



## Robots in Motion: Innovations Move Forward

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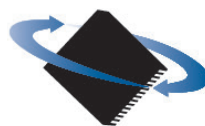
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# ROBOTS IN MOTION: INNOVATIONS MOVE FORWARD

*New robot designs are making motors and controllers smaller and more innovative.*

**By Phil Britt**

As more robots are deployed in factories, warehouses, and across new industries, finding ways to get them to move faster and correctly challenges both researchers and the robotics components creators. In this special report, we will give you highlights of the latest information around robotic motion, controls, motors, precision, as well as how innovations in robot designs are driving the market for servo drives and motors.

While they've always been important, motion control, servo drives and related components are becoming even more integral for robotics than ever before, as customers want robots that can do more work with robotic arms, or mobile robots that can deliver from place to place with even heavier loads.

The idea is to have the robots do more so humans will have to do less, alleviating humans of repetitive stress issues and traversing 10 or more miles a day in a warehouse. Beyond relieving humans of the much of the physical work, robots in motion are a necessity in today's growing e-commerce world:

- The robots can move faster and with more precision than humans – critical to meet the demands of a supply chain demanding faster deliveries.
- With unemployment near historic lows, there simply aren't enough humans to meet the demands in e-commerce and other industries.

As a result, there's growth and innovation throughout motors, servos, controllers and other related components that drive robots in motion.

## SERVO MARKETS, DRIVES

Servo control is used in industrial processes to move specific loads in a controlled system. The drive translates low energy controller signals into high energy signals to power the motor. The motor converts current and voltage from the drive into mechanical motion.

Earlier this year, Persistence Market Research predicted [the global market value of servo motors and drives](#) will grow at a compound annual growth rate (CAGR) of 8% percent for the next 10 years, reaching \$28 billion by the end of 2029. The firm said the market is expected to surpass \$12 billion by the end of this year.

Much of the growth will be in robotics “due to the unprecedented developments in the robotics industry and heavy adoption of robotic techniques in various end-use industries.”

The newer motors are smaller, better integrated and have much better precision than their predecessors, says Pras Velagapudi, director of engineering for Berkshire Grey. “The biggest change in motors and servos is that the motor drives are getting smaller,” said Velagapudi. “There’s also greater modularity in the systems we build. That way we don’t have to centralize all of the control hardware, we can distribute it.”

Another recent change is that drives and motors are integrated rather than separate, which reduces the complexity of the design and interconnections, according to Velagapudi.

## SUPPORTING HEAVIER LOADS



Image: Waypoint Robotics

Users want cobots and automated mobile robots that can handle heavier loads, which means motors need to be up to the task.

Jason Walker, co-founder of Waypoint Robotics, pointed to the customer need to move heavier loads as the driving force behind the introduction of MAV3K, the newest member of Waypoint’s industrial grade autonomous

mobile robot (AMR) family. MAV3K features a 3,000-pound carrying capacity and omnidirectional mobility.

The robot was in development from a couple of years so the company could incorporate all the features that users wanted, Walker says.

MAV3K comes equipped with Waypoint's Dispatcher software enabling users to set up and operate the robot within 15 minutes as well as batteries that enable it to run all day. Waypoint's EnZone wireless charging system enables MAV3K to charge itself. "The batteries and the motors are becoming more powerful and more efficient," Walker added. Sensors enable users to push or pull the robot with just a nudge.

Those moving heavier payloads also need motors with higher torque and motor density, said Zach Dydek, chief technology officer at Vecna Robotics. Increased simplicity is another factor, with motors built directly onto the drive shaft and other changes that help drive down the total number of parts, and therefore, the cost.

Locus Robotics has a different take on the heavier loads, recommending instead that AMR users employ multiple robots and split up the loads, said Karen Leavitt, the company's chief marketing officer. The reason is two-fold. With multiple robots, they can complete tasks faster and get products from one place to the next (i.e., warehouse shelves to shipping) so the next task can be completed more quickly, rather than waiting for larger loads. Secondly, robots with lighter loads are more nimble, and have less inertia.



