485 port.

Modbus Mapping Screen



Motion Setup

Exlar configuration provides several templates for various applications. These can serve as your configuration, or as a starting point for your configuration. You can also begin by selecting configuration details specific to your application. At the click of a button, you can configure a move to position, move to switch, or move to force motion. Tritex II products offer absolute and incremental motion, as well as moves ending on a condition, such as a specific force or torque.

Control Page

The Expert control page gives you the ability to initiate all motion functions from one simple screen. This screen provides you with very easy system start-up and testing, without all the inconvenience of machine wiring.

The control page offers the capability to enable and disable the drive, and perform fast and slow jogs. This gives you the ability to verify motion, before needing any I/O wiring.

Monitoring and Diagnostics

All input functions can be monitored and activated from the Expert monitor page, and all output functions can be monitored. Critical fault and status data is available as a separate page, or as a fixed window on the bottom of each page of the software.

Configuring I/O

A drop down menu allows all I/O to be set up in a matter of minutes. Inputs can be configured to be maintained or momentary, depending on the application requirements. Input and output logic can be inverted with a single click.

Scope

The Expert Software includes a four-channel digital oscilloscope feature.

You can select up to four Tritex drive parameters to be monitored simultaneously.

For high speed requirements, the data can be captured in the drive's memory at an adjustable rate, down to 100 micro seconds, and then uploaded for plotting. The plots can be saved or printed, and the captured data can be saved as a comma separated file for further analysis with Excel.

Homing

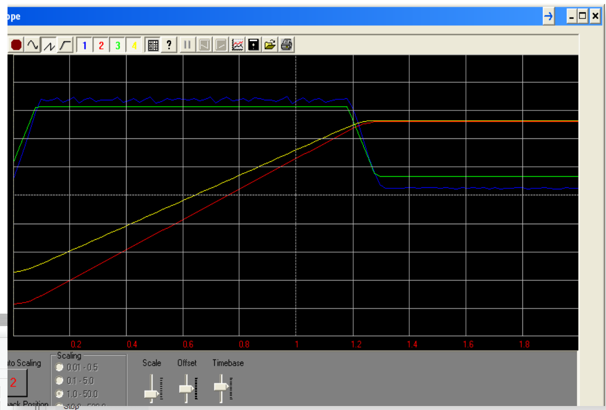
You can home to an input, by using a proximity or limit switch, or home to a specific force or torque.

Homing to a force or torque is ideal for setting up applications that require motion referenced to a hard stop, like the closed position of a valve, or the final position of a press.

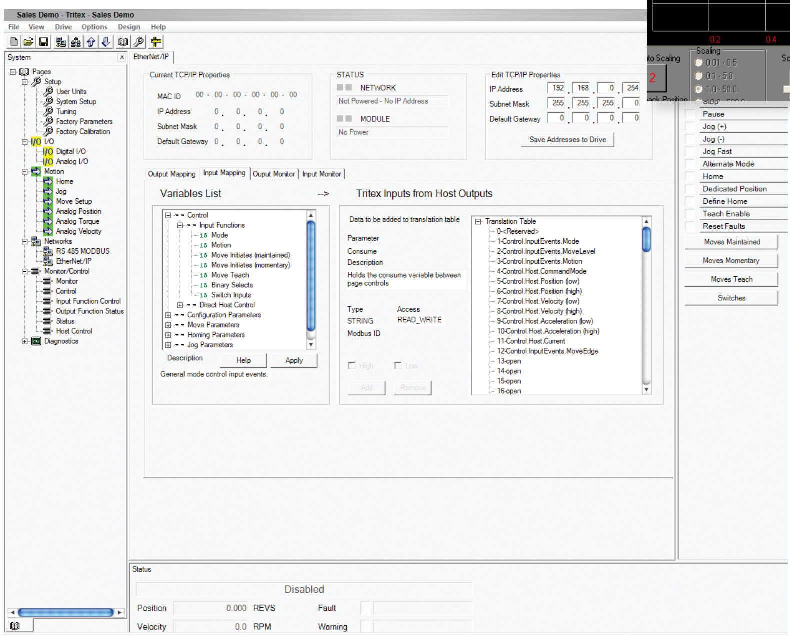
Teach Mode

In this mode, you can jog the actuator to the desired position, and activate an input. Alternatively, you can click a button in the Expert software and the current position of the actuator becomes the defined distance or absolute position associated with a particular move command.

Scope



EtherNet IP Mapping Screen



Process Control Functionality

Precise valve and damper control are perfect applications for Tritex II actuators. They outperform other electric, hydraulic and pneumatic actuators by providing small hysteresis and dead band, quick response to small signal changes, and stable dynamic responses. Fully programmable to follow an analog or digital signal representing either position or force, the Tritex II linear actuator is well suited for control valve applications with thrust requirements up to 3225 lbf or rotary torque applications up to 95 lbf-in continuous.

The Tritex II Rotary actuators are also ideal for directly operating quarter-turn valves. Gear ratios of 4:1 to 100:1 allow the power of Tritex II to be applied to a broad range of applications, providing high turndown without loss of accuracy.

Additionally, Tritex II actuators can be mounted on any valve from any manufacturer giving you maximum flexibility.

Valve Software

The valve software is simple to use and features a teach mode for foolproof stroke configuration. A programmable valve cut off position enables a firm valve seat on either new valves or retrofitted valves. Several diagnostics and auxiliary I/O options are also available.

Class I Division 2 Rating

Exlar Tritex II actuators are available for applications requiring CSA Class I Division 2 certification. Ordering a standard I/O interconnect with or without 4-20 mA Analog I/O, and the N option for the NPT port will provide you with a Class I Division 2 rated product.

Benefits for Process Control Applications

Extreme Accuracy

The Exlar actuators stroke the valve based on position, not air or oil pressure. Accuracy and repeatability are better than 0 .1%.

100% Duty Cycle

A roller screw provides a unique way of converting rotary motor motion to a linear force, and offers full modulation capability. Life is measured in hundreds of million strokes vs. thousands like typical electric actuators.

Built in Positioner

Tritex II actuators include a built in positioner with a 4-20 mA or digital signal to tell you the exact stroke position. An analog output is also available.

Flexibility

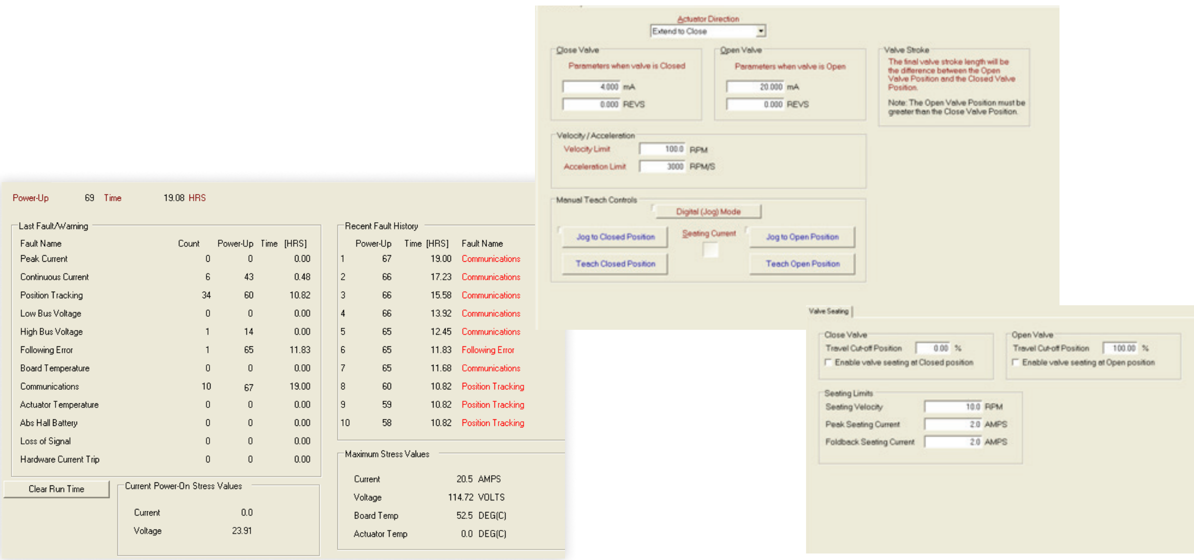
These actuators include digital I/O and analog control. This provides the user with options for additional control such as emergency stop, +/- jog, or various diagnostic conditions.

Low Power Consumption

The Tritex II actuator only uses the current needed for a given force. This extreme efficiency makes it suitable for use with solar panels and batteries.

Fast Response and Stroke Speeds

Most other electric actuators are known for being slow—a major disadvantage. Tritex II response rate is measured in milliseconds. Stoke speeds can be up to 33 in/sec.

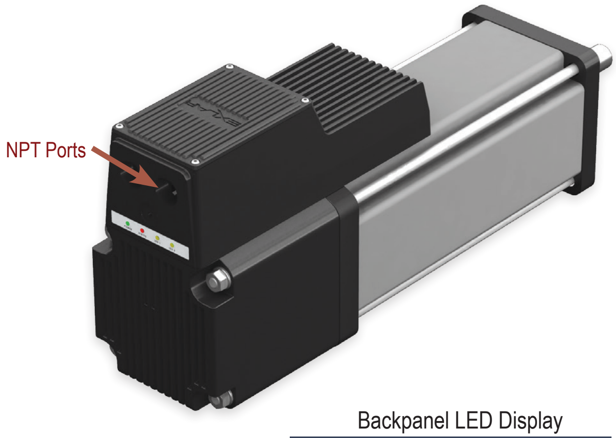


Hydraulic Replacement
Tritex actuators have the same capabilities as a hydraulic equivalent, but without the cost or maintenance issues. High force, fast speeds and precise movements make it a superior substitute for hydraulic applications.

Absolute Feedback
The absolute feedback option gives the actuator memory after teaching the valve limits. So upon power loss, the battery backup will maintain the valve limits.

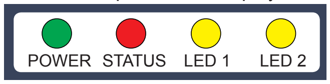
Manual Override
Two options are available. The hand wheel option gives you a manual engagement switch that can be used to disable the power to the actuator. The side drive option allows emergency operation in a power down condition, using a standard socket wrench.

Diagnostics
All inputs and outputs can be monitored including position, temperature, current, and many more. An oscilloscope feature allows you to select up to four parameters to be monitored simultaneously. The data can be captured in the drive's memory at an adjustable rate, down to 100 micro sec, and then uploaded for plotting.



Tritex II AC linear actuator with threaded ports.

Backpanel LED Display



Tritex II Agency Approval
If your application requires CSA Class I, Division 2 Certification, please order the "N" connection option for the NPT port. This, in combination with one of the following I/O option boards, will provide Class I, Division 2 Certification:

• SIO • EIN • TCN • IA4 • PIN • CON

Shown below are additional agency approvals applied to Tritex II Actuators.

