Solenoids

Principle of Operation

Why use solenoids?

Actuation for machine and process automation must range from the most basic on-off function to extremely complex sequencing. When the process involves linear or rotary motion, solenoids are among the best actuation devices in terms of size, cost, simplified installation and ease-of-use.

On the following pages, we've shown several application examples that demonstrate the wide range of markets and applications to which our solenoid products are applied.

In keeping with recent industry trends, we have developed many solenoid designs to be especially advantageous for specific application demands including:

- Saving Energy with magnetic latching solenoids for power off engagement
- Quiet operation
- Miniature size for space-restricted applications
- Long-life designs for extremely consistent and dependable operation
- High speed designs for maximum throughput and productivity

Whether your design includes linear or rotary actuation, we can help you determine the best solenoid to meet your application design requirements, such as:

Exceptional Force/Torque

A linear solenoid can provide up to 30 pounds of force from a unit less than 2-1/4 inches long. A rotary solenoid can provide well over 100 lb-in of torque from a unit also less than 2-1/4 inches long.

Compact Size

Need low profile? Minimum volume? Ledex solenoids can pack more work per cubic inch than motors. Many of our new miniature series units are in the 1/2 to 1” size.

Simplified Control

Being a pulsed device with minimal components optimizes solenoids for digital control. This results in faster cycling and higher reliability with fewer interfaces.

Uncompromising Reliability

Ledex solenoids provide repeatable, predictable performance with a specified life of up to 100 million cycles.
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Primary Solenoid Operational Functions

**Divert**
Gate diverters, depending on the application, can be used continuously or very infrequently. In this example, a BTA rotary actuator is chosen for its field-proven long life rating of 100+ million actuations.

**Kick**
Immediate, snap-acting response and electric operation are inherent solenoid attributes that are ideal for interfacing with motion electronics and detection sensors for part rejection processes.

**Position**
Positioning applications can range from a simple ratcheting device, such as the one illustrated, to precise variable positioning sub-assemblies using linear Soft Shift solenoids or rotary BTA actuators.

**Lock/Latch**
Low cost, compact size, reliability and long life are all reasons for the growing demand for Ledex solenoids in a wide variety of locking applications including vault doors, cash registers, disk drives and missile systems.

Whether rotary or linear, a Ledex solenoid is easily configured into machine designs requiring a platform or stage to be latched in position during a particular machine process.

**Pinch**
Tubes carrying body fluids on many medical systems must have accurate control of flow regulation. In this example, a Soft Shift linear solenoid is chosen for its variable positioning capability to smoothly pinch the tube to the operator's precise demand. Using a solenoid in this manner eliminates valves and other connecting apparatus which pose a potential threat for contamination or leakage.
**Solenoids**

**Principle of Operation**

### Rotary Solenoids

<table>
<thead>
<tr>
<th>Functional Comparison</th>
<th>At-a-Glance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BTA® Actuators</strong></td>
<td><strong>Ultimag® Actuators</strong></td>
</tr>
<tr>
<td><strong>Stroke</strong></td>
<td>Up to 45°; CW or CCW</td>
</tr>
<tr>
<td><strong>Functional Attribute:</strong></td>
<td>- Battery Powered</td>
</tr>
<tr>
<td><strong>Max Power Output</strong> (Torque or Force)</td>
<td>12.9 lb-in (1.5 Nm)</td>
</tr>
<tr>
<td><strong>Power Consumption</strong></td>
<td>Average</td>
</tr>
<tr>
<td><strong>Duty Cycle</strong></td>
<td>Continuous or intermittent</td>
</tr>
<tr>
<td><strong>Housing Style (with a variety of options for):</strong></td>
<td>Completely enclosed</td>
</tr>
<tr>
<td>Shaft Ends</td>
<td>-</td>
</tr>
<tr>
<td>Mounting Styles</td>
<td>-</td>
</tr>
<tr>
<td>Power Termination</td>
<td>-</td>
</tr>
<tr>
<td>Imperial and Metric</td>
<td>-</td>
</tr>
<tr>
<td><strong>Operational Characteristics</strong></td>
<td>- High speed cycle rate</td>
</tr>
<tr>
<td></td>
<td>- Can provide closed loop velocity and position control</td>
</tr>
<tr>
<td></td>
<td>- Quiet, shock-free operation</td>
</tr>
<tr>
<td></td>
<td>- True rotary motion with no axial displacement</td>
</tr>
<tr>
<td><strong>Life (millions of cycles)</strong></td>
<td>100</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>5 sizes:</td>
</tr>
<tr>
<td></td>
<td>- Diameters from 1-1/8&quot; to 2-3/8&quot; (30 to 59 mm)</td>
</tr>
<tr>
<td></td>
<td>- Lengths from 3/4&quot; to 1-5/8&quot; (18 to 41 mm) long</td>
</tr>
</tbody>
</table>
# Solenoids