Jason Walker,  
co-founder  
of Waypoint  
Robotics



Image credit: Universal Robots

Universal  
Robots' new  
UR16e can lift  
heavier loads.

Another advantage is that by staying with small robots and small loads, they can better maneuver in crowded aisles, Leavitt adds.

Locus recently changed from belt-driven motors to direct drive motors, which Leavitt says provides the robots with better precision in starting, stopping and positioning throughout the work area.

On the cobot front, Universal Robots unveiled its new UR16e, with a 16kg (35.3 pounds) payload earlier this year, up from the previous maximum of 10 kg. It is the company's strongest cobot ever, combining a high payload capacity with 900mm radius and +/- 0.05mm repeatability. This makes it ideal for automated tasks such as heavy-duty material handling, packaging, and palletizing, nut and screw driving, and high-payload and CNC machine tending. Like the rest of the e-Series, the UR16e has built-in force sensing, 17 configurable safety functions, including customizable stopping time and stopping distance intuitive programming flow.

The company was able to increase the payload without changing the motor by shortening the robot arm, says Edward Chan, sales support engineer.

The company's eSeries robots also feature the ability to monitor electricity loads centrally, eliminating the need for a load sensor at each joint. Instead, there's a single load cell at the very end. This means less rigidity, better fluidity and more accurate measurement.

## FRAMELESS MOTORS

There are times when a standard housed servo motor won't work, so users opt for frameless motors, which offer efficiency in many regards, greater system bandwidth, and a smaller footprint, says Tom Wood, a frameless motor product specialist at Kollmorgen. When the application calls for a compact, lightweight motor that delivers significant power and torque, Wood said frameless is the way to go. Frameless motors may also be as much as 20 decibels quieter in operation when compared to conventional servo motors, which depend on operating at 4,000 to 8,000 rpm and often depend on noisy gearing to develop useful power.



Tom Wood

The frameless motor has no couplings, belts or pulleys, so there is no lost motion, Wood explains. But to get the full advantage of these motors, they need to be designed with the entire interconnected system in mind, with performance requirements, safety, ease of use and maintenance taken into account.

Among the typical applications are:

- Joint motors – collaborative and industrial (geared)
- Direct drive – indexing tables and direct drive joint (waist axis)
- Traction/propulsion – direct drive and geared solutions
- Compact rotary to linear actuation (screw and belt drives)

Though there are new market entrants all of the time, Wood says users of frameless motors will want to partner with a frameless motor provider with a full understanding of the key types of motion in robotics and automation; knowledge of holistic motion system design for robotics and automation applications; and awareness of what pitfalls to avoid when designing frameless motor-based systems.

## BRUSHLESS MOTORS

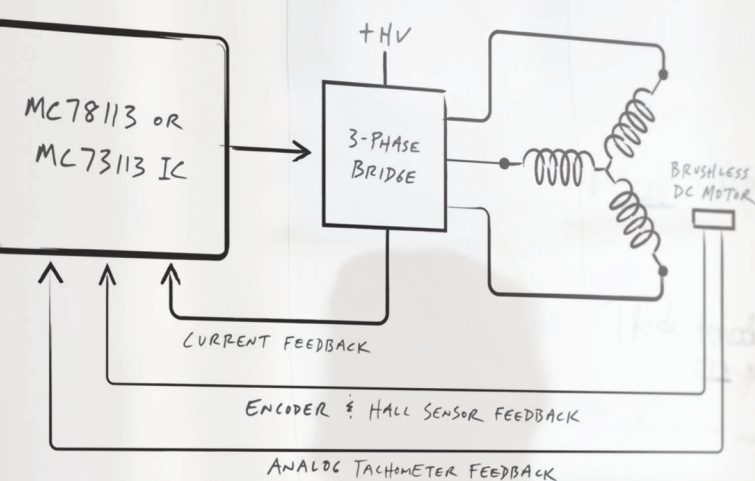
The global brushless DC motors industry garnered \$34.15 billion in 2018, and is estimated to reach \$71.94 billion by 2026, growing at a CAGR of 9.3% from 2019 to 2026, according to a report from Allied Markets.

