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MARCH 2016
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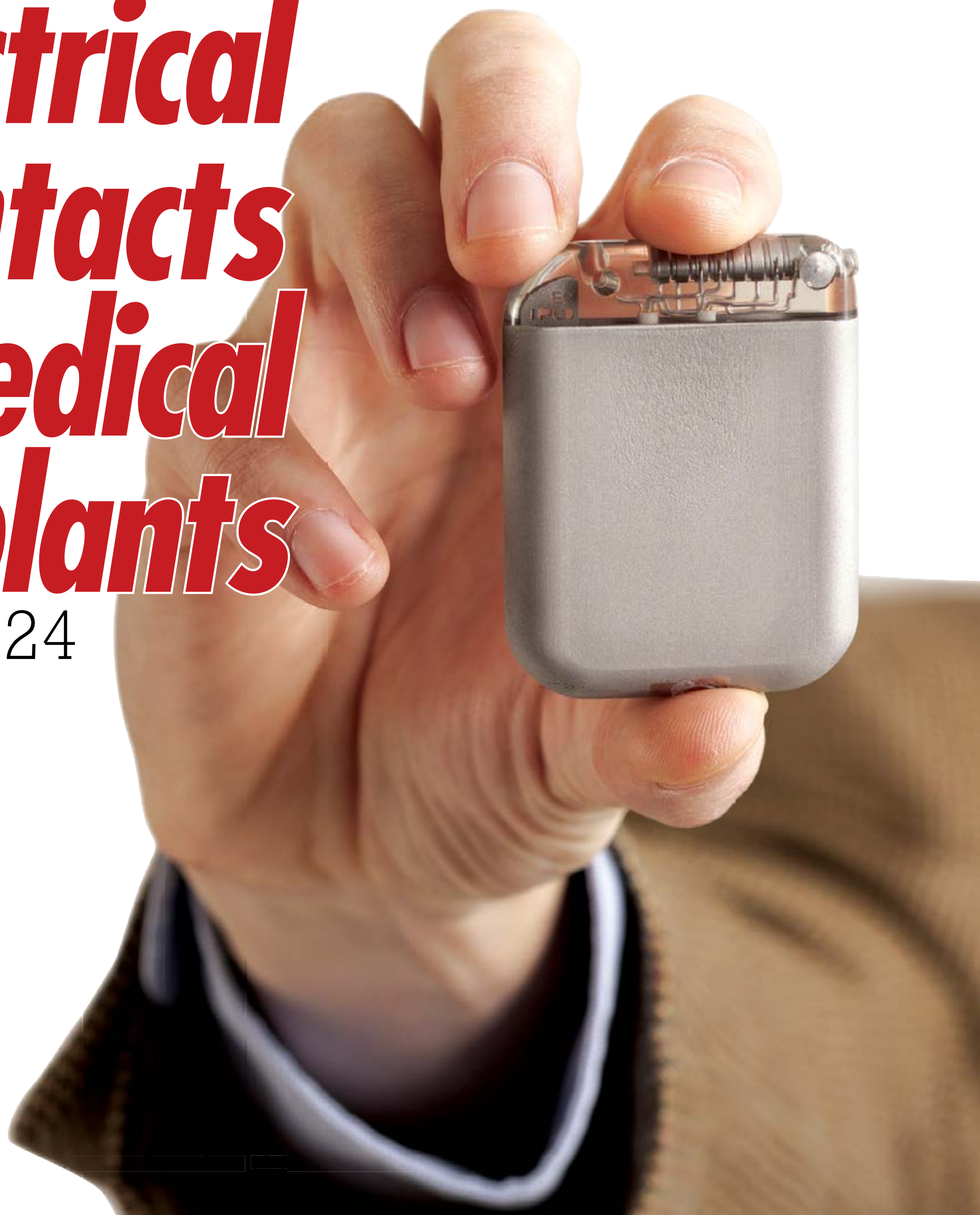
p|24



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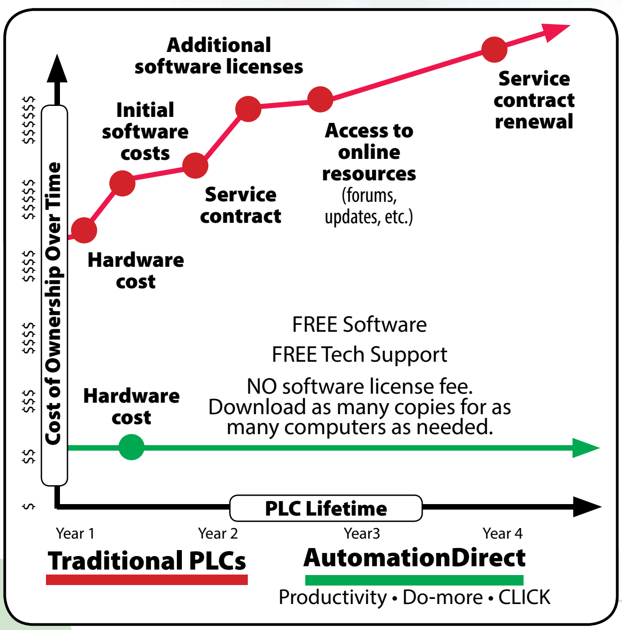

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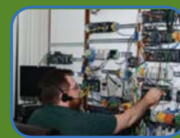

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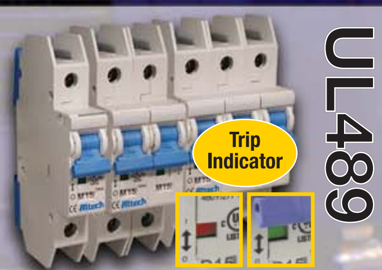

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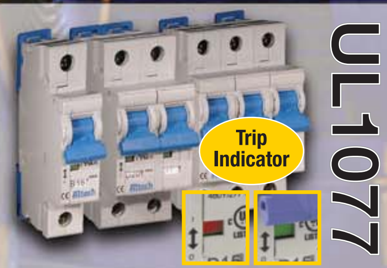

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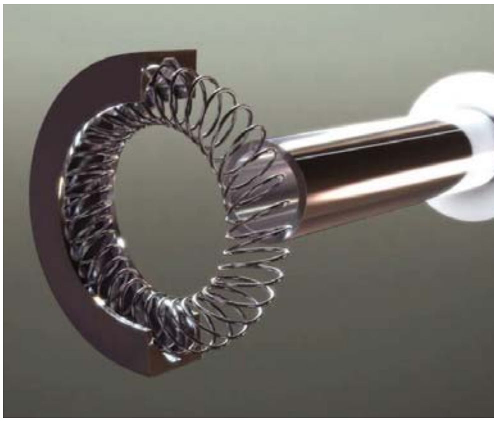
In This Issue

FEATURES



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DEPARTMENTS

COLUMNS

ON THE COVER: A medical implant is topped with a SYGNUS Connector System from Bal Seal.

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Paid subscriptions include issues 1-12. Rates: U.S.: $139/year; $199/two years. Canada/Mexico: $159/year; $239/two years; All other countries: $199/year; $299/two years. Cost for back issues are U.S. $10.00 per copy plus tax, Canada $15.00 per issue plus tax, and Int'l $20.00 per issue. OEM Handbook and Supplier Directory, $50.00 plus tax. Prepaid subscription: Penton Media (Machine Design), P.O. Box 2100, Skokie IL 60076-7800. Periodicals postage paid at Kansas City, MO and additional mailing offices.

Can GST #R126431964. Canadian Post Publications Mail Agreement No.40612608. Canada return address: IMEX Global Solutions, P.O. Box 25542, London, Ont., N6C 6B2.
Digital subscription rates: U.S.: $69/year. Canada/Mexico: $79/year. All other countries: $99/year. Print/Digital combo subscription rates: U.S.: $174/year; $249/two years. Canada/Mexico: $199/year; $299/two years; All other countries: $249/year; $374/two years.
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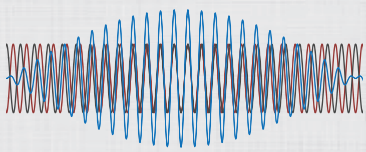

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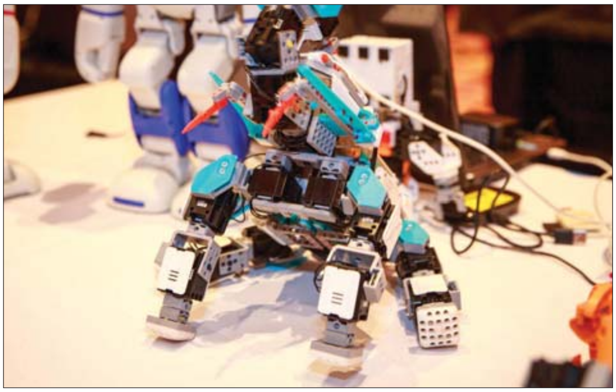

THIN LINE BETWEEN TOYS AND ENGINEERING

http://machinedesign.com/blog/vanishing-line-between-engineering-and-toys

After attending Pacific Design West and the International Toy Fair back to back, Technology Editor Carlos Gonzalez was struck by how the latest engineering innovations have been integrated into the latest toys—and impressed by how many new toys for kids are designed with STEM education in mind. Read his blog for his observations, and don't miss the gallery of images from Toy Fair (*http://machinedesign.com/news/latest-stem-kits-and-toys-international-toy-fair-2016*).

HISTORY'S MOST OVER-ENGINEERED AIRCRAFT

http://machinedesign.com/blog/4-incredibly-over-engineered-aircraft

Why is it that some airplanes seem to fly well past what anyone could've hoped for in terms of an operational life? Is it overdesign or good design or both? Technology Editor Stephen Mraz takes a look at four legendary planes that have outflown others of their eras.

MICROBE METABOLISMS MAY REVEAL CLUES ABOUT ATMOSPHERE

http://machinedesign.com/news/analysis-microbe-metabolism-could-reveal-clues-about-atmosphere

Woods Hole Oceanographic Institution (WHOI) is studying the biochemistry of microbes in low-oxygen maritime regions—also known as dead zones— where aerobic lifeforms that depend on free oxygen in the water cannot survive. They hope to gain insight on current cycles of organic materials in dead zones and their effects on Earth's atmosphere.