Tritex II DC Standards/Agency Approvals

Agency/Standard	Tritex II Models/Options
CE, EMC EN61800-3	All models
CSA 139	All models, when supply voltage is 24 VDC or less
CSA Class I, Div 2, Groups A, B, C, D	75 and 90 mm frames require NPT connection option (N/A with 60 mm frame)
IP Rating	TDM = IP54S, TDX = IP66S, RDM/G = IP66
Vibration Rating	IEC 60068-2-64 random vibration standard, 5g rms, 50 to 500 Hz.
ODVA	EIP
PROFINET	PIO

Tritex II AC Standards/Agency Approvals

Agency/Standard	Tritex II Models/Options
CE, EMC EN61800-3, Safety EN 61800-5-1	All options
CSA 139	All options
CSA Class I, Div 2, Groups A, B, C, D	Requires NPT connection option. Option Board EIN, PIN, TCN and CON, SIO, or IA4
UL 508 C, Type 4 Enclosure T2M090/R2M090 T2M115/R2M115	Requires NPT connection option. Option Board EIN, PIN, TCN and CON, SIO, or IA4
IP Rating	T2M/TDM = IP54S, T2X/TDX = IP65S, T2M/X075, TDM/X075 = IP66S R2M/R2G/RDM/RDG = IP65S, R2M/G075, RDM/G075 = IP66S
Vibration Rating	IEC 61800-5-1 safely standard for drives. 1g peak, up to 150 Hz for <2 hrs. IEC 60068-2-64 random vibration standard, 2.5 g rms, 5 to 500 Hz.
ODVA	EIP

Up-to-date certifications for all products shown on www.exlar.com.

Tritex II AC

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No Compromising on Power, Performance or Reliability

With forces to approximately 3,225 lbf (14 kN) continuous and 5,400 lbf peak (24 kN), and speeds to 33 in/sec (800 mm/sec), the AC Tritex II linear actuators also offer a benefit that no other integrated product offers: POWER! No longer are you limited to trivial amounts of force, or speeds so slow that many motion applications are not possible. And the Tritex II with AC power electronics operates with maximum reliability over a broad range of ambient temperatures: -40˚C to +65˚C. The AC powered Tritex II actuators contain a 1.5 kW servo amplifier and a very capable motion controller. With standard features such as analog following for position, compound moves, move chaining, and individual force/ torque control for each move, the Tritex II Series is the ideal solution for most motion applications.

Tritex II Models

- T2M standard mechanical capacity actuator, 75, 90, and 115 mm
- T2X high mechanical capacity actuator
- R2M rotary motor
- R2G rotary gearmotor

Power Requirements

- AC Power 100V - 240V, +/- 10%, single phase
- Built-in AC line filter
- Connections for external braking resistor

Feedback Types

- Analog Hall with 1000 count/motor rev resolution
- Incremental encoder with 8192 count resolution
- Absolute Feedback (analog hall with multi-turn, battery backup)

Connectivity

- Inernal terminals acessible through removable cover
- Threaded ports for cable glands
- Optional connectors:
  –M23 Power
  –M16 I/O (M23 on 75 mm)
- M8 connector for RS485
- M12 connector for Ethernet options
- Custom connection options

Technical Characteristics	
Frame Sizes in (mm)	2.9 (75), 3.5 (90), 4.5(115)
Screw Leads	0.1 (2), 0.2 (5), 0.5 (13), 0.75 (19)
Standard Stroke Lengths in (mm)	3 (75), 4 (100), 6 (150), 10 (250), 12 (300), 14 (350), 18 (450)
Force Range	up to 3225 lbf (14 kN)
Maximum Speed	up to 33.3 in/s (846 mm/s)

Operating Conditions and Usage		
Accuracy:		
Screw Lead Error	in/ft (µm / 300 mm)	0.001 (25)
Screw Travel Variation	in/ft (µm / 300 mm)	0.0012 (30)
Screw Lead Backlash	in	0.004 (T2X), 0.008 (T2M) maximum
Ambient Conditions:		
Standard Ambient Temperature	°C	0 to 65
Extended Ambient Temperature**	°C	-40 to 65
Storage Temperature	°C	-40 to 85
IP Rating		T2M = IP54S, T2X = IP65S T2M/X075 = IP66S, R2M/R2G = IP65S R2M/G075 = IP66S
NEMA ratings	T2M090/R2M090 T2M115/R2M115	UL Type 4 UL Type 4
Vibration		2.5 g rms, 5 to 500 hz

*Ratings for T2M075/R2M075 at 40°C, operation over 40°C requires de-rating. Ratings for T2M090/R2M090 and T2M115/ R2M115 at 25°C, operation over 25°C requires de-rating.
**Consult Exlar for extended temperature operation.

Communications & I/O

Digital Inputs:
10 to 30 VDC Opto-isolated

Digital outputs:
30 VDC maximum
100 mA continuous output Isolated

Analog Input AC:
0-10V or +/-10V
0-10V mode, 12 bit resolution
+/-10V mode, 12 bit resolution on 90/115, 13 bit resolution on 75 assignable to Position, Velocity,
Torque, or Velocity Override commands.

Analog Output AC:
0-10V
12 bit resolution on 90/115, 11 bit resolution on 75

IA 4 option:
4-20 mA input
16 bit resolution Isolated
Assignable to Position, Velocity, or Torque command

4-20 mA output
12 bit resolution
Assignable to Position, Velocity, Current, Temperature, etc

Standard Communications:
- 1 RS485 port, Modbus RTU, opto-isolated for programming, controlling and monitoring

The IO count and type vary with the actuator model and option module selected.

All models include isolated digital IO, and an isolated RS485 communication port when using Modbus RTU protocol.

Tritex II AC I/O

	75/90/115 mm frame with SIO, EIP, PIO, TCP	90/115 mm frame with IA4	75 mm frame with IA4	90/115 mm frame with CAN	75 mm frame with CAN
Isolated digital inputs	8	8	4	8	4
Isolated digital outputs	4	4	3	4	3
Analog input, non isolated	1	1	0	0	0
Analog output, non isolated	1	1	0	0	0
Isolated 4-20ma input	0	1	1	0	0
Isolated 4-20ma output	0	1	1	0	0

Mechanical Specifications

R2M/G075

Rotary Motor Torque and Speed Ratings

	Stator	1 Stack	2 Stack	3 Stack
	RPM at 240 VAC	4000	3000	2000
Continuous Torque	lbf-in (Nm)	13 (1.47)	21 (2.37)	28 (3.16)
Peak Torque	lbf-in (Nm)	25 (2.8)	42 (4.75)	56 (6.33)
Drive Current @ Continuous Torque	Amps	3.1	3.8	3.8
Operating Temperature Range*	-20 to 65˚ C (-40˚C available, consult Exlar)			
Continuous AC Input Current**	Amps	4.3	4	3.6

*Ratings based on 40˚C ambient conditions.
**Continuous input current rating is defined by UL and CSA.
For output torque of R2G gearmotors, multiply by ratio and efficiency. Please note maximum allowable output torques shown below.

Inertia

	Stator	1 Stack	2 Stack	3 Stack
R2M Motor Armature Inertia (+/-5%)	lb-in-sec^2 (kg-cm^2)	0.000545 (0.6158)	0.000973 (1.0996)	0.001401 (1.5834)
R2G Gearmotor Armature Inertia* (+/-5%)	lbf-in-sec^2 (kg-cm^2)	0.000660 (0.7450)	0.001068 (1.2057)	0.001494 (1.6868)

*Add armature inertia to gearing inertia for total R2G system inertia.

Radial Load and Bearing Life

RPM	50	100	250	500	1000	3000
R2M075 lbf (N)	278 (1237)	220 (979)	162 (721)	129 (574)	102 (454)	71 (316)
R2G075 lbf (N)	343 (1526)	272 (1210)	200 (890)	159 (707)	126 (560)	88 (391)

Side load ratings shown above are for 10,000 hour bearing life at 25 mm from motor face at given rpm.

Gearmotor Mechanical Ratings

Model	Ratio	Maximum Allowable Output Torque-Set by User lbf-in (Nm)	Output Torque at Motor Speed for 10,000 Hour Life: 1000 RPM lbf-in (Nm)	2500 RPM lbf-in (Nm)	4000 RPM lbf-in (Nm)
R2G075-004	4:1	1618 (182.8)	384 (43.4)	292 (32.9)	254 (28.7)
R2G075-005	5:1	1446 (163.4)	395 (44.6)	300 (33.9)	260 (29.4)
R2G075-010	10:1	700 (79.1)	449 (50.7)	341 (38.5)	296 (33.9)

Two torque ratings for the R2G gearmotors are given in the table above. The left hand columns give the maximum (peak) allowable output torque for the indicated ratios of each size R2G gearmotor. This is not the rated output torque of the motor multiplied by the ratio of the reducer.

It is possible to select a configuration of the motor selection and gear ratio such that the rated motor torque, multiplied by the gear ratio exceeds these ratings. It is the responsibility of the user to ensure that the settings of the system do not allow these values to be exceeded.

The right hand columns give the output torque at the indicated speed which will result in 10,000 hour life (L10). The setup of the system will determine the actual output torque and speed.

Gearing Reflected Inertia

	Single Reduction	
Gear Stages	lbf-in-sec^2	(kg-cm^2)
4:1	0.000095	(0.107)
5:1	0.000062	(0.069)
10:1	0.000017	(0.019)

Backlash and Efficiency

	Single Reduction	Double Reduction
Backlash at 1% Rated Torque	10 Arc min	13 Arc min
Efficiency	91%	86%

Motor and Gearmotor Weights

		R2M075 without Gears	R2G075 with 1 Stage Gearing	Added Weight for Brake
1 Stack Stator	lb (kg)	7.4 (3.4)	9.8 (4.4)	1.0 (0.5)
2 Stack Stator	lb (kg)	9.2 (4.2)	11.6 (5.3)	
3 Stack Stator	lb (kg)	11 (4.9)	13.4 (6.1)	

R2M/G090

Rotary Motor Torque and Speed Ratings

	Stator	2 Stack	2 Stack	3 Stack
	RPM at 240 VAC	4000	3000	2000
Continuous Torque	lbf-in (Nm)	30 (3.4)	40 (4.5)	52 (5.9)
Peak Torque	lbf-in (Nm)	60 (6.8)	80 (9.0)	105 (11.9)
Drive Current @ Continuous Torque	Amps	7.5	7.5	6.6
Operating Temperature Range*	-20 to 65˚ C (-40˚C available, consult Exlar)			
Continuous AC Input Current**	Amps	6.3	6.3	6.3

*Ratings based on 25˚C ambient conditions.
**Continuous input current rating is defined by UL and CSA.

For output torque of R2G gearmotors, multiply by ratio and efficiency. Please note maximum allowable output torques shown below.

Inertia

	Stator	2 Stack	3 Stack
R2M Motor Armature Inertia (+/-5%)	lb-in-sec^2 (kg-cm^2)	0.00097 (1.09)	0.00140 (1.58)
R2G Gearmotor Armature Inertia* (+/-5%)	lbf-in-sec^2 (kg-cm^2)	0.00157 (1.77)	0.00200 (2.26)

*Add armature inertia to gearing inertia for total inertia.