One of the major drivers is expected to be increasing use of brushless DC motors for robots that create new opportunities in the industry. The inner rotor brushless DC motors segment to contribute the highest share during the forecast period.

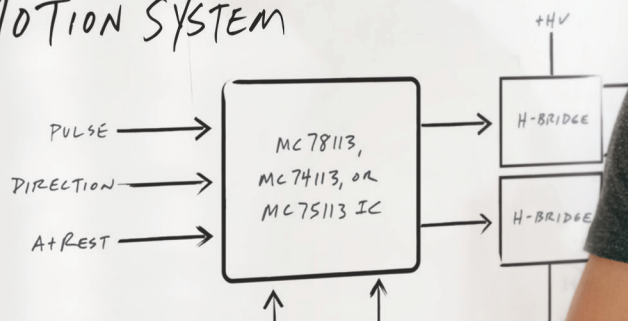
Based on rotor type, the inner rotor brushless DC motors segment will account for the major share in the global brushless DC motors market in 2018, contributing to more than two-thirds of the total share, and is expected to contribute the highest share during the forecast period. This is due to rising trend toward automation and technical improvements in industrial robots, the Allied report states.

Industrial machinery dominates this sector, and is expected to increase the application of brushless servo motors in various types of machinery such as labeling and packaging machinery, CNC machine tool, pick-and-place PCB assembly machines, and machinery in other industries such as textile and food.





## MOTION SYSTEM



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# CONTROLLERS

[Future Markets Insights](#) puts the robot controller market at \$632.6 million last year, and forecast a 9.1% CAGR growth rate between now and 2019, driven by adoption of human machine interaction, data and cloud capabilities boosting hardware control, as well as the optimization of industrial robot cost.

“For about 40 years, robots have looked the same, then in the last 10 years, there’s been a lot of innovation,” said Christian Fritz, director of sales (electronics and motion control), U.S., for Maxon Group.

In the past 10 years, new motion control architectures have been developed that offer reduced wiring and improved reliability, wrote Chuck Lewin, founder and CEO of Performance Motion Devices in an [article](#) on the company’s website.

Depending on needs, users can choose from:

- Multi-axis motion cards, which features straightforward, essentially automatic synchronization among axes;
- The stand-alone motor drive, also known as a smart amplifier. In this approach, the controller is a “box,” and is usually rack- or rail-mounted;
- A distributed drive, which combines the synchronization ability of multi-axis motion cards with the reduced wiring and increased robustness of stand-alone drives;
- An integrated motion card, which offers the advantages of reduced wiring combined with easy multi-axis synchronization by locating the amplifiers on the multi-axis card itself.

There is no single “best” approach, according to Lewin, adding that some applications may use multiple motion control architecture.

Choosing the right architecture is a matter of understanding the requirements of your application, Lewin adds. Many factors will impact the final decision in choosing the

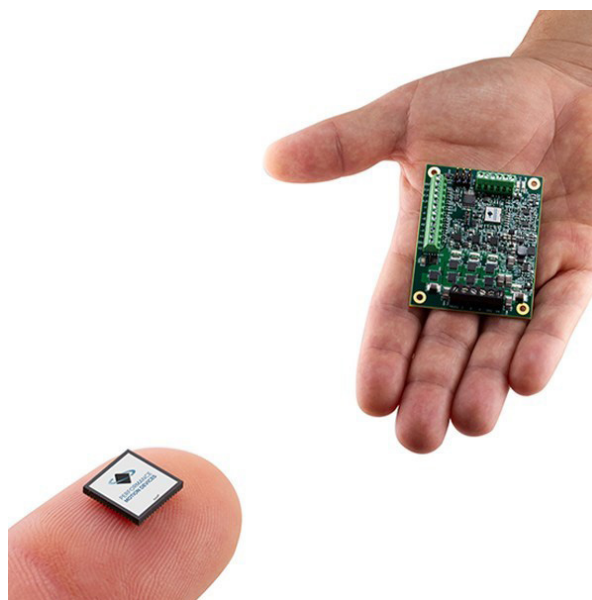


Image credit: Performance Motion Devices

correct architecture, including whether the axes are tightly synchronized or not, the total number of axes in the application, the desired system cost, the size of the machine, and whether more than one motor type will be used.

