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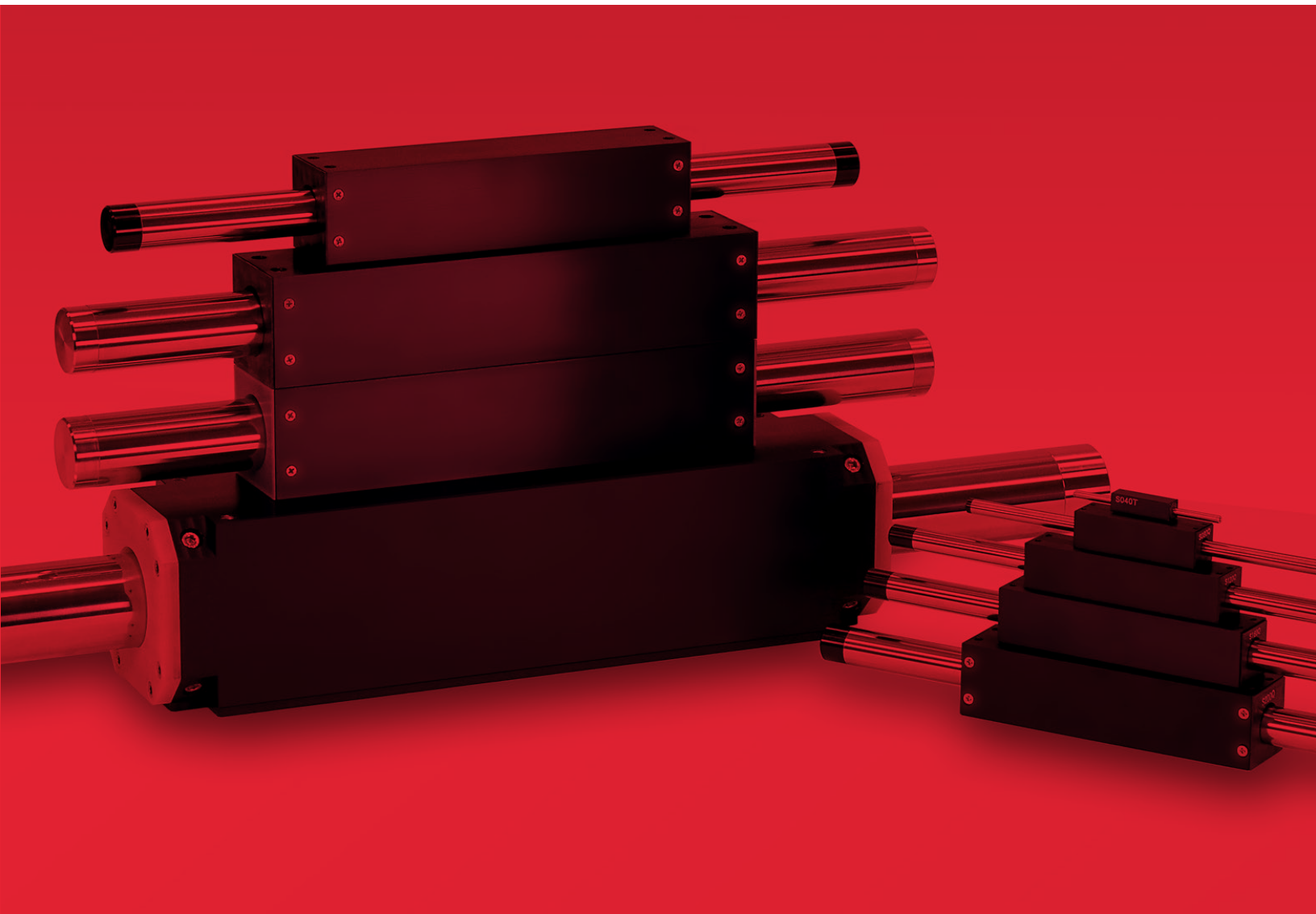


LINEAR SHAFT MOTORS AND ACTUATORS:

The secret weapon OEM engineers don't know they have

Linear shaft motors — also called tubular linear motors — are a permanent-magnetic-based technology to generate linear motion in one axis. These linear motors are relatively simple to build, design, and integrate. What's more, their extremely high reliability and increasing power density make them excel in a vast array of automated machines. In this article, we answer four frequently asked questions about linear shaft motors.

HOW DO TUBULAR LINEAR MOTORS WORK?

Like some linear motors with a flat morphology, linear shaft motors have a stack of permanent magnets and a stator with windings. However, instead of being affixed to a flat track, the magnets in a linear shaft motor have a disc shape and embed in a stainless tube … and the forcer (containing the electromagnetic coil for input) wraps around this shaft for electromechanically based linear motion upon the application of current into the forcer's coil.

WHY HAVEN'T I HEARD OF THESE BEFORE?