Radial Load and Bearing Life

RPM	50	100	250	500	1000	3000
R2M090 lbf (N)	427 (1899)	340 (1512)	250 (1112)	198 (881)	158 (703)	109 (485)
R2G090 lbf (N)	350 (1557)	278 (1237)	205 (912)	163 (725)	129 (574)	89 (396)

Side load ratings shown above are for 10,000 hour bearing life at 25 mm from motor face at given rpm.

Gearmotor Mechanical Ratings

		Maximum Allowable Output Torque-Set by User lbf-in (Nm)	Output Torque at Motor Speed for 10,000 Hour Life		
Model	Ratio		1000 RPM lbf-in (Nm)	2500 RPM lbf-in (Nm)	4000 RPM lbf-in (Nm)
R2G090-004	4:1	2078 (234.8)	698 (78.9)	530 (59.9)	460 (51.9)
R2G090-005	5:1	1798 (203.1)	896 (101.2)	680 (76.8)	591 (66.8)
R2G090-010	10:1	1126 (127.2)	1043 (117.8)	792 (89.4)	688 (77.7)
R2G090-016	16:1	2078 (234.8)	1057 (119.4)	803 (90.7)	698 (78.9)
R2G090-020	20:1	2078 (234.8)	1131 (127.8)	859 (97.1)	746 (84.3)
R2G090-025	25:1	1798 (203.1)	1452 (164.1)	1103 (124.6)	958 (108.2)
R2G090-040	40:1	2078 (234.8)	1392 (157.3)	1057 (119.4)	918 (103.7)
R2G090-050	50:1	1798 (203.1)	1787 (201.9)	1358 (153.4)	1179 (133.2)
R2G090-100	100:1	1126 (127.2)	1100 (124.3)	1100 (124.3)	1100 (124.3)

Two torque ratings for the R2G gearmotors are given in the table above. The left hand columns give the maximum (peak) allowable output torque for the indicated ratios of each size R2G gearmotor. This is not the rated output torque of the motor multiplied by the ratio of the reducer.
It is possible to select a configuration of the motor selection and gear ratio such that the rated motor torque, multiplied by the gear ratio exceeds these ratings. It is the responsibility of the user to ensure that the settings of the system do not allow these values to be exceeded.
The right hand columns give the output torque at the indicated speed which will result in 10,000 hour life (L10). The setup of the system will determine the actual output torque and speed.

Gearing Reflected Inertia

Single Reduction			Double Reduction		
Gear Stages	lbf-in-sec^2	(kg-cm^2)	Gear Stages	lbf-in-sec^2	(kg-cm^2)
4:1	0.000154	(0.174)	16:1	0.000115	(0.130)
5:1	0.000100	(0.113)	20:1, 25:1	0.0000756	(0.0854)
10:1	0.0000265	(0.0300)	40:1, 50:1, 100:1	0.0000203	(0.0230)

Backlash and Efficiency

	Single Reduction	Double Reduction
Backlash at 1% Rated Torque	10 Arc min	13 Arc min
Efficiency	91%	86%

Motor and Gearmotor Weights

		R2M090 without Gears	R2G090 with 1 Stage Gearing	R2G090 with 2 Stage Gearing	Added Weight for Brake
2 Stack Stator	lb (kg)	14 (6.4)	22 (10)	25 (11.3)	1.5 (0.7)
3 Stack Stator	lb (kg)	17 (7.7)	25 (11.3)	28 (12.7)	

R2M/G115

Rotary Motor Torque and Speed Ratings

	Stator	1 Stack	2 Stack	2 Stack
	RPM at 240 VAC	3000	2000	1500
Continuous Torque	lbf-in (Nm)	47 (5.3)	73 (8.3)	95 (10.7)
Peak Torque	lbf-in (Nm)	94 (10.6)	146 (16.5)	190 (21.5)
Drive Current @ Continuous Torque	Amps	8.5	8.5	8.5
Operating Temperature Range*	-20 to 65˚ C (-40˚C available, consult Exlar)			
Continuous AC Input Current**	Amps	8.3	8.3	8.3

*Ratings based on 25˚C ambient conditions.
**Continuous input current rating is defined by UL and CSA.

For output torque of R2G gearmotors, multiply by ratio and efficiency. Please note maximum allowable output torques shown below.

Inertia

	Stator	1 Stack	2 Stack
R2M Motor Armature Inertia (+/-5%)	lb-in-sec² (kg-cm²)	0.00344 (3.89)	0.00623 (7.036)
R2G Gearmotor Armature Inertia*	lbf-in-sec² (kg-cm²)	0.00538 (6.08)	0.00816 (9.22)

*Add armature inertia to gearing inertia for total R2M system inertia.

Radial Load and Bearing Life

RPM	50	100	250	500	1000	3000
R2M115 lbf (N)	579 (2576)	460 (2046)	339 (1508)	269 (1197)	214 (952)	148 (658)
R2G115 lbf (N)	858 (3817)	681 (3029)	502 (2233)	398 (1770)	316 (1406)	218 (970)

Side load ratings shown above are for 10,000 hour bearing life at 25 mm from motor face at given rpm.

Gearmotor Mechanical Ratings

Model	Ratio	Maximum Allowable Output Torque-Set by User lbf-in (Nm)	Output Torque at Motor Speed for 10,000 Hour Life		
			1000 RPM lbf-in (Nm)	2000 RPM lbf-in (Nm)	3000 RPM lbf-in (Nm)
R2G115-004	4:1	4696 (530.4)	1392 (157.3)	1132 (127.9)	1000 (112.9)
R2G115-005	5:1	4066 (459.4)	1455 (163.3)	1175 (132.8)	1040 (117.5)
R2G115-010	10:1	2545 (287.5)	1660 (187.6)	1350 (152.6)	1200 (135.6)
R2G115-016	16:1	4696 (530.4)	2112 (238.6)	1714 (193.0)	1518 (171.0)
R2G115-020	20:1	4696 (530.4)	2240 (253.1)	1840 (207.9)	1620 (183.0)
R2G115-025	25:1	4066 (459.4)	2350 (265.5)	1900 (214.7)	1675 (189.2)
R2G115-040	40:1	4696 (530.4)	2800 (316.4)	2240 (253.1)	2000 (225.9)
R2G115-050	50:1	4066 (459.4)	2900 (327.7)	2350 (265.5)	2100 (237.3)
R2G115-100	100:1	2545 (287.5)	2500 (282.5)	2500 (282.5)	2400 (271.2)

Two torque ratings for the R2G gearmotors are given in the table above. The left hand columns give the maximum (peak) allowable output torque for the indicated ratios of each size R2G gearmotor. This is not the rated output torque of the motor multiplied by the ratio of the reducer.
It is possible to select a configuration of the motor selection and gear ratio such that the rated motor torque, multiplied by the gear ratio exceeds these ratings.
It is the responsibility of the user to ensure that the settings of the system do not allow these values to be exceeded.
The right hand columns give the output torque at the indicated speed which will result in 10,000 hour life (L10). The setup of the system will determine the actual output torque and speed.

Gearing Reflected Inertia

Single Reduction			Double Reduction		
Gear Stages	lbf-in-sec²	(kg-cm²)	Gear Stages	lbf-in-sec²	(kg-cm²)
4:1	0.000635	(0.717)	16:1	0.000513	(0.580)
5:1	0.000428	(0.484)	20:1, 25:1	0.000350	(0.396)
10:1	0.000111	(0.125)	40:1, 50:1, 100:1	0.0000911	(0.103)

Backlash and Efficiency

	Single Reduction	Double Reduction
Backlash at 1% Rated Torque	10 Arc min	13 Arc min
Efficiency	91%	86%

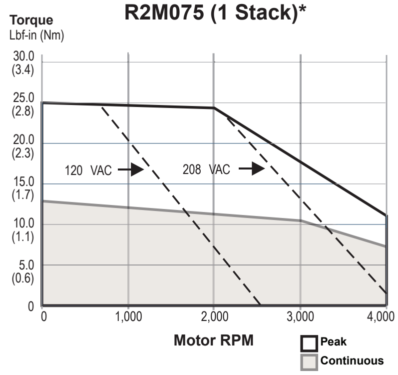
Motor and RTG115 Gearmotor Weights

		R2M115 without Gears	R2G115 with 1 Stage Gearing	R2G115 with 2 Stage Gearing	Added Weight for Brake
1 Stack Stator	lb (kg)	19 (8.6)	34 (15.4)	40 (18.1)	2.7 (1.2)
2 Stack Stator	lb (kg)	27 (12.2)	42 (19.1)	48 (21.8)	
3 Stack Stator	lb (kg)	35 (15.9)	50 (22.7)	56 (25.4)	

