machine design
BY ENGINEERS FOR ENGINEERS

FEBRUARY 2016
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Internal Returns

Drive Ball-Screw Performance

p|24

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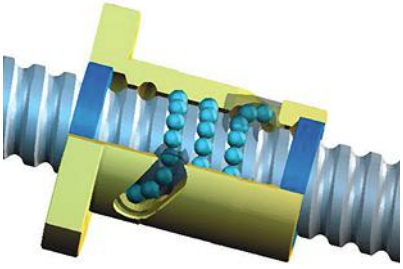
In This Issue

FEATURES



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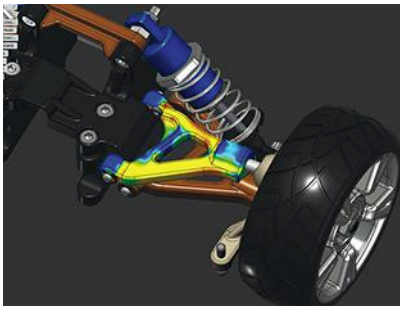

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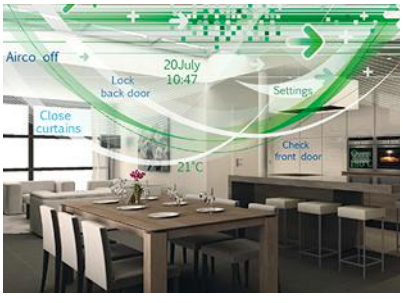

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DEPARTMENTS

COLUMNS

ON THE COVER: A ball screw from Steinmeyer Inc. with a through-the-nut Ultra-Fast ball return.

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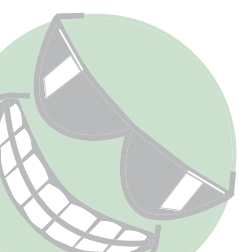

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INFORMATION SUPERHIGHWAY GOES OFF-ROAD

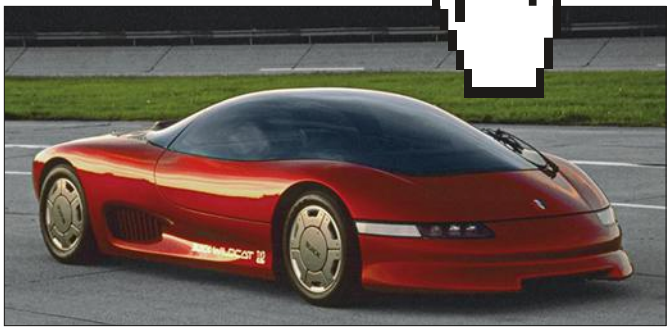
http://machinedesign.com/iot/information-superhighway-goes-road

The value proposition for the Internet of Things (IoT) in heavy construction and mining equipment encompasses increased productivity, decreased down time, and a healthier bottom line.

SHEDDING SMART LIGHT ON SLEEP DISORDERS

http://machinedesign.com/iot/shedding-some-smart-light-sleep-disorders

The Smart Lighting Engineering Research Center at Rensselaer Polytechnic Institute developed, and subsequently delivered, its first inpatient testbed for monitoring the effects of LED lighting on psychological and neurological health. An addition to the inpatient sleep laboratories and sleep-medicine clinics at the University of New Mexico Health Center in Albuquerque, the testbed will be used in clinical research led by a team from the University of New Mexico.



KING OF THE CONCEPT VEHICLE

http://machinedesign.com/blog/buick-king-concept-vehicle

Concept vehicles have long been a good idea for both car companies and consumers. They let carmakers show off new engineering tricks and technologies, as well as potential style and color trends without committing to actually manufacturing the car, truck, SUV, or whatever. At the same time, they give car buyers a peek at what auto engineers are capable of and the styles and designs those engineers believe are trending. Find out why Tech Editor Steve Mraz crowns Buick the king of the concept vehicle.

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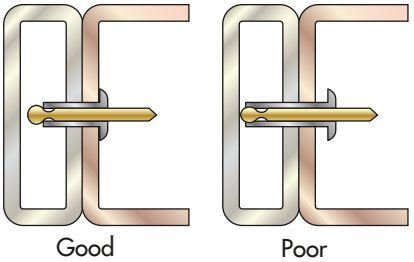
4 TIPS FOR STRONGER BLIND-RIVET JOINTS

http://machinedesign.com/fasteners/4-tips-stronger-blind-rivet-joints-0



When using blind rivets in product design, engineers need to pay close attention to these four over-arching rules:

- Select setting tools carefully.
- Select rivet size and mating joint elements for maximum strength.
- Match rivet material and type to joint materials.
- Match rivet length to joint thickness.

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Editorial

JEFF KERNS | Technology Editor
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Is the Death of the American Garage Inevitable?

When looking at the origins of American innovations that have developed a part of our culture and a large part of our economy, time and time again we find a garage with someone tinkering inside. With this in mind, Bob Swartz of Impossible Objects asked me, "What's one new invention that a large corporation has presented in the last 20 years?" I wasn't able to answer off the top of my head. So, if our innovative culture is still being forged inside the garage, could service agreements, warranties, and complex electronics end the innovative culture that has led the United States to so much success?

There always seems to be a call for more hands-on experience, or someone who isn't afraid to mechanically explore (tear apart) and observe the world around them. However, I feel it is not just an American culture, but an animal instinct to push limits and build; to be fearless of failure, and curious of the world around us. The world is constantly changing and so must tools and inventors. Today, open-source electronic boards and 3D printers are inspiring a new generation of inventors.

Inventors are being rebranded as "makers." The "garage" is turning into collective spaces, such as tech shops, hacker spaces, and maker spaces. Programs like Baja and Formula 1 SAE, FIRST Robotics Competition, Idea Labs, and Hack-a-Thons are inspiring young engineers. There are crowdsourcing sites that compile ideas and problem-solving in new ways. While this new breed of maker might not be taking apart cars or phones, they are exploring, observing, and tinkering.

An open-source mentality is changing the scene, too. Having an Arduino or other open-source tool with an online library can help a beginner or professional start building an idea. Some companies resist, holding tightly to their intellectual property, while others have decided to loosen their grip. There is a hybrid strategy that helps makers tinker and expand the technology while providing protection and control to the companies that own it.

With unknown budgets and return on investments, tinkering might be too uncertain for corporations. But discouraging these new inventors with closed-source technology won't lead to the death of the American garage, but rather, the downfall of corporations. Big Business is also starting to see this, as companies sponsor competitions and events for them. The American garage and our innovative culture are not dead. It has diversified into smaller segments. Ranging from anyone who has a drawer full of old electronics and a soldering gun, to collaborative massive warehouses filled with people from all over the globe that meet and tinker, the American garage is the melting pot of culture and sciences. If people want to support jobs and innovation, they need to support the thought creators, and those who tinker. Our future is in the hand of the wrench holder. md

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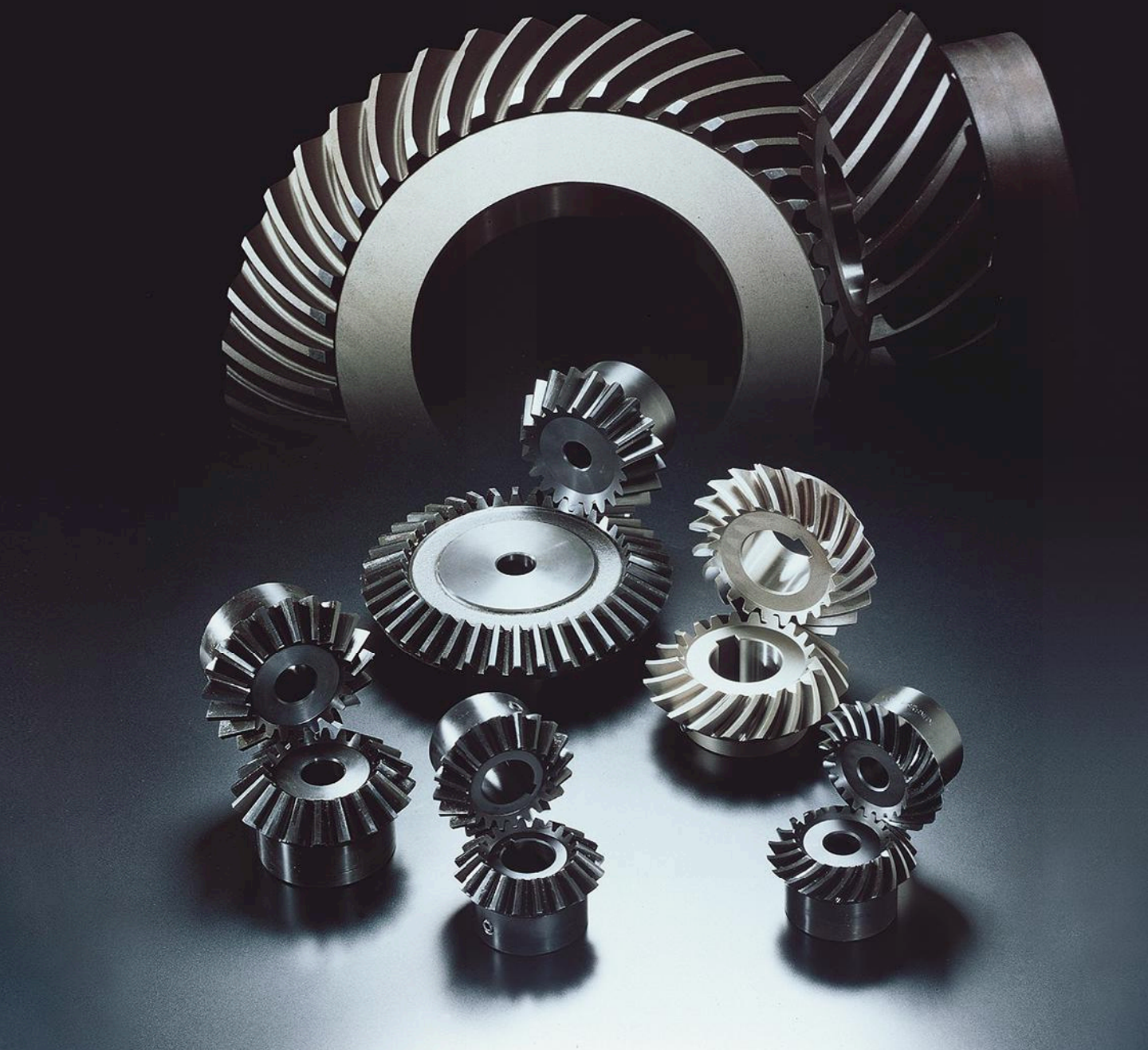

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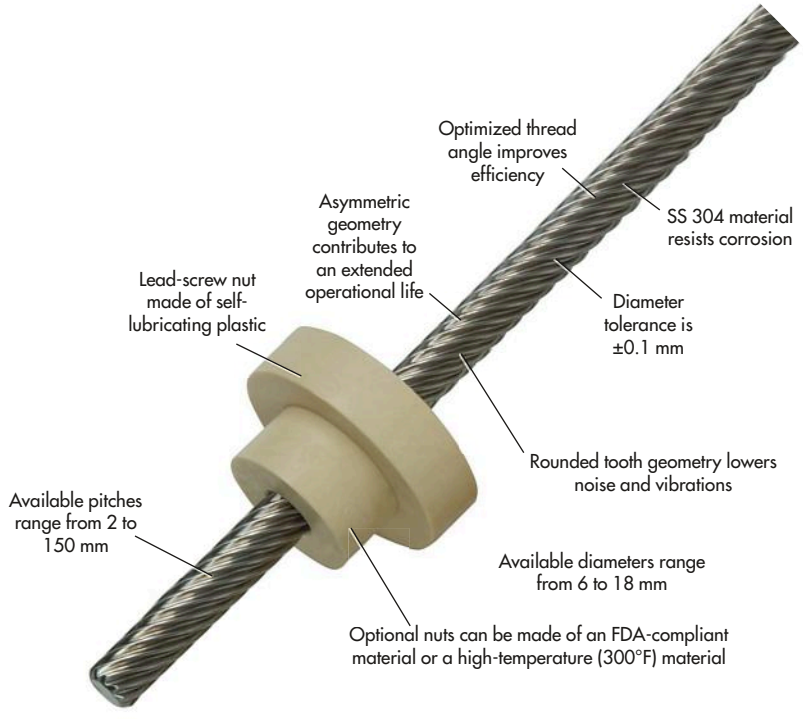
Lead Screw Uses Plastic Nut to Eliminate Lubrication

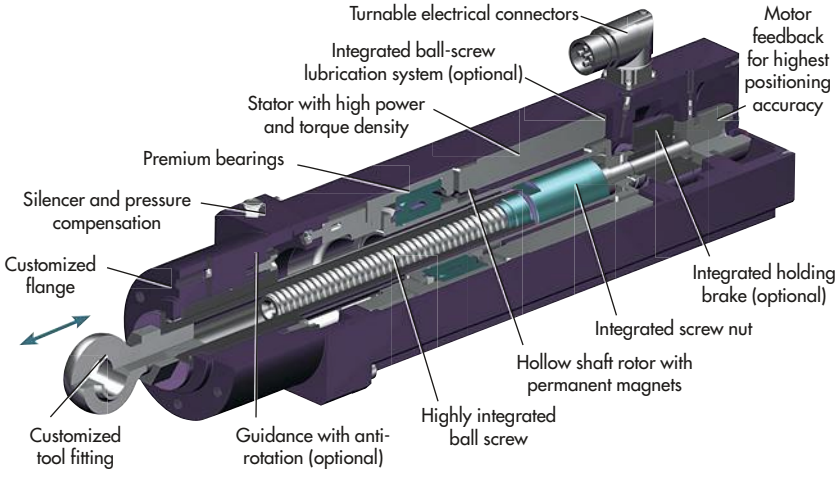


LEAD SCREWS FROM igus (*www.igus.com*), Providence, R.I., use high-performance self-lubricating plastic material nuts, eliminating the need for lubrication and making the motion-control devices suitable for clean rooms and other hygienic environments. Matching plastic nut and spindle properties offer excellent service life and high efficiency for high-helix lead screws.