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MAKING SHAPES OUT OF COLD-DRAWN STEEL

Groove is too wide and deep; die would break too often.

http://machinedesign.com/metals/tips-making-shapes-out-cold-drawn-steel

Special-section steel bars are hot-rolled bars that have been cold-drawn to a designer's or manufacturer's specifications. Usually they are given the cross-section and size of a part they will be used to make. They are made like standard shapes (rounds, squares, hexagons, and flats), except the die is shaped to precut the required cross-section. Here are illustrated tips to making shapes out of cold-drawn steel.

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vacuum generators permit easy adjustment by simply loosening the locknut and turning the exhaust to increase or decrease the level of vacuum. Four models available. Ideal for porous and non-porous applications.

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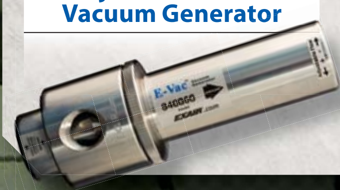

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Editorial

STEPHEN MRAZ | Senior Editor
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What to Expect in Solar Power

To get an idea of what the year might have in store for solar power, here's a quick look at a few predictions from Sven Lindström, CEO of Midsummer, a Swedish firm that designs and builds equipment for making thin-film solar cells.

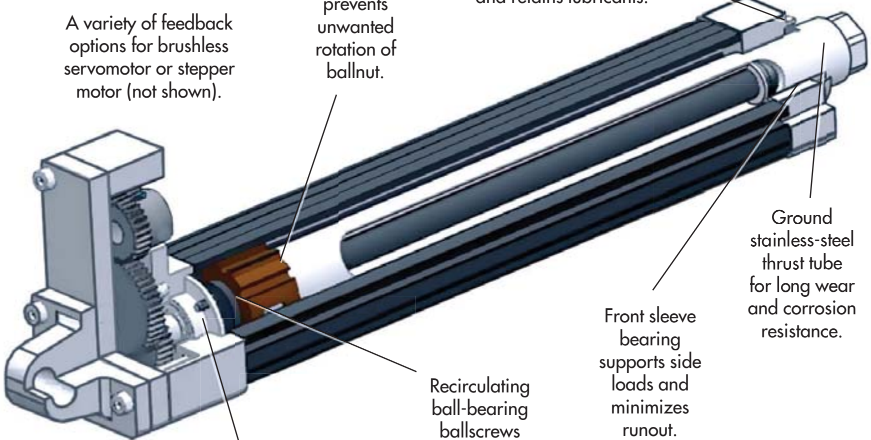
1. China will strengthen its position as the world's leading producer of photovoltaic solar cells. China is already the most prominent player in this field. And political stability, large government subsidies, and a host of innovative home-grown entrepreneurs will keep China at the top in terms of solar-cell production. In fact, few companies elsewhere in the world dare invest in production capacity with China so far ahead.

2. Governments won't be able to resist solar-energy taxes on private citizens. In most countries, the government earns more from taxes on solar power than the utilities that build solar-power plants provide it. So as feed-in tariffs on solar power generated by individuals decrease and installations of rooftop systems increase, governments will extend their reach into the pockets of homeowners and private citizens, installing them for their own use. In fact, many countries will follow Germany's lead in establishing a self-consumption levy. That means all those hoping to generate "free" electricity could be in for a surprise (new taxes).

3. Price cuts in solar power will depend on innovations in installation. Factory prices for photovoltaic modules will not fall dramatically, but there is still some room for improvements in installation and system costs. Module-level efficiencies will be improved, but the majority of the production overcapacity is now gone, so price cuts will have to come from innovations and improvements in installation costs.

4. It will be a disappointing year for batteries that back up solar power. Batteries might have a future in solar power, but only for off-grid systems and those built in sun-rich countries where the amount of sunlight does not vary much over the year. Battery technology is also still uncertain and the limited life of battery systems makes large investment in them unlikely. That's why batteries will not boom in 2016 when it comes to those targeted at solar power systems. md

Compact, Electric Cylinders Lower Costs

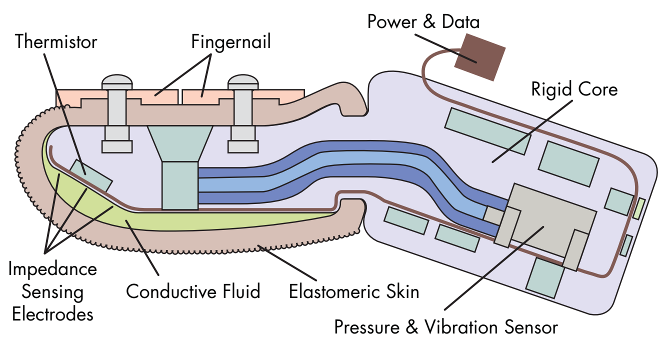


THE EC1 LINEAR Positioner from Kollmorgen (www.kollmorgen.com), Redford, Va., has a maximum stroke length of 200 mm and delivers thrusts of up to 150 lb at 13 ips. It operates in temperatures from –30 to 70°F. The positioner can be used either with the company's AKM brushless servomotor or its CT stepper motor. Engineers have reduced the size of the unit by 33% compared to alternatives. It is designed as a clean, efficient replacement for hydraulic actuators as well as pneumatic cylinders.

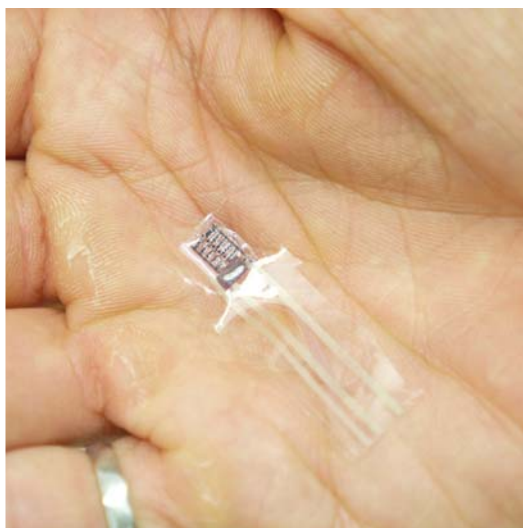
The unit is available in both standard and custom lengths. In addition, it can be equipped with either threaded, spherical, or clevis rod ends. For feedback, optional home and limit sensors are also available. md

Simulating Human Touch

A NEW TACTILE sensor from SynTouch (www.syntouchllc.com) performs three notable functions. First, the impedance is measured by using a flexible bladder against an array of sensing electrodes in a rigid core. It thus obtains a deformity measurement, much like the human finger uses ductile skin and flesh against a rigid bone. This is where the fingernail is needed—it causes budges in the skin that allow shear forces to be detected.



Second, micro-vibrations are registered by a pressure sensor mounted on the inside of the sensor's core, enabling the measurement of surface roughness and texture. It's at this point where the fingerprints add a lot of value, since they interact with textures.



Third, in the sensor's thermistor, the electrical resistance depends on temperature. The sensor (like a human finger) generates heat, and the thermistor allows the sensor to detect how it's exchanged when it touches something.

By placing all electronics inside a rigid core and covering them with a compliant replaceable bladder, this sensor is able to function more robustly while providing sensitive human-like measurements. Electronics such as this could someday be a normal sight on robotic hands, offering a real human touch that allows a robot to identify material and grip it appropriately. md

News

NASA, BOEING, AND MIT

Team Up on "Modeling Complex Systems" Course

Ever-increasing complexity of systems in manufacturing and aerospace pushed MIT, Boeing, and NASA to offer a four-part online course on how to model and analyze intricate systems. As the first manifestation of the Space Act Agreement signed by NASA and Boeing last year, "Architecture and Systems Engineering: Models and Methods to Manage Complex Systems" is a certificate-based course aimed toward generating a workforce that is up-to-date on the latest standards and capabilities in science, technology, engineering, and mathematics.

The four-part course, available this summer, focuses on modern complex systems from hybrid cars to aircraft, and presents students with real-life case studies. Participants should expect to finish the class with the skills to frame system architecture as a series of decisions that can be actively sorted and managed.

THE FOUR TOPICS

Students will first be introduced to architecture, system thinking, and the modern challenges faced when creating complex systems. Then they will move on to analyzing complex systems to determine function, costs, and benefits.

The second track will look at different ways to model complex systems, determining the parametrics, physics, and estimations needed to model dynamic systems and calculate optimization and final outputs.

The third part of the class introduces students to two standard languages used to generate model-based systems: Object Process Methodology (OPM) and Systems Modeling Language (SysML). The languages are useful for managing complexity, enabling programmers to model structure, features, specializations, functions, operands, lifecycle, assumptions, curation, end of life, and instances.

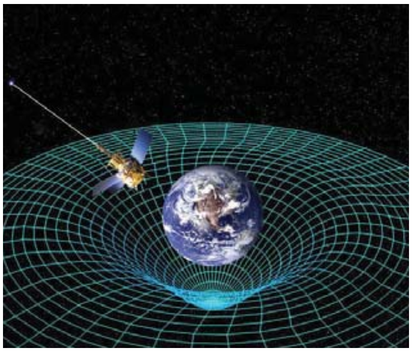
In the last track, students will explore quantitative methods in systems engineering. They will build models based on architectural decisions using tools for collaborative model building. In the end, students will try to come up with their own designs for systems in space exploration.

"To manage these complex, highly interdependent designs, traditional systems, engineering methods need to evolve to incorporate modern modeling and simulation capabilities. Incorporating these capabilities into systems engineering enables designs that would be nearly impossible to produce affordably with current methods," says Christi Gau Pagnanelli, director of systems engineering at Boeing.

Dr. Bruce Cameron, director of the System Architecture Lab at MIT, will direct the program. The cost for the class has not yet been determined, but interested parties can visit *http://bit.ly/1TBodbV* for more information and to register for email updates. ■

RIPPLES IN TIME-SPACE Caused by Colliding Black Holes

FIFTEEN YEARS AGO, scientists set up Laser Interferometer Gravitational Wave Observatories (LIGO) in two U.S. states (Washington and Louisiana) with the hopes of detecting ripples in time-space caused by two massive colliding black holes 1.3 billion light years away. In 2014, a major breakthrough was made—sensors were developed that could pick up on very minuscule changes in interference between two lasers. In turn, teams at both observatories were finally able to detect contractions in time-space caused by the gravitational waves.