## Principle of Operation

### Linear Solenoids

### Functional Comparison

<table>
<thead>
<tr>
<th>Stroke</th>
<th>STA® Tubular</th>
<th>Soft Shift®</th>
<th>Low Profile</th>
<th>Open Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>Up to 2.5” (63.5 mm)</td>
<td>Up to 0.42” (10.7 mm)</td>
<td>Up to 0.7” (17.78 mm)</td>
<td>Up to 1.00” (25.4 mm)</td>
</tr>
</tbody>
</table>

### Attributes:

- Battery Powered
- High Speed
- Long Life
- Magnetic Latching
- Miniature Size
- Quiet Performance

### Max Power Output (Torque or Force)

<table>
<thead>
<tr>
<th>STA® Tubular</th>
<th>Soft Shift®</th>
<th>Low Profile</th>
<th>Open Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Power Output</td>
<td>Up to 9.8 lbs (43.61 N)</td>
<td>Up to 29.5 lbs (131.28 N)</td>
<td>Up to 145 lbs (645.2 N)</td>
</tr>
</tbody>
</table>

### Power Consumption

- Average
- Continuous or intermittent

### Duty Cycle

- Average
- Continuous or intermittent

### Housing Style (with a variety of options for):

- Shaft Ends
- Mounting Styles
- Power Termination
- Imperial and Metric

### Operation Characteristics

- Economical design for volume applications
- Multiple plunger designs
- Greatest shock/vibration integrity
- On/off operation
- Push or pull models; ideal for lock/latch operations
- Slow, smooth motion or snap action
- Can provide closed loop velocity control
- Quiet operation with 3-5 times the starting force of standard solenoids
- Push or pull models
- Ideal for high force, short stroke applications
- On/off operation
- Push or pull models; ideal for lock/latch operations
- Most economical design for volume applications
- DC activated
- Continuous or intermittent duty
- On/off operation
- Pull models standard (push models available)

### Life (millions of cycles; field-proven)

<table>
<thead>
<tr>
<th>STA® Tubular</th>
<th>Soft Shift®</th>
<th>Low Profile</th>
<th>Open Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life (millions of cycles; field-proven)</td>
<td>25+; for STA; 1 for Size 125-175</td>
<td>10</td>
<td>1 to 5</td>
</tr>
</tbody>
</table>

### Size

<table>
<thead>
<tr>
<th>STA® Tubular</th>
<th>Soft Shift®</th>
<th>Low Profile</th>
<th>Open Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>10 sizes:</td>
<td>5 sizes:</td>
<td>9 sizes:</td>
</tr>
<tr>
<td>Diameter</td>
<td>1/2&quot; to 1-3/4&quot; (13 to 45 mm)</td>
<td>1-1/8&quot; to 2-1/4&quot; (29 to 57)</td>
<td>3/4&quot; to 3-3/8&quot; (10 to 86 mm)</td>
</tr>
<tr>
<td>Lengths</td>
<td>4.75&quot; (13 to 121 mm)</td>
<td>2-1/4&quot; (25 to 57 mm)</td>
<td>1-2/8&quot; (13 to 54 mm)</td>
</tr>
</tbody>
</table>