The lead-screw nut withstands temperatures from 32° to 122°F, but a high-temperature version is available that handles temperatures to 300°F. An FDA-compliant nut is also available. Backlash can be minimized by using the optional zero-backlash thread nut with built-in spring pretension from igus. Lead screws can be up to 3,000 mm.

The rounded tooth flanks on the shaft reduce the contact area between the nut and screw. This reduces noise and vibration. md

Linear Actuators Optimal in Standard or Extreme Applications



HIGHLY COMPACT, HIGH torque, customized—these are three outstanding attributes of the linear actuators used for cyber force motors in a wide range of applications. They are just as impressive at assembly workstations as they are in complex mating and pressing processes; in capping systems for filling and packing food and beverage products; when reshaping plastic film or metal sheets; or for closing and dispensing axes in injection-molding machines.

The **WITTENSTEIN** (*www.wittenstein-us.com*) cyber motor builds screw-type actuators based on a modular system with customized sizing and configuration. Flange sizes range from 40 mm to 270 mm, with maximum linear speeds of up to 2 m/s, and maximum forces of up to 750 kN (170,000 lbf). Motor winding and ball-screw pitch selection are optimized to design the perfect linear actuator for every application, minimizing footprint while maximizing efficiency and reliability ratings. Operating temperature may range between –40° and +300°C.

The linear and combined linear-rotary actuators of cyber force motors are well established as compact, ready-to-mount, and technically and commercially optimized solutions. Due to their modular design, these actuators can be adapted to almost any requirements. They meet application needs without compromises—and with benefits that directly impact cost of ownership.

For more information about WITTENSTEIN cyber motors, contact will.vinson@wittenstein-us.com. md

News

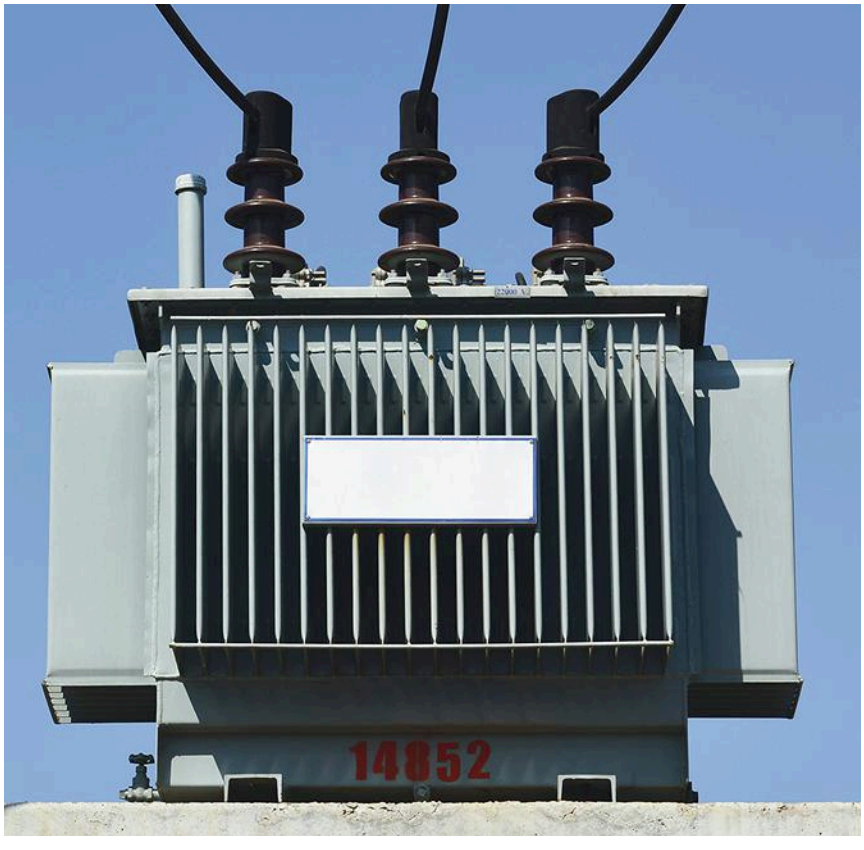
High-Efficiency Transformer
Promoted for Sub-Licensing Contract

After recently taking ownership of the worldwide license and marketing rights for PowerWinding E Transformers, InventionShare is now looking to offer an exclusive license with sub-licensing rights to a single partner. It's also offering sub-licenses to non-competing transformer manufacturers in vertical and geographical markets. The transformers are claimed to achieve high energy efficiency for high- and low-power applications while using fewer materials than standard transformers, thus lowering manufacturing costs.

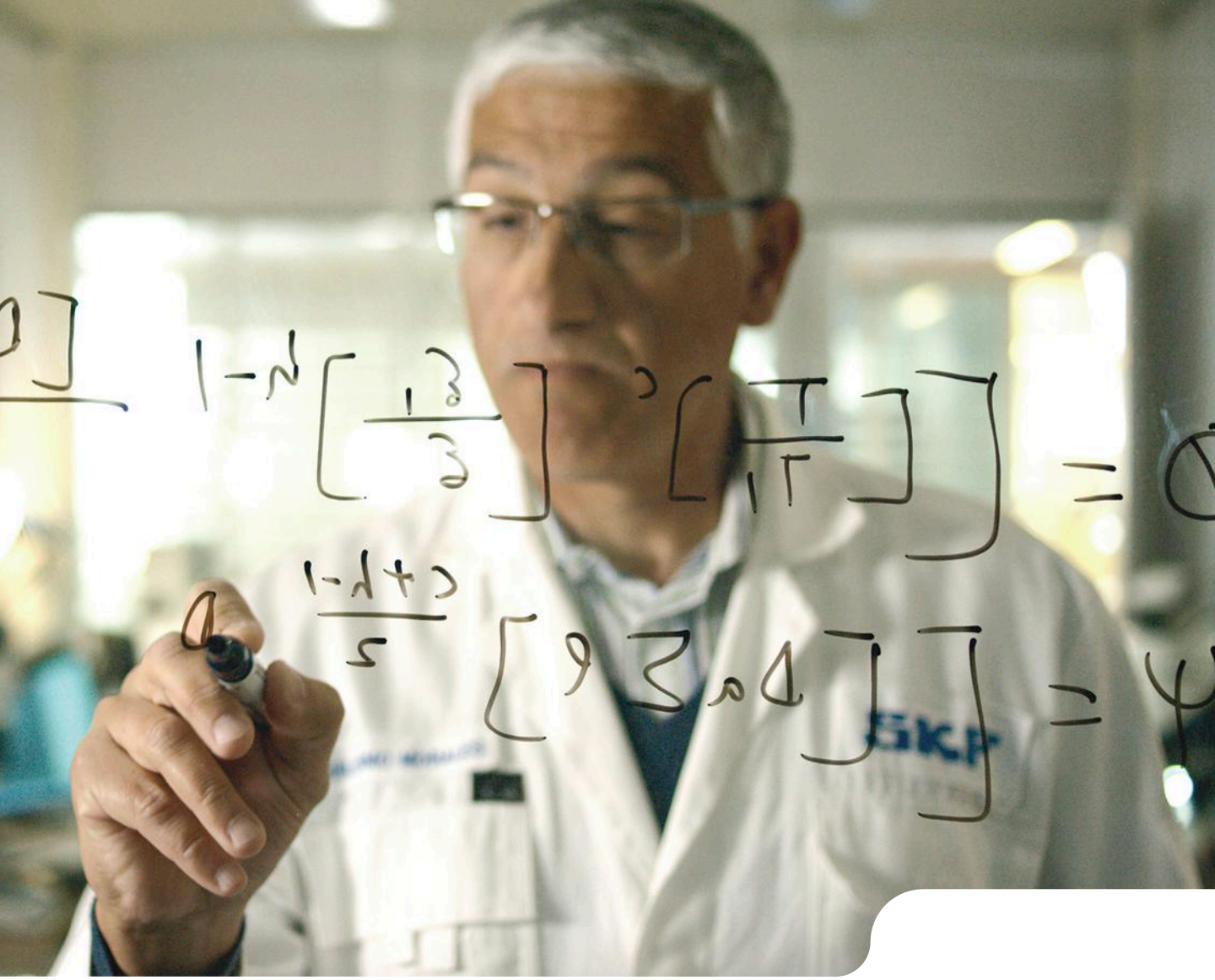
Bench tests show a 35% decrease in iron-core and winding materials to get the same output as standard transformers in the same application. Due to a shorter winding length for the same output, the transformers feature increased capacity and reduced losses. Yuanxun Evan Wang, UCLA Professor of Engineering, obtained the same result in a Maxwell software simulation: Efficiency versus input voltage increased by 5.74%, and the output-power-to-input-voltage average ratio surpassed that of standard transformers by 63.7%.

The design dissipates less energy to heat, thus suiting it for the micro-transformer market. InventionShare and the two inventors of the design will continue research to bring the design into the grid transformer market.

Patent and test results are available to interested parties by contacting Kensel J. Tracy, V. P. Invention Catalyst. ■



Though the transformer technology currently targets micro transformers, InventionShare anticipates that further developments will make it useful in large grid transformers.



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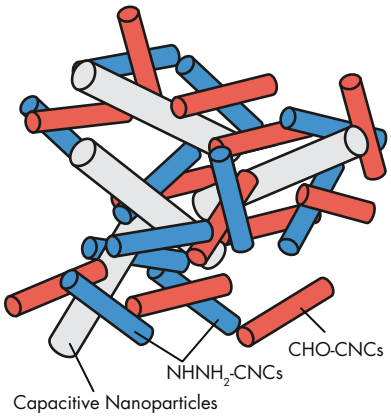
CELLULOSE SUBSTRATE Eyed for 3D Supercapacitor Technology

AS TECHNOLOGY FORGES ahead, design engineers also continue to search for sustainable solutions to benefit future generations and minimize negative effects on the environment. To that end, engineers at McMaster University are currently researching cellulose's capabilities as a substrate for conductive nanoparticles as they look to reform supercapacitors and regenerative-energy technology.



The self-standing cellulose 3D superconductor does away with binding materials that would otherwise increase the weight of the material.

According to the abstract of the report in Advanced Materials, the cellulose-based supercapacitors demonstrate "excellent capacitance retention, low internal resistance, and fast charge-discharge rates."

Cellulose, a renewable and sustainable material found in the cell walls of plants, algae, and bacteria, has been widely analyzed as a substrate in nanotechnology. But methods to seed cellulose with functional nanoparticles are often complex, requiring the use of heavy binders and complicated preparatory cellulose-coating processes. Furthermore, additives are often required to make the cellulose aerogel self-standing; these, in addition to functional particles, increase the weight of the aerogel.

The McMaster team presents a one-step method to seed cellulose gels with conductive nanoparticles during construction of the gels. The resulting lightweight conductive aerogel can be formed into a range of different 3D, self-standing shapes with high resilience and flexibility.

The conductive aerogel consists of cellulose nanocrystals and nano-conductors that are crosslinked in a random, net-like arrangement to create a porous aerogel. This new in-situ approach preserves the porous microstructure, shape-recovery abilities, and mechanical properties of a pure cellulose-nanocrystal aerogel. ■

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REPLACING PNEUMATICS with Electronic Motors Enhances Construction Gripper

IN LARGE MACHINERY such as construction vehicles and pounding machines, pneumatics may be chosen over electric-motor actuation for their holding strength, energy density, and robustness in applications with high force ratings. Smaller cylinders can also be candidates for use in precision devices. However, designers often opt to use electric motors in sensitive applications that require a wide variation in force because they are easier to maintain and fine tune. Designers at Keller HCW made several observations when they replaced pneumatic actuators on their robotic gripper with 12 electric motors from LinMot.

The robot gripper developed by Keller HCW uses linear motors to safely and gently pick up even sensitive products and group them prior to setting them down.

(Courtesy of Keller HCW)

The LinMot PS01-37Sx120-HP-N linear motor from the PS01 series takes up very little space and has a large stroke and high maximum force. *(Image source: LinMot)*

The linear motors are actuated by compact and lightweight servo controllers from LinMot that use ProfiNet interfaces.

(Courtesy of F. Rossmann)

As demonstrated at the Automatica show in Munich this past spring, replacing pneumatic cylinders to direct-drive linear motors enables Keller HCW's robotic grippers to safely pick up objects ranging from bricks to champagne glasses and tissue packs. In practice, the upgraded gripper is suitable for lifting and aligning bricks of various types during construction. The company also recognizes the upgrade for its improvements in functionality, maintenance, repeatability and precision, and energy efficiency.

With stroke adjustment restricted to a mere 10 mm, the use of pneumatic cylinders limited the gripper's ability to grasp bricks of different sizes, shapes, and cross-sections. As a result, builders were required to switch out the grip ends between tasks, which increased work time and ultimately wasted worker and mechanical energy. The cost of four or five additional gripper types also contributed to the expenses of construction. It was proposed that a rotary servo drive be used to adjust the stroke length for improved variability in grasping, but this solution does not eliminate the problem of adjustment repeatability.