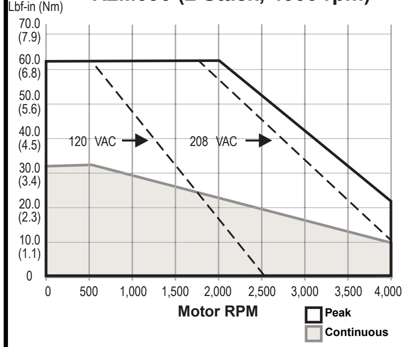
Speed vs. Force Curves

R2M075	R2M090	R2M115

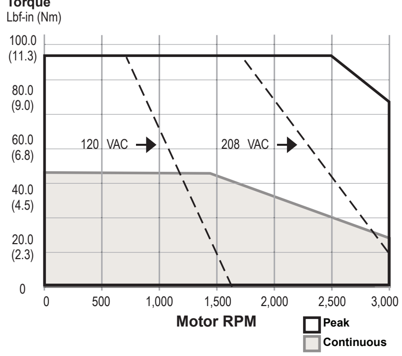
R2M075 (1 Stack)*



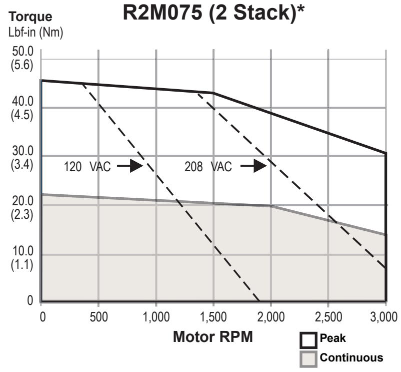
R2M090 (2 Stack, 4000 rpm)**



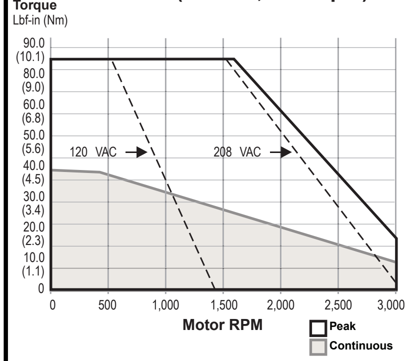
R2M115 (1 Stack)***



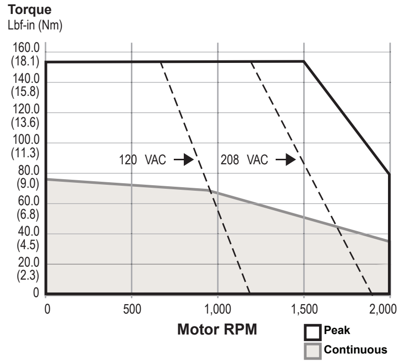
R2M075 (2 Stack)*



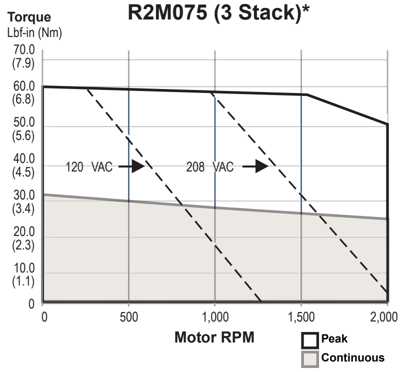
R2M090 (2 Stack, 3000 rpm)**



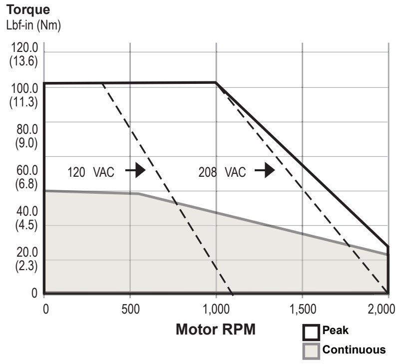
R2M115 (2 Stack, 2000 rpm)***



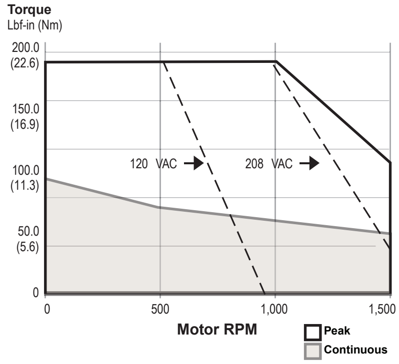
R2M075 (3 Stack)*



R2M090 (3 Stack)**



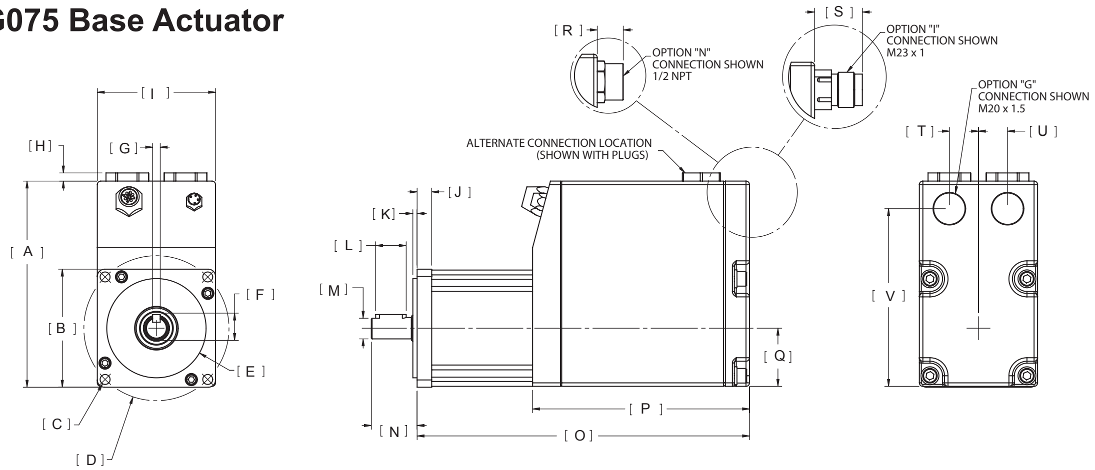
R2M115 (2 Stack, 1500 rpm)***



For R2G gearmotors, multiply torque by gear ratio and efficiency. Efficiencies: Divide speed by gear ratio; 1 Stage = 0.91, 2 Stage = 0.86
*R2M075 test data derived using NEMA recommended aluminum heatsink 10” x 10” x 3/8” at 40°C ambient.
**R2M090 test data derived using NEMA recommended aluminum heatsink 10” x 10” x 3/8” at 25°C ambient.
***R2M115 test data derived using NEMA recommended aluminum heatsink 12” x 12” x 1/2” at 25°C ambient.

Dimensions

R2M/G075 Base Actuator



		R2M075	R2G075			R2M075	R2G075
A	in	5.32	5.32	L	in	0.79	0.79
	mm	135.1	135.1		mm	20.0	20.0
B	in	□ 3.05	□ 3.05	M	in	Ø 0.5512 / 0.5508	Ø 0.6302 / 0.6298
	mm	77.4	77.4		mm	14 h6	16 j6
C	in	4X Ø 0.26 ON BC	4X Ø 0.26 ON BC	N	in	1.18	1.18
	mm	6.5	6.5		mm	30.0	30.0
D	in	Ø 3.74 BC	Ø 3.74 BC	O	in	See Below	See Below
	mm	95.0	95.0		mm	See Below	See Below
E	in	Ø 2.5587 / 2.5580	Ø 2.5587 / 2.5580	P	in	5.59	5.59
	mm	65 g6	65 g6		mm	142.0	142.0
F	in	0.70	0.70	Q	in	1.50	1.50
	mm	17.9	17.9		mm	38.1	38.1
G	in	Ø 0.1969 / 0.1957	Ø 0.1969 / 0.1957	R	in	0.67	0.67
	mm	5 h9	5 h9		mm	17.0	17.0
H	in	0.21	0.21	S	in	1.23	1.23
	mm	5.3	5.3		mm	31.3	31.3
I	in	3.05	3.05	T	in	0.75	0.75
	mm	77.4	77.4		mm	19.1	19.1
J	in	0.38	0.45	U	in	0.75	0.75
	mm	9.5	11.5		mm	19.1	19.1
K	in	0.11	0.11	V	in	4.58	4.58
	mm	2.8	2.8		mm	116.4	116.4

R2M075

With Brake Option			
DIM	1 Stack Stator	2 Stack Stator	3 Stack Stator
O	9.85 (250.2)	10.85 (275.6)	11.85 (301.0)

Without Brake Option			
DIM	1 Stack Stator	2 Stack Stator	3 Stack Stator
O	8.57 (217.7)	9.57 (243.1)	10.57 (268.5)

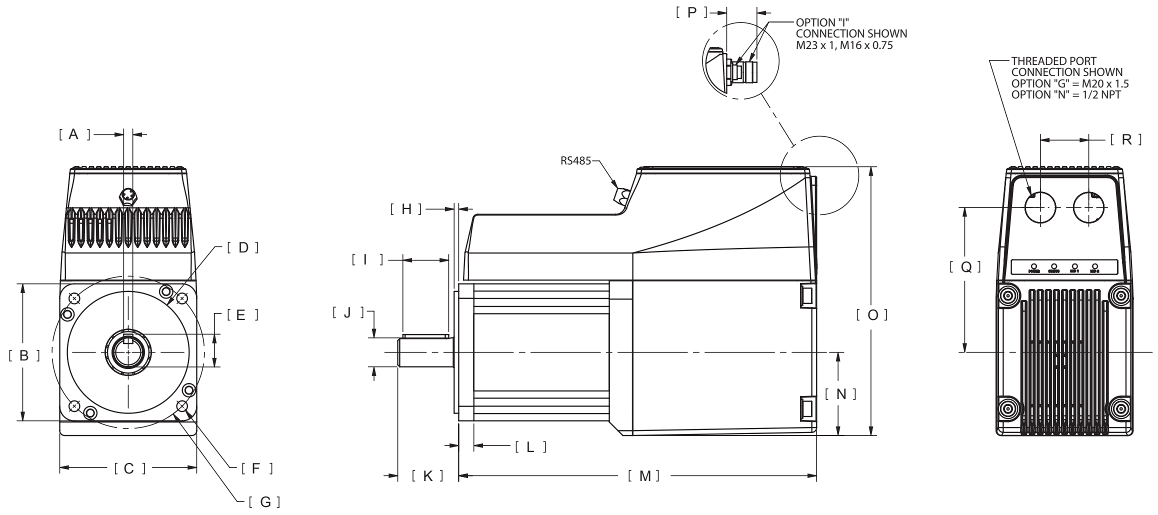
R2G075

Without Brake Option			
DIM	1 Stack Stator 1 Stage Gearhead	2 Stack Stator 1 Stage Gearhead	3 Stack Stator 1 Stage Gearhead
O	10.19 (258.8)	11.19 (284.2)	12.19 (309.6)

With Brake Option			
DIM	1 Stack Stator 1 Stage Gearhead	2 Stack Stator 1 Stage Gearhead	3 Stack Stator 1 Stage Gearhead
O	11.42 (290.1)	12.42 (315.5)	13.42 (340.9)

Pre-sale drawings and models are representative and are subject to change. Certified drawings and models are available for a fee. Consult your local Exlar representative for details.

R2M/G090 Base Actuator



		R2M090	R2G090			R2M090	R2G090
A	in	0.2360 / 0.2348	0.2362 / 0.2350	**J**	in	Ø 0.7480 / 0.7475	Ø 0.8665 / 0.8659
	mm	6 h9	6 h9		mm	19 h6	22 j6
B	in	3.54	3.54	**K**	in	1.57	1.89
	mm	90	90		mm	40	48
C	in	3.54	3.54	**L**	in	0.39	0.63
	mm	90	90		mm	10	16
D	in	Ø 3.1492 / 3.1485	Ø 3.1492 / 3.1485	**M**	in	See Below	See Below
	mm	80 g6	80 g6		mm	See Below	See Below
E	in	0.85	0.96	**N**	in	2.15	2.15
	mm	21.5	24.5		mm	55	55
F	in	4X Ø 0.28 ON BC	4X Ø 0.257 ON BC	**O**	in	6.95	6.95
	mm	7	6.5		mm	177	177
G	in	Ø 3.94 BC	Ø 3.94 BC	**P**	in	1.30	1.30
	mm	100	100		mm	33	33
H	in	0.12	0.118	**Q**	in	3.74	3.74
	mm	3	3		mm	95	95
I	in	1.38	1.417	**R**	in	1.25	1.25
	mm	35	36		mm	32	32

R2M090

Without Brake Option		
DIM	2 Stack Stator	3 Stack Stator
M	10.25 (256.3)	11.25 (285.8)

With Brake Option		
DIM	2 Stack Stator	3 Stack Stator
M	11.6 (294.6)	12.6 (320.0)