With changes in design and capabilities of robots, including more motion and collaboration, the motors and controllers for these devices had to change as well, with new designs, more force sensing capabilities, (to avoid collisions, particularly with working with humans, and for other uses), according to Fritz. “It used to be robots worked in a cage and did repetitive tasks really fast, now they need to be able to work side-by-side with humans, be able to sense their environment and do some of their own decision making.”

As a result, the controllers have more software, artificial intelligence, more communication with humans and with other robots and other devices. The gear boxes need to be able to handle higher torque as well as to change it quickly, meaning a faster loop control rate.

Controllers are continuing to become smaller, says Leith Nader, technical manager for Kawasaki. “They used to be the size of a refrigerator, now they’re the size of a handbag. There are fewer failure points and lower cost of ownership.”

The company’s F series controllers are designed to be the smallest and lightest in their class and are designed to enable users to digitally connect their machines and benefit from Internet of Things (IoT) technology. The Bluetooth-enabled controller allows for the collection and analysis of both robot and production data and provides the ability to link to the cloud, other robots or machines, tablets, vision cameras and various fieldbuses.

Nader said he foresees controllers eventually being incorporated into robotic arms, with more integrated components, though he doesn’t expect the controllers to get smaller than they are today.

## IMPROVED PRECISION

With less rigidity, the robot arms, with the right end effectors, can now perform higher-precision work, such as polishing an item.

Fewer load sensors also mean lower total cost, Chan says. “Load sensors are expensive.”

Improved precision was also the driver behind the development of Conic Systems’ new Lifetime (LT) Series, a precision, zero backlash harmonic

gearbox designed as a direct replacement for traditional high ratio planetary gearheads. The LT series is available in metric sizes and NEMA 17, 23, 34 and 42 frames.

The zero backlash characteristic is maintained for life, and high ratios of 50:1 to 200:1 are achieved in a single stage, thereby reducing length and weight as compared to traditional planetary designs, which require multiple stages. The proprietary harmonic and cup designs allows for a high number of teeth to be engaged, giving the LT Series higher torque and inertial loading capacity, along with zero backlash, repeatability better than 10 arc-sec.

In late September, Conic Systems unveiled its CSF-CR1 gearheads, featuring zero backlash harmonic gearing and an integrated cross roller output bearing. This high-performance harmonic gearing is designed for automation applications such as SCARA and gantry robots. The CSF-CR1 offers superior motion control with superb positional accuracy and repeatability to  $\pm 0.25$  arc-sec, the company says. An optimized tooth profile and wave generator shape are designed to provide a greater area of tooth engagement, high torque capacity and torsional stiffness.



## MAKING ADJUSTMENTS

Even with a variety of different options and sizes around motion components, users will often ask to make adjustments to fit a particular design, depending on the industry and robot type. Rene Ymzon, marketing manager at Advanced Motion Controls, discussed some of the needs of robots in different markets at the RoboBusiness CRO Summit earlier this year, including:

- For a warehouse robot, a customer needed drive traction wheels with safe torque off. Advanced Motion Controls added Safe Torque Off, with an extended operating temperature range to meet the customer's needs.



- For a cleaning robot, Advanced Motion Controls modified the servo drive interface so it could interface with the controller, while also using automotive-style connectors to increase IP rating to give the robot better autonomy. For a separate company that needed to power its cleaning robot's traction wheels, Advanced Motion Controls customized a 2-axis servo drive.
- For a collaborative robot arm, the company built controls to size and shape to fit in arm, incorporating the customers connectors as well as a way to supply power to and control the solenoid that activates a holding brake.