Continued on page 19

SHEDDING SOME SMART LIGHT on Sleep Disorders

THE SMART LIGHTING Engineering Research Center (ERC) at Rensselaer Polytechnic Institute (RPI) developed, and subsequently delivered, its first inpatient testbed for monitoring the effects of LED lighting on psychological and neurological health. An addition to the inpatient sleep laboratories and sleep-medicine clinics at the University of New Mexico Health Center (UNMHC) in Albuquerque, the testbed will be used in clinical research led by a team from the University of New Mexico (UNM).

"Knowing more about the effects of lighting may actually help physicians prevent disease and increase productivity in healthy persons," says Lee Brown, M.D., professor of internal medicine and director of the UNM Health Sciences Center's Sleep Disorders Program.

The first experiment will study variations in light spectrum throughout the day and its influence on sleep behavior in patients with delayed sleep-wake phase disorder. Later experiments may focus on other circadian rhythm disorders, depression, and neurological disorders such as Parkinson's disease.

The ERC's fully automated and programmable lighting system can also be set to respond to stimuli, such as weather changes and sunlight, to provide light at different frequencies, spectra, intensities, and directions throughout the day. The system integrates feedback sensors to ensure that light settings remain correct during testing.

Smart-lighting systems from the ERC can be fine-tuned to display a range of colors at different intensities and angles. The new testbed the University of New Mexico Health Center will use such a system to study the effects of LED lighting on human behavior and mental health. *(Courtesy of the Smart Lighting Engineering Research Center (ERC) at Rensselaer Polytechnic Institute)*

"At the ERC, we are building smart lighting systems that automatically adjust the right lighting for us at any given time, with light coming from the right direction, with the right color and intensity, optimized for human health and productivity," says ERC Director Robert Karlicek.

Funded by the National Science Foundation, the ERC is an interdisciplinary, multi-university center with members from academia, industry, and government who work together to develop automated lighting systems. Smart lighting systems from the ERC are intended to reduce the carbon footprint of homes and offices, creating smart agricultural settings, finding innovative medical testing and procedures, and other applications. ■

Continued from page 17

Since the behavior of the pneumatic cylinders is highly influenced by environmental factors such as air humidity and ambient temperature, it is extremely difficult to predict how the cylinders will react to any adjustments. By replacing the cylinders with motors, the system is less affected by the surroundings. They also respond to feedback and enable incremental adjustments with acceptable repeatability.

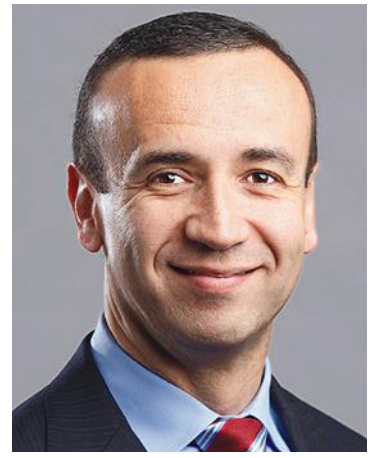
"Linear motors can be controlled more precisely and are more dynamic than pneumatic drives. They can also cover a much longer stroke in a short time," says the Keller specialist for automation and electrical engineering.

One may inquire whether the switch to electric motors from pneumatics affected the strength and holding force of the gripper. Though it's been established that variability in strength is achieved by the motors, the designers ensure that force is not compromised. The design employs 12 PS01-37Sx120-HP-N LinMot motors that can achieve a maximum stroke of 120 mm with incremental stroke lengths, and a maximum force of 122 N with an especially compact form factor.

To reduce manual control, the motors are actuated via 12 ProfiNet servo controllers from LinMot's C1100 series. The system includes a user interface so that brick arrangements can be directly inputted for automatic pick-and-place. The grip force and stroke length is controlled directly through the interface. The motors are positioned directly on the gripper jaws for a fairly compact and lightweight finished design. In the next model, Keller HCW plans to incorporate LinMot multi-axis modules or distributed motors with integrated drive electronics onto the gripper to further reduce the final product's weight and space occupied on the gripper. ■

Interview

JON DESOUZA | CEO, HARTING USA



The Growth of IIoT and the Role of Connectors

Please tell me a little bit about yourself and your background with HARTING Inc.

I joined HARTING in December of 2008 as head of HARTING's North America sales and business operations and was appointed the president and CEO of HARTING Inc. of North America in 2013. The last years were very exciting as we gained significant market share and triple-digit revenue growth by designing and executing an extensive restructuring process and business development plan. We focused on educating the industry on new technologies, which resulted in a shift to connectorization in industrial applications. Today, HARTING is positioned as one of the leaders in industrial connectivity across North America.

How long has HARTING been a leader in the world of heavy-duty industrial connectors?

HARTING was first established in 1945 in Minden, Germany. Now HARTING Technology Group is a global connectivity company and is still owned and managed by the HARTING family, with 13 manufacturing facilities in 11 countries and subsidiaries and branch offices in 43. While the company has diversified into device and PCB connectivity, Ethernet, RFID, and other future-looking technologies, industrial connectivity remains the main focus. Vertical integration allows the company to have in-house-expertise in various interrelated technologies such as PCB simulation and metallurgic.

We have taken a step beyond connectivity where we were able to design and manufacture custom and complete solutions to our customers, such as connectorized enclosures, cable assemblies, and backplane systems. That kind of commitment has made it the world leader in heavy-duty connector sales. HARTING spends an amount equal to about 6% of its annual sales on R&D. It holds more than 1,700 patents, 100 registered designs, and 760 trademarks. In Europe, Asia, and in some North America markets, "Han" is used as a noun, like Coca-Cola or Kleenex; another way of saying "heavy-duty connector."

What industries use HARTING products?

HARTING connectors are dominant in the machinery, robotic, and transportation industries, from auto assembly plants to high-speed trains. HARTING's products include electrical and electronic connectors, device terminations, backplanes, network components, as well as cable harnesses for networks and machinery, and for power and data application in factories.

HARTING hosted an Industrial Internet of Things (IIoT) Panel in the fall of 2015 to help introduce the topic to its employees and customers. How does HARTING see the future of IIoT?

The Internet of Things is swiftly gaining momentum in North America's industrial markets. It's primarily driven by the need for automation, smart-factory (predictive maintenance), and communication between the factory (hardware) and IT (software). U.S. companies recognize the opportunity to improve efficiency through automation of the manufacturing process. Companies are beginning to realize the opportunity for improved productivity and cost savings by adopting plug-and-play industrial technologies. Entry-level contractors as opposed to highly skilled electricians/technicians, which allows for higher efficiency and cost savings, can easily install products. Furthermore, these products will eliminate or reduce the need for additional components, such as rigid or semi-rigid conduits that protect point-to-point wiring from damage that would require extensive re-wiring.

What role does HARTING have in the IIoT world?

Industry 4.0 is changing the world of manufacturing and this major technological shift is bringing change to manufacturing systems and industrial devices. HARTING connectors are accompanying these changes—by

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Han connectors with built-in RFID transponders can communicate with mobile devices to provide data and information.

simply being integrated in industrial devices. The HARTING approach remains unique: Taking a standardized work plan on the basis of Business Process Model and Notation, and using it directly to control the work sequences of a machine. What is new is the higher degree of modularization within the cells, on the basis of production components with the standardized interfaces of the Han-Modular connector system. This fulfills the basic requirements for the implementation of plug-and-play applications in the future.

Extended machine visualization allows improvements in direct control. The whole plant is now connected over the HARTING infrastructure boxes, which provide the connections to the lifelines of power, signal, data, and compressed air for each production cell, and monitor the energy flow. In the future, the modules will offer a human-machine interface to support helper functions for increasing flexibility and configuration in a personalized and efficient form. In this way, it should be possible to combine flexible mechatronic components in production lines without the need for any manual programming on site.

What research efforts is HARTING participating in to develop IIoT technology?

HARTING is a member of the Industrial Internet Consortium (IIC). This association aims to develop Internet technologies for industrial deployment. It was founded in March 2014 by AT&T, Cisco, General Electric, IBM, and Intel. Over 200 companies, including HARTING, belong to the organization worldwide.

HARTING also participates in the joint project "Fleximon—flexible assembly concept" with autonomous mechatronic production components. The project forms part of the "excellence cluster competition" of the German Federal Ministry for Education and Research in the framework of the Hightech Strategy 2020 for Germany. HARTING and the University of Bielefeld (CoR-Lab & Citec) jointly developed

the "FlexiMon" plant. At the plant, one can experience how modification of work scheduling on the level of the ERP system leads to changes in the behavior of the plant, without the need for any explicit programming.

What new IIoT products are coming to 2016 from HARTING?

As machines become serviceable, there is the need for a plug-and-play solution so that companies can quickly service and maintain the machines. The Han connector solutions for PCBs form the perfect bridge between industrial devices and leading installation standards. It is now possible to have a combination of power, signal, and data in only a single connector.

PCB adapters from the Han-Modular program can supply the PCB with currents of up to 40 A. This direct contacting is even possible with semi-flexible PCBs from HARTING; using both together saves considerable space and assembly costs. The Han-Fast Lock enables even more amps—up to 60 A to be precise. The PCB connector is simply inserted into the drilled hole provided for the contact, locked into place with a latching pin, and released again if necessary. HARTING is in the process of developing additional modules to provide higher density. This also opens another door to the ones who are not using connectors currently.

HARTING is offering the HARTING IIC Modular Industry Computing Architecture (MICA). MICA makes it possible to temporarily save, evaluate, and process data in the immediate vicinity of machinery and equipment. Its modular open platform allows for customization of the HARTING IIC MICA with custom hardware, software, and interfaces to suit your individual requirements for Integrated Industry.

HARTING's Han connectors can now also be equipped with RFID transponders in order to link information and data from real components with the virtual world. Han connector systems offer users optimum protection against external physical influences. This is made possible by the use of materials and seals that are UV- and ozone-resistant and which function are within a temperature range of –40° to +125°C. Impermeability to moisture, humidity, dust, and dirt must also be assured throughout the connectors' useful life. Consequently, HARTING connectors are designed to meet IP 65/67. These requirements not only apply to connectors, but to RFID transponders as well. The integration of an RFID transponder in the rectangular connectors now permits the development and use of the full range of the identification of specific data, through to the ordering of spare parts, all in a convenient, quick, and reliable manner. Thanks to the RFID transponders and their software functions, the HARTING Technology Group has now integrated its proven connectors with business database structures—all the way through to the ordering of replacement parts. md

BRUCE GRETZ | National Key Accounts Manager
Steinmeyer Inc.

BALL-SCREW DESIGN: The Advantages of Internal Ball Returns

Exterior tube returns create noise, slow the balls down, and cause jams. They are also a source of lubrication leaks. Internal returns solve all these problems and much more.

Steinmeyer's UltraSpeed return system uses through-the-nut technology. Axial deflectors (the two black pieces on the end of the nut) send balls recirculating back through the nut, helping give the screw a speed rating (D_N) of 160,000.

Lead screws are one of the most common linear-motion devices, thanks to their low cost and reliability. And recent advances in modern machining can make them extremely precise with lead errors below 1 micron. That's why they can be found in linear drives for machine tools, aerospace controls, precision stages, and a host of industrial devices.

However, lead screws are fundamentally limited. The sliding between the threads of the shaft and nut generates high frictional forces. As a result, lead screws struggle to reach even 50% in efficiency. Of course, the friction also generates heat, which limits the rotational speed to a few hundred rpm. Furthermore, there is backlash because of play between the threads.

For some applications, such as actuation and coarse, low-load positioning, efficiency is not that important and backlash can be tolerated. But for many others, particularly high-load CNC machining, these limitations are critical. Low efficiency requires much larger drive motors, and backlash interferes with precision servo control. Any attempt to eliminate backlash by pre-loading causes even higher friction and lowers efficiency to below 30%.

Placing ball bearings inside the nut assembly and pre-loading them to maintain contact overcomes these problems; efficiency soars to over 90% and backlash is eliminated. Adding those bearings gave rise to the ball screw.

PROBLEMS OF TUBE RETURNS

One challenge in ball-screw design is ball recirculation. Historically, the most common designs used tubes that jutted outside the nut and provided a return path back to the beginning of the ball track inside the nut. But tube returns force each ball to change direction by 90 deg. at the end of each tube. This extreme change in motion causes higher frictional losses and increases the risk of balls jamming. It also increases the variation in frictional torque.

Tube returns suffer a loss of lubricant, too. The port where the tube enters or leaves the nut body is difficult to seal. As a result, tube-return ball screws tend to leak, a costly and messy maintenance problem.

Tubes are also generally incompatible with rotating nut configurations. The reason is that the tubes create asymmetric radial forces as the nut rotates. Radial forces cause vibrations and instability at high speeds.

The Saginaw steering gear was a ball screw used on several automobiles in the 1950s and '60s. It features a dual-tube return that recirculates several ball bearings in separate circuits.

Over the past decade, CNC machine tools have been a leading user of ball screws. This application requires pre-loading, which presents challenges for tube returns. One key measure of ball-screw performance is the speed rating (D_N), expressed as the shaft diameter (mm) times the maximum rotation rate (rpm). Tube-return ball screws are limited to a D_N of around 70,000. Not only that, the pins required to deflect the balls in tube returns are subject to failure.