R2G090

Without Brake Option		
DIM	2 Stack Stator 1 Stage Gearhead	3 Stack Stator 1 Stage Gearhead
M	12.36 (313.9)	13.36 (339.3)
DIM	2 Stack Stator 2 Stage Gearhead	3 Stack Stator 2 Stage Gearhead
M	13.63 (346.2)	14.63 (371.6)

With Brake Option		
DIM	2 Stack Stator 1 Stage Gearhead	3 Stack Stator 1 Stage Gearhead
M	13.67 (347.2)	14.67 (372.6)
DIM	2 Stack Stator 2 Stage Gearhead	3 Stack Stator 2 Stage Gearhead
M	14.94 (379.5)	15.94 (404.9)

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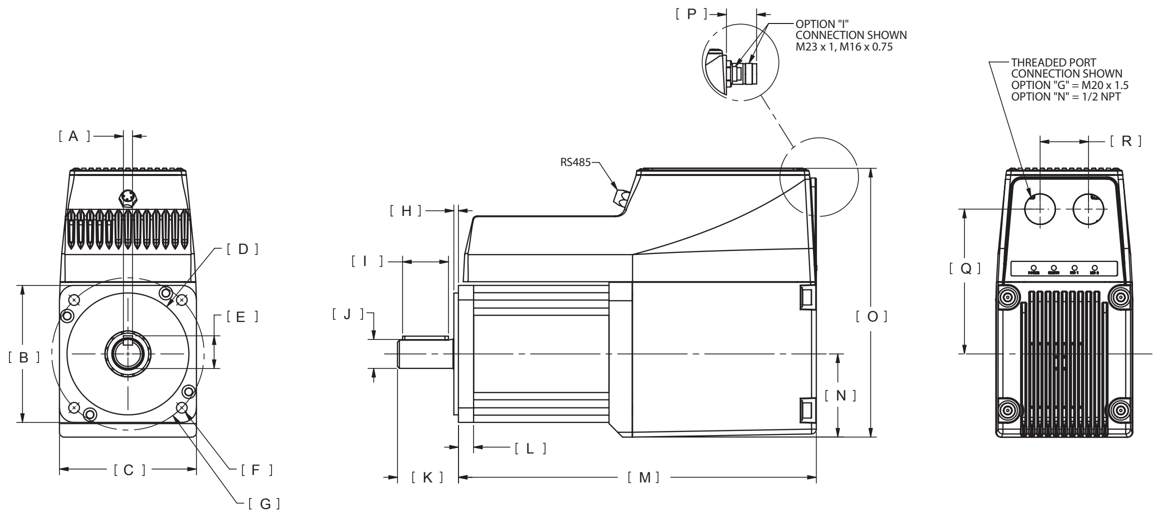
R2M/G115 Base Actuator



		R2M115	R2G115			R2M115	R2G115
A	in	0.3150 / 0.3135	0.3937 / 0.3923	J	in	Ø 0.9449 / 0.9444	Ø 1.2603 / 1.2596
	mm	8 h9	10 h9		mm	24 h6	32 j6
B	in	4.53	4.530	K	in	1.97	2.55
	mm	115	115		mm	50	65
C	in	4.53	4.530	L	in	0.45	0.64
	mm	115	115		mm	12	16
D	in	Ø 4.3302 / 4.3294	Ø 4.3302 / 4.3294	M	in	See Below	See Below
	mm	110 g6	110 g6		mm	See Below	See Below
E	in	1.06	1.380	N	in	2.27	2.27
	mm	27	35		mm	58	58
F	in	4 X Ø 0.34 ON BC	4 X Ø 0.34 ON BC	O	in	7.56	7.56
	mm	8.5	8.5		mm	192	192
G	in	Ø 5.12 BC	Ø 5.12 BC	P	in	1.30	1.30
	mm	130	130		mm	33	33
H	in	0.16	0.16	Q	in	4.23	4.23
	mm	4	4		mm	108	108
I	in	1.41	1.58	R	in	1.25	1.25
	mm	35.9	40		mm	32	32

R2M115

Without Brake Option		
DIM	1 Stack Stator	2 Stack Stator
M	9.87 (250.7)	11.87 (301.5)

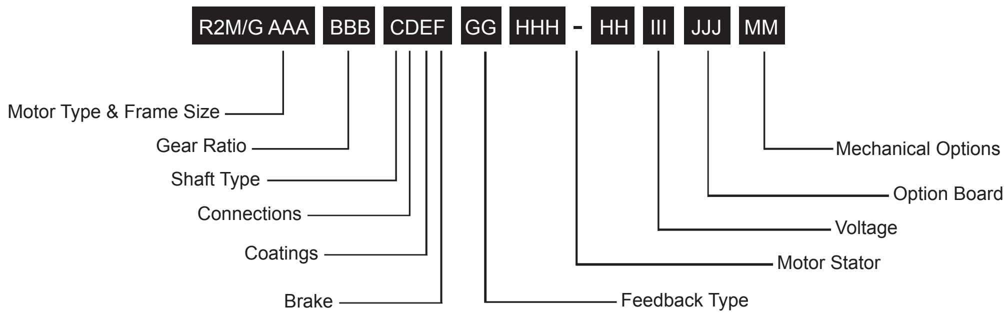
With Brake Option		
DIM	1 Stack Stator	2 Stack Stator
M	11.60 (294.6)	13.60 (345.4)

R2G115

Without Brake Option		
DIM	1 Stack Stator 1 Stage Gearhead	2 Stack Stator 1 Stage Gearhead
M	13.88 (352.6)	15.88 (403.4)
DIM	1 Stack Stator 2 Stage Gearhead	2 Stack Stator 2 Stage Gearhead
M	15.49 (393.4)	17.49 (444.2)

With Brake Option		
DIM	1 Stack Stator 1 Stage Gearhead	2 Stack Stator 1 Stage Gearhead
M	15.43 (391.9)	17.43 (442.7)
DIM	1 Stack Stator 2 Stage Gearhead	2 Stack Stator 2 Stage Gearhead
M	17.04 (432.8)	19.04 (483.6)

Pre-sale drawings and models are representative and are subject to change. Certified drawings and models are available for a fee. Consult your local Exlar representative for details.



Commonly Ordered Options Shown in BOLD

R2M/G = Motor Type
R2M = Tritex II AC Rotary Motor
R2G = Tritex II AC Rotary Gearmotor

AAA = Frame Size
075 = 75 mm
090 = 90 mm
115 = 115 mm

BBB = Gear Ratio
Blank = R2M
Single Reduction Ratios
004 = 4:1
005 = 5:1
010 = 10:1
Double Reduction Ratios (N/A on 75 mm)
016 = 16:1 020 = 20:1
025 = 25:1 040 = 40:1
050 = 50:1 100 = 100:1

C = Shaft Type
K = Keyed
R = Smooth/Round

D = Connections
G = Standard Straight Threaded Port with Internal Terminals, M20 x 1.5
N = NPT Threaded Port with Internal Terminals, 1/2" NPT
I = Intercontec style - Exlar Standard, M16/M23 Style Connector
J = Embedded leads with "I" plug 3' standard

E = Coating Options
G = Exlar Standard

F = Brake Option
S = No Brake, Standard
B = Electric Brake, 24 VDC

GG = Feedback Type
HD = Analog Hall Device
IE = Incremental Encoder, 8192 Count Resolution
AF = Absolute Feedback

HHH-HH = Motor Stators
R2M/G075 Stator Specifications
138-40 = 1 Stack, 230 VAC, 4000 rpm
238-30 = 2 Stack, 230 VAC, 3000 rpm
338-20 = 3 Stack, 230 VAC, 2000 rpm

R2M/G090 Stator Specifications
238-40 = 2 Stack, 230 VAC, 4000 rpm
238-30 = 2 Stack, 230 VAC, 3000 rpm
338-20 = 3 Stack, 230 VAC, 2000 rpm

R2M/G115 Stator Specifications
138-30 = 1 Stack, 230 VAC, 3000 rpm
238-20 = 2 Stack, 230 VAC, 2000 rpm
238-15 = 2 Stack, 230 VAC, 1500 rpm

III = Voltage
230 = 115-230 VAC, Single Phase

JJJ = Option Board
SIO = Standard I/O Interconnect
IA4 = 4-20 mA Analog I/O
COP = CANOpen w/M12 connector
CON = CANOpen, without M12 connector [1]
EIP = SIO plus Ethernet/IP w/M12 connector
EIN = SIO plus Ethernet/IP without M12 connector [1]
PIO = SIO plus Profinet IO w/M12 connector
PIN = SIO plus Profinet IO without M12 connector [1]
TCP = SIO plus Modbus TCP w/M12 connector
TCN = SIO plus Modbus TCP without M12 connector [1]

MM = Mechanical Options [2]
HW = Manual Drive, Handwheel with Interlock Switch

For options or specials not listed above or for extended temperature operation, please contact Exlar

NOTES:
1. Requires customer supplied Ethernet cable through I/O port for Class 1 Division 2 compliance only.
2. For extended temperature operation consult factory for model number.