The gravitational field and spinning motion of the earth has a proven effect on the space-time continuum, warping it so that time and space are defined differently than they are here on earth. (Courtesy of NASA)

The phenomenon is coherent with Einstein's theory of general relativity, where the gravitational field of massive bodies causes warping in the fabric of time-space. For example, in 2004, NASA scientists found that the axes of gyroscopes in satellites orbiting the earth were shifting over time due to an alteration in time-space caused by the earth's spinning gravitational field. At LIGO, they detected gravitational waves that were generated by two massive colliding bodies with enormous gravitational fields, causing a big ripple that propagated through the universe.

Detection of gravitational waves marks a new era in identifying cosmic phenomena across the universe. Light is no longer the sole source of deep-space information gathering. This advance in research may map out changes in time-space caused by interactions between bodies with their own gravitational fields.

WHAT IS THE FABRIC OF TIME-SPACE?

As proposed by Einstein in his theory of special relativity, the relationship between time and space is actually determined by the speed of a moving body. This was met with

LIGO scientists were able to detect ripples in time-space, or gravitational waves, caused by colliding massive black holes.

skepticism, since time seems like a constant entity on Earth that just keeps moving forward. However, the speed of light is actually the upper limit that defines time and space, and both variables can change, depending on the speed at which they are observed. For example, a traveling body that approaches the speed of light will begin to observe time moving slower. And since light can travel far distances over a very short time, this indicates that space contracts for a light beam. ■

FREE TRAINING FOCUSES on PLC/PC-Based Control Automation, Programming

A THREE-DAY TRAINING program for automation technology and IEC 61131 programming—available for free from WAGO—will occur on five separate dates in 2016: March 8-10, May 3-5, August 2-4, September 13-15, and October 25-27. The sessions will be held at WAGO's headquarters in Wisconsin. They are tailored to individuals who have hands-on experience with programming and installing PLC- or PC-based industrial-control systems.

The program combines lectures and hands-on exercises with CODESYS-based programming on live nodes. IEC 61131 programming topics include application-specific functions, custom-library and function-block development using WAGO-I/O-PRO, and software diagnostic tools like I/O Check.

Seminars are limited to 12 attendees per session, so enrolling online early is encouraged. Attendees should bring their own laptops.

Contact Training.us@wago.com with inquiries. ■

DOE REVEALS NEW STANDARDS
on Commercial, Industrial Pumps

THE U.S. DEPARTMENT of Energy's (DOE) Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) released a new Energy Conservation Standard and test procedure for commercial and industrial pumps (CIPs), including circulator pumps. Developments and supportive data were presented to the DOE by the Hydraulic Institute (HI).

The new standards on pumps are expected to save 0.29 quadrillion BTUs in 30 years after their implementation. These standards will become mandatory in 2020, four years after the date of publication in the federal register.

According to the DOE, the standards provided by HI are technologically feasible, economically justified, and will significantly conserve energy on a national scale. The extensive report, released on Dec. 31, 2015, covers the final energy-conservation rules for CIPS and defines the products affected by these new rules. It reviews the benefits and costs to consumers, impact on manufacturers, and national benefits of the new standards.

Circulator-pump manufacturers and other interested parties can contact Peter Gaydon, Technical Director, Hydraulic Institute, at pgaydon@pumps.org with any questions, or if they would like to become involved with the institute.

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Interview

SCOTT STEFFAN | Deputy Director
Space Access, Moog

3D Printing for Space

Deputy Director for Space Access Scott Steffan talks about Moog's new metal 3D-printing facility.

Tell us about your background.

I earned a B.S. in Mechanical Engineering from Clarkson University, and an M.S. in Mechanical Engineering from Rensselaer Polytechnic Institute (RPI). Starting as a senior structures engineer at United Technologies, then Pratt & Whitney, I performed mechanical design and structural analysis for numerous turbine components and other responsibilities.

I joined Moog in 2001 as a design engineer for their Aircraft Division, and have held a few positions, but now as deputy business unit director, I provide oversight to engineering and program teams to ensure technical and cost objectives are achieved.

What is Moog's background in 3D printing?

Moog has been investing in 3D metal printing, primarily in the form of additive manufacturing since 2014. We created an Additive Manufacturing Center (AMC) at our headquarters in East Aurora, N.Y., that now has two powder-bed fusion machines and has plans to continue to expand. These machines have been established for specific materials. We are working with titanium, Inconel, aluminum, copper, cobalt chrome, and stainless steel. The most common materials we use for space are aluminum, stainless, and titanium. We are also growing the AMC to be a turnkey center with all necessary pre and post processing capabilities needed to continue technology development.

Why focus on space, and why now?

The focus on lower hardware cost and more efficient product development is very strong in the space access, space exploration, and spacecraft markets today. With our investments in the capability over the last years, Moog has already been involved in the development of a large array of space products. 3D printing is beginning to become an integral part of the commercial space industry. It's used to increase the speed of product development, as well as overall manufacturing lead time.

From a design perspective, it has also opened up new opportunities to improve solutions. The benefits can come in the form of lower recurring cost, lighter weight, and higher performance—offering a higher overall value to customers and partners. Improvements are realized through part-count optimization, material and size optimization, and the ability to manufacture more complex, highly integrated geometries. 3D printing reduces non-recurring costs significantly because there are no special tools or fixtures needed to manufacture the parts.

As for why now, it is tied to the need to create innovative

Moog recently acquired Linear Mold and Engineering (Linear AMS), bringing significant additive manufacturing capability and capacity into the fold.

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solutions that continue to help accelerate space access and in-space use cases. This goes hand in hand with both growing the commercial space sector and enabling space exploration. We want to be part of the organizations leading this research and development and providing valuable innovative solutions to the industry. Looking at both NASA's pursuits and commercial interests, it would likely be tough to find companies or engineers that wouldn't want to be a part of these innovations.

3D printing metal has been able to demonstrate very good material properties. The isolation valve shown above was additively manufactured and development tested well beyond the anticipated capabilities. This titanium body survived pressure testing to levels up to 20,000 psig.

Where does 3D printing come into play when talking about commercial space applications?

These advantages come at a time where the space market is transforming. Commercial and new-space markets are growing, with many new launch vehicle and space companies emerging. These companies are very focused on a fail fast, learn quickly, spiral development model that can benefit from the lead time savings that additive manufacturing brings. For example, we used rapid prototyping to optimize for mass and a 3D-printed enclosure was rapidly prototyped for performance and environmental testing. Later this part transitioned to a vacuum sand cast-aluminum for production, but the quick testing allowed us to test the part and make any changes so we were able to get to a production part faster.

What are the benefits 3D printing brings to designing for space?

In addition to the previous benefits is the ability for 3D printing to mitigate the risk of obsolescence issues. 3D printing provides the ability to reconstruct virtually any component geometry through the use of simplified reverse engineering. Existing component geometries can be obtained quickly using scanning and x-ray techniques and efficiently integrated into the additive manufacturing process. This provides the ability to recreate a part without the costs and lead times associated with conventional reverse engineering and remanufacturing techniques.

The real-time nature of 3D printing allows companies to capitalize on ideas while they are still warm, facilitating the ability to do "what-if" type developments quickly and at less cost than in the past.

What does a company need to enter this space?

Some of the things that have helped us evolved from years of design, development, and production heritage across a wide range of industries include in-house material expertise for assistance in analysis, and to perform material certifications. The process to design, build, and test space hardware needs to be well understood as tolerances and finishes are imperative. Access to non-destructive inspection capability and associated procedures, as well as the ability for x-ray type scanning capabilities has also been very helpful. md

MARK RUSSELL | Global Market Manager for Medical Electronics
Bal Seal Engineering Inc., Foothill Ranch, Calif., *www.balseal.com*

The Next Generation of Electrical Contacts for Medical Implants

Canted coil-spring-based electrical contacts ensure reliability and redundancy of the electrical connections in neuro devices, pacemakers, and other implants.

Here is a cutaway view of a canted coil-spring assembly that serves as an electrical contact. The male connector (shown) goes through the middle and makes contact with many of the spring's coils.

Medical devices that alter brain, spine, or nerve activity for therapeutic benefit are a fast-growing segment of the healthcare industry, notes a 2015 report from Life Science Alley, a Minnesota-based medical device trade association. *Sector Landscapes: Neuromodulation* projects that the strong global market for neuromodulation devices will double by 2018, reaching $6 billion to $7 billion. This article examines the electrical contact technologies that are driving this market toward the next generation of device development.

The global neurostimulation/neuromodulation market is surging as an aging population faces diseases such as Alzheimer's, epilepsy, spinal-cord injury, and Parkinson's disease. The therapies for these diseases are dominated by implantable neurostimulation devices, which make up the largest part of this market with a 96% share of the total. According to the Life Science Alley report, neuromodulation devices are registered in more than 1,000 ongoing FDA-regulated clinical trials worldwide, in which more than 1,300 indications, including metabolic disorders, inflammation, migraine, and psychiatric disorders, are being investigated.

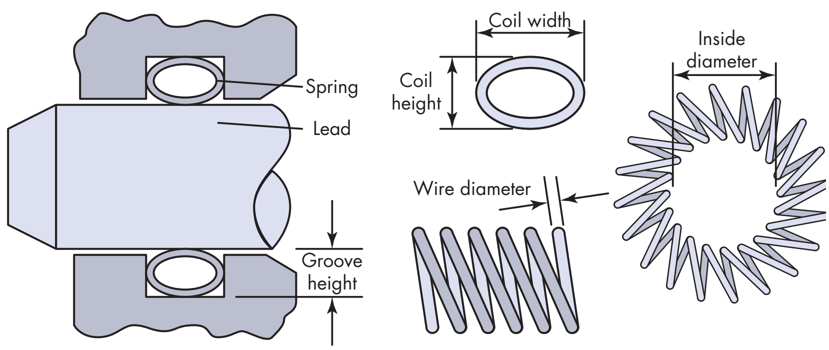
The report also notes that one of the key developments within this growing market is the emergence of closed-loop systems that are "capable of sensing ongoing brain or nerve activity and incorporating it into stimulation parameters for optimized therapeutic efficacy in real-time." This closed-loop functionality in active implantables requires optimal power efficiency and signal isolation, and much of this depends upon the performance of electrical contacts and contact systems used to connect leads to batteries and electronics in these devices.

Highly conductive and space-efficient components, such as the Bal Conn electrical contact and the Sygnus implantable contact system, are designed to support the signal-isolation requirements of closed-loop, high-connector-count arrays. With the use of closed-loop devices becoming more widespread, the ability to support smaller footprint connections for active implantables in a proven and reliable design will be increasingly critical.