INTERNAL RETURNS

At Steinmeyer, engineers have taken a different approach, exclusively favoring internal returns over tubes. Their overriding design principle with returns is to follow the natural trajectory of the ball. Consequently, all Steinmeyer returns are based on tangential deflection. This minimizes the required deflection forces, resulting in higher efficiencies and reliability. And with no tube connection, no lubricant escapes the nut.

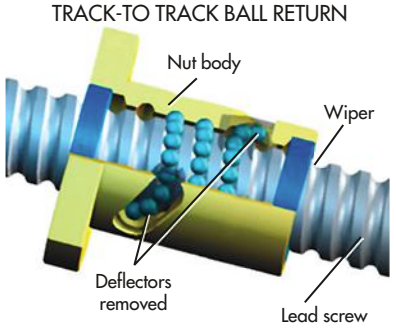
One historical argument against internal returns is that they are incompatible with rapid design and high-volume manufacturing. After all, the reasoning went, external returns require only a hole in the nut and a bent tube. To make internal returns easier to manufacture, Steinmeyer fabricates deflectors in-house by milling (steel or brass) or other additive methods (plastic). Combining these fabrication techniques with modern CAD tools, the company economically designs and manufactures a variety of complex shapes in high volume.

Steinmeyer's internal returns fall into six categories: track-to-track, liner, and four variations on through-the-nut—Z-UltraSpeed, Deflector, endcap, and heavy duty.

Track-to-track: The track-to-track return is the original Steinmeyer design and still the most widely used. It is available on the widest range of shaft diameters and nut types. It uses ball deflectors to lift balls across the shaft's outer diameter and guide them directly into the next (or previous) track. Each deflector serves one turn, which corresponds to one ball circuit.

Deflectors are made of metal or plastic and sealed into bore holes in the shaft. It's impossible for lubricant to leak out. The deflectors are arranged symmetrically to balance radial forces and are flush with the nut's outer surface.

This design is compact and features the smallest nut diameters of all ball returns. It is also the preferred choice for small



Track-to-track ball returns are a feature of the original "tubeless" ball screw from Steinmeyer and remain the most widely used. These work well with small balls and lead/diameter ratios under 0.5.

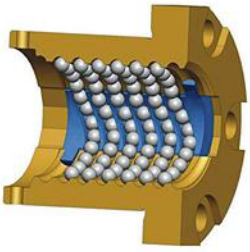
A SHORT HISTORY ON BALL SCREWS

FOR CENTURIES, THE conventional lead screw (threaded shaft and nut) was the primary mechanism for converting rotary motion to linear motion. They were inexpensive to manufacture and reliable.

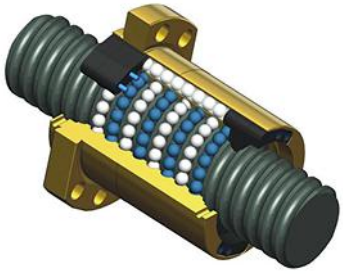
Ball screws date all the way back to the late 19th century, when some ingenious engineer placed ball bearings inside the nut threads to reduce friction. This eventually led to efficiencies of over 90% and the elimination of backlash.

In 1898, *The Practical Machinist* published what may have been the first publicly documented ball screw. The Cleveland Machine Screw Co. is credited with the design. However, the performance of this device was probably quite limited. Ball bearings were just emerging around that time, so the most likely limitation was inconsistently sized balls, making recurring jams in the return tubes a problem. It was not until the post-war era that ball-bearing fabrication caught up, which partially took care of the problem. But return tubes were still a problem.

One of the first commercial ball screws was designed into the famous Saginaw steering gear. This gear was used on many vehicles as diverse as the Ford Fairlane (1956-78) and Chevrolet Corvette (1962-82). The Saginaw design used a ball screw to transform rotation of the steering wheel into perpendicular linear motion of a rack. It featured a tube return. Actually, two tubes were employed to recirculate the several dozen balls on separate circuits. No pre-loading was necessary due to the coarse positioning requirements. However, the tubes were still subject to jamming. To mitigate this problem, some designs used alternating balls, with every other one 0.001 in. larger than its neighbors.



The liner return developed at Steinmeyer is popular for aerospace applications because it provides both safety and reliability. In case of failures, balls cannot leave the nut and interfere with other machinery.



Through-the nut ball returns were developed for high-speed operations. Their D_N can be as high as 160,000, and the nut can travel at up to 1.5 meters per second.

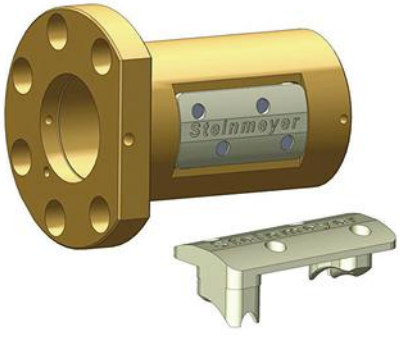
balls and lead/diameter ratios less than 0.5. It can have a D_N as high as 120,000.

Liner: The liner return is a variation on track-to-track deflectors. The liner essentially consists of several deflectors arranged and manufactured as a single component. It is placed entirely inside the nut, eliminating the need for bore holes.

It was developed for the aerospace industry, where coarse-positioning ball screws must reliably control aerodynamic surfaces, cargo doors, and cockpit-seat adjustments. None of these applications require pre-loading, so tube returns dominate older, legacy designs. But liner returns have many advantages especially suited to aerospace applications:

- They generate higher load capacities per unit nut length, so shorter and lighter nuts can be used.
- They are easier to assemble compared to individual ball deflectors because there are no holes in the nut and fewer parts.
- Unlike tube returns, liners require no additional hardware for the return, and lubricant leaks are impossible.

Liner returns provide safety and reliability. Unlike tube returns, balls cannot leave the nut if a deflector or the liner fails.



The Z Deflector, a variation on the through-the-nut return, is for shafts with solid shoulders on both ends. It simplifies installation of the nut and balls.

Through-the-nut ("UltraSpeed"): Through-the-nut returns were originally developed for high-speed operation of high-lead ball screws. The UltraSpeed, for example, uses deflectors at each end of the nut. Balls get lifted off the shaft, guided through a bore inside the nut body, and set back onto the shaft. One pair of deflectors serves one circuit, which includes several turns.

This nut design is normally used for lead/diameter ratios greater than 0.5 and dual start threads (that is, two separate thread paths on the shaft) It can reach a D_N of 160,000. This speed corresponds to more than 90 m/min (1.5 m/s). Dual-start threads are typically employed in vertical-axis applications, because two deflectors per start are able to provide redundancy against failure.

Through-the-nut ("Z-Deflector"): The Z-Deflector is another version of the through-the-nut return. It was designed for shafts with solid bearing shoulders on both ends of the threaded shaft. On these shafts, it is impossible to thread the nut on from a sleeve with the balls in place. Thus,

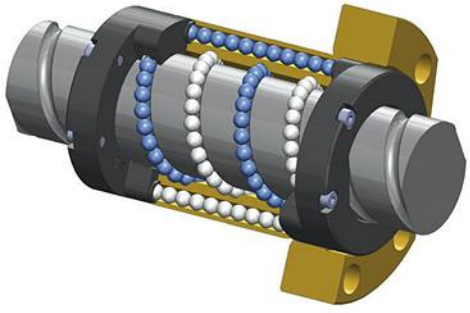
technicians install the nut on the shaft without balls, then insert balls through the opening in the nut body, and finally affix the Z-Deflector.

Through-the-nut (endcap): The endcap return is similar to the UltraSpeed return, except that caps at both ends of the nut serve as ball deflectors. This design is normally used for lead/diameter ratios greater than 0.5, and nuts with two or more start threads for high load capacity in a short nut. The endcap is usually made of plastic, which lowers weight and keeps the ball screw 50% quieter when operating. Furthermore, the extra length of the endcaps accommodates combination wipers, which include both a felt ring and plastic fingers.

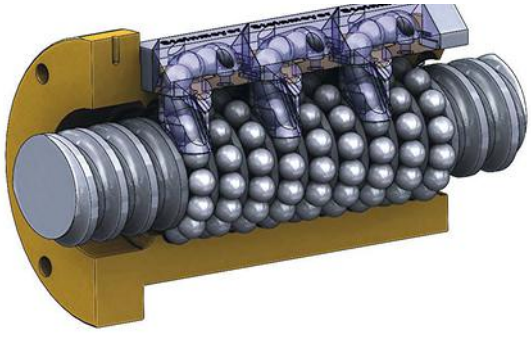
Endcap returns are available on shaft diameters from 5 to 20 mm and leads from 2 to 30 mm. They can handle up to five ball circuits, which pushes the dynamic load capacity to over 30 kN.

This return withstands accelerations over 1 g. As a result, one of its main applications is in devices requiring speeds greater than 2 m/s.

Through-the-nut (UltraThrust): To increase the load capacity of ball screws, Steinmeyer engineers placed oversized balls (15 to 19 mm) in their standard track-to-track return. (Previously, the largest balls were about 11 mm in diameter.)The resulting ball screws had dynamic capacities up to about 800 kN. More recently, the firm developed a ball return that consists of several through-the-nut returns along the length of the nut. Plastic deflectors move balls tangentially out of the nut raceway.



Endcap returns use plastic caps on each end of the nut to serve as deflectors. They can handle accelerations over 1 g and are known to be exceptionally quiet in operation.



Heavy-duty nut returns use oversized balls to carry larger loads. Their capability of handling larger loads—up to 1,400 kN in dynamic capacity—lets it replace hydraulics in many heavy-duty applications.

The return is available in shaft diameters from 32 to 160 mm and leads of 10 to 30 mm. For the smallest diameters, they have a dynamic capacity of over 100 kN (about four times as high as a standard 32-mm screw). For the largest diameter, dynamic capacity approaches 1,400 kN.

The main purpose of the UltraThrust return is to let ball screws replace hydraulics in a greater number of applications. Electromechanical drives offer improved efficiency and lower environmental impact, which is leading to increased demand for high-thrust screws.

Steinmeyer is constantly working on further development of deflectors, both in terms of improving the geometry as well as minimizing size and cost. We expect to achieve these advances through better materials and manufacturing processes. md

CARLOS GONZALEZ | Technology Editor
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Learn to Stop Worrying and Love the Cloud

The Internet of Things is driving engineering to wireless connections and cloud use, including the world of computer-aided design.

The idea of "the cloud" for many has become a punchline. Since the term came about for online storage, people have a hard time grasping how to define it. Simply put, the cloud is the location of data or software that does not reside on a local personal computer or area network; rather, it resides on "the cloud"—a global network of linked computers via the Internet.

Use of the cloud is on the rise thanks to the Internet of Things (IoT). Data from automation plants and factory floors is being collected and subsequently shared to floor workers, engineers, plant managers, and CEOs via the Internet. Alert Logic's *2015 Cloud Security Report* predicts that companies will invest $200 billion in cloud services in 2016.

Computer-aided design (CAD) has also gone the cloud route. In the last few years, major CAD companies have promoted not only cloud CAD computing, but also collaboration. They want users to be able share access on design files, taking CAD from the individual user to the multiple user experience.

LATEST CAD SOLUTIONS

The basic purpose of the cloud is online storage; a place where one can save files on network computers instead of your local desktop. Since 2010, Autodesk Inc.'s Autodesk 360, or A360 (formerly AutoCAD WS), service has offered users a way to save their 2D and 3D design models on the cloud. They can access these files remotely from multiple platforms and applications via a computer, laptop, or tablet.

The image above highlights how A360 promotes collaboration and the different roles people can assume in a project.

The A360 service also allows users to share their files with others. They can view the document while the originating user controls the original file. One can setup a review session to invite other team members to comment directly within files. The team tracks the latest updates and provides comments to the file on the A360 service. A360 supplies metadata for each file in the cloud and enables users to navigate through older versions of the file.

Increasing access and size of consumer cloud services has pushed the company to extend its capabili-

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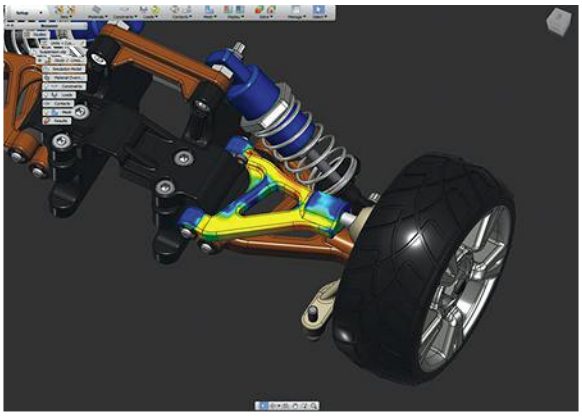
ties. The next level of Autodesk's cloud services is Fusion 360. This takes the entire product-development process to a single cloud-based platform.

Originally introduced in 2012, Fusion 360 uses the cloud not only as cloud storage, but also for the software experience. This allows for certain functions: collaboration, infrastructure-free architecture, and automatic updates. Infrastructure-free helps prevent loss of data due to the program being located in the cloud and not on your computer. Automatic updates to the program are performed on Autodesk's cloud service; hence, you are always working with the latest and greatest software.



The new updates to Fusion360 introduce cloud-based simulation. A new web browser client was unveiled in January 2016; now users can access and run analysis on cloud-based models.

Collaboration is the real draw to using Fusion 360. The current world of IoT is pushing for more connected devices, which compels engineers to work closer together. Fusion 360 allows for distributed design. Designers can work concurrently and update assemblies of the same file. Future updates to Fusion360 will let individual users create their own branches from the original design. Users will review each other's design, accept changes, and then merge the two separate files back into one file.