* Select models
Solenoids

Principle of Operation

**BTA® Brushless Torque Actuators**

The BTA® has a single phase coil with three stator poles and matching rotor poles. When the coil is energized, the poles align along the flux path. With the three pole design, it is possible to have a stroke of up to 45°. In practical usage, external stops should be used to attain maximum unit life. Subsequently, the stroke angle is slightly shorter. Use of such mechanical stops also serve to limit the actuator stroke to its optimum stroke/torque capacity. By not requiring full stroke actuation, the BTA offers maximum design flexibility across a wide range of stroke angles and torque requirements.

BTA rotary, non-axial stroke actuators are a good solution for applications requiring reliable, low hysteresis operation with a good torque profile as required for proportional operation.

Using simple pulse width modulation (PWM) to control coil current, the BTA allows open or closed loop velocity and position control. Such proportional control is ideal for silent, shock-free actuation applications. (In open loop applications, PWM improves hysteresis over variable DC voltage control.)

The addition of position feedback, and the subsequent improved system stiffness and accuracy, enables the BTA to be used in closed loop applications.

The bearing system consists of two ball-type bearings which are key to low hysteresis operation.

- Controllable velocity and position
- Quiet, shock-free operation
- 100+ million cycle life
- No axial stroke
- Adaptable to closed loop operation
- Completely enclosed construction
- Excellent unit-to-unit performance consistency
- Low power consumption
Solenoids

Principle of Operation

Ultimag® Rotary Actuators

Ultimag® operates on the simple principle of attraction and repulsion of opposite and like magnetic poles. The permanent magnetic armature has twice as many poles as the stator. In the de-energized state, the armature poles each share half a stator pole, causing the shaft to seek mid-stroke. When power is applied, the stator poles are polarized. This attracts half and repels the other half of the armature poles, causing the shaft to rotate. When the voltage is reversed, the stator poles are polarized with the opposite pole. Consequently, the opposite poles of the armature are attracted and repelled, thus causing rotation in the opposite direction.

The Ultimag Series has been developed in response to application needs for higher speed and higher torque motion control components. We have found that many applications require a working stroke less than 360°, yet still employ motors with their associated complex and expensive controls and linkages. As a result, a powerful, extremely fast short stroke actuator has many design advantages for industrial, office automation, automotive and medical applications.

We have been designing and manufacturing world class, innovative motion control components for over 60 years. Our patented Ultimag series is the latest of our state-of-the-art developments in rotary actuation products.

- Speeds over 100 Hz
- Peak torque of over 225 oz-in
- 100 million actuation life
- Three standard sizes
Solenoids

Principle of Operation

Ledex® Rotary Solenoids

**Physical Characteristics**

The rotary solenoid is a compact and rugged direct current electromagnet—almost solid steel and copper so as to give maximum power output with minimum size and weight. The coil is wound by a special precision winding process which puts the maximum amount of copper into the allowable space, thus resulting in each solenoid developing a tremendous torque for its size and power output. Heat-treated steel surrounds and protects the coil. The steel also provides a magnetic path of high permeability and low residual flux characteristics for efficient conversion of electrical energy to mechanical energy and fast response.

**Determining Rotary Stroke**

The three ball races which determine the rotary stroke are produced by a coining process. The coining of the solenoid case and armature plate determines the length and direction of the stroke and the value of starting torque. Refer to the selection charts for the standard strokes available. Special rotary strokes can be engineered for solenoids which are made to order.

**Converting Linear to Rotary Motion**

The rotary solenoid armature is supported by three ball bearings that travel around and down inclined ball races. When power is applied, a powerful linear electromagnetic force pulls in the armature. Rotation continues until the balls have traveled to the deep ends of the races. The result is almost frictionless conversion from linear to rotary motion.