Linear shaft motors were once quite costly. However, falling prices and proliferation of applications using high-power permanent magnets similar to those used in linear shaft motors have (thanks to economies of scale) made linear shaft motors an increasingly suitable solution for wafer manufacturing and other precision motion designs. In fact, linear shaft motors (more powerful than those of even a few years ago) now compete with generic off-the-shelf linear actuators based on rotary-type motors paired with ballscrews or leadscrews.

Of course, there are rare cases for which linear shaft motors are unsuitable. For example, they aren't a good choice for products necessitating that design

Nippon Pulse linear shaft motors come in diameters (shaft sizes) ranging from just a couple millimeters (about the diameter of a pencil lead) to 1,300 mm … and in fact Nippon Pulse offers the largest variety of linear shaft motor diameters in the world. The motors can replace a variety of other linear-motion technologies.

OEMs can buy separate linear-motor shafts and forcers (the coil set that moves over the shaft) to build their own actuators ... or specify the motors as integrated linear actuators and stages (complete with linear shaft motor, linear encoder, linear bearings, and extruded aluminum housing) for turnkey integration. For engineers who don't want to design their own linear actuators (but need to push and pull loads at a certain speed, power, and accuracy).

costs be kept to within pennies. Otherwise, the 20% or so cost premium for linear shaft motors is typically justified by their simplicity and high reliability. There are numerous cases where the additional cost is offset by reduced component count due to the design simplicity.

To be clear, though: The increased use of linear shaft motors has less to do with decreasing prices than increased industry education. Many OEMs' engineering teams have zero familiarity with linear shaft motors, and only come to appreciate the motors' distinct benefits (such as simplicity, accuracy, and speed) after learning about and applying the motors.

HOW DO I INTEGRATE LINEAR SHAFT MOTORS?

OEMs can integrate linear shaft motors in two ways:

- By specifying and integrating separate linear-motor shafts and forcers to build their own axis actuation
- By specifying the motors pre-integrated as linear actuators and stages (complete with linear encoder, linear bearings, and extruded aluminum housing) for turnkey integration.

With the former option, strokes are essentially unlimited — though (due to practical considerations related to air-freight and other shipping and transport constraints) tubular motor shafts can be sold in versions up to ~14 ft long.

> In one design, a small tabletop-sized design based on Nippon Pulse linear shaft motors has replaced an 80-ton stamping press. The water-cooled design applies 6,000 N to workpieces.

No matter the format, linear shaft motors allow for integration with off-the-shelf motor controller drives from dozens of manufacturers — including Panasonic, Rockwell Automation, Mitsubishi, Omron, and Siemens. That's in part because the drives recognize linear shaft motors as simple three-phase brushless dc

motors. (The linear shaft motors have a common three-phase wiring connection.) In fact, Nippon Pulse now offers its own user-friendly motion controllers that can be purchased in standard or customized formats ... and Nippon Pulse now offers the COMMANDER controller and Titan Drive series drive-controller modules to run small to medium-sized motors. (Higher-power axes using Nippon Pulse motors drawing thousands of watts necessitate drives from other manufacturers.)

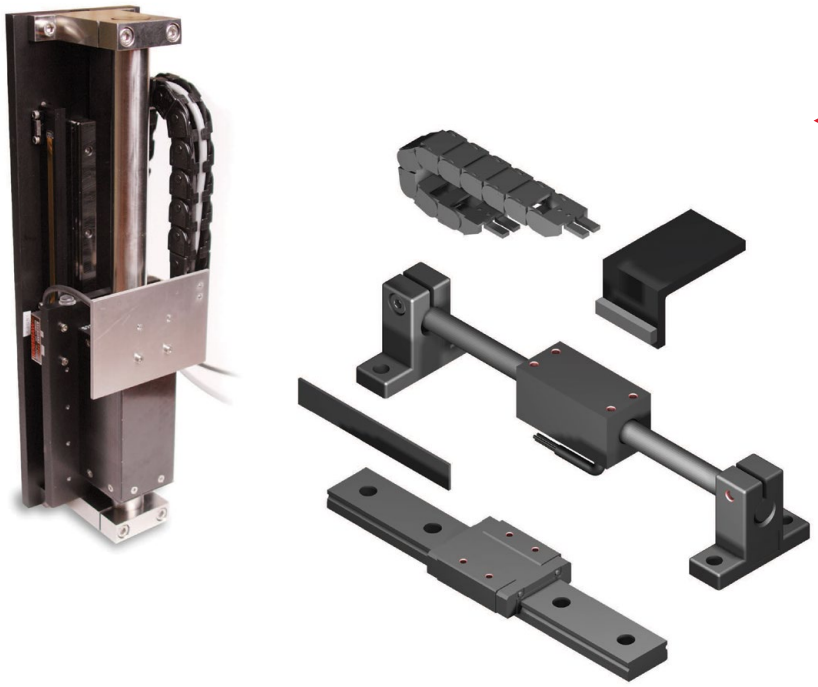
> Nippon Pulse offers its shaft motors as a total solution (in a complete actuator form), which some prefer for fast integration.