Simulation is a big factor within Fusion 360. Users can run simulation on local computers or cloud-based software. In January of 2016, Autodesk introduced a new browser-based client that can run simulation, like thermal simulations, which run completely in the cloud. This has the potential to perform simulations more rapidly, free from the limitations of single-computer systems.

Dassault Systemes 3DEXPERIENCE platform is an all-in-one industry approach to collaborative computer design. The platform includes ENOVIA, Dassault SystemesWYM, EXALEAD, NETVIBES, 3DVIA, DELMIA, SIMULIA, CATIA, GEOVIA, and SolidWorks. It targets several industries, 12 in all, including aerospace/defense, energy, utilities, architecture, engineering, construction, and transportation. For example, the industry package for architecture, engineering, and construction has three industry experiences: optimized construction, façade design for fabrication, and civil design fabrication. Each experience helps provide a complete design path.

On the cloud services, users can assign individual roles. These roles have particular tools and capabilities to work within the project. The 3DEXPERIENCE on the cloud has roles for different industries, including engineering, simulation, ergonomics, machining, robotics, and product planning. "Engineering On Cloud" roles include: 3D master conceptual designer, 3D master designer, mechanical designer, mechanical part designer, mechanical shape and designer, mechanical simulation designer, composite designer, and composite manufacturer. In total, there are 219 assignable roles for on-premises local use and 115 roles on the cloud, whether public or private.

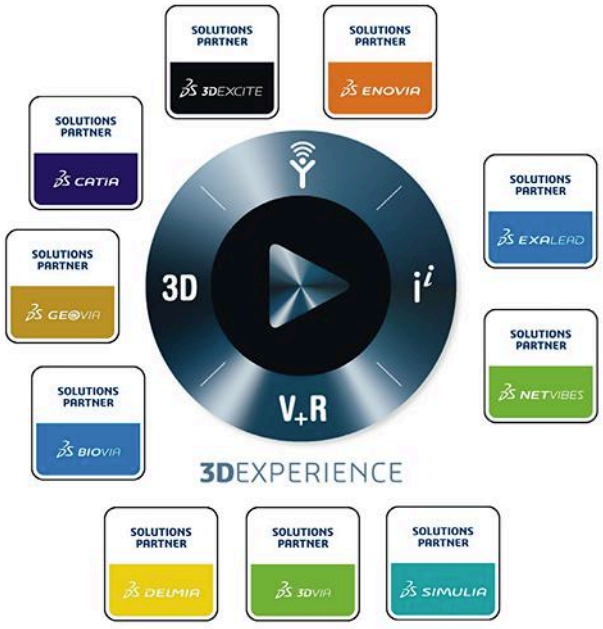
By laying out the architecture through the experiences, users approach their project through the specific industry instead of a direct modeling application approach. For example, instead of using CATIA for 3D modeling or SIMULIA for part simulation, the user will reach those steps by working through the specific industry package.

Other programs have taken alternative approaches to cloud CAD computing by abandoning installed applications altogether. Onshape is a full-cloud 3D CAD system that runs in a web browser and on all mobile platforms, including Android and Apple devices. As compared to Dassault Systemes or Autodesk, no physical version of the application can be installed on your computer. It uses existing product-life-management (PLM) systems, and links to the online model versions can be stored on those PLM systems.

Onshape can read native CAD (SolidWorks, Pro/ENGINEER, CATIA, NX, DWG, etc.) and neutral CAD formats (IGES, SAT, STEP, ACIS, JT, Parasolid, DXF, etc). It offers collaborative cloud design similar to that of Fusion 360 by creating separate versions or branches of files

	Country/region	Q3 2015 avg. Mb/s
-	Global	5.1
1	South Korea	20.5
2	Sweden	17.4
3	Norway	16.4
4	Switzerland	16.2
5	Hong Kong	15.8
6	Netherlands	15.6
7	Japan	15.0
8	Finland	14.8
9	Latvia	14.5
10	Czech Republic	14.5

Listed are the countries with the fastest Internet connections at the end of the third quarter in 2015, according to Akamai, a content-delivery network services company.



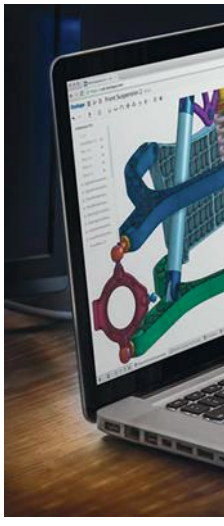
The 3DEXPERIENCE Compass will guide users through the design. The center play button brings them to the real-time 3DEXPERIENCE platform. Other areas of the compass include social/collaboration, information intelligence apps, 3D-modeling apps, and finally content and simulation apps.

Cloud misconception	Reality
Public clouds are more vulnerable.	• Cloud services require security measures like encryptions and password protection.
	• These are similar services found as on-premises security.
Applications in the cloud are less secure.	• Applications in the cloud are continuously monitored.
	• They are maintained and monitored more quickly than traditional software, which rely on users to apply patch updates.
Lack of data control.	• Cloud-service providers offer global data-center options so that users can choose where their data is stored.
Data more secure on premise.	• Cloud vendors offer numerous data centers, backup, disaster recovery, and layers of security.
	• Frequent audits are performed to keep security up-to-date.
	• Data stored on-premises can be easily accessed by people on-premises once they have passed outside security.
Data allocation and infrastructure responsibility is solely with the cloud provider.	• Users are responsible as cloud providers for their data.
•	Cloud providers will secure their infrastructure, but users must secure their passwords and access to their machines.

This table highlights some of the misconceptions around cloud services.

as multiple users work on the same model. There are no license fees or service packs; users pay a monthly subscription.

Another interesting approach to online collaboration and use of the cloud is to provide online simulation applications instead of full access to the software. COMSOL Multiphysics is an advanced modeling and simulating physics-based software platform. The software can simulate 25 different physics-based scenarios, including heat transfer, pipe flow, plasma, acoustics, and CFD. The user can construct 3D models within COMSOL or import files from SolidWorks, AutoCAD, Pro/ENGINEER, and CATIA, among other modeling programs.



The platform will create meshes for finite element analysis that can be automatically generated or user-defined. It allows for multiple levels of user-defined input. One can define boundary conditions, materials, direction flow of heat or fluid, source/sink terms, or a unique set of partial differential equations. The COMSOL platform offers each simulation a preset list of equations. However, users can create their own equations or modify the preset equations. The software also features a set list of variables, expressions, and lookup tables.

The Application Builder for COMSOL is the company's method of providing simulation software through the cloud. Instead of having users simultaneously work on the same file, you can create an application based on your simulation. The Application Builder takes the analysis and creates a plug-and-play web-based application. The user of the application will have inputs and settings that can be modified while still being a full functional analysis.

For example, if you have developed an analysis of fluid through a pipe, which includes temperature changes, volumetric flow-rate changes, and changes in pipe diameter, these values are modifiable via cloud user inputs. Applications can be hosted on COMSOL's server or through other third-party cloud services like Amazon or Rescale's pay-per-use computing cloud platforms.

CURRENT OBSTACLES AND TACKLING SECURITY

The resistance to using cloud services rises from a lack of trust in the technology. First, many companies do not like not owning the software. By using cloud-

The rise in IoT connections companies will increase their use of mobile devices. The ability to operate on multiple devices and browsers will boost the popularity of services like Onshape.

only platforms, the user is paying for a license to use the software remotely. Hence, they are "renting" the software. You could say this is equivalent to using media stream services; you only have access to the media as long as you continue your subscription.

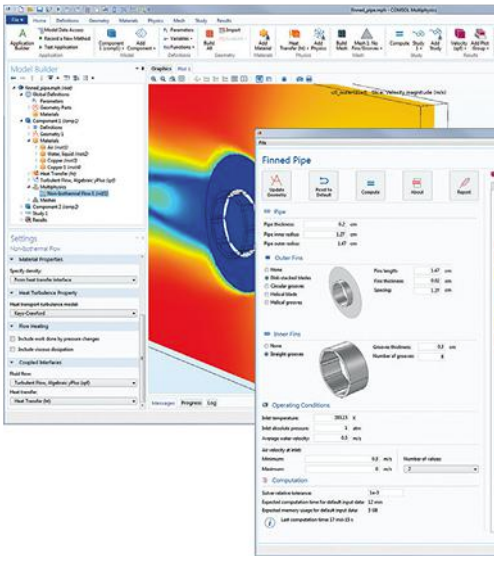
If the software is physically owned, meaning installed on a physical hard drive, a user or company can continue using the software regardless of subscriptions, support contracts, or non-supported software. Many companies that have legacy software continue to keep those computers around to service legacy programs. This also leads to the next issue—Internet speed and access.

Cloud computing requires fast Internet speed because the files being designed or analyzed can be quite large. Dependence on the Internet means that work comes to a stop once the connection is lost or the server is down. According to Akamai, a global leader in content-delivery network services, the United States ranked 16th in the world with an average Internet speed of 12.6 megabits per second (Mb/s), according to its third quarter report for 2015. While no state in particular falls in the low broadband category (<4 Mb/s), parts of the country fall to as low as 7 Mb/s. In these areas, it may be difficult to implement cloud services.

Besides Ethernet connections, there is Wi-Fi access, which tends to be more complicated. The theoretical maximum speed of 802.11ac Wi-Fi is 1300 Mb/s. The real speed will vary on distance and antennae connected. In 2013, Anand Tech tested different 802.11ac routers and found max speeds to reach 364 Mb/s at a 5-ft. distance and 140 Mb/s at a 20-ft. distance. These test values are best-case scenarios. Real-world numbers of Wi-Fi are lower when distance,

obstructions, and electronic interference are considered.

Security is the biggest concern when it comes to the cloud. Users and organizations fear that they will not control their data or hackers will compromise the data. The *2015 Cloud Security Report* concluded that 70% of cloud consumers received application attacks, 56% brute force, and 37% Trojan activity. Compared to on-premises attacks, 52% were application attacks, 47% brute force, and 57% Trojan activity. The increase of attacks on cloud services is most likely because more people are using them more, making them a larger target.



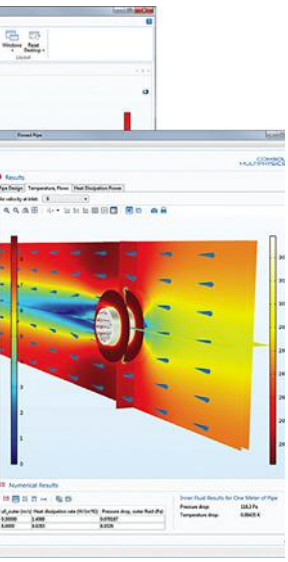
EMBRACING THE CLOUD

Acceptance of CAD cloud services will be a challenge in the years to come. Problems will revolve around overcoming fears and understanding the reality of security *(see table, p. 31)*.

Many companies already use some form of cloud service. Companies that have PLM systems to store and manage their design models use the cloud. Such PLM data centers are often located off-site. The next step is to include the modeling software off-site, as well. Advances in technology, security, and standards will help push the cloud forward.

New Wi-Fi connections like Li-Fi hope to increase speeds to 224 gigabits per second (Gb/s). It achieves these speeds by using LEDs to deliver high-speed communication in a similar manner to Wi-Fi. The Wi-Fi Alliance announced a new version of Wi-Fi called HaLow, which transmits Wi-Fi at 900 MHz (current standards are 2.4 GHz and 5 GHz). HaLow is intended to provide connection for small battery devices like wearables or mobile devices, helping to maximize and not drain battery life.

The increase in standards governing cloud services will help to boost user as well as company trust in them. Some of the standards already in place now, followed by companies like Autodesk and Dassault, include:

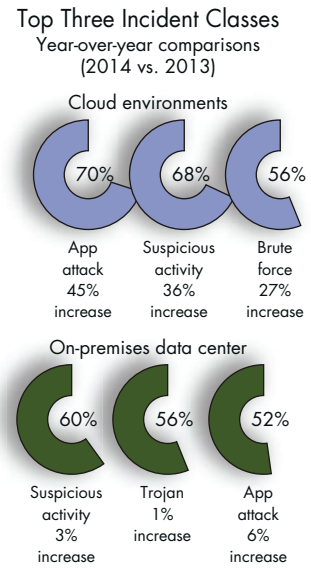


The first window in the background is COMSOL's simulation software designed to exact requirements of the user. The foreground image is the application that is built upon the design user model, which can be operated by anyone on the cloud.

supplier relationship management that is planned to include a part relevant to the cloud supply chain.