Cable and Accessories

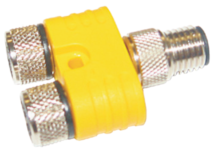
Tritex II AC Series Cable & Accessories	Part No.
Communications Accessories - Tritex uses a 4 pin M8 RS485 communications connector	
Recommended PC to Tritex communications cable-USB/RS485 to M8 connector - xxx = Length in feet, 006 or 015 only	CBL-T2USB485-M8-xxx
Multi-Drop RS485 Accessories	
RS485 splitter - M8 Pin plug to double M8 Socket receptacle	TT485SP
Multidrop Communications Cable M8 to M8 for use with TT485SP/RS485 splitter - xxx = Length in feet, 006 or 015 only	CBL-TTDAS-xxx
“G” Connection Accessories	
Nickel plated cable gland- M20 x 1.5 - CE shielding- 2 required	GLD-T2M20 x 1.5
Power cable prepared on one end for use with GLD-T2M20 x 1.5 xxx = Length in ft, Standard lengths 015, 025, 050, 075, 100	CBL-T2IPC-RAW-xxx
I/O cable prepared on one end for use with GLD-T2M20 x 1.5 xxx = Length in ft, Standard lengths 015, 025, 050, 075, 100	CBL-T2IOC-RAW-xxx
“N” Connection Accessories	
M20 x 1.5 to 1/2" NPT threaded hole adapter for use with conduit	ADAPT-M20-NPT1/2
“I” Connection	
Power cable with M23 6 pin xxx = Length in feet, std lengths 015, 025, 050, 075, 100	CBL-T2IPC-SMI-xxx
I/O cable (75 mm) with M23 19 pin xxx = Length in feet, std lengths 015, 025, 050, 075, 100	CBL-TTIOC-SMI-xxx
I/O cable (90 & 115 mm) with M16 19 pin xxx = Length in feet, std lengths 015, 025, 050, 075, 100	CBL-T2IOC-SMI-xxx
Multi-Purpose Communications Accessories for long runs, requires terminal block interconnections	
USB to RS485 convertor/cable - USB to RS485 flying leads - xxx = Length in feet, 006 or 015 only	CBL-T2USB485-xxx
Communications cable M8 to flying leads cable xxx = Length in feet, standard lengths 015, 025, 050, 075, 100	CBL-TTCOM-xxx
Option Board Cables and Accessories	
CAN Male to Female Molded 3 ft. cable	CBL-TTCAN-SMF-003
CAN Male to Female Molded 6 ft. cable	CBL-TTCAN-SMF-006
CAN Cable, no connectors – per foot	CBL-TTCAN-S
CAN Male connector, field wireable	CON-TTCAN-M
CAN Female connector, field wireable	CON-TTCAN-F
CAN Splitter	CON-TTCAN-SP
EIP, PIO and TCP option Ethernet cable - M12 to RJ45 cable xxx = Length in feet, std lengths 015, 025, 050, 075, 100.	CBL-T2ETH-R45-xxx
Electrical Accessories	
Dynamic Braking Resistor - 100W47Ohm	T2BR1
Replacement -AF Battery - used for absolute feedback option	T2BAT1
Replacement Normally Closed External Limit Switch (Turck Part number BIM-UNT-RP6X)	43404
Replacement Normally Open External Limit Switch (Turck Part number BIM-UNT-AP6X)	43403
Mechanical Accessories	
Clevis Pin for T2M/X090 male “M” rod end 1/2-20 thread	CP050
Clevis Pin for T2M/115 male “M” rod end 3/4-16 thread	CP075
Spherical Rod Eye for T2M/X090 male “M” rod end 1/2-20 thread	SRM050
Spherical Rod Eye for T2M/X115 male “M” rod end 3/4-16 thread	SRM075
Rod Eye for T2M/X090 male “M” rod end 1/2-20 thread	REI050
Rod Eye for T2M/X115 male “M” rod end 3/4-16 thread	RE075
Rod Clevis for T2M/X090 male “M” rod end 1/2-20 thread	RCI050
Rod Clevis for T2M/X115 male “M” rod end 3/4-16 thread	RC075
Jam Nut for T2M/X090 male rod end, 1/2 - 20	JAM1/2-20-SS
Jam Nut for T2M/X115 male rod end, 3/4-16	JAM3/4-16-SS

CBL-T2USB485-M8-xxx
Our recommended communications cable. No special drivers or setup required for use with MS Windows™.

CBL-T2USB485-xxx
Use for terminal connections with CBL-TTCOM for long cable runs. No special drivers or setup required for use with MS Windows™.

CBL-TTCOM-xxx
Use with CBL-T2USB485-xxx for long cable runs.

CBL-TTDAS-xxx
For use with TT485SP for multi-drop applications.



TT485SP
RS485 communications splitter. Use to daisy-chain multiple Tritex actuators.

CON-TTCAN-SP
CAN splitter

CON-TTCAN-M
M12 Field wireable connector

Sizing and Selection of Exlar Linear and Rotary Actuators

Move Profiles

The first step in analyzing a motion control application and selecting an actuator is to determine the required move profile. This move profile is based on the distance to be traveled and the amount of time available in which to make that move. The calculations below can help you determine your move profile.

Each motion device will have a maximum speed that it can achieve for each specific load capacity. This maximum speed will determine which type of motion profile can be used to complete the move. Two common types of move profiles are trapezoidal and triangular. If the average velocity of the profile, is less than half the maximum velocity of the actuator, then triangular profiles can be used. Triangular Profiles result in the lowest possible acceleration and deceleration. Otherwise a trapezoidal profile can be used. The trapezoidal profile below with 3 equal divisions will result in 25% lower maximum speed and 12.5% higher acceleration and deceleration. This is commonly called a 1/3 trapezoidal profile.

The following pages give the required formulas that allow you to select the proper Exlar linear or rotary actuator for your application. The first calculation explanation is for determining the required thrust in a linear application.

The second provides the necessary equations for determining the torque required from a linear or rotary application. For rotary applications this includes the use of reductions through belts or gears, and for linear applications, through screws.

Pages are included to allow you to enter your data and easily perform the required calculations. You can also describe your application graphically and fax it to Exlar for sizing. Reference tables for common unit conversions and motion system constants are included at the end of the section.

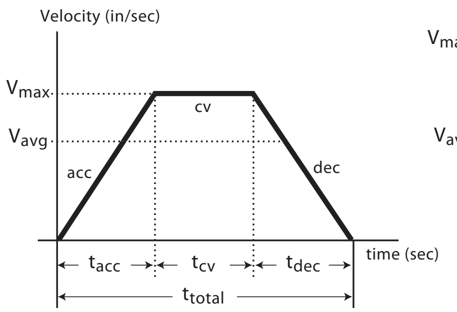
Linear Move Profile Calculations

Vmax = max.velocity-in/sec (m/sec)
Vavg = avg. velocity-in/sec (m/sec)
tacc = acceleration time (sec)
tdec = deceleration time (sec)
tcv = constant velocity (sec)
ttotal = total move time (sec)
acc = accel-in/sec^2 (m/sec^2)
dec = decel-in/sec^2 (m/sec^2)
cv = constant vel.-in/sec (m/sec)
D = total move distance-in (m) or revolutions (rotary)

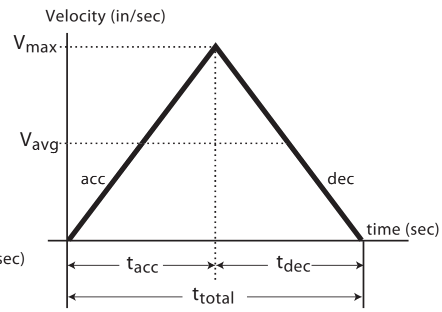
Standard Equations

Vavg = **D** / ttotal
If tacc = **t**dec **Then: V**max = (**t**total/(**t**total-tacc)(**V**avg)
and
D = Area under profile curve
D = (1⁄2(**t**acc+**t**dec)+**t**cv)(**V**max)

Trapezoidal Move Profile



Triangular Move Profile



Trapezoidal Equations

If tacc = **t**cv = **t**dec **Then:**
Vmax = 1.5 (**V**avg)
D = (2⁄3) (**t**total) (**V**max)
acc = dec = **V**max / **t**acc

Triangular Equations

If tacc = **t**total/2 **Then:**
Vmax = 2.0 (**V**avg)
D = (1⁄2) (**t**total) (**V**max)
acc = dec = **V**max / **t**acc

Terms and (units)

THRUST = Total linear force-lbf (N)
Ø = Angle of inclination (deg)
Ffriction = Force from friction-lbf (N)
tacc = Acceleration time (sec)
Facc = Acceleration force-lbf (N)
v = Change in velocity-in/sec (m/s)
Fgravity = Force due to gravity-lbf (N)
μ = Coefficient of sliding friction
Fapplied = Applied forces-lbf (N)
(refer to table on page 136 for different materials)
WL = Weight of Load-lbf (N)
g = 386.4: Acceleration of gravity - in/sec^2 (9.8 m/sec^2)

Thrust Calculation Equations

THRUST = **F**friction + [**F**acceleration] + **F**gravity + **F**applied

THRUST = **W**Lμcosø + [(**W**L /386.4) (**v**/tacc)] + **W**Lsinø + **F**applied

Sample Calculations: Calculate the thrust required to accelerate a 200 pound mass to 8 inches per second in an acceleration time of 0.2 seconds. Calculate this thrust at inclination angles(ø) of 0˚, 90˚ and 30˚. Assume that there is a 25 pound spring force that is applied against the acceleration.

WL = 200 lbm, v = 8.0 in/sec., **t**a = 0.2 sec., **F**app. = 25 lbf, μ = 0.15

ø = 0˚

THRUST = **W**Lμcosø + [(**W**L /386.4) (**v**/tacc)] + **W**Lsinø + **F**applied
= (200)(0.15)(1) + [(200/386.4)(8.0/0.2)] + (200)(0) + 25

= 30 lbs + 20.73 lbs + 0 lbs + 25 lbs = **75.73 lbs force**

ø = 90˚

THRUST = **W**Lμcosø + [(**W**L /386.4) (**v**/tacc)] + **W**Lsinø + **F**applied
= (200)(0.15)(0) + [(200/386.4)(8.0/0.2)] + (200)(1) + 25

= 0 lbs + 20.73 lbs + 200 lbs + 25 lbs = **245.73 lbs force**

ø = 30˚

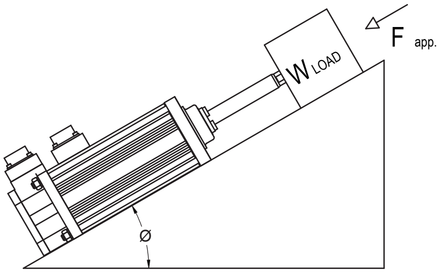
THRUST = **W**Lμcosø + [(**W**L /386.4) (**v**/tacc)] + **W**Lsinø + **F**applied
= (200)(0.15)(0.866) + [(200/386.4)(8.0/0.2)] + (200)(0.5) + 25

= 26 lbs + 20.73 lbs + 100 + 25 = **171.73 lbs force**

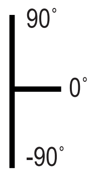
Thrust Calculations

Definition of thrust:

The thrust necessary to perform a specific move profile is equal to the sum of four components of force. These are the force due to acceleration of the mass, gravity, friction and applied forces such as cutting and pressing forces and overcoming spring forces.



Angle of Inclination



Note: at ø = 0˚
cosø = 1; sinø = 0
at ø = 90˚
cosø = 0; sinø = 1

It is necessary to calculate the required thrust for an application during each portion of the move profile, and determine the worst case criteria. The linear actuator should then be selected based on those values. The calculations at the right show calculations during acceleration which is often the most demanding segment of a profile.

Motor Torque Calculations

When selecting an actuator system it is necessary to determine the required motor torque to perform the given application. These calculations can then be compared to the torque ratings of the given amplifier and motor combination that will be used to control the actuator's velocity and position.

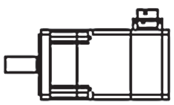
When the system uses a separate motor and screw, like the FT actuator, the ratings for that motor and amplifier are consulted. In the case of the GSX Series actuators with their integral brushless motors, the required torque divided by the torque constant of the motor (Kt) must be less than the current rating of the GSX or SLM motor.

Inertia values and torque ratings can be found in the GSX, FT, and SLM/SLG Series product specifications.

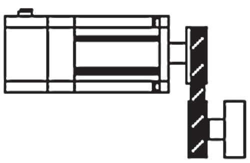
For the GSX Series the screw and motor inertia are combined.

