How to Specify & Size Electromechanical Linear Actuators

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By Robert E. Ward, Jr.
“About half of all of our projects involving linear actuators have a problem of some sort – major to minor – with an actuator before it ships out the door”

- CEO & President of a Large Systems Integrator, 2013
Common Types of Linear Actuators

- Hydraulic
- Pneumatic
- Electromechanical
Common Industrial Electromechanical Actuators

Belt Drive

Ballscrew Drive
What Are the Elements of a Linear Actuator?

- An attachment point or platform to hold the payload or workpiece
- A linear load handling guidance system
- A rotary-to-linear motion converter system
- A rigid and accurate housing or structure to secure and contain all the elements
Specification

- Your project demands an electromechanical linear actuator
  - But how do you specify what you need?
  - Where do you begin?
The Minimum Requirements

• There are just 7 Technical pieces of information to know and understand in order to completely characterize a linear motion electromechanical actuator for service.

• And 1 Commercial piece of information that can be equally vital to implementation of a successful linear actuator installation.
A Useful Mnemonic

<table>
<thead>
<tr>
<th>A</th>
<th>Accuracy &amp; Repeatability</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Capacity</td>
</tr>
<tr>
<td>T</td>
<td>Travel</td>
</tr>
<tr>
<td>U</td>
<td>Use Factor</td>
</tr>
<tr>
<td>A</td>
<td>Ambient Environment</td>
</tr>
<tr>
<td>T</td>
<td>Timing</td>
</tr>
<tr>
<td>O</td>
<td>Orientation</td>
</tr>
<tr>
<td>R</td>
<td>Rates</td>
</tr>
</tbody>
</table>
**Accuracy & Repeatability**

- **Accuracy:**
  - There are 2 components
    - Travel accuracy
    - Positioning accuracy
  - It's common to specify in units of microns (µm) or thousandths of an inch (0.001 in.)

- **Repeatability (or Precision):**
  - This also has 2 components
    - Unidirectional
    - Bi-directional
  - Specify in same units as Accuracy
Accuracy & Repeatability

1. Accurate - Not Repeatable
2. Repeatable - Not Accurate
3. Accurate & Repeatable
4. Not Accurate - Not Repeatable
Capacity

- There are several types to think about when specifying
  - Static Capacity, C.o (Fy,Fz)
  - Dynamic Capacity, C (Fy, Fz)
  - Moment Capacity, (Mx, My, Mz)
  - Thrust Capacity, (Fx)
  - Units of force & moment kg, N, lb & N-m, ft-lbf, in-lbf
  - 6 DoF, good actuator constrains 5
Capacity
Travel

- Also known as “stroke” in mm or inch units
- Specifying the TOTAL distance you want to move is a critical value
- The TOTAL move needs to include “safety stroke” (“stop-to-stop” distance)
- ROT widely used = 2x motor rev at each end
- Be careful to distinguish between Stroke and Overall Length
Travel

\[ \text{Travel} = \text{Stroke} \]

\[ 4 \times \text{Motor Rev} = \text{Safety Stroke} \]

Overall Length (OAL)
Usage Factor & Useful Life

- This spec defines how frequently you need your actuator to run & how long you would like it to live
- Usage factor also known as Duty Cycle (On Time/Total Time)
- Expressed in cycles/minute (cpm) is common
- An actuator cycle = 2x the Stroke
- Useful life is number of hours, years, cycles or linear distance you desire or require the linear unit to last
Ambient Environment

- For best results you need to think about what environment that the actuator will live in
  - Operating Temperature range
  - Relative Humidity range
  - Type and amount of contaminant particles
  - Presence of corrosive fluids or chemicals
  - Periodic cleaning or washdown requirements
Timing

- **Project Time**: What is the timing of the project milestones? Budget approval? Engineering? Procurement? Assembly? Check out?
- **Installation Time**: When do you need to be up and running?
- **Engineering Time**: How much time is needed for actuator integration? Are there special or custom features that you need the actuator to have?
- **Test Time**: Do you need a test & development prototype first?
Orientation

- This parameter tells your vendor how the linear actuator is oriented in 3-D space
  - Horizontal, table mount, 0 degrees
  - Horizontal, wall mount (aka transverse)
  - Horizontal, ceiling mount (aka upside down)
  - Vertical, upright, 90 degrees
  - Angular, variable slant angle between 0 and 90.
# Orientation

## Actuator Positions

<table>
<thead>
<tr>
<th>Position</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal position</strong></td>
<td><img src="image1.png" alt="Diagram" /></td>
</tr>
<tr>
<td>1. Carriage up</td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>2. Carriage down</td>
<td><img src="image3.png" alt="Diagram" /></td>
</tr>
<tr>
<td><strong>Vertical position</strong></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
<tr>
<td><strong>Angular position</strong></td>
<td><img src="image5.png" alt="Diagram" /></td>
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</tbody>
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Specify angle $\alpha$ and carriage position as viewed from behind drive end:

$U$, $D$, $R$, $L$ ($U$ as shown)
Rates

• These values define the motion profile of the actuator carriage that is carrying your workpiece

• There are 2 key values to specify or know:
  – The Rate of **Velocity** or Speed (mm/sec, in/sec)
  – The Rate of **Acceleration**, m/sec^2, in/sec^2

• If you know how far you want to move (stroke or travel) and how much time to accomplish that move, then the velocity and acceleration can be easily calculated
Rates

**t/3 Trapezoidal Motion Profile**

- **“Fwd” STROKE**
- **Accel ramp**
- **Constant V**
- **Decel ramp**
- **Dwell time**
- **“Return” STROKE**
Rates

Velocity Graph

Torque Graph
Final Step

• You now have the 8 pieces of information generated
• The actuator can now be selected & engineered to fit the application
• Motor-Encoder-Brake/Gearbox/Coupling can be selected
• Drive components matched to actuator based on load, speed, accel, force & torque, positioning, service life & environmental requirements

\[ \frac{J_{\text{load}}}{J_{\text{motor}}} = \text{Inertia Ratio} \]
Summary

• **Goal:** to be able to fully characterize and specify the requirements for error-free installation & operation of an electromechanical linear actuator to perform a given work task

• **Method:** Using the mnemonic device- ACTUATOR – you can accomplish your goal
For Applications Assistance

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