Security will always be a battle between hackers and the guards of the Internet. While these concerns exist and still loom over full cloud adoption, it seems that the future lies in cloud computing. Dell's "Global Technology Adoption Index" for 2015 predicts that companies adopting on-premises cloud will have 46% higher growth rates and those adopting off-premises cloud 51% higher growth than companies without cloud services. Like all new technologies, the more it is adopted, the stronger it will become. mc

- ISO/IEC 27001:2013: Information technology—Security techniques—Information security management systems —Requirements.
- ISO/IEC 27017: Cloud Computing Security and Privacy Management System-Security Controls.
- ISO/IEC 27036-x: Multipart standard for the information security of



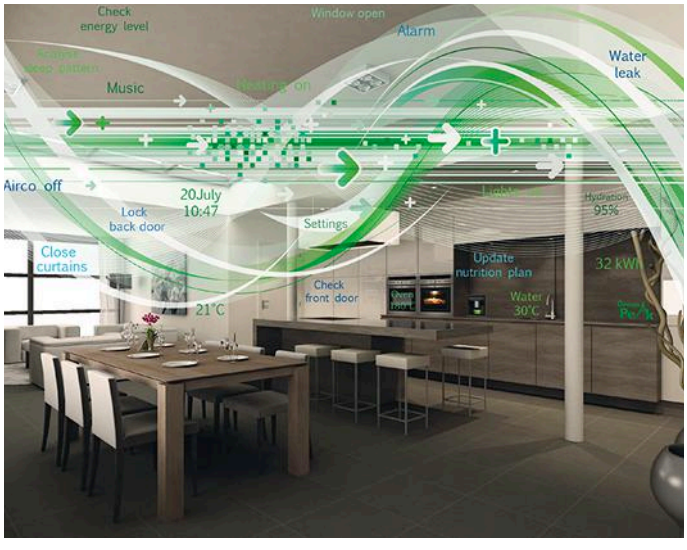
According to Alert Logic's *2015 Cloud Security Report,* these are the top three incident attacks for both cloud environments and on-premises data centers in 2014. It also highlights how those attacks increased from 2013 to 2014.

CEES LINKS | Founder and CEO
GreenPeak Technologies, The Netherlands, www.greenpeak.com

What's the Difference Between ZigBee RF4CE and ZigBee Green Power?

ZigBee, which is named after the dance honeybees do to communicate to other honeybees, was developed and standardized as IEEE 802.15.4 in 2004. Originally designed as an ultra low-power wireless standard to support energy harvesting, it is now widely accepted as a low-cost, low-power wireless mesh-network standard. It is also one of the wireless standards being eyed for use in the Internet of Things (IoT) network of sensors, actuators, and Internet servers. (The other two major standards being evaluated and used are Wi-Fi and Bluetooth.)

ZigBee has several advantages over competing standards. They include the years of experience programmers, designers, and companies have working with ZigBee, as evidenced by the more than 1,000 certified ZigBee products on the market. In addition, it supports a large application library that has gone through several updates and rounds of improvements. IoT and smart-home firms also prefer ZigBee because it is easy to use and maintains strong security protocols.



Some form of ZigBee could evolve into a standard for remote controls and other IoT controls for smart homes.

ZigBee is also fully Wi-Fi- and IP-compatible, so there is no need to have a ZigBee chip in a smartphone to find and control ZigBee-connected smart-home and IoT devices. It all happens through any Web-connected hub (ZigBee-enabled router, set-top box, or gateway), which means connected PCs and smartphones (via Wi-Fi or cellular) can function as dashboards, as they can find and communicate with any ZigBee devices without a problem.

The attraction of ZigBee centers on cost and scale. It is the first scheme, say its followers, which is inexpensive enough to be practical for use in isolated controls with sensors that must work reliably while consuming little power. ZigBee manages both feats by sending data at a super-low rate and using a special networking scheme called meshing. The low rate, about 250 kb/s, is too low for beaming audio, real-time video, or complicated Web pages. It is fine, however, for sending small packets of data and keeping tabs on temperature sensors, proximity switches, and similar uses characterized by relatively low data-rate changes.

There are several subsets of ZigBee 3.0, including ZigBee RF4CE and ZigBee Green Power. Let's take a closer look at both of them.

ZigBee RF4CE (Radio Frequency for Consumer Electronics) was initially an offshoot of ZigBee developed to replace the infrared remote controls for consumer electronics (TVs, stereos) with radio-based controls. This meant the controller no longer had to be aimed at the device being controlled or even be within line of sight. Since then, the standard has been expanded, and in its latest version (ZRC 2.0), it is fully integrated with the entire ZigBee application library. This means that a remote control designed for a TV or a set-top box can also control

lamps, lights, curtains, sun shades, and so on in the home. The expectation is that over time, consumer electronics and smart-home technology will continue to overlap and merge, and ZRC 2.0 is well positioned to be a controller in both arenas.

ZigBee RF4CE also provides full backward compatibility with older IR-controlled electronics. ZigBee RF4CE controllers automatically detect and download the required code-sets for legacy equipment that originally needed an IR controller. Because of all these features, as well as its international acceptance, it is not a surprise that RF4CE makes ZigBee a key enabler for the smart home, and that the smart home is a major new service opportunity for the cable and TV operators.

In addition to ultra-low power requirements (comparable to Bluetooth Low Energy, but with much better range), another key feature of ZigBee RF4CE is its low latency. User-interface devices benefit from low latency, because they let designers provide users with immediate feedback (usually required to be less than 30 milliseconds). Normally meshing networks tend to see latency going up to 100 milliseconds or more, making the user experience quite unpleasant. Almost everyone has had the experience of pushing a button, nothing happens, and then pushing the button again: The light finally turns on and then, immediately turns off again. Arggh! That is not what happens with wired light switches today, so nobody needs to accept this delay just because it is now wireless.

ZigBee Green Power was originally developed as an ultra-low-power wireless standard to support energy-harvesting devices. Energy-harvesting devices lack batteries, but extract the energy they need from the environment by tapping into motion, light, piezo/pressure, or the Peltier effect. The most common application is the light switch, where the flipping the switch generates the energy to send a communication package ("on," "off") through the air to the lamp. Green Power is especially effective for devices that are only sometimes on the network (when they have power). Green Power lets these devices securely go on and off the network, so they can be off most of the time and not need any energy.

As an ultra-low-power wireless technology, Green Power is also an effective option for using battery-powered devices as it lets them run off a battery for years. Green Power also works with low-cost end nodes that communicate with the rest of the network, specifically in situations where no meshing is required. md

BILL SAVELA | P.E.
Delta Computer Systems Inc.

Newest Motion Controllers EXPAND APPLICATIONS

Delta Computer Systems takes us through some of the latest advances in motion controllers by analyzing modern industry applications.

Motion controllers are among the most ubiquitous electronic system elements used in today's factories and laboratory environments. The latest motion controllers can synchronize multiple motion axes, control both position and pressure/force being applied, and interface easily to other system elements to enhance the capabilities of a production machine or test system.

The Voss leveler represents one stage in the Hagerty Steel cut-to-length line. Virtually all of the machine hardware was still useful, and only the motion-control system needed to be retrofitted.

RETROFITTING OBSOLETE CONTROL SYSTEMS

A major trend currently pervading machine design is the use of best-in-class motion controllers to retrofit older machines in order to increase productivity and maintainability of the work cell. Older machines often contain worn and obsolete control elements, causing product quality to suffer and making the machines difficult and expensive to maintain.

At the same time, the latest controllers generally offer capabilities not available with the older varieties. Since a machine's mechanical components may still be serviceable, simply replacing the controller can give an older machine renewed value, let alone the capabilities of a new machine, at much lower cost.

Faster processors in the new controllers allow for closed-loop times in the microsecond and millisecond range compared to slower loops in older controllers, and can bring flexibility, accuracy, precision, and speed to machine operation. With the major hardware elements in older machines being reused, control upgrades typically require only a new controller, new sensors, and more precise actuators (drives or hydraulic valves).

Higher-end controllers augment proportional (P) gain with integral (I) and derivative (D) gain terms, which respond, respectively, to reduce errors that would build over time, or to errors that would build very quickly. Some new controllers employ predictive gains in the control-

loop equation called feed forwards, which act to contribute to the controller output during the required position movement or force profile.

The combination of P, I, and D terms and feed-forward terms are all available for adjustment when tuning the control algorithm. Feed forwards refer to the parameters that are separate from the P, I, and D terms. P, I, and D act on the feedback signal coming from the transducers, and as such, the action of these terms follow the action of the system. Once set, the controller operates a servo-quality proportional valve to cause the motion to go to the target positions using precise velocities, accelerations, and decelerations. The programmable acceleration and deceleration parameters help produce smooth motion and reduce wear and tear on the system.

In the case of presses, one can ramp down the velocity of the appropriate axes. Therefore, when the tooling makes contact with the work piece, the press will have just the right amount of kinetic energy to do the necessary work—without causing excessive shock or vibration.

An example of a control system retrofit that improved machine productivity was recently executed by Hagerty Steel, East Peoria, Ill. Hagerty added a new control system for its heavy-gauge steel coil cut-to-length line; it had been upgraded three times previously over the years, but was still not cutting sheets precisely. "One of our customers requested that we tighten our tolerance, and with the old system it was impossible," says Thomas Boon, Hagerty Steel maintenance manager.

To fix the problem, they needed an electronic motion controller that could perform complex multi-axis synchronization tasks. Based on experience with an upgrade of another machine at the Hagerty plant, Delta Computer Systems' RMC150 eight-axis motion controller was deemed the best choice. The controller has several built-in multi-axis gearing, camming, and synchronization functions that enable multiple

The RMC75 two-axis motion controller (left) and RMC150/151 eight-axis motion controller (right) can control and synchronize multiple axes simultaneously.

slave motion axes (in this case, controlling multiple different-sized roller drive motors) to produce tightly controlled motion in relation to that of a master axis.

Hagerty's controller upgrade did resolve the production quality issues. "Whereas the old machine was only able to produce steel sheets to within tolerances of approximately ±1/4 inch, and out-of-tolerance material was wasted, we were ultimately able to tune the machine to achieve the required dimension to within 1/1000 of an inch," says Glenn McIntyre, controls engineering manager at systems engineering firm Advanced System Integration & Control Inc. (ASIC), West Chester, Ohio. "And we were able to get the system to settle down quickly so our customer could fire the shear more quickly and increase their production rate."

AUGMENTING PCs IN NEW TESTING APPLICATIONS

Old "stress it until it breaks" test platforms are being replaced by smart test platforms that exercise a product in a manner very similar to real-world conditions in the field. Such systems can gather data on product performance to profile wear-out conditions before the product breaks. The PC computing platform is often the nexus for the development of testing and instrumentation software, but the PC by itself is not reliable enough to control test hardware that depends on real-time application for stimulus to the device under test.

Test engineers and designers in R&D labs are increasingly using motion controllers to add new capabilities to augment the functionality and performance improvements delivered by the evolving PC architecture. Tightly coupling a PC with a motion controller can leverage the wealth of PC instrumentation and data-acquisition software, while at the same time apply test stresses in a precise manner to a device under test.

An example of such a system is Houston-based Dril-Quip's test platform for subsea oil pipe connectors. Applying large forces, like those required to place bending forces on pipe assemblies similar to that shown in the figure *(p. 41)*, is the domain of the largest of hydraulic rams. Controlling them requires an electrohydraulic motion controller with special capabilities for closed-loop force control.

In the Dril-Quip test system, the RMC150 receives commands over an

Ethernet link from a LabWindows/CVI program running on the PC. These commands provide instructions to the motion controller on how to move the hydraulic cylinders and at what pressure. A software package supplied by Delta facilitates the connection between the motion controller and PC software applications, which allows the PC to send and receive data from the motion controller over Ethernet.

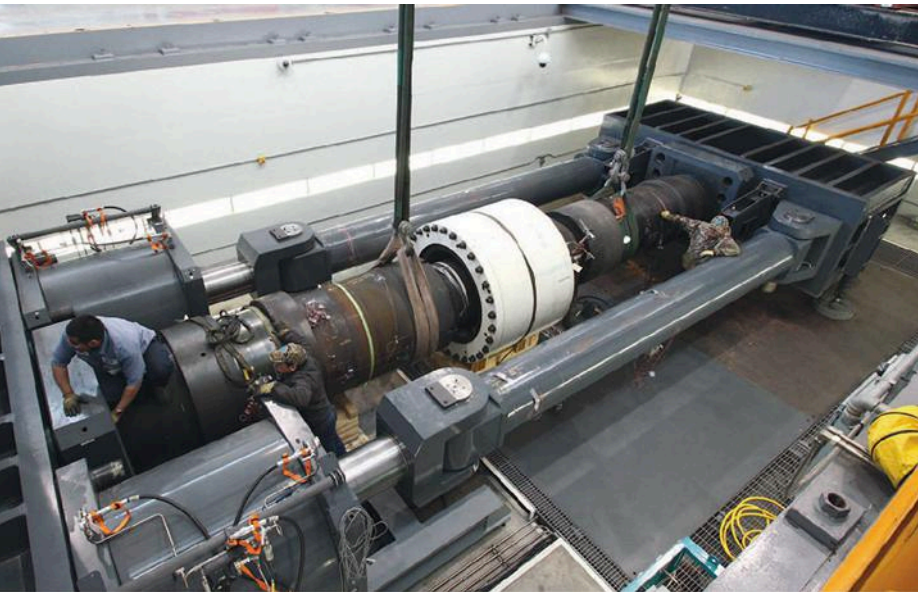
The motion controller reads the differential hydraulic pressure across the piston of each cylinder in order to calculate and control the force being applied to the specimen. The controller uses position feedback from magnetostrictive displacement transducers (MDTs), mounted between the cylinder housing and the cylinder rod, to measure the deflection of the specimen. A multi-axis controller can simultaneously control a different motion profile for each axis.

To complete the instrumentation of the system, strain gauges mount directly onto the specimen at specific places and send the strain signal to the LabWindows/CVI Strain Gauge module in the chassis. Pressure and temperature transducers mount on various parts of the test fixture and connect to another LabWindows/CVI data-acquisition chassis. The transducer signals are converted to engineering units inside of the LabWindows/CVI program. Process status, parameter values, and limit warnings are updated on operator screens attached to the PC.