Motor with screw (GSX, GSM, FT, & EL)

Motor & motor with reducer (SLM/SLG & ER)



Motor with belt and pulley



Terms and (units)

λ	=	Required motor torque, lbf-in (N-m)
λa	=	Required motor acceleration torque, lbf-in (N-m)
F	=	Applied force load, non inertial, lbf (kN)
S	=	Screw lead, in (mm)
R	=	Belt or reducer ratio
TL	=	Torque at driven load lbf-in (N-m)
vL	=	Linear velocity of load in/sec (m/sec)
ωL	=	Angular velocity of load rad/sec
ωm	=	Angular velocity of motor rad/sec
η	=	Screw or ratio efficiency
g	=	Gravitational constant, 386.4 in/s^2 (9.75 m/s^2)
α	=	Angular acceleration of motor, rad/s^2
m	=	Mass of the applied load, lb (N)
JL	=	Reflected Inertia due to load, lbf-in-s^2 (N-m-s^2)
Jr	=	Reflected Inertia due to ratio, lbf-in-s^2 (N-m-s^2)
Js	=	Reflected Inertia due to external screw, lbf-in-s^2 (N-m-s^2)
Jm	=	Motor armature inertia, lbf-in-s^2 (N-m-s^2)
L	=	Length of screw, in (m)
ρ	=	Density of screw material, lb/in^3 (kg/m^3)
r	=	Radius of screw, in (m)
π	=	pi (3.14159)
C	=	Dynamic load rating, lbf (N)

Velocity Equations

Screw drive: $\mathbf{V}_L = \omega m * S / 2\pi$ in/sec (m/sec)

Belt or gear drive: $\omega m = \omega_L * R$ rad/sec

Torque Equations

Torque Under Load

Screw drive (GS, FT or separate screw): $\lambda = \dfrac{S \cdot F}{2 \cdot \pi \cdot \eta}$ lbf-in (N-**m**)

Belt and Pulley drive: $\lambda = \mathbf{T}_L / R\,\eta$ lbf-in (N-**m**)

Gear or gear reducer drive: $\lambda = \mathbf{T}_L / R\,\eta$ lbf - in (N-**m**)

Torque Under Acceleration

$\lambda a = (\mathbf{J}_m + \mathbf{J}_R + (\mathbf{J}_s + \mathbf{J}_L)/R^2)\alpha$ lbf-in

α = angular acceleration = ((RPM / 60) x 2π) / $\mathbf{t}_{acc}$, rad/sec^2.

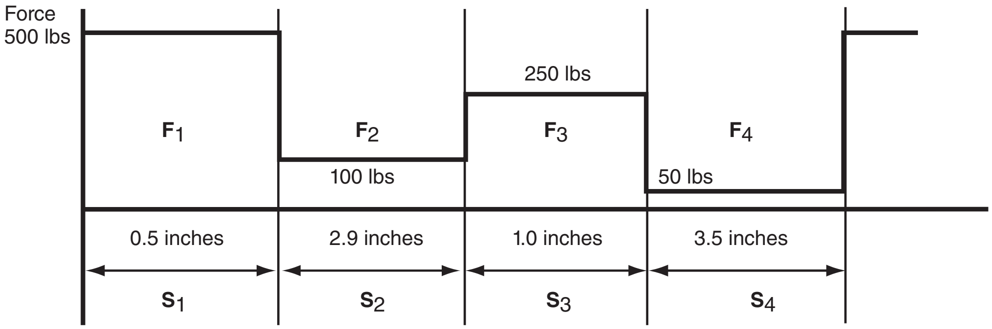
$\mathbf{J}_S = \dfrac{\pi \cdot \mathbf{L} \cdot \rho \times r^4}{2 \cdot g}$ lb - in - s^2 (N - **m** - s^2)

Total Torque per move segment

$\lambda T = \lambda a + \lambda$ lbf-in (N-m)

Mean Load Calculations

For accurate lifetime calculations of a roller screw in a linear application, the cubic mean load should be used. Following is a graph showing the values for force and distance as well as the calculation for cubic mean load. Forces are shown for example purposes. Negative forces are shown as positive for calculation.



S = Distance traveled during each move segment

Cubic Mean Load Equation

$$F_{cml} = \sqrt[3]{\frac{F_1^3\, S_1 + F_2^3\, S_2 + F_3^3\, S_3 + F_4^3\, S_4}{S_1 + S_2 + S_3 + S_4}}$$

Value from example numbers is 217 lbs.

Lifetime Calculations

The expected $\mathbf{L_{10}}$ life of a roller screw is expressed as the linear travel distance that 90% of the screws are expected to meet or exceed before experiencing metal fatigue. The mathematical formula that defines this value is below. The life is in millions of inches (mm). This standard $\mathbf{L_{10}}$ life calculation is what is expected of 90% of roller screws manufactured and is not a guarantee. Travel life estimate is based on a properly maintained screw that is free of contaminants and properly lubricated. Higher than 90% requires de-rating according to the following factors:

95% x 0.62	96% x 0.53
97% x 0.44	98% x 0.33
99% x 0.21	

Note: The dynamic load rating of zero backlash, preloaded screws is 63% of the dynamic load rating of the standard non-preloaded screws. The calculated travel life of a preloaded screw will be 25% of the calculated travel life of the same size and lead of a non-preloaded screw for the same application.

Single (non-preloaded) nut:

$$L_{10} = \left(\frac{C_a}{F_{cml}}\right)^3 \times \ell$$

If your application requires high force over a stroke length shorter than the length of the nut, please contact Exlar for derated life calculations. You may also download the article “Calculating Life Expectency” at www.exlar.com.

Total Thrust Calculations

Terms and (units)		Variables		
THRUST	= Total linear force-lbf (N)	Ø	= Angle of inclination - deg...................... =	______
$\mathbf{F}_{friction}$	= Force from friction-lbf (N)	**t**acc	= Acceleration time - sec......................... =	______
$\mathbf{F}_{acc}$	= Acceleration force-lbf (N)	**v**	= Change in velocity - in/sec (m/s)........... =	______
$\mathbf{F}_{gravity}$	= Force due to gravity-lbf (N)	µ	= Coefficient of sliding friction .... =	______
$\mathbf{F}_{applied}$	= Applied forces-lbf (N)	$\mathbf{W}_L$	= Weight of Load-lbm (kg)....................... =	______
386.4	= Acceleration of gravity - in/sec^2 (9.8 m/sec^2)	$\mathbf{F}_{applied}$	= Applied forces-lbf (N) .... =	______

Thrust Calculation Equations

THRUST = [$\mathbf{F}_{friction}$] + [$\mathbf{F}_{acceleration}$] + $\mathbf{F}_{gravity}$ + $\mathbf{F}_{applied}$

THRUST = [$\mathbf{W}_L \times \mu \times \cos ø$] + [($\mathbf{W}_L$ /386.4) x ($\mathbf{v}$ / $\mathbf{t}_{acc}$)] + $\mathbf{W}_L \sin ø$ + $\mathbf{F}_{applied}$

THRUST = [( )x( )x( )] + [(/386.4) x (/)] + [( ) ( )] + ( )

THRUST = [ ] + [( ) x ( )] + [ ] + ( )

= ________________ lbf.

Calculate the thrust for each segment of the move profile. Use those values in calculations below.
Use the units from the above definitions.

Cubic Mean Load Calculations

$$\sqrt[3]{\frac{F_1^3\,S_1 + F_2^3\,S^2 + F_3^3\,S_3 + F_4^3\,S_4}{S_1 + S_2 + S_3 + S_4}}$$

F_1= __________	S_1= __________	$F_1^3\,S_1$ = __________
F_2= __________	S_2= __________	$F_2^3\,S_2$ = __________
F_3= __________	S_3= __________	$F_3^3\,S_3$ = __________
F_4= __________	S_4= __________	$F_4^3\,S_4$ = __________

Move Profiles may have more or less than four components. Adjust your calculations accordingly.

Torque Calculations

Terms and (units)

λ	= Torque, lb-in (N-m)	= ----------------------
F	= Applied Load, non inertial, lbf (N)	= ----------------------
S	= Screw lead, in (m)	= ----------------------
η	= Screw or ratio efficiency (~85% for roller screws)	= ----------------------
g	= Gravitational constant, 386 in/s2 (9.8 m/s2)	= ----------------------
α	= Acceleration of motor, rad/s2	= ----------------------
R	= Belt or reducer ratio	= ----------------------
$\mathbf{T}_L$	= Torque at driven load, lbf-in (N-m)	= ----------------------
$\mathbf{V}_L$	= Linear velocity of load, in/sec (m/sec)	= ----------------------
ω_L	= Angular velocity of load, rad/sec	= ----------------------
ω_m	= Angular velocity of motor, rad/sec	= ----------------------
m	= Mass of the applied load, lbm (kg)	= ----------------------
$\mathbf{J}_R$	= Reflected Inertia due to ratio, lb-in-s2 (N-m-s2)	= ----------------------
$\mathbf{J}_S$	= Reflected Inertia due to screw, lb-in-s2 (N-m-s2)	= ----------------------
$\mathbf{J}_L$	= Reflected Inertia due to load, lb-in-s2(N-m-s2)	= ----------------------
$\mathbf{J}_M$	= Motor armature inertia, lb-in-s2 (N-m-s2)	= ----------------------
π	= pi	= 3.14159
$\mathbf{K}_t$	= Motor Torque constant, lb-in/amp (N-m/amp)	= ----------------------

* For the GS Series J_S and J_M are one value from the GS Specifications.

Torque Equations

Torque From Calculated Thrust.

$\lambda = \dfrac{SF}{2 \cdot \pi \cdot \eta}$ lb - in (N - m) = (   ) x (   )/2π (0.85) = (   ) x (   )/5.34 = ----------------------------

Torque Due To Load, Rotary.

Belt and pulley drive: $\lambda = T_L / R\,\eta$ lbf-in (N-m)

Gear or gear reducer drive: $\lambda = T_L / R\eta$ lbf-in (N-m)

Torque During Acceleration due to screw, motor, load and reduction, linear or rotary.