**High Starting Torque**

In ordinary electromagnets, magnetic pull increases sharply as the air gap closes. In Ledex rotary solenoids, this is compensated for by the compound angle of incline of the ball races. The incline of the ball races is steep at the beginning of the rotary stroke and gradually decreases as the balls approach the deep end of the ball races, thus transferring torque to the start of the rotary stroke where it is usually needed.
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Principle of Operation

STA® Tubular Linear Solenoids

In Pull type solenoids, the plunger is pulled into the solenoid coil when the coil is energized. In Push type solenoids, the same is true, however, the plunger has a shaft extension which then pushes out through a hole in the end of the solenoid case. Please note, however, that the magnetic field cannot be reversed to cause the opposite action to occur.

STA® Series tubular solenoids improve performance and provide longer life, quieter operation and improved reliability for demanding applications. STA models are constructed with a low friction nylon bobbin which insures a 25 million actuations life rating on all models.

The problems associated with powdered metal flaking in typical tubular designs is eliminated with the metal-to-plastic bearing surface. In addition, the new design’s case is rolled over both ends of the unit for greater shock and vibration integrity, allowing the STA to withstand severe applications in which typical solenoids may come apart.

Both push and pull models offer a built-in combination air gap spacer and plunger stop. This feature eliminates the need for external E-rings and impact washers which typically fail prematurely, as well as get in the way of your attached mechanisms. All units are provided with 10” PVC lead wires as standard, and are rated for a maximum coil temperature of 130°C. UL-approved materials are used in the construction.

For heavy duty applications requiring larger forces, Ledex Size 125, 150 and 175 standard tubular models are recommended. These standard models are all pull type with 60° plungers, and feature heavy duty welded mounting brackets or bushing mounts (depending on model), and heavy duty plunger stops to limit plunger travel, provide positive stopping, and keep pole faces from slamming together at the end of stroke. An impact cushion made of resilient non-magnetic material absorbs energy at the end of the stroke and helps eliminate residual magnetism.

For higher temperature applications up to 180°C, please consult the factory for alternate materials which are available in some models. Mechanical and electrical ratings may also be affected. Other options include: special plunger configurations, springs, special mounting features, and anti-rotation flats on mounting bushings. Please consult the factory with details about your application as tooling may apply to some features.
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Soft Shift® Linear Solenoids

Soft Shift® solenoids have a unique construction which allows easy transition from snap action to variable position.

Using the same power, starting force is three to five times higher than standard solenoids at the fully de-energized position. This is advantageous for starting inertial loads or detented mechanisms, and for conserving electrical power.

In snap action applications, typical solenoids move to the end of the stroke within milliseconds, with a characteristic increase in ending force and acceleration. With the Soft Shift solenoid plunger, however, velocity can be controlled by ramping the input current for slow, noiseless operation.

For applications where variable positioning is desired, closed loop control can be accomplished by adding electronic controls. This gives accurate, repeatable action.

The essentially horizontal force curves prevent rapid acceleration at the end of the stroke, avoiding the excessive wear, noise and vibration that characterize standard solenoids. A Soft Shift solenoid can be a low-cost alternative to a linear stepping motor with a lead screw for up to and including a 0.420” stroke.

- Variable positioning linear device
- Slow, smooth motion
- High starting force
- Quiet operation
- 10 million actuation life rating
Solenoids

Principle of Operation

Ledex® Low Profile Linear Solenoids

The low profile shape, besides contributing to smaller size, optimizes the magnetic flux paths for maximum force versus stroke characteristics. The construction of the plunger assembly provides an auxiliary flux path which permits a significant increase in force. The low profile solenoid construction not only provides long life, but also provides a rugged design for both military and commercial applications.

Conical-faced designs extend the useful range of a solenoid to provide higher forces for strokes typically over 0.060 inches. The pole surface area is greater and the distance between the tapered cone faces is approximately one-half that of the gap between the land faces (for 30° angles), providing the effect of a closer air gap. While some of the force component is lost because the force vector is not parallel with the plunger motion, the shorter gap and higher flux density combine to provide more output force for longer strokes.