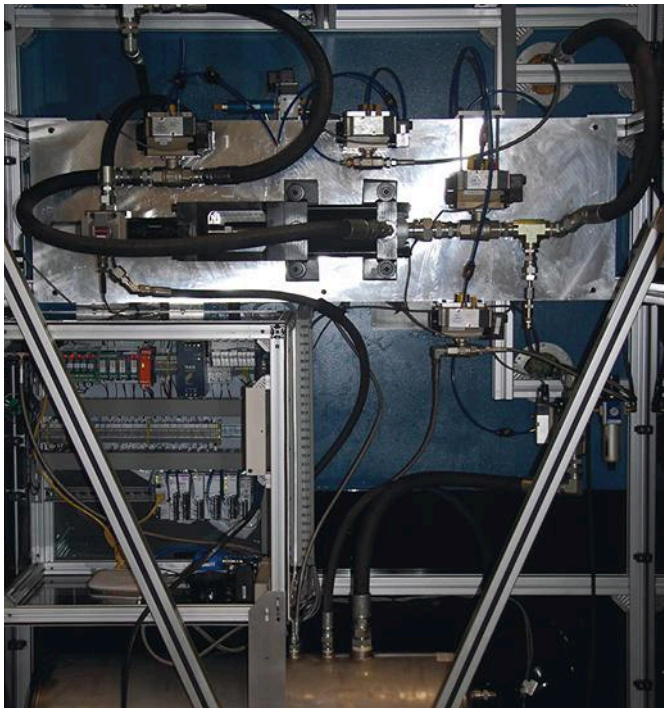
With the new test system, Dril-Quip is able to simulate field conditions with load, bending, and internal pressure that would otherwise be impossible in a lab setting using PC software alone. The system has given Dril-Quip an increased understanding of wellhead performance, and the knowledge to increase their customers' confidence in the Dril-Quip's subsea wellhead system.

CONTROLLING NO MOTION

It may sound strange at first to discuss using a motion controller for an application that does not involve actual movement of a machine axis, but consider the fact that motion controllers excel at closed-loop control. Sometimes the parameter being controlled is something other than the position of a mechanical axis; for example, the pressure of a fluid. An automotive test system manufactured by Innkeeper LLC, Livonia, Mich., embodies one such example.



The Dril-Quip test stand uses two large hydraulic cylinders, mounted horizontally, to apply large amounts of bending and tension force to an assembled pipe stand (center).



Innkeeper's transmission cooler test system uses a hydraulic cylinder like a syringe to apply high-frequency pressure pulses to the product under test, mimicking real-world stress conditions.

As with Dril-Quip in the previous section, Innkeeper bases its automotive test controls on two key elements: an electro-hydraulic motion controller to deliver real-world stresses, and a PC with a standardized user interface, which in this case can be used to set up and control a wide range of automotive testing applications and gather test data.

One application developed by Innkeeper tests heat exchangers used in transmission coolers. The system uses a servo hydraulic cylinder acting like a syringe to inject high-frequency pressure pulses into the test specimen. In this manner, the machine can accurately reproduce the pressure fluctuations that occur under actual vehicle conditions. The cylinder is operated via a high-performance servo valve, which is in turn driven by the motion controller.

Different Innkeeper test systems use RMC75 (1-2 axes) or RMC151 (2-8 axes) motion controllers, which connect to the PC via Ethernet and perform all of the closed-loop control, limit checking, and cycle counting. The controller holds the custom test profiles, allowing the PC to stay out of the loop and focus on monitoring/acquiring data.

The "series controllers provide us with great control on all tests ranging from quasi-static through 50-Hz operation, with a loop update rate between 1,000 and 4,000 Hz and supporting data acquisition of all signals up to 1,000 samples per second per channel," explains Kevin Kretschmann, Innkeeper principal. "We are able to build and then accurately control

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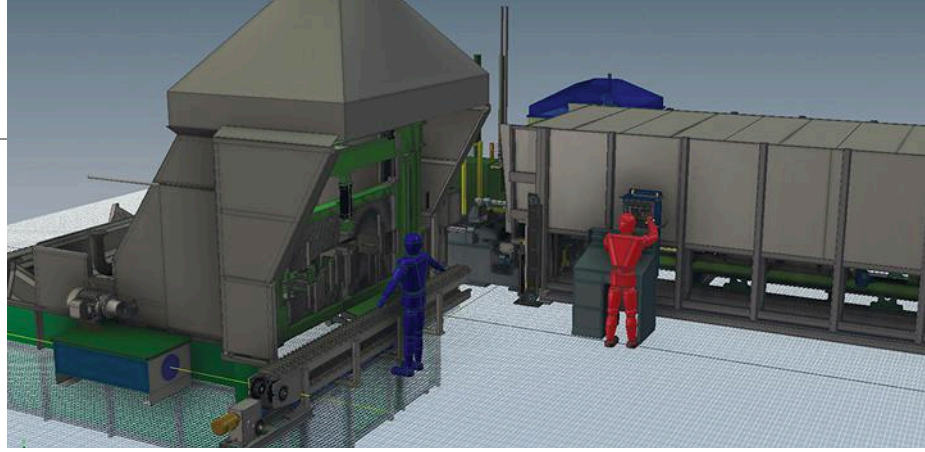

A Dayton Parts CAD rendering of the integrated line shows the leaf-spring forming station (right) and the punch press (left), with the furnace in the middle. The material moves right to left from the furnace to the punch press, and then left to right to the forming station.

any waveform or combination of waves within this range."

SAVE ENERGY, SUPPORT THE CONNECTED ENTERPRISE

To improve productivity, new machines are typically network-enabled by sharing process data between subsystems, as well as sharing production information with the enterprise. Even with older machines, machine builders can cut hardware costs and make it easier to maintain and expand their systems by replacing outdated, discretely connected motion elements with network-enabled versions.

For example, productivity can be increased in many metal-forming applications by joining work cells together and streamlining the output from one stage into the next. Proof of this can be found at Dayton Parts, Harrisburg, Pa., a manufacturer of formed metal products for the vehicle after-market. The company's leaf-spring manufacturing process, which was part of a manufacturing operation dating back to the 1920s, was upgraded this past year to automate the punching process and connect the punching and forming processes into a smooth flow.

Achieving fast cycle times for the combined machine requires precise control and close communications between the motion operations performed in the process stages. Supervisory control is performed by a PLC, but control of the individual motion axes required programmable motion controllers with special capabilities for multi-axis coordination. Dayton Parts' engineers chose the RMC150 and RMC75 motion controllers.

The combined Dayton Parts punching and forming work cell exemplifies how machine-to-machine (M2M) communications can improve a process. The supervisory PLC connects via Ethernet interfaces to the two motion controllers, multiple HMI terminals, and a series of I/O racks. Communicating via the networks, the PLC adjusts the cycle time of the furnace and sets the speed of subsequent stages in the line. For maximum productivity, and to ensure that heat transfer from the hot parts passing through the system does not affect sensitive system components, it is critical that the process proceeds as smoothly and expediently as possible.

The local machine network also connects to the factory LAN so that production information is available to corporate SPC and quality analysis software. This can help optimize performance and identify maintenance issues for resolution before they become a problem.

The PLC is connected to a Microsoft Access database containing the manufacturing parameters of all leaf springs made by Dayton Parts. The operator selects to make the next leaf spring via a touchscreen interface, and the PLC downloads the appropriate process parameters to the temperature/pressure controllers, and motion sequences to the motion controllers.

"The system automatically processes via recipe to speed production changeovers and gain repeatability, which we didn't have before," says Greg Shortridge, Dayton Parts electrical engineer. "We often have relatively small production runs where a spring may contain up to 12 different leaves. In the old days, we would have to manually dial in new furnace temperatures, forming pressures, and quench timer settings when we would change parts to be manufactured, which was time-consuming and could introduce errors and downtime that we can't afford."

The updated line has minimized reheat and changeover downtime, as well as cut cycle times down to 17 seconds per part. "We're seeing 95% combined uptime for the machines," says Joe Garcia, Dayton Parts project manager. "And the material-handling and energy savings for the company were sufficiently large to pay for this project in one year."

The applications described in this article highlight how today's modern motion controllers extend machine life, save time, reduce energy consumption, increase production, and improve quality. Any application in which closed-loop control can deliver smoother or more precise process operation is a likely candidate to use a motion controller. md

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VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR victoria.kickham@penton.com JANUARY 2015

Image courtesy of Thinkstock

How Distributors Are Shaping the IoT Movement

Education, the latest products, support services, and firm footing in the B2B world put distributors at the center of the Internet of Things craze.

VICTORIA FRAZA KICKHAM | DISTRIBUTION EDITOR

TE CONNECTIVITY'S ROB Shaddock took to the podium at the Executive Conference of the Electronic Components Industry Association (ECIA) to talk about the Internet of Things—specifically, the "hype versus reality" of the IoT and how it is shaping the business-to-business world.

There is no denying the hype: A quick search for the term or its acronym will yield a plethora of news headlines from consumer as well as B2B media outlets, not to mention the how-to's and product and service offerings you will find from a range of technology companies.

It is also difficult to deny the IoT's potential. As Shaddock explained to the distributors and manufacturers of electronic components in attendance at the ECIA event, the volume of IoT products and applications and their accompanying revenue projections are large and headed in the right direction. Gartner Research estimates that more than 6 billion devices will be connected by the end of 2016, a number the firm expects will grow to more than 20 billion by 2020. Revenue projections are staggering as well. Shaddock pointed to an estimated $50 billion in IoT revenue this year, which is projected to jump to $250 billion by 2020.

Such figures are fueling the hype surrounding the IoT, as consumers and business leaders try to grasp its world-changing potential. Shaddock echoed those sentiments at ECIA, held in Chicago last fall. He pointed to the greatest potential market for IoT technologies: the business-to-business environment, particularly utility, energy, and manufacturing.

There are challenges, particularly in manufacturing environments that need standardization to enable communication between equipment and systems. But the potential for productivity gains and cost savings is likely to outweigh such concerns, he says, as organizations of all sizes begin to sense and connect a wide range of products and equipment.

"These are the real opportunities now," Shaddock told the audience. "You need to establish connections first, and B2B is where much of those connections start."

Some of the most recent industry research bears this out, at least for the near-term. Gartner Research said this past fall that although consumer uses will continue to account for the largest number of connected devices—4 billion in 2016, rising to 13.5 billion in 2020—businesses will spend the most on IoT technology. Enterprise IoT spending will reach $868 billion next year, with consumer spending coming in at $546 billion.

This presents a large and growing opportunity for manufacturers and distributors, who serve as the pipeline for delivering the products and services to make those connected devices work. Many of them relish this role and are stepping up their capabilities in the IoT realm.

DELIVERING INFO, EDUCATION

Distributors have long been information providers, and as the IoT gains speed, that role will further expand. A survey by *Global Purchasing* and Penton Media revealed that staying up-to-date on new IoT products and services is a key challenge for buyers of electronic components—72% of purchasing managers listed it as a top concern in 2015. Distributors should embrace this role of educator and information provider, says David Hofer, executive director and board member of Intercomp USA, a distributor of electronic components based in Florida.

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"The challenge for many companies is that they need to stay on top of this technology—and they need seasoned expertise," explains Hofer. "You'd be surprised, but the buyer on the client side often doesn't have the understanding [of these products]. We have the knowledge and expertise to advise them on the right products and the right mix."

Intercomp USA supplies hard-to-find and obsolete electronic components to original equipment manufacturers and contract manufacturers, and offers design and bill-of-materials management services—all of which are increasingly in demand in the IoT age.

"We're trying to get closer to our customers through engineering innovation—collaborating with design [engineers] and even offering engineering staffing on a project-by-project basis," explains Hofer. "More companies are downsizing … and we're kind of a relief valve [so that they can] concentrate [on their core business] and not worry about other things."

Sagar Jethani, global head of content for distributor element14, adds that advances in sensors and greater access to them is driving much of the IoT craze and allowing manufacturers, distributors, and design engineers to develop more life-changing products and services.

"We have had Internet data and sensors for years. What's new now, I think, is that the falling price of sensors is enabling [design engineers] to use them in ways that make it bend around our everyday lifestyles," explains Jethani. "[The Internet of Things] is really making us rethink how we interact with information."

Customer projects are a key window to this trend, and Jethani points to element14's online community as a place that's experiencing much of the change. The community hosts design challenges that ask customers to solve problems in various fields (e.g., healthcare) using the company's products and services.

As one example, a combination of sensors, development kits, and other components allowed one element14 customer to design a pollen and allergen sensor that would help him better manage his own severe allergies. Using a sensor to sample the air quality outside, the product then runs calculations based on a range of factors and sends a message to the user's iPhone detailing the pollen and allergen levels in the air.