**About the author:** *Phil Britt is the owner of S&P Enterprises, and a technology writer who lives in the greater Chicago area. His work has appeared in several national technology, financial services and business publications, including magazines, newsletters, conference dailies and online sites.*



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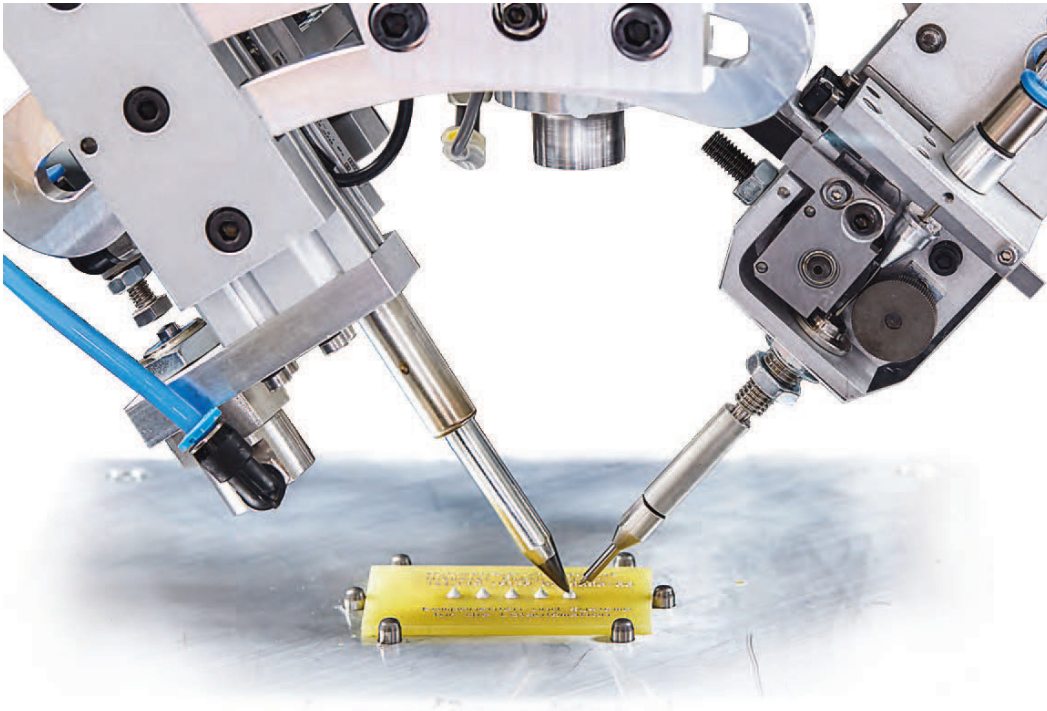
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## HOW ROBOT PRECISION HAS EVOLVED, ENABLING MORE USES

*From welding to robot-assisted surgery, robot precision is a critical enabling technology. Three experts explain the importance of accuracy and precision, the rate of change, and the market prospects.*

**By Kayla Matthews**

Robotics has evolved considerably over the past 70 or so years, becoming ever more capable, efficient, reactive, flexible, and precise. This robot precision is the key to future applications.

The earliest industrial automation took on repetitive tasks that didn't require high precision, such as painting car doors. As motion control, actuators, and other technologies progress, industrial robots can complete a broader range of tasks.

From materials handling and machine tending to working alongside humans in pick-and-place operations, robot precision is transforming the manufacturing, medical, and logistics sectors, among others. We asked three industry professionals about how robot precision has improved over the years, and what it needs to continue growing.

# TECHNOLOGIES THAT INCREASE ROBOT PRECISION

First, we must address the differences between robot precision and accuracy.

“Precision, also referred to as repeatability [in robotics], is the ability of an industrial robot to bring its end effector to the same position and orientation, over and over again,” explained Ilian Bonev, co-founder of the small robotic arm company [Mecademic Inc.](#) and a professor of precision robotics at the École de Technologie Supérieure (ÉTS or School of High Technology), part of the Université du Québec. “Accuracy is the ability of a robot to move its end effector to a desired position and orientation that has never been attained before.”