UNPACKING THE TECHNOLOGY

For over two decades, the Bal Conn electrical contact has been helping manufacturers improve implantable medical-device performance and push the technology envelope. OEMs developing each generation of active implantables have relied on electrical connections that use canted coil springs as contacts.

Sizing a Canted Coil Spring



Coils can be made in a variety of sizes, such as these from Bal Seal Engineering Inc.

It's estimated that canted coil spring-based contacts have been used in more than a million pacemakers, defibrillators, neurostimulators, and other active implantables that deliver life-improving therapies to patients worldwide. These electrical contacts have also dramatically simplified the process used by surgeons to connect leads to implantables across the therapy spectrum, including cardiac healthcare, pain management, and sensing therapies, ultimately shortening procedure times.

Developed in cooperation with a medical electronics manufacturer seeking to reduce package size while increasing reliability, the Bal Conn electrical contact is an electrically conductive component consisting of a precision-engineered canted coil spring retained in a metal housing. The contact, which is molded into a device header, facilitates a uniform, consistent electrical connection between the lead and the battery in active implantable devices.

The Bal Conn's individual spring coils provide multipoint conductivity, adjusting individually to maintain maximum contact with electrodes on the lead that is inserted into the device header. The contact's compact size allows for greater connector density where space is limited, and its unique design eliminates the need for tools during the connection process.

Due to its redundant contact points, the Bal Conn offers low contact resistance, and its canted coils provide excellent resistance to fatigue. With its ability to offer low insertion force and exceptional electrical conductivity, it is ideal for use in devices that have high connection counts, such as neurostimulators.

In a typical neuromodulation device, the lead diameter ranges from 0.9 to 1.4 mm. The Bal Conn is sized so that its spring coils exert a measured, consistent force, also called the breakout force, on the lead when it is first inserted. The force needed to slide the lead further in, the running force, is as predictable and reliable as the breakout force, and engineers can adjust these forces through design. These forces are low enough to make it easy for surgeons to insert and remove the lead.

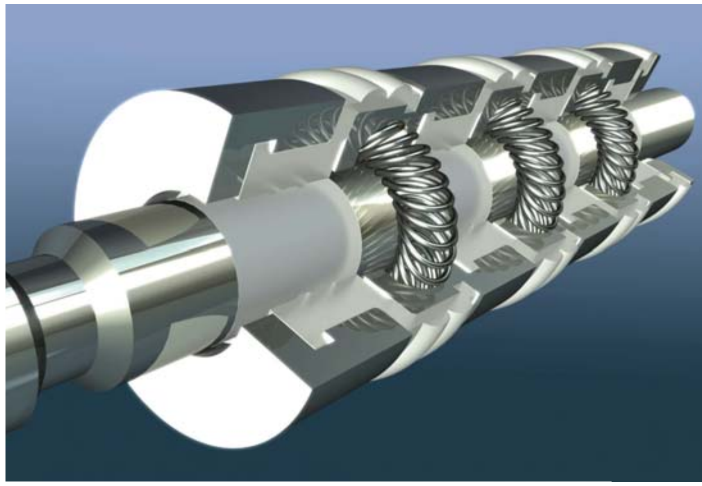
Applications requiring light forces have a theoretical breakout force as low as 0.5 N and a running force as low as 0.2 N, depending on design parameters. For those applications requiring heavy forces for latching, the theoretical breakout forces are as high as 15 N and the running forces are as high as 4 N with a single spring.

The spring material utilized for neuromodulation applications is typically platinum/iridium. Platinum/iridium is selected for its biocompatibility, durability, electrical conductivity, and radiopacity. The housing for neuro applications can be created using a variety of materials, including

TECH SPECS FOR COILED SPRING CONNECTORS

Applications	Lead diameter (mm)	Force category	Max. breakout force (N)	Running force range (N)	Housing material	Spring material	Static dry contact resistance (mΩ)
Neuro (bi-directional)	1.35	Medium	1.2	0.009 to 0.4	MP35N	Platinum/iridium	70±20
					316L	Platinum/iridium	600±200
		Light	0.70	0.07-0.3	Medical-grade titanium	Platinum/iridium	350±150
					MP35N	Platinum/iridium	80±30
					Platinum/iridium	Platinum/iridium	40±15
IS-1 (bi-directional)	2.67	Medium	3.1	0.25 to 0.75	316L	MP35N	100±60
IS-4/DF-4 (uni-directional)	3.2	Heavy	2.7	0.5 to 1.0	MP35N	MP35N	80±50
IS-4/DF-4 (bi-directional)	3.2	Medium	2.7	0.25 to 0.75	MP35N platinum/ iridium	Platinum/iridium	40±20
VAD	3.2	Medium	2.7	0.25 to 0.75	Platinum/iridium	Platinum/iridium	30±20

Neuro applications are usually neurostimulators; the IS-1 and IS-4 connectors are for cardiac pacemakers. IS-4 I is replacing IS-1 as the standard. VAD stands for ventricular assist device, a pump inserted into the heart to keep cardiac patents alive until a donor heart becomes available, though it is often left in patients long-term.



This cutaway view of a Sygnus connector shows a lead segmented into three sections inserted to mate with three canted coil-spring contacts.

MP35N, 316L stainless steel, medical-grade titanium, or platinum/iridium.

Within the contact, both the coils of the spring and the spring itself have precise diameters, but there is no "standard" size for neuromodulation devices. Each Bal Conn is custom-designed to fit the particular unit's lead interface, and the lead is held in place via frictional fit. A set screw or locking detent, located at either end of the channel into which the lead slides, anchors the lead in place. Once the electrodes are aligned with each Bal Conn, the device becomes operational. The spring electrically connects the implantable pulse generator to the lead through all of its individual coils.

Using the spring as an electrical contact provides redundant paths for power and information signals, and the redundant contact points provide for low contact resistance. Their canted coil design helps ensure that they resist compression set and fatigue, providing consistent performance over a long operational life, one that typically exceeds the implantable device itself. The springs compensate for imperfections on the surface of leads, accommodating a certain amount of misalignment.

Engineers at Bal Seal Engineering work with medical OEMs to ensure that they have the right design for the application. With its long history of designing for active implantables, the company has developed both uni-directional and bi-directional contacts, which enables OEM integrators to choose which design works best for their particular requirements. With uni-directional versions, the lead must be inserted from one specific side of the contacts. With bi-directional contacts, the lead can be inserted from either side. For neuro devices, the contacts are always bi-directional. Both types are available for other active implantables; however, once integrated into the IPG header, the distinction is no longer significant and has no impact on the surgeon or device functionality.

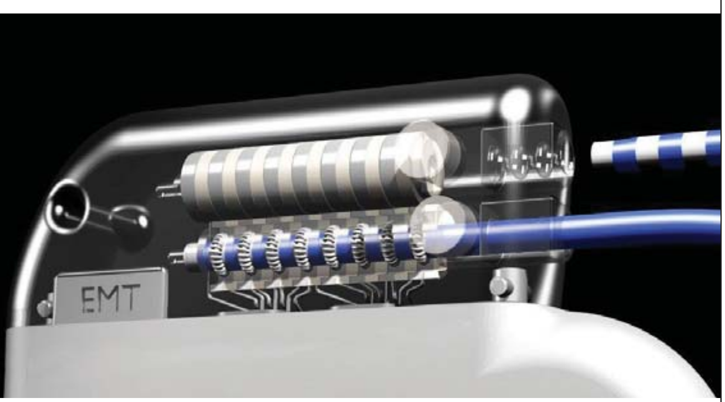
SIMPLIFYING DESIGN FOR OEMs

The Sygnus implantable contact system, which combines electrical contacts and isolation seals in a standardized, platform-ready stack configuration, is designed to improve time to market and eliminate the need for procurement and testing of individual components. It lets OEMs concentrate on the design and function of the implantable rather than worrying about the intricacies and technology behind the connectors. It also creates greater connector density with pitches, or distances between contacts.

Implantable-grade silicone isolation seals keep the contacts electrically separated, as well as separating the different segments of the lead. The seals help prevent signal leakage that can disrupt the active implantable's function. The result is a densely packed connector stack that accommodates leads with diameters down to 0.7 mm. A 0.64-mm version is currently under development. Sygnus can be modified to suit device-manufacturer requirements for size and number of connections, as long as they are within design limits.

The seal design and dielectric materials were tested in accordance to industry standards by submerging them in saline, a good substitute for the conditions inside the human body. The goal of the testing is to measure impedance between connectors in a simulated body condition. The seals are cleaned to 10K cleanroom standards and packaged in antistatic bags to prevent contamination.

Evergreen Medical Technologies has used Sygnus technology in its device development, including in its Encompass Lead-Interconnect System. In the Encompass, the Sygnus system is combined with a pre-molded 16-channel header. By combining the header, connector, sealing components, and lead into a single, reliable system, it lets companies developing neurostimulators shorten the time needed to design, develop, source, and test the final device. Although it was originally designed for implanted neurostimulator devices, the system could find use in other implantables as well.



The Encompass implantable multi-contact connector accepts two leads, each with eight separate contacts or signal paths. The bottom one is rendered so that you can see the inner workings.

PREPARING FOR THE NEXT GENERATION

Future developments are being driven by the need for higher connection counts, more compact footprints, closed-loop configurations, and high levels of manufacturability. One reason for such improvements, especially the move toward smaller lead interfaces, is to give OEMs the platform on which to build cutting-edge treatments for hearing and vision loss. One of the engineering challenges they must overcome is that as the connectors get smaller, tolerances become more crucial and manufacturability becomes more complex.

With the use of closed-loop devices becoming more widespread, the ability to support smaller-footprint connections for active implantables in a proven and reliable design will become increasingly critical. To address this, Bal Seal Engineering has developed a new sub-assembly concept to help engineers dramatically improve device functionality while reducing overall package size. The concept, which can incorporate a "cap" or cover design, uses vertically positioned pins or rods of varying diameters to double or triple the amount of connections available to the device lead. It can be engineered to minimize insertion-force issues that present challenges in serial arrays with small leads, and it offers designers new opportunities for improved contact density.

Essentially a "build up, not out" approach that challenges the established linear contact/header layout, the high-density vertical array was conceived to help OEMs pack more functionality into active implantables and shrink the size of the electrical connectors in medical devices. The array combines one or more canted coil-spring contacts, a non-conductive polymer interface, and implant-grade silicone. Some of the uses envisioned for the vertical array are in implantables where small size is critical, such as cochlear implants and deep-brain simulators.