For shorter strokes, the magnetic flux density increases and causes the iron to saturate rapidly as the poles move closer, thus reducing the efficiency of the conical-faced design. At this point, the flat-faced plunger is more efficient.

The main advantage of the flat-faced pole over the conical is that the full component of force is usable because the force vector is parallel with the pole motion.

A key to the efficiency and compact form factor of the low profile solenoid is our special precision coil-winding process. With maximum copper packed into the allowable space, each solenoid develops tremendous force for its size and power input. The low profile form, in addition to contributing to smaller size, permits maximum pole face surface area for the magnetic flux.

Another factor that contributes to high efficiency is the additional iron surface on the external portion of the plunger; it provides an auxiliary flux path and a significant increase in force.

The force is also affected by other interrelated features, such as the length of the iron path, the magnetic saturation properties of the solenoid case and plunger, and the area and shape of the pole pieces.

The enclosed construction of the solenoid not only provides an iron path with minimum losses at the ring gap, but also provides a rugged design for critical environment applications.
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**Ledex® Open Frame Linear Solenoids**

The open frame solenoid is the simplest solenoid device consisting of an open iron frame, an overmolded or taped coil, and a movable plunger in the center of the coil.

Open frame solenoids are designed with two frame styles, the C Frame style, in which the coil is enclosed on one side, and the Box Frame style in which the coil is enclosed on two sides. The Box Frame style provides slightly higher force output and is more rugged in design.

Tapped mounting holes are used for easy installation and interchangeability. Most models have slotted and cross drilled plungers for easy load attachment.

The plunger is plated for corrosion resistance, and provides a low coefficient of friction and long life.

Over molded coils are available in both Box Frame and C Frame solenoids and offer excellent protection from moisture and humidity. Some solenoids are UL recognized. Most have UL recognized coil insulation systems.

Open frame solenoids are the most economical of all the solenoid types, and are typically selected for applications in which extremely long life and precise positioning are not critical.

- Low cost, high volume products
- Selected Designs with Extremely long life operation
- Strokes to 1.00 inch
- Custom design work is our strength

Applications for Ledex® DC open frame devices are numerous. As with all types of solenoids, open frame models are well suited for applications which require either locking or latching functions. Applications include residential and commercial door locks, credit card key “smart” locks, pharmaceutical compartment locks, circuit breakers, pinch valves, and many more.
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Magnetic Latching Linear Solenoids

Magnetic latching solenoids are designed for low duty cycle applications where the solenoid's energized position is needed for an extended period of time. When power is applied to the solenoid, the plunger moves to its energized position. The plunger latches magnetically in this position and remains there, consuming no power, until a negative electrical pulse is applied to allow the plunger to unlatch.

The reverse voltage applied is dependent on the load attached to the plunger but must be well below the initial energizing value.

While continuous duty, on/off solenoids tend to develop heat, magnetic latching solenoids do not since no power is consumed in the energized state.

Since magnetic latching solenoids are typically used in low duty cycle applications, they are also perfect candidates for battery operation. These products are therefore cataloged as standard as low as 3-6 volts.

Typical applications for magnetic latching solenoids include door closers, locks, latches and security devices. Almost any solenoid type can be developed as a magnetic latching version. We offer open frame and tubular varieties as catalog standard products.

- Designed for low duty cycle applications
- Ideal for prolonged energized position
- Well-suited for battery operation
- Tubular and open frame designs available
- Forces to 32 lbs.
- Stroke lengths to 0.6 inches

Magnetic Latching Solenoid Types...

STA® Tubular

In the pull type tubular design, the plunger is pulled into the solenoid coil when the coil is energized. The tubular design offers the most compact package size to force ratio and substantially longer life.

Open Frame — Box Frame

This solenoid has a 4-sided closed box frame and solid plunger and is, therefore, more electrically efficient than the C Frame solenoid. The closed, box frame also provides improved mechanical strength.

Open Frame — C Frame

C Frame solenoids consist of a formed C-shaped steel frame and solid plunger. Therefore, these solenoids are less efficient and less costly than their Box Frame counterparts.