Technically, no robot or manufacturing process is 100% accurate, he said. There’s always some margin of error. The average positioning error of a robot determines its accuracy and the kinds of tasks it can perform. Over time, this average error has decreased dramatically due to various technological improvements.

“The main factor affecting precision in an industrial robot is the gearboxes in its joints,” said Bonev, who noted that factors like encoders and the rigidity of a particular arm will also affect robot precision. However, these are already fairly accurate or easy to improve, he said.

“The most precise gearboxes on the market are those from [Harmonic Drive](#),” Bonev said. “The gearboxes that we use from them were not available several years ago, so our [Meca500](#) could not exist, say, 10 years ago.”

Because Mecademic’s Meca500 is so small and rigid compared with other industrial robots, it is the most precise [six-axis industrial robot arm](#), he added. The longer a robot arm is, the larger the effects of errors in the gearboxes, according to Bonev.

Thus, as miniaturization benefits everything from cellphones to industrial and service robots, robot precision has been able to increase.





## LASERS, CONCRETE, AND SOFTWARE

Earlier technological advancements [included using a laser tracker](#) to increase accuracy. This tracker can measure the position of the robot arms, compare it with a programmed position, and then correct any error it detects.

The robot can perform these checks on a regular basis — often many times throughout completing a task — compensating for any errors and resulting in an overall more accurate system.

To improve accuracy, robot manufacturers and operators also need to consider external factors that may have an effect. These variables include payload and vibration.

A concrete foundation can help reduce vibration and keep robot arms steady. To avoid errors from excessive vibration, energy must be transferred through the robot's foundation and into the floor. Otherwise, it can harm robot precision. The arms also need to be designed in a way that reduces vibration.

Software also plays a role, as it controls the robot's movements. Developers often run multiples of an automation software program to ensure accuracy. In some cases, the software may need to make corrections for problems that arise.

A laser cutting robot, for example, might need to slow down to cut around a corner, but going slowly allows more heat to build up. The robot would have to be programmed to reduce power when it slows down to reduce heat.

## ROBOT PRECISION IN WELDING

Today, robots are accurate enough to perform wire welding along a seam, a job in which position, speed, acceleration, and deceleration all matter. They can even perform laser welding, which typically requires extreme precision.

“The precision in robotic soldering today is not only limited to a handful of precise



Image credit: Hirebotics

*In welding, robots require position, speed, acceleration, and deceleration.*

applications,” said Gerald Gardener, senior technical application specialist at [Weller](#). “Every aspect of each solder joint can be precisely controlled.”

For example, Germany-based Weller’s automated soldering options are able to precisely control everything from the angle of the soldering iron and the temperature to the speed and amount of solder fed into each joint.

“It’s this number of highly controlled variables that results in a precise soldering process,” Gardener said.

However, this level of robot precision has been at close to today’s level for a while. That’s not to say that precision in robotics today isn’t good. It is, in fact, very good.

As an important component in the success of robotics, robot precision and accuracy were honed relatively early in hardware and software development. Such industrial robots still function well, even in many of today’s advanced automation applications.

## COBOTS AND THE PACE OF CHANGE

Mathieu Bélanger-Barrette, senior production engineer at collaborative robot company [Robotiq](#), pointed out that core subjects like robot precision don’t undergo much innovation over time, even though the robotics industry as a whole may seem to be advancing rapidly.

He acknowledged that his views on robot precision, as someone who works with cobots and grippers, may be somewhat different than engineers in other industries. He says:

“In my opinion, accuracy is a concept that totally doesn’t need to exist in collaborative robots,” Bélanger-Barrette said. “In fact, such modern robots only [need to be repeatable](#) — place the part at the same time, each and every time.”

“The thing is, the robot is programmed by human guiding, so it needs to perform a task as it’s been shown to do it,” he said. “It needs to repeat the same process again and again. However, if the robot encoder are off by a centimeter ... it doesn’t change a thing for the user.”