STEPPING UP SUPPORT

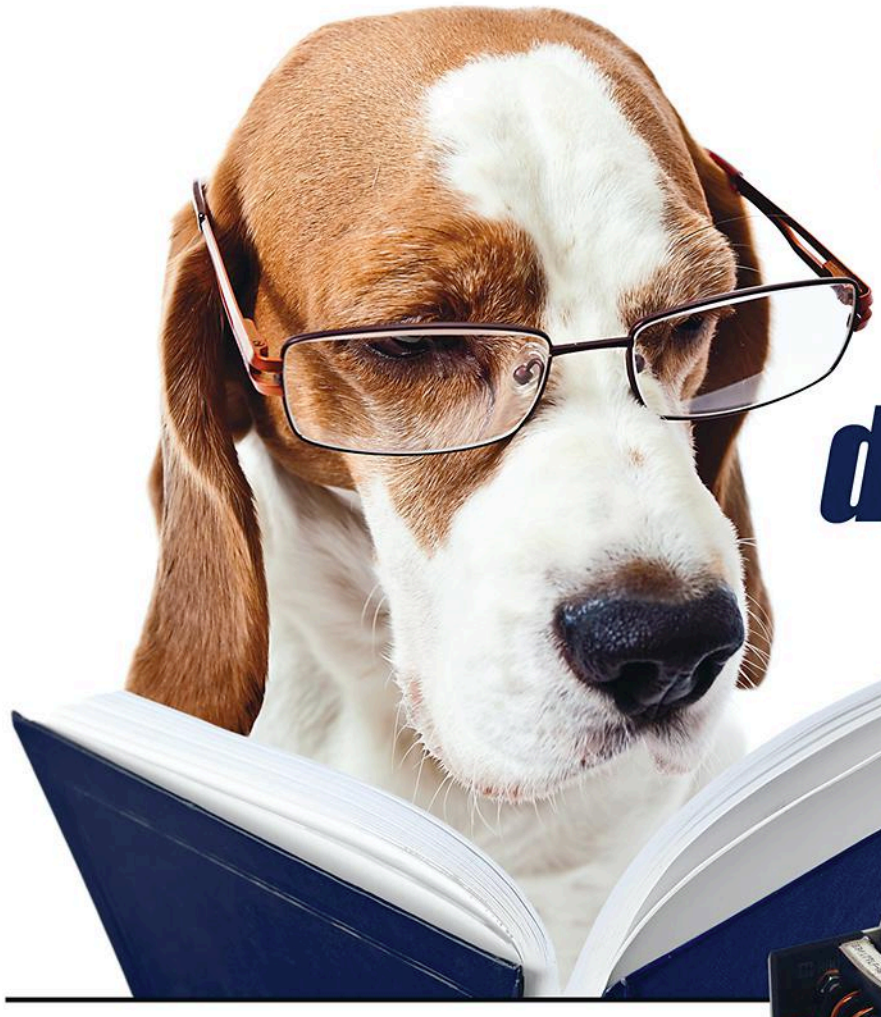
Providing access to the latest products and services is paramount for global distributors such as Avnet, which is stepping up efforts to provide support across its wide-ranging capabilities. Those capabilities include everything from providing sensors and other electronic components to IT hardware, embedded products, and cloud-based software and services. The idea is to support customers from "the edge to the enterprise" says Alex Iuorio, senior vice president, supplier marketing for Avnet Electronics Marketing.

"If you think of it 'from sensors to servers,' that's a big part, but it only speaks to the functionality, and IoT is much, much more than that," says Iuorio, noting Avnet's expertise in both electronic components and information technology solutions. "The IoT is also information management; it's a connected world—so all of those things are important."

That's why Avnet is leveraging its ability to provide additional services such as data analytics and supply-chain management to meet customers' needs to manage their IoT projects. This means supporting customers' components, embedded products, technology, and supply-chain needs across one IoT offering.

"We believe that we'll be one of those companies that is uniquely positioned, where a customer could enter anywhere along that continuum, move up and down, and get support at any point," explains Iuorio.

IoT services, in which external providers design, install, and operate IoT systems, are a large and growing part of the puzzle, too. According to Gartner Research, the services segment is expected to rise 22% in 2016 to $235 billion. ■



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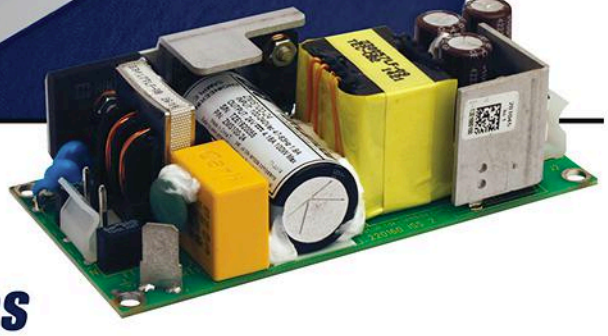

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equipment or special inlets to secure it, and includes a cage-release mechanism that is red to mark critical power sources. The connector is LSZH (low-smoke zero halogen) compatible for use in military, broadcast, transportation, and data centers.

MEGA ELECTRONICS INC., 4B Jules Lane, New Brunswick, NJ 08901, (732) 249-2656

tation, telecommunication, civil applications, and industry. It includes over-voltage protection at the output, as well as protection from short-circuiting and overheating. An application circuit is suggested for high EMC environments.

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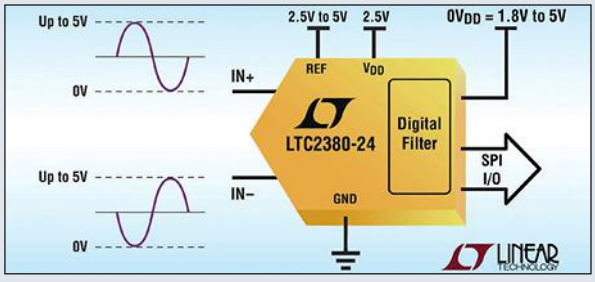

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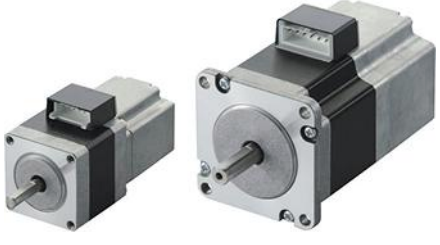

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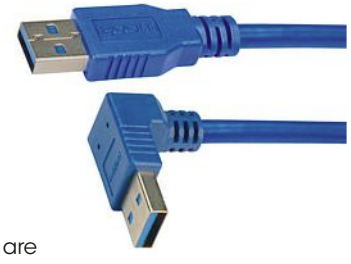

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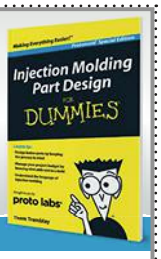

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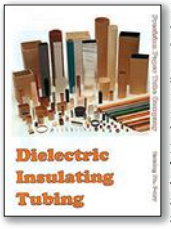

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BRADFORD L. GOLDENSE | Contributing Technical Expert

The Top 12 Trends in the Science of Managing R&D and Product Development: Part Two

Continuing on from our previous installment, here are the remaining six top trends in the science of product development and R&D management. When looked at collectively, these 12 trends will give you an idea of how much change is on the horizon for engineering and product-development organizations.

Trend 7. Engineering and Development Automation: Many engineers are seeing the changes brought on by rapid prototyping. Soon, robots, real-time software testing, and many other technologies will permeate the downstream end of product development. There will be less people involved in developing and delivering products. Conversely, there will be more people involved in solution planning, designing, and developing data-based software for customers that wraps products in blankets of information throughout its lifecycle (*Harvard Business Review*, November 2014 and October 2015).

Trend 8. Micro-Nano Effects: Product values will increasingly be defined by software, and products will continue to shrink in size. As sensors, motors, actuators, and other fundamental components get smaller, engineering activities and disciplines will change as well. Gradually, the importance of materials science and atomic-scale knowledge will supplant today's primary macro-scale competencies. Processes such as design reviews will eventually be conducted via electronic media and through microscopes.

Trend 9. Physical versus Virtual Work: More than half of all business email is now processed on handheld devices. Three-quarters of a typical company's product cost is outsourced. Globalization is officially business-as-usual. Engaging contractors in lieu of employees is a mainstream tactic. Commuting and business travel time is increasingly variable. Employee leave and PTO policies are changing. We are nearing a point where employers no longer strive to police employees' physical location, so long as the job gets done. The infrastructure to address industry's rapid transition to an increased level of virtual work will soon emerge.

Trend 10: Measurement and Correlation: In the paper age, the cost of calculating metrics was expensive. Today, with databases already holding all the numbers, the incremental cost of a metric is nearly zero. This is why the number of metrics, measures, data points, and info bytes we encounter each day is increasing rapidly. Soon, all the data for activities and products will be available for every point in a product or activity's lifecycle. When we reach that point, analysts will be able to reconcile causes and effects, letting them correlate nearly all measures and metrics to an outcome. With known correlations, the number of measures needed to manage with certainty will decrease. We will know which measures are predictive.

Trend 11. Open Innovation: Benchmarking in the 1980s changed what corporations historically considered to be private information. The fortresses surrounding most companies soon had doors. Globalization and outsourcing in the 1990s added more doors. Open innovation is installing even more doors, and is here to stay. All companies will learn to create doors to acquire innovation or invention wherever it is economical and timely to do so.

Trend 12. Intellectual Property: For almost a decade, the ability to monetize intellectual property (IP) has been increasing. Each year there are public auctions where companies can buy or sell IP. Company-to-company IP transactions are now an everyday norm. Little by little, IP is becoming a tradeable commodity—just like products. Experience is building and making it easier to assign values to both registered and unregistered IP. Soon, business and financial plans will regularly include forecasts for both products and the IP in those products. Many companies will elect to monetize the IP and not build anything. Folks in research and advanced engineering who are not generally involved in executing business plans—in other words, those who create IP—will also gradually be drawn into the financial cycle. md

THERE WAS AN ERROR in Bradford Goldense's Jan. article. In Trend 6, the sentence "Functional competencies, on the other hand, are the many skills and capabilities a company needs to make use of its core competencies such as HR, accounting, and the mailroom," should read: "Functional competencies are the dozens of specific technical and business skill sets across marketing, engineering, materials, and production that get a product out the door." *MD* apologizes for the error, and the online version of the article has been corrected.

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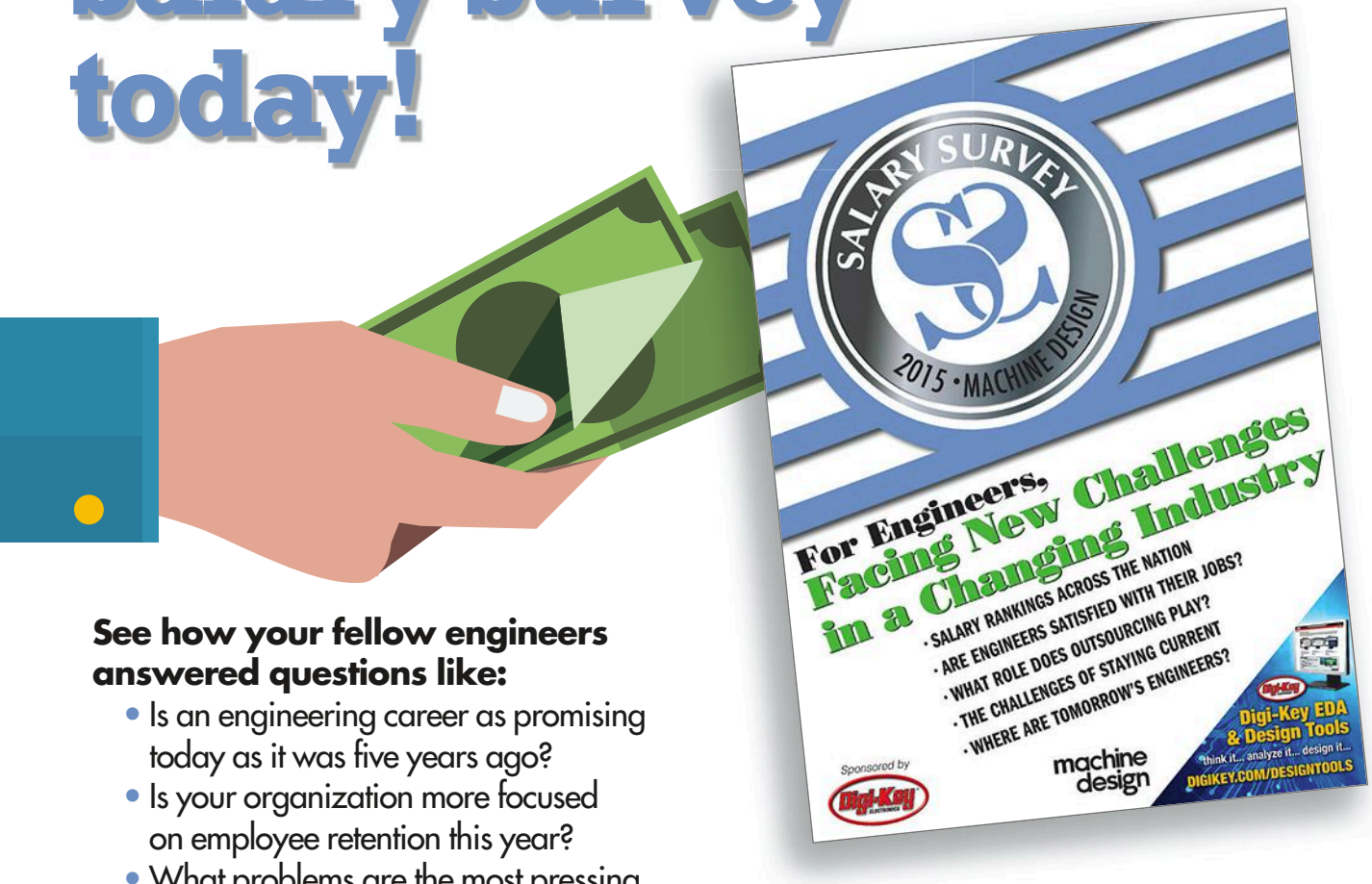

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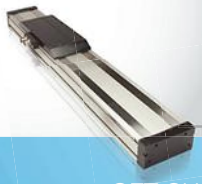

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