Life Science Alley's report points out that the complex nature of neurodegenerative disorders has set the stage for "numerous potential physiological targets, low competition in treatment-resistant diseases, and significant drive for innovative treatments and novel technology." As active implantables in neurotechnology continue to advance and prove to be the gold standard for therapy, there will be increased adoption of these life-changing devices. And, as advances such as closed-loop configurations lead to the need for higher connection counts and more compact footprints, design engineers will be faced with the challenge of making the required number of connections in less space with proven underlying technologies. md

JEFF KERNS | Technology Editor
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New Materials Push the Embedded Tech Envelope

Research in materials science and embedded sensors have led to advances such as rubber-bound metal nano blobs to increase conductivity and machines that can "feel."

Researchers have been finding new ways to embed sensors and other value-added devices into what some refer to as "smart materials." While the definition can be debated, material properties and sensors are working hand-in-hand, opening doors to new applications that could change how engineers test and design parts.

"Engineers have been embedding sensors into materials for over 40 years," notes Richard Claus, founder of NanoSonic. "I worked on some of this research in the 1970s with NASA, and the field has grown more popular and interesting ever since. It allows for creativity and out-of-the-box thinking, but it also means new challenges."

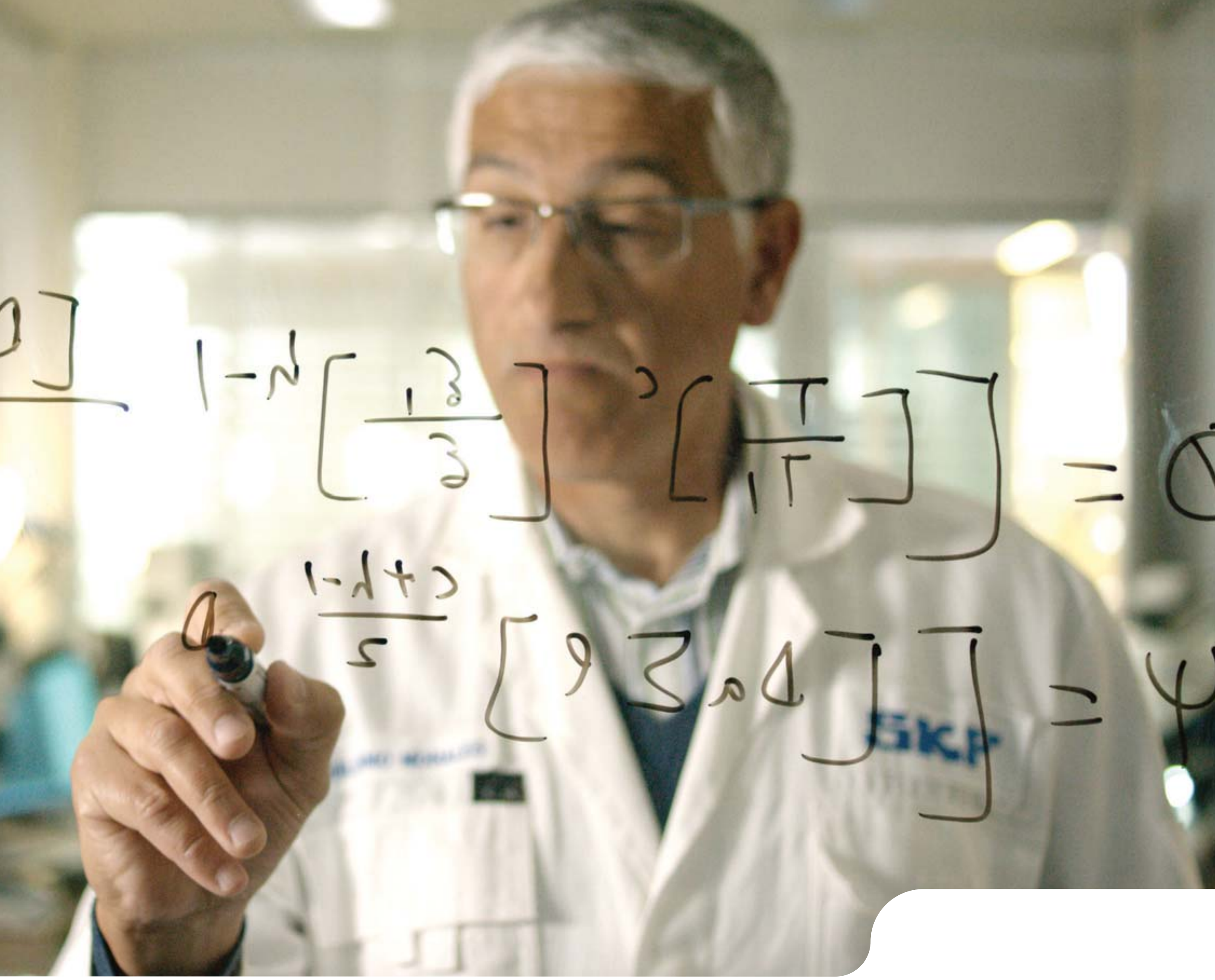
Syntouch developed a small fingertip-like sensor that uses fingerprints, nails, and bladders to increase sensitivity and simulate human touch for machines.

For example, stress concentrations are a concern when embedding sensors into materials. Any inclusion can limit a product's lifecycle or inhibit testing. Designing with new composite material was one way to solve this challenge. Engineers layered composites strategically around inclusions to redirect stresses around any electronics. Many of the electronics used are for testing in order to see stresses on materials during operation. This data can help calculate failure initiation loads.

"However, sensors can only collect data from the point at which contact is made," says Michael Heflin, CEO for Sensuron. "This is limiting and makes it possible for engineers to design beyond their ability to test." Using Von Mises criterion and, more recently, computer-aided drafting with finite-element-analysis (FEA) software, engineers can predict stresses and strains between sensor contact points.

Although FEA offers accurate calculations on a wide array of materials properties with simulations, some applications require more data. Aerospace engineers, for example, rigorously test designs and materials. In one case, Boeing tested the wing box for the 787 using over 1,700 strain gages, which are still connected and wired manually (the wing box connects the wing to the fuselage and supports other subsystems, such as the landing gear). Testing for the wing box required hooking up over 3,400 wires, which increased time spent, weight, and cost.

However, engineers have found new materials that could offer data from any point along a wing. It requires one wire that's about the diameter of a human hair. By using a laser in the process of drawing out a fiber-optic cable, it makes a Bragg grating in the fiber that's able to reflect light. These gratings can be put anywhere along



the length of the fiber-optic cable.

"Fiber Bragg grating is able to acquire so much data at high speeds you would need a whole new testing platform in order to be able to process it all," says Heflin. "Allen Parker is a systems engineer, and he developed algorithms that made this possible. This platform is changing how we think about testing and design."

Thin films are used with conductive materials and inks to provide thin, easy-to-integrate, highly sensitive pressure sensors. Some companies offer custom geometries and ranges by simply altering the inks and shape of the film.

FIBER BRAGG GRATING

NASA was researching fiber Bragg gratings (FBGs) decades ago. "Traditional testing gages were not providing enough data. There are only so many strain gages you can affix to a part," says Heflin. "After a lot of research into better testing practices, scientists could use Bragg technology to measure stress at 1,400 points along the distance of a single fiber. It not only saved weight and time, but provided higher fidelity."

Limiting factors affect the operating temperature and strain range of fiber-optic sensors. "It is the fiber that typically limits these ranges," says Alex Tongue, applications engineer for Sensuron. "For example, different types of coatings can be used on a fiber-optic sensor to monitor different temperature ranges. Fiber sensors can have operational ranges of −422° to 1292°F, depending on the coating and type of fiber. Individual applications typically do not require this range, so most sensors fall somewhere in the middle. Sensuron usually uses fibers that operate from −422° to 599°F."

A common coating that covers a wide temperature range is Ormocer, an organic modified ceramic hybrid polymer. It's possible to reach higher temperatures by coating the fiber-optic sensors with different types of metals.

FBG can detect strain from −18,000 to 18,000 με (micro-strain). The range depends on the laser used and type of fiber. Some sensors set the strain range using software. With the use of software, it's possible to alter the strain range.

Companies that make FBG equipment are working with universities to teach students how to use this technology, which has many potential applications. For example, aerospace engineers could use it to determine wing loading while also providing accurate fuel readings. Automotive designers can determine maintenance and operational lives of vehicles. Civil engineers could monitor infrastructure "health" with the sensors. Overall, by embedding these fibers into products, it can save the time, money, and, weight associated with traditional strain gages and other sensors.

MATERIALS BECOME SENSORS

As sensors shrink and consume less power, they become easier to integrate with materials. Two forces driving the demand for smart materials are the need for more information and simplicity. Engineers can make more informed design decisions with more data obtained from testing. Collecting data during operation allows for better maintenance and offers real-world data for design.

Researchers are also working on complexity. Using materials science to generate multifunctional structures helps simplify products. For example, in 2002, the Naval Research Laboratory was developing multifunctional aircraft structures. One idea was to use a lithium polymer to serve as a battery while having the shape and function of a plane's wing, reducing complexity and weight.

"We made a conductive rubber that measures strain, load, deformation, and extension," says Claus. "In its fabric form, it can be incorporated into other fabrics and materials like an embedded sensor. It works well with stiffer matrixes, so when it is deformed, the lower modulus stretchable sensor goes along for the ride without affecting the material's dynamics."

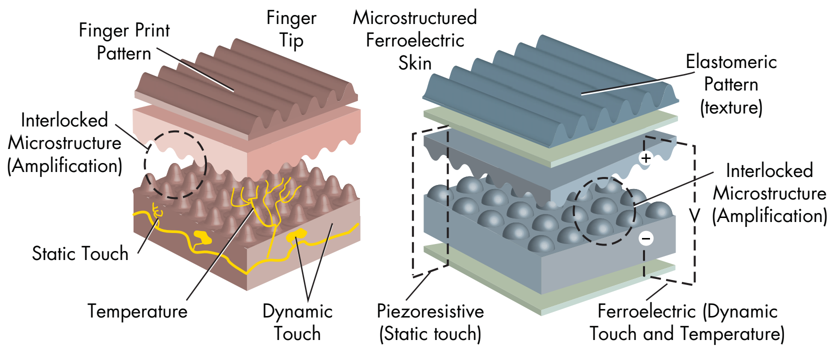
Ionomers and nanotechnology also allow new flexible materials to be conductive. "Manufacturing them is much more interesting than some of the traditional processes," says Claus. "Our approach is not taking an ingot and machining it down into a part. Instead, we use self-assembly. Chemists design the molecules, so they essentially grow the way you want them to."