*Because a human can assist a cobot, they don’t necessarily have to be as precise as other robots.*

Although robot precision might not be as big of a deal for cobots as for other automation, Bélanger-Barrette said that cobots now have more sensors to make sure that they are [accurately perceiving](#) their environment, making them more precise.

“They have sensors to tell them what force they are applying on a certain surface, but also sensors that allows them to see what kind of part they are going to grab,” he said.

“I think the next step in accuracy is to refine the sensors so much that it will be easy for a robot to perceive the real world,” Bélanger-Barrette said. “If you can accurately identify an object, it is easier to deal with it.”

“I think that robot manufacturers such as Universal Robots or Techman Robot [that have very poor accuracy in position] are starting to apply this concept by implanting sensors in their robots,” he added. “UR, for example, now has an embedded force torque sensor and can execute tasks that were impossible before. TM [is] opting for the vision solution that allows them to program their robot with the sense of sight.”

Bélanger-Barrette said he thinks that not only will robots become more position-accurate, but they will be able to better interpret their surroundings. This development could be “the game-changer in future robotic applications,” he said.

## MARKETS FOR ADVANCED ROBOT PRECISION

Despite a slow rate of innovation, robot precision has come a long way since the early days of industrial automation. Today, robots increasingly [assist in sensitive surgeries](#). A hospital in the U.K. has tested a robot that can perform a delicate eye surgery. The study found that the robots were [10 times more precise](#) than a human surgeon. The robot can make movements that are accurate within 1 micron.

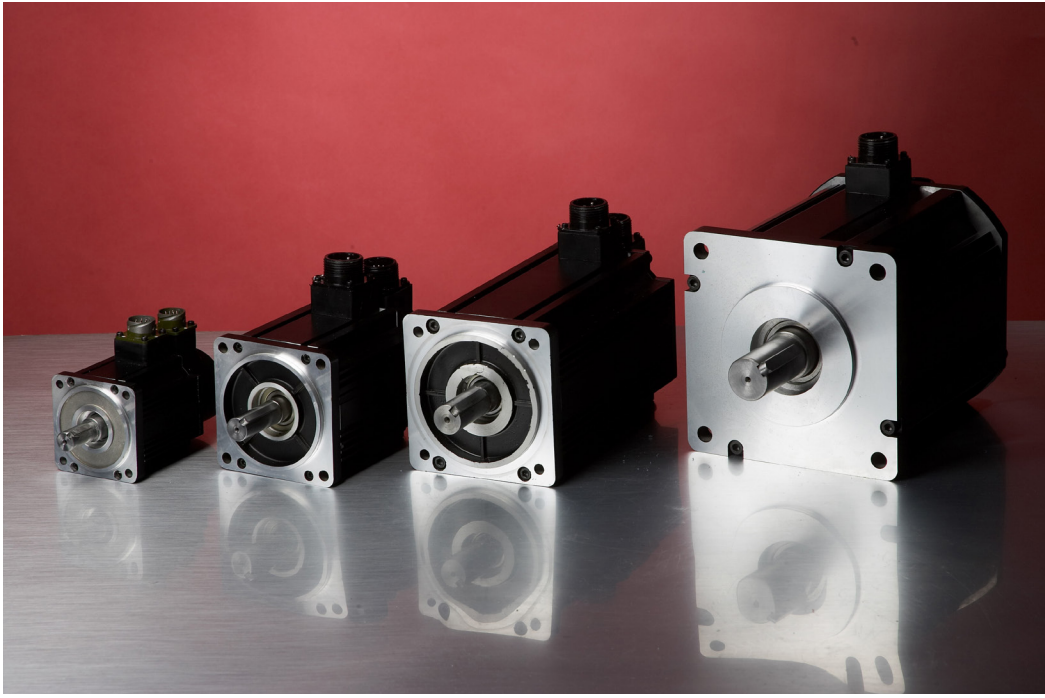
As technology progresses, robots are becoming even more precise — and more commonplace. The global robotics market is expected to increase to approximately [\\$67 billion by 2025](#), up from about \$15 billion in 2010.