$I = (\mathbf{J}_m + (\mathbf{J}_S + \mathbf{J}_L) / \mathbf{R}^2)\,\alpha$ lb-in (N-**m**) = [(   ) + (+   ) / (   )] (   ) = ------------------------

Total Torque = Torque from calculated Thrust + Torque due to motor, screw and load

(   ) + (   ) + (   ) = ________________

Motor Current = $\lambda / \mathbf{K}_t$ = (   ) / (   ) = ____________________

Exlar Application Worksheet

FAX to:
Exlar Actuation Solutions
(952) 368-4877
Attn: Applications Engineering

Date: ______________________ Company Name: ____

Address: ____

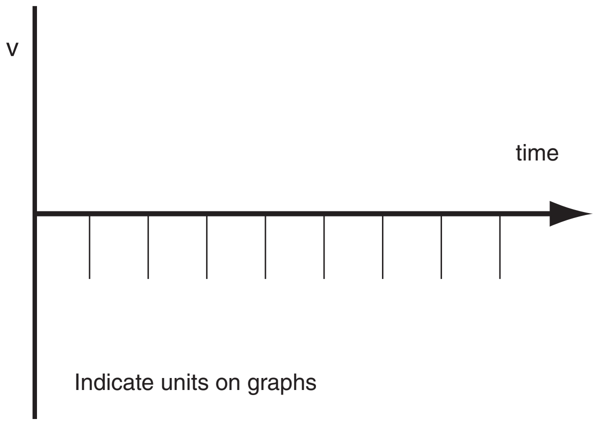
City: ____________________________________ State: ________________ Zip Code: ________

Phone: ____________________________________ Fax: ______________________________

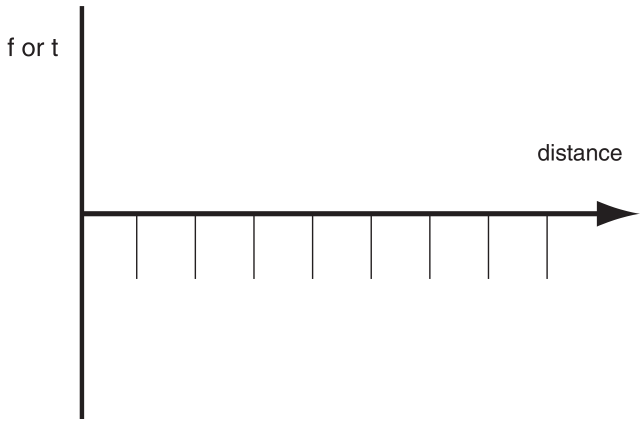
Contact: ___________________________________ Title: ______________________________

Sketch/Describe Application

Velocity vs. Time



Force or Torque vs. Distance



Exlar Application Worksheet

Date: ____________________ Contact: ___________________________ Company: __________________________

Stroke & Speed Requirements

Maximum Stroke Needed .... __________________ inches (mm), revs

Index Stroke Length .... __________________ inches (mm), revs

Index Time .... __________________ sec

Max Speed Requirements .... __________________ in/sec (mm/sec), revs/sec

Min Speed Requirements .... __________________ in/sec (mm/sec), revs/sec

Required Positional Accuracy .... __________________ inches (mm), arc min

Load & Life Requirements

Gravitational Load .... _________________ lb (N)

External Applied Load .... _________________ lbf (N)

Inertial Load .... _________________ lbf (N)

Friction Load .... _________________ lbf (N)

Rotary Inertial Load .... _________________ lbf-in-sec^2 (Kg-m^2)

or rotary mass, radius of gyr. .... lb (kg) ________________ in (mm)

Side Load (rot. or lin. actuator) .... ________________ lb (N)

Force Direction _____ Extend _____ Retract _____ Both

Actuator Orientation _____ Vertical Up _____ Vertical Down _____ Horizontal

_____ Fixed Angle _____ Degrees from Horizontal

_____ Changing Angle _____ to _____

Cycling Rate .... ___________________ Cycles/min/hr/day

Operating Hours per Day .... ___________________ Hours

Life Requirement .... ___________________ Cycles/hr/inches/mm

---

Configuration

Mounting: _____ Side _____ Flange _____ Ext Tie Rod _____ Clevis _____ Trunnion

Rod End: _____ Male _____ Female _____ Sph Rod Eye _____ Rod Eye _____ Clevis

Rod Rotation Limiting: _____ Appl Inherent _____ External Required

Holding Brake Required: _____ Yes _____ No

Cable Length: _________ ft (m)

Rotary Inertia To obtain a conversion from A to B, multiply by the value in the table.

B	Kg-m^2	Kg-cm^2	g-cm^2	kgf-m-s^2	kgf-cm-s^2	gf-cm-s^2	oz-in^2	ozf-in-s^2	lb-in^2	lbf-in-s^2	lb-ft^2	lbf-ft-s^2
A												
Kg-m^2	1	10^{4}	10^{7}	0.10192	10.1972	1.01972×10^{4}	5.46745×10^{4}	1.41612×10^{2}	3.41716×10^{3}	8.850732	23.73025	0.73756
Kg-cm^2	10^{-4}	1	10^{3}	1.01972×10^{5}	1.01972×10^{3}	1.01972	5.46745	1.41612×10^{-2}	0.341716	8.85073×10^{-4}	2.37303×10^{-3}	7.37561×10^{-5}
g-cm^2	10^{-7}	10^{-3}	1	1.01972×10^{-8}	1.01972×10^{-6}	1.01972×10^{-3}	5.46745×10^{-3}	1.41612×10^{-5}	3.41716×10^{-4}	8.85073×10^{-7}	2.37303×10^{-6}	7.37561×10^{-8}
kgf-m-s^2	9.80665	9.80665×10^{4}	9.80665×10^{7}	1	10^{2}	10^{5}	5.36174×10^{5}	1.388674×10^{3}	3.35109×10^{4}	86.79606	2.32714×10^{2}	7.23300
kgf-cm-s^2	9.80665×10^{-2}	9.80665×10^{2}	9.80665×10^{5}	10^{-2}	1	10^{5}	5.36174×10^{3}	13.8874	3.35109×10^{-2}	0.86796	2.32714	7.23300×10^{-2}
gf-cm-s^2	9.80665x10-5	0.980665	9.80665×10^{2}	10^{-5}	10^{-3}	1	5.36174	1.38874×10^{-2}	0.335109	8.67961×10^{-4}	2.32714×10^{-3}	7.23300×10^{-5}
oz-in^2	1.82901×10^{-5}	0.182901	1.82901×10^{2}	1.86505×10^{-6}	1.86505×10^{-4}	0.186506	1	2.59008×10^{-3}	6.25×10^{-2}	1.61880×10^{-4}	4.34028×10^{-4}	1.34900×10^{-3}
oz-in-s^2	7.06154×10^{-3}	70.6154	7.06154×10^{4}	7.20077×10^{4}	7.20077×10^{-2}	72.0077	3.86089×10^{2}	1	24.13045	6.25×10^{-2}	0.167573	5.20833×10^{-4}
lb-in^2	2.92641×10^{-4}	2.92641	2.92641×10^{3}	2.98411×10^{5}	2.98411×10^{3}	2.98411	16	4.14414×10^{2}	1	2.59008×10^{-3}	6.94444×10^{-3}	2.15840×10^{-4}
lbf-in-s^2	0.112985	1.129×10^{3}	1.12985×10^{6}	1.15213×10^{2}	1.15213	1.51213×10^{3}	6.1774×10^{3}	16	3.86088×10^{2}	1	2681175	8.3333×10^{-2}
lbf-ft^2	4.21403×10^{-2}	4.21403×10^{2}	4.21403×10^{5}	4.29711×10^{3}	0.429711	4.297114	2.304×10^{3}	5.96755	144	0.372971	1	3.10809×10^{-2}
lbf-ft-s^2	1.35583	1.35582×10^{4}	1.35582×10^{7}	0.138255	13.82551	1.38255×10^{4}	7.41289×10^{4}	192	4.63306×10^{3}	12	32.17400	1

Torque To obtain a conversion from A to B, multiply A by the value in the table.

B	N-m	N-cm	dyn-cm	Kg-m	Kg-cm	g-cm	oz-in	ft-lb	in-lb
A									
N-m	1	10^{-2}	10^{7}	0.109716	10.19716	1.019716×10^{4}	141.6199	0.737562	8.85074
N-cm	102	1	10^{5}	1.019716×10^{3}	0.1019716	1.019716×10^{2}	1.41612	7.37562×10^{-3}	8.85074×10^{-2}
dyn-cm	10-7	10^{-5}	1	1.019716×10^{-8}	1.019716×10^{-6}	1.019716×10^{-3}	1.41612×10^{-5}	7.2562×10^{-8}	8.85074×10^{-7}
Kg-m	9.80665	980665×10^{2}	9.80665×10^{7}	1	10^{2}	10^{5}	1.38874×10^{3}	7.23301	86.79624
Kg-cm	9.80665x10-2	9.80665	9.80665×10^{5}	10^{-2}	1	10^{3}	13.8874	7.23301×10^{-2}	0.86792
g-cm	9.80665x10-5	9.80665×10^{-3}	9.80665×10^{2}	10^{-5}	10^{-3}	1	1.38874×10^{-2}	7.23301×10^{-5}	8.679624×10^{-4}
oz-in	7.06155x10-3	0.706155	7.06155×10^{4}	7.20077×10^{-4}	7.20077×10^{-2}	72,077	1	5.20833×10^{-3}	6.250×10^{-2}
ft-lb	1.35582	1.35582×10^{2}	1.35582×10^{7}	0.1382548	13.82548	1.382548×10^{4}	192	1	12
in-lb	0.113	11.2985	1.12985×10^{6}	1.15212×10^{-2}	1.15212	1.15212×10^{3}	16	8.33333×10^{-2}	1

Common Material Densities

Material	oz/in^3	gm/cm^3
Aluminum (cast or hard drawn)	1.54	2.66
Brass (cast or rolled)	4.80	8.30
Bronze (cast)	4.72	8.17
Copper (cast or hard drawn)	5.15	8.91
Plastic	0.64	1.11
Steel (hot or cold rolled)	4.48	7.75
Wood (hard)	0.46	0.80
Wood (soft)	0.28	0.58

Coefficients of Sliding Friction

Materials in contact	μ
Steel on Steel (dry)	0.58
Steel on Steel (lubricated)	0.15
Aluminum on Steel	0.45
Copper on Steel	0.36
Brass on Steel	0.44
Plastic on Steel	0.20
Linear Bearings	0.001

Standard Ratings for Exlar Actuators

The standard IP rating for Exlar Actuators is IP54S or IP65S. Ingress protection is divided into two categories: solids and liquids.

For example, in IP65S the three digits following "IP" represent different forms of environmental influence:

- The first digit represents protection against ingress of solid objects.
- The second digit represents protection against ingress of liquids.
- The suffix digit represents the state of motion during operation.

Digit 1 - Ingress of Solid Objects	
The IP rating system provides for 6 levels of protection against solids.	
1	Protected against solid objects over 50 mm e.g. hands, large tools.
2	Protected against solid objects over 12.5 mm e.g. hands, large tools.
3	Protected against solid objects over 2.5 mm e.g. large gauge wire, small tools.
4	Protected against solid objects over 1.0 mm e.g. small gauge wire.
5	Limited protection against dust ingress.
6	Totally protected against dust ingress.

Digit 2 - Ingress of Liquids	
The IP rating system provides for 9 levels of protection against liquids.	
1	Protected against vertically falling drops of water or condensation.
2	Protected against falling drops of water, if the case is positioned up to 15 degrees from vertical.
3	Protected against sprays of water from any direction, even if the case is positioned up to 60 degrees from vertical.
4	Protected against splash water from any direction.
5	Protected against low pressure water jets from any direction. Limited ingress permitted.
6	Protected against high pressure water jets from any direction. Limited ingress permitted.
7	Protected against short periods (30 minutes or less) of immersion in water of 1m or less.
8	Protected against long durations of immersion in water.
9	Protected against high-pressure, high-temperature wash-downs.

Suffix			
S	Device standing still during operation	**M**	Device moving during operation

Notes