Simply explained, NanoSonic creates a solid matrix out of metal nano blobs in rubber that lets electrons move more freely than in the original material. Electrons "hop" between these blobs. The electrical resistance changes by altering the distance between blobs. It takes little metal to make some of these materials conductive. In fact, just 0.007% in volume can lead to good conductivities.

However, challenges still lay ahead. Engineers are looking for better ways to communicate with smart materials and the devices inside them. Conductive materials connected by wires would mean stiff or brittle solder joints on what could be a moving, flexible part. In addition, stretching a wire or material that is transporting data or power can alter electrical resistance and interrupt the electric field, which could hinder the electronics performance.

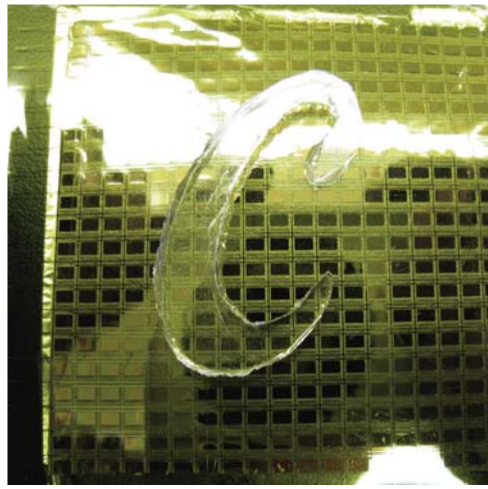
"Designers are looking at the factory workers and field engineers needed to keep equipment functioning. If new materials can generate information to communicate better with these workers, it can save companies time and money," says Claus. "Imagine if we could have coatings or materials like human skin. Seeing a machine tan or bruise could indicate something is wrong."

A factory worker might be able to see a problem and prevent unscheduled maintenance, reducing downtime. A big focus for some things in the Internet of Things (IoT) is a reduction in complexity to decrease power, thus allowing remote sensing. Access to remote data has proven to diminish the need for working on location.



A human-skin-inspired multifunctional e-skin uses a micro ferroelectric material that can discriminate static and dynamic pressure and temperature. Professor Zhenan Bao and her team of researchers at Stanford are focusing on integrating solar cells, self-healing mechanisms, and lights. Last year, they were able to synthesize materials with pigments that change color.

(Courtesy of advances.sciencemag.org)



A FEEL FOR APPLICATIONS

Being able to mimic human skin would have more value than just bruises. The ability to feel provides valuable information about the environment in which we interact. Researchers believe that if machines were able to feel, it could prove valuable for many markets. For example, automation lines need to be dynamic, handle multiple products, and change easily. Engineers have developed scanners and grippers to accommodate these demands. But researchers are still trying to mimic human touch that can provide data on how to identify, pick up, and handle myriad objects.

For more than a decade, many techniques have processed data that make it possible for a machine to feel. By using sophisticated torque sensors, the U.S. Defense Advanced Research Projects Agency (DARPA) was able to sense the resistance in picking up or making contact with objects. Stanford University was able to collect pressure readings with what are essentially rubber micropyramids with conductive nano-carbon tubes. As the material is compressed, the nano-tubes become closer, increasing the conductivity. The amount of electricity flowing to the processor would then indicate pressure. These techniques could tell how hard or soft a machine or robot was gripping objects.

Scientists used chemistry to increase the amount of sensing elements on these new materials. Georgia Tech's Zhong Lin Wang grew thousands of small, hair-like, zinc-oxide piezoelectric nanowire transistors. This technique led to a 15-fold increase in sensor density and spatial resolution when compared to the previous technology.

Beyond growing better sensors, materials science has presented new flexible composites and polymers. These materials are able to connect devices or provide data. A new polymer called polydimethylsiloxane, or PDMS, is a flexible transparent silicone with embedded nanoribbons. The electricity generated when the material is deformed can be processed to present tactical feedback. PDMS can detect temperature and humidity while offering a flexible and stretchable matrix, allowing for more complex electronics work in or on the material.

PDMS is used in the bulk of research for some of the most advanced materials. In general, organic field effect transistors like PDMS are merging materials and sensors.

"Human touch is more complex than just collecting data. Our skin interacts with objects," says Matt Borzage, the head of business development for SynTouch. "Our sense of touch has three main components. Skin feels an increased surface area as it wraps around an object. A fingerprint and nail can provide micro vibrations, and even the temperature of the skin interacts with the material being touched. Giving a robot features like a fingerprint or nails is not for aesthetics, but can increase sensitivity by a factor of 30. All of these features offer better data that can work with software to interpret hardness, surface roughness, temperature, thermal conductivity, and more. A person uses this information to determine how hard to grip, or what an object is. This is the same data we want a robot to offer to a production line or medical prosthetic.

"A challenge is when you find a blend of materials and sensors to mimic touch, and then realize the component isn't robust enough for real-world applications," continues Borzage. "By placing all electronics inside a rigid core and covering them with a compliant replaceable bladder, we came up with a sensor that is able to be more robust while providing sensitive human-like measurements."

While this might sound like a convenience rather than a necessity, companies face having to justify the resources on an embedded device with the value added by simplifying systems, obtaining more data, or gaining better operation. The ability to "feel" an object to identify, handle, and process multiple objects dynamically has many manufacturers interested to see what will emerge from materials science. md

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Making Piezoeletronics Work for You

Piezoelectrics can add value to manufacturing if they are designed and applied correctly. Learn about this phenomenon, how it is used, and how it might change the future of the IoT.

Although electronics are getting smaller and using less power, other mechanisms and hardware might not be able to follow suit. Undeterred by this prospect, designers are using the piezoelectric effect to continue shrinking products.

Piezoeletric tiles convert pressure and vibration from people walking on them into electricity to light walkways and fields. *(Credit: Pavegen Systems)*

BENDING ACTUATORS

The converse piezoelectric effect uses an electric field to generate deformation. It is used for actuators and transducers. Bending actuators are normally laminated materials—often a ceramic or quartz layered with a passive, conductive substrate formed into rectangles that bend when electricity is applied. One application is in piezoelectric valves for precise medical and laboratory devices.

Using bending actuators to open and close valves offers several benefits. For one, the operating power is reduced compared to solenoid valves. Solenoids are held closed by compression springs. Once the valve opens, it takes continuous power to resist the energy of this spring. A piezoelectric valve uses just enough energy (often called the switch-on energy) to charge and deform the actuator material. After power is removed, the valve stays open until actively discharged. The switch-on energy is relatively simple to calculate:

$$E=CU^2/2$$

where:
E = energy;
C = capacitance of the transducer;
U = the control voltage.

The capacitance is generally about 30 nanofarads, and the control voltage can be up to 300 V; that means the switch-on energy normally lies between 0.5 to 5 milli-Watt seconds (switch on energy is always presented in mWs).

Instead of closing the valve by grounding out the charge in the material, the energy can discharge into a capacitor or energy recovery device. This technique recovers up to 50% of the energy needed to open the valve. By recovering the energy some applications save up to 95% in power.

"Piezovalves work great for portability," says Sam Stoney, Festo's medical device specialist. "In one application, solenoids were used with AA batteries for portable supplemental oxygen. But the batteries only lasted about a month. When we redesigned it with our piezovalves, the life of the batteries was extended by over two years."

Solenoids still make up the majority of the valve market. That's because piezoelectronics offer control only up to about

44 psi and flows to about 6.6 gal/min. While direct-acting solenoids achieve pressures of over 400 psi, that control flows of hundreds of gallons per minute. “But the sweet spot is getting broader as more piezoelectric valves are released to market,” says Stoney. “For example, some piezoelectric valves can now reach 150 psi.”

Piezoelectric valves can often simplify equipment while reducing cost, energy, and size. “But piezoelectric valves likely won’t ever replace solenoid valves,” Stoney notes. “Solenoid valves have staying power because they’re relatively inexpensive, reliable, and simple to understand. Its design is proven and effective.”

Piezoelectronics valves might be used instead of solenoids when heat buildup is a concern. For lab and medical applications where precision is required, the metal components—specifically, the spring keeping the valve closed—can negatively impact repeatability and accuracy. Thermal expansion of metal components can change the pressure required to open the valve, called the cracking pressure.

Engineers can compensate for thermal concentrations with different techniques, but when using piezoelectronics, the problem is circumvented. Due to the minimum energy used in activating piezovalves and actuators, any thermal concentrations are usually nominal. In addition, applications with multiple solenoids generate heat concentrations that could reach temperatures that might degrade materials around it.

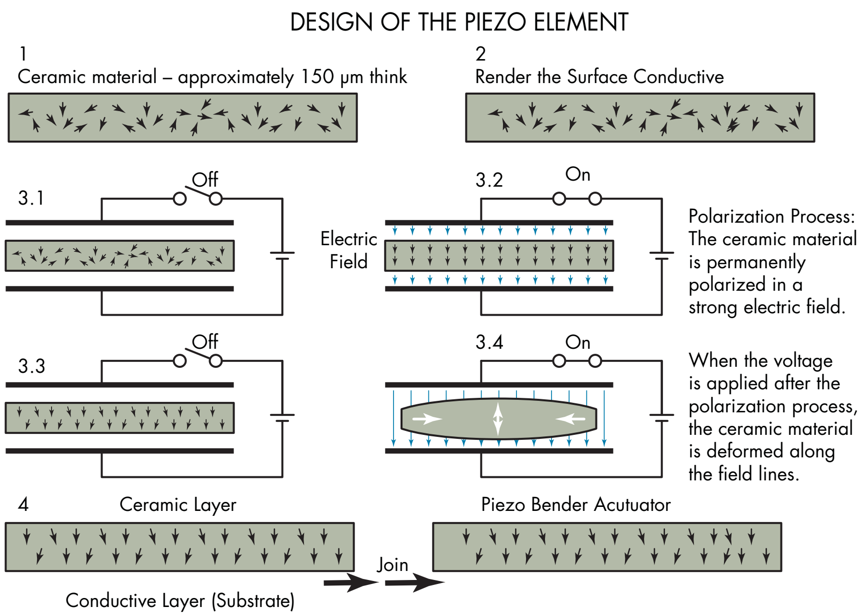
It is important to understand how piezoelectronics work when designing devices such as valves. For example, it is possible to vary the electric field to control actuators. “Piezoelectronics make great proportional valves,” says Stoney. “The wider you need to open a piezovalve, the more power you need. Using piezovalves as a low power alternative for mobile uses, or to add control in a process by using it as a proportional valve, are a couple ways piezovalves have excelled.”