Today’s robots of today can perform much more detailed work than their predecessors. The cobots and [service robots](#) of the future will be able to do complex tasks more accurately than humans can, agreed the experts.

**About the author:** Kayla Matthews is a technology journalist and robotics writer whose work has appeared on Vice, VentureBeat, RoboticsTomorrow, and Robotiq's blog. To read more posts from Kayla, visit her blog [Productivity Bytes](#).







## STEPPER MOTORS: THE KEY TO ACHIEVING MOTION CONTROL

*A quick primer on the different types of motors and how they are important in achieving precision.*

**By Jeson Pitt**

One of the most essential parts of a motion control system is a stepper motor, an electromechanical tool that transforms electrical power into mechanical power. Similar to a switched reluctance motor or a legacy AC induction-type motor, the rotation of a stepper motor can be easily controlled with a certain degree of precision. This gives the motion control system the potential to break up a complete rotation into various steps.

Known as a type of DC synchronous motor, a stepper motor has the power to immediately produce complete rotation, even when not running. This is why they are largely used in motion control applications. What's adding to their popularity further are dedicated stepper motor driver cards that enable interfacing to PC-based systems.

In this article, we will examine the different types of stepper motors, as well as the different operating modes. You can choose from different types based on your requirements, including:

## 1. PERMANENT MAGNET

Using a rotor's permanent magnet (PM), this type of a stepper motor runs on magnetism and repulsion between the PM and stator electromagnets. Also known as the tin-can or can-stack motor, PM motor is one of the most common motor control types of stepper motors, which has 48 to 24 steps for every revolution. What makes this kind of stepper motor popular is its low cost of manufacturing.

## 2. VARIABLE RELUCTANCE

Variable reluctance is a basic type of stepper motor, which makes it easier to understand the principle of operation from an organizational angle. This type of motor control works on the principle of "minimum reluctance comes with minimum gap," and has a plain iron rotor.

These types of motors are named "variable reluctance" because the rotor's position varies according to the reluctance of the motor circuit, which forms between the stator teeth and rotor teeth.

## 3. HYBRID SYNCHRONOUS

The most accepted form of a stepper motor is a hybrid synchronous stepper motor. It uses the best of both permanent magnet and variable reluctance stepper motors. A hybrid synchronous stepper has a permanent magnet core rotor and a circumference made of plain iron, which also has teeth.

Having high angular resolution and high rotation, a hybrid synchronous motor offers improved performance over a permanent magnet in terms of [industrial motor control](#) and step resolution.

Now that you understand the different types, let's look at the operating modes:

### 1. Full Step Mode

The rotor moves through 200 steps during each rotation of 360° of the motor channel. Each degree measures 1.8°, to be precise.

Two stator phases get energized during full-step operation, which ensures maximum torque. However, the number of rotor teeth may affect the angular resolution.

## 2. Half Step Mode

In this case, the rotor moves through 400 steps during each rotation of 360°, where each step equals 0.9°. Either one or two phases on the stator get energized to offer almost two-fold improved angular resolution, which brings higher accuracy in position and affects torque.

## 3. Micro Step Mode

In the micro-step mode, the rotor moves through 51,200 steps and each step accurately measures 0.007°. A stator phase may get energized, de-energized or partially energized. The micro-step operation is required in case of applications that demand accurate positioning. You can reduce the torque rating by up to 30%.

## CONCLUSION

Selecting a stepper motor for motion control requires proper analysis of the torque-speed curve of the motor. It's important for the torque-speed curve to match the application requirements, in the absence of which the system will not deliver its best performance.

**About the author:** *Jeson Pitt works with the marketing department of D & F Liquidators in Hayward, Calif., and regularly writes to share his knowledge while enlightening people about electrical products and solving their electrical dilemmas. Jeson lives in Hayward and loves to explore different cuisines that the food trucks in the Bay area have to offer.*