Linear shaft motors lend themselves to good electronics control for systems that support edge analytics and machine learning for predictive maintenance and other IoT functions. That's because (unlike actuators with no electronic capabilities) linear shaft motors allow elegantly simple data collection via electrical and electronic signals. No wonder hydraulic and pneumatic actuators are increasingly being replaced by electric actuators. Electric actuators (including those based on linear shaft motors) are capable of A-B (bang-bang) strokes as well as positioning over the full linear stroke.

Markets making the most use of edge computing and predictive maintenance (thanks to an ROI that justifies it) include:

- Automotive, where one minute of downtime can cost upwards of $50,000
- Semiconductor, where one wafer can be worth upwards of $50,000.
- Energy, where one system hiccup in the refinery, coke plant, or petroleum processing can cost tens of thousands of dollars

Other industries where linear shaft motors (along with edge computing) find use include medical-device manufacturing as well as laboratory automation.

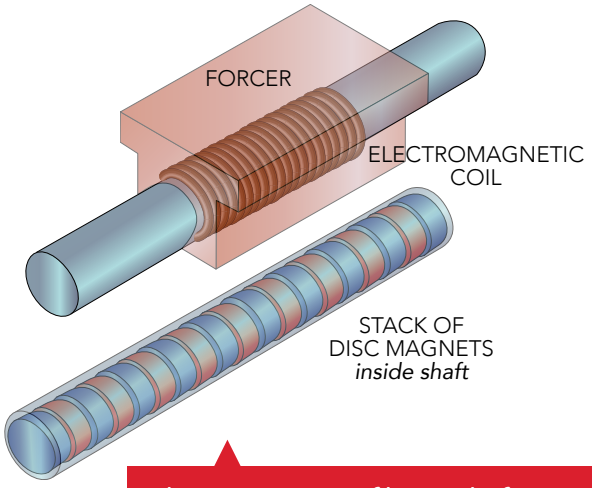


Nippon Pulse offers three pre-integrated linear-shaft-motor actuator options in a dozen standard shaft sizes (and more than 20 custom shaft sizes) in lengths to 2 m. These Nippon Pulse actuators include premium HEIDENHAIN or Renishaw encoders and THK or NB Corp. linear bearings. Of course, the encoder is ultimately what limits these actuators' accuracy. That's why Nippon Pulse offers actuators sporting cost-effective linear encoders having 1-µm encoders (standard) or 50 nm upon request.

HOW GOOD IS THE PERFORMANCE?

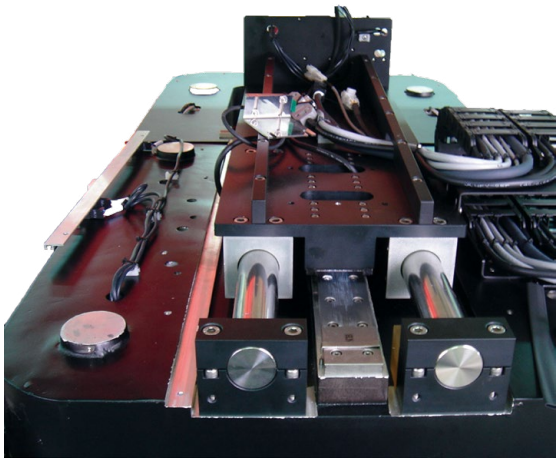
Linear shaft motors are quiet and exhibit zero cogging — and can move up to 10 meters per second even with heavy loads.

No cogging means linear shaft motors can deliver accuracies down to molecules wide — even to a few picometers in some cases. That allows their use in lithography (as used by Intel and Micron during semiconductor manufacture) where the accuracy of the moving tools must be controllable to within a couple nanometers. Strangely enough, the same exact linear shaft motors used in that application can also be used on arms loading bread ovens with 300-lb trays of raw dough.



The construction of linear shaft motors give them their inherently fine positioning capabilities. Image courtesy Design World

One last note: Though here we focus on how linear shaft motors can replace more traditional single-axis linear actuators, the linear motors often impart motion on multiple coordinated machine axes. Here, Nippon Pulse controllers (with command over four axes per chip) can be daisychained to allow coordination of four, eight, twelve, or even more extra linear axes. Linear shaft motors have been used in Cartesian (X Y Z) tables (used in all automated industries), six-axis robots (most common in life-science applications), and SCARA robot end effectors (so common for high-speed pick-and-place as well as other tasks in semiconductor production).



Linear shaft motor applications abound ... from medical designs to elevators to proprietary designs pushing tons of weight at high speed.

In one automotive-testing application, Nippon Pulse linear shaft motors test the four wheels of a Formula One racecar to simulate g forces that car will experience on the open track. Each linear motor repeatedly lifts the car from below with 3,000 N of power.