DISK AND STACK ACTUATORS

Disk actuators are similar to bending actuators, except arranged in a disk. With the piezo-materials in the middle and a passive, conductive substrate along the outside, an electric charge causes the ceramic to expand in the direction

THE PIEZOELECTRIC EFFECT

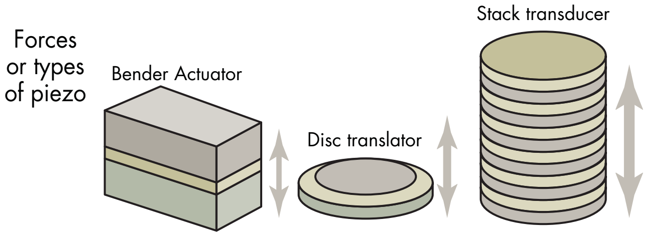
CRYSTALLINE STRUCTURES GOT a lot more interesting around 1880, when Pierre and Jacques Curie discovered the piezoelectric effect. They found out that after polarizing crystalline structures like quartz, tourmaline, and even salt—and subjecting them to mechanical stress—they generated a small electric current. The phenomenon was named piezoelectricity (from the Greek word piezien or pizo, meaning to push or press).



The high charge used to polarize a material allows it to effectively develop the piezoelectric properties. If the material is subject to a strong electric field after it has been polarized it further permanent changes may be elicited. *(Credit: Festo)*

Crystalline materials can be polarized by a high voltage, often several kV/mm that causes molecules to align, changing the material’s shape. For example, a square might become a thinner and taller rectangle when electricity is applied. When the voltage is switched off, the material retains its new shape. If the charge is actively removed by grounding it or passing the charge to an energy recovery device, the shape mostly returns to its original size. Some molecules remain aligned while others return to their original position, thanks to internal mechanical stresses.

The piezoelectric effect can work in two ways. In the direct piezoelectric effect, stress applied to a material creates an electric field. In the converse piezoelectric effect, which was discovered in 1881 by Gabriel Lippmann, an electric field causes the material to deform.

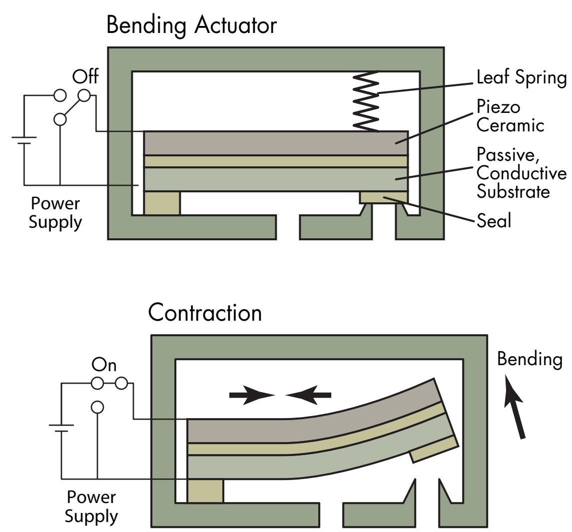


Displacement	100 to 1,000 μm	10 to 100 μm	10 to 100 μm
Force	0.1 to 2 N	1 to 10N	1,000 to 10,000 N

Understanding the displacement and force associated with various transducer types will help reveal what piezoelectric technology is capable of. *(Credit: Festo)*

of the electric field. This normally makes the disk thicker and the diameter smaller. Overall, a spherical bend occurs which makes the disk actuator work well in high-frequency speakers, ultrasounds generators, and automotive distance sensors.

Stacked actuators, also called piezo-stacks, use the material's expansion rather than its bending reaction. This creates actuating forces up to10 kN and 0.2% (maximum) change in overall height. The minimal displacement limits its applications. However, Maurizio Porfiri, a professor at New York University's Tandon School of Engineering, notes that,



This piezoelectric valve can be used for precise control, reduced power consumption, and size. It also works well as a proportional valve. *(Credit: Festo)*

"Researchers have experimented with integrating piezo-stacks into mechanical structures, such as trusses, to create active joints that reduce structural vibrations."

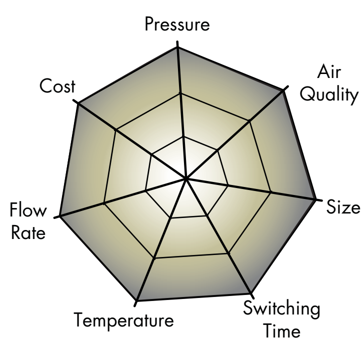
DESIGN CONSIDERATIONS

Safety is always a concern. Emergency stops (E-stop) normally shut off power to machinery, causing components to stop working or valves to close. With the piezoelectric effect, material acts like a capacitor and hold its charge—keeping its shape and for piezoelectric valves this means staying open. It is important to determine whether leaving a valve open could lead to a safety concern. To ensure valves close, a resistor in parallel with the valve could discharge it slowly, or a single-pole, double-throw relay could ground the circuit, depending on application. However, these devices might make the system more complicated and hinder the benefit of the piezoelectric's efficiency.

Many electrical systems operate off 12 to 24 V. Piezoelectric can use up to 300 V, which sounds like a safety concern. However, few amps (often in the milliamps range) are needed, so piezoelectronics are intrinsically safe.

Piezoelectronics also last a long time: Up to a billion cycles are possible if designed properly. Designers know many sensors, actuators, and valves are made of brittle materials. If they are switched too quickly to fully open, they can slam into the end stop, lowering the material's operational life. It's preferable for applications to have transducers or actuators that slow before hitting end stops, or else never hit them. Designers can change switching speeds by changing the resistance. Unfortunately, they can't get all of the benefits of piezoelectronics in one product. Motion can be fast or smooth, but not both.

The main idea to keep in mind when designing with piezoelectronics is to



This graph shows the relationship of piezoceramic materials. Different piezoelectric materials will change how the properties are related, but in general you cannot have all the benefits in one product. *(Credit: Festo)* exploit their low power, low temperature, and proportional response. Don't design piezoelectric-devices as you would solenoids. "It's like when engineers started using robotics to replace humans," says Stoney. "They designed the robot to act like a human; the result was inefficient. Once engineers started designing robots like robots, their efficiency greatly increased.

"When designing with piezoelectrics, ask yourself if you want to turn something on and off, or something else. If you want something else, you might want to look into piezoelectronics."

TRENDS IN PIEZOELECTRONICS

New efficient electronics and a desire for obtaining operating information remotely are opening the door to use piezoelectronics for energy harvesting. This technology will not be running power plants. Just as the piezo-actuators use only milliamaps, some harvesting electronics are only registering nanoamps. However, for some applications that's sufficient. As IoT and remote sensing become more popular and electronics need less energy to operate, the direct piezoelectric effect is being research as a viable power source for future device that do not have an easily accessible power source.

Porfiri has showed how piezoelectric technology can generate electricity from vibrations caused by oscillating flows, impacting vortices, or underwater oscillations. "Power-harvesting piezoelectrics could provide a sustainable power source to operate sensors," he says. "Engineers and scientists are aggressively researching materials science to engineer efficient and performing devices, such as micro-fiber composites called MFCs. They could lead to flexible fabrics that control a material's deformation, or let the deformation generate electricity."

This technology can allow for aquatic animals to be tagged with a sensor that has a sustainable power source, as long as the animal or water is moving. Not only could this revolutionize underwater electronics, but with the growth of the mobility and IoT markets, piezoelectric technology could have some interesting future applications.

For remote and longer-term sensing and data applications a battery can lose power and eventually need to be replaced. A piezoelectric generator, on the other hand, could be without a charge for an extended period of time, and as soon as an outside force acts on it the generator is able to start producing power again. If the electronics are still functioning, you will start collecting data again—even if years have passed. md

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What's the Difference Between Friction and Regenerative CAR BRAKES?

Let's take a closer look at conventional friction car brakes and how electric vehicles regain energy with regenerative brakes.

Conventional car brakes serve only one purpose—stopping the car. They are such an essential part of the car, yet hold a greater potential in energy efficiency, particularly in terms of regenerative braking.

Regenerative braking is not a new invention, as hybrid and electric cars currently use it to help recapture lost energy. The idea is simple: Recollect some of the energy lost in braking and convert it into electric energy for the large high-capacity battery. The creation of energy when braking is where regenerative brakes differ from conventional brakes.

CONVENTIONAL BRAKES: BRAKING AND THE HYDRAULIC SYSTEM

Before we dive into the difference between car brakes, let's describe the hydraulics behind braking. The hydraulic brake circuit consists of a fluid-filled master cylinder, which connects to a separate slave cylinder. The brake pedal connects to the master cylinder and when pushed, depresses the piston in the master cylinder, forcing fluid along connected pipes. The fluid reaches the slave cylinders at each wheel, which in turn forces the piston to apply the brakes.

The surface area of the combined slave pistons, where the brake-pedal force is applied, is greater than that of the master-cylinder piston. Hence, the master piston has to travel a greater distance to move the slave pistons compared to the fraction of distance required

The image above is an example of a typical disc brake that has a caliper applying pressure to the friction or brake pads. This friction force slows down the wheel and allows the car to stop.

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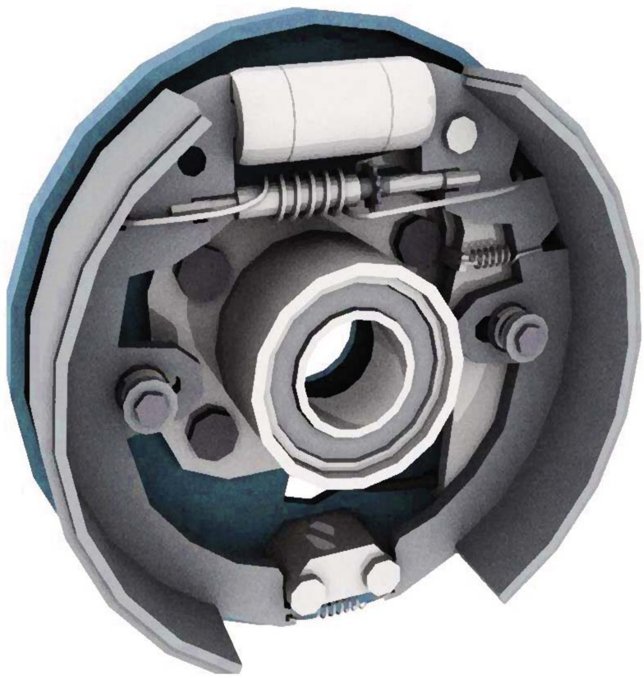
by the slave pistons to apply the brakes. This setup allows for the exertion of a large force by the brakes, comparable to how a long-handled lever can lift a heavy object a short distance.

In most modern cars, two master cylinders use twin hydraulic circuits in tandem for redundancy purposes. The circuits can be arranged to control different pairings of brakes: one circuit for the front pair and the other for the back pair; or one circuit for one in front and one in back, and the other circuit for the other side.

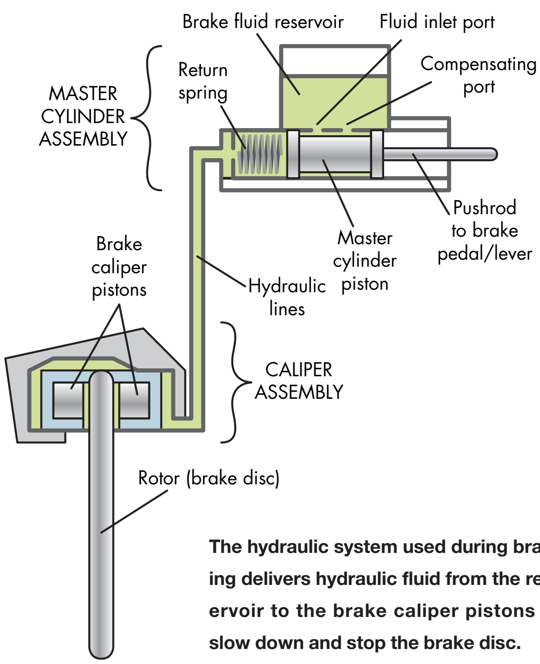
By design, rear brakes are less powerful to prevent the rear wheels from locking and skidding. A load-sensitive pressure-limiting valve prevents locking in most cars by controlling high rises in hydraulic pressure. Limiting valves help prevent brake locking situations, along with anti-lock brake systems that monitor wheel locking. Modern cars also apply power-assisted brakes.

A servo unit, using the pressure difference between the partial vacuum in the inlet manifold and the outside air, provides braking assistance via a pipe connection to the inlet manifold. The servo is fitted between the master cylinder and the brake pedal. When a driver pushes on the brake pedal, it in turn pushes on the master-cylinder piston and a set of air valves.

A large rubber diaphragm connects to a master-cylinder piston. Prior to applying the brakes, both sides of the diaphragm are exposed to the vacuum from the manifold. Applying the brakes closes the valves that link the rear side of the diaphragm to the manifold and opens a valve to let in outside air. The high pressure of the outside air pushes the diaphragm forward on the master-cylinder piston to assist the braking effort. If the brake pedal is kept in place, the air valve stops drawing on the outside air, keeping the brake pressure constant.



Inside the drum brake are two curved brake shoes. When hydraulic pressure is applied, the brake shoes are forced outward, causing the linings to apply a friction force against the drum. The drum is connected to the wheel and slows down as a result.



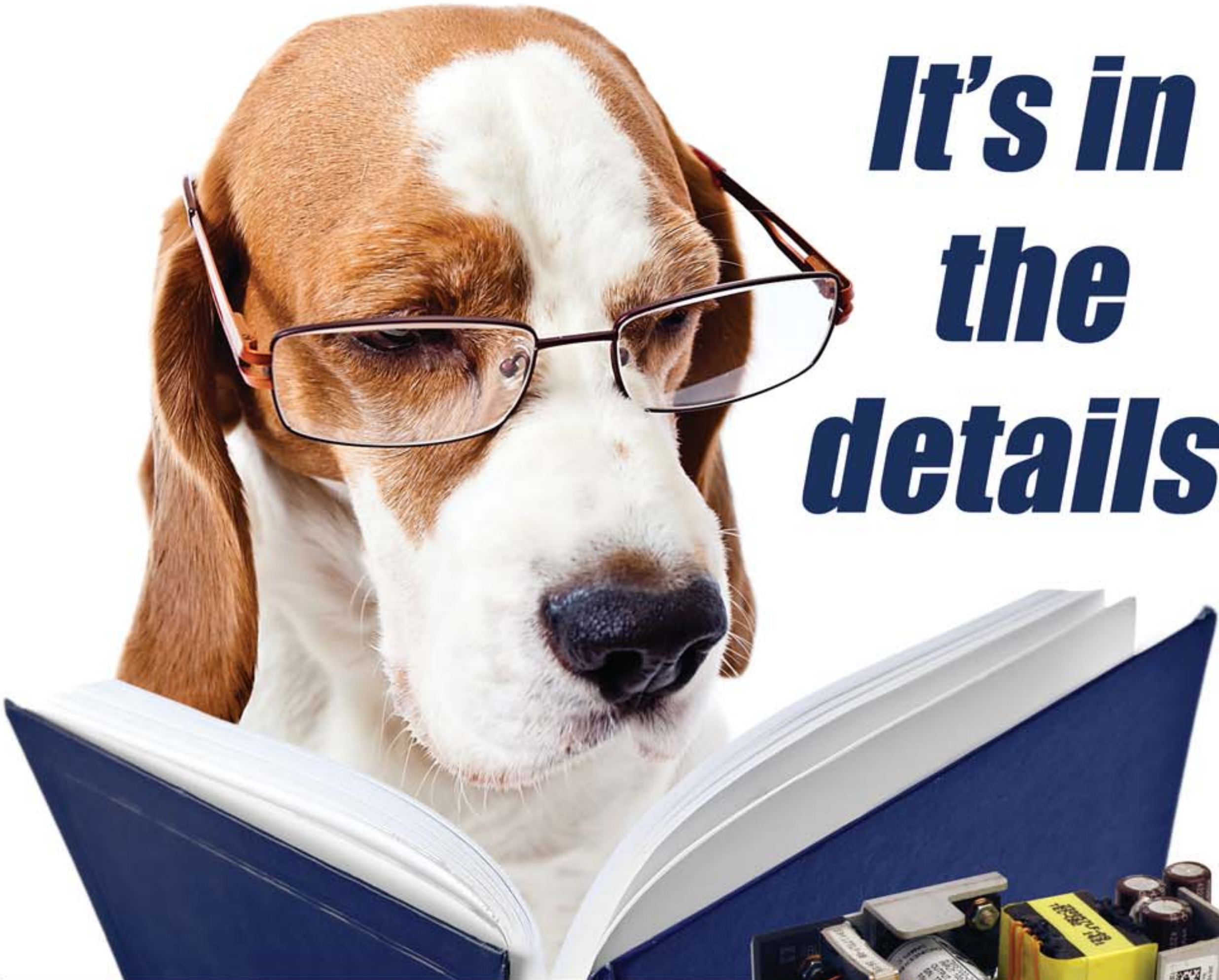
The hydraulic system used during braking delivers hydraulic fluid from the reservoir to the brake caliper pistons to slow down and stop the brake disc.

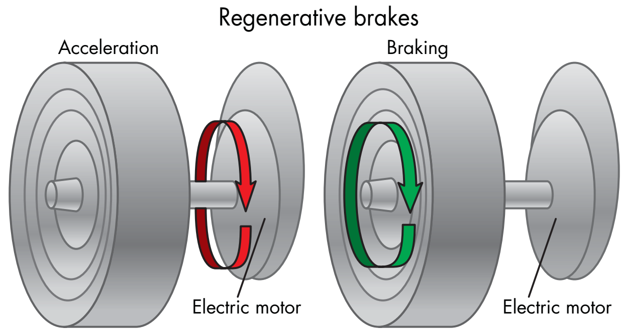
DISC AND DRUM BRAKES

Disc brakes are typically located on the front two wheels. A caliper straddles a disc and the disc turns with the wheel. Small hydraulic pistons in the caliper operate via pressure from the master cylinder. Friction pads clamp against the disc once the small hydraulic pistons apply the pressure, which slows down the disc and the wheel.

The pistons only move a small distance to apply the brakes, and when released, the friction pads barely clear the disc since they have no return springs. The small gap is maintained by allowing the pistons to slip forward gradually as the pads become worn down. Rubber sealing rings around the pistons make this possible, preventing constant brake adjustment. Modern cars implement wear sensors to indicate when pads need replacement.

The rear wheels typically use drum brakes, which use a hollow drum that turns with the wheel. A stationary back plate covers the open back of the drum. The back plate has two curved brake shoes carrying friction linings. Hydraulic pressure provided by pistons in the brake wheel force the shoes





When the electric motor reverses direction, it becomes a generator that stores the energy in the vehicle's battery.

outward, causing the linings to press against the inside drum and in turn making the wheel slow down or stop completely. As opposed to disc brakes, return springs are used to pull the brake shoes back when the brake is released. Drum brakes have a tendency to fade if applied repeatedly in a short time—they heat up and lose their efficiency until the heat dissipates.

REGENERATIVE BRAKING: CREATING ENERGY

As mentioned earlier, a conventional braking system's disc and drum brakes use friction to slow and stop modern cars. However, most hybrid and electric vehicles use regenerative brakes due to the added benefit of recharging electric batteries.

Vehicles with regenerative brakes achieve braking by driving the motor in reverse. As the driver steps on the brake pedal, the vehicle's electric motor is placed in reverse mode, causing it to run backwards. This operation not only slows the car's wheels, but also acts as an electric generator for the car. The reverse motion produces electricity that feeds into the car's battery. Hybrid and electric vehicles also have friction brakes that act as a backup system when the regenerative braking is not supplying enough power to stop the vehicle.

Reverse motor motion can be achieved by using the vehicle's own momentum. The electronic circuitry and the car's onboard computer determine when to use the conventional frictional brake system or whether to put the motor into reverse. A slight reduction in the car's momentum, determined by the driver's force on the pedal, causes the vehicle's electronics to activate the regenerative brakes and place the motor in reverse. In contrast, if the vehicle needs to come to a quick stop, to avoid a collision for example, the conventional brakes will be engaged.

A brake controller controls regenerative braking. Brake controllers are electronic devices that determine when, via remote control, braking begins and ends, as well as the speed of application. Similar to an ABS controller that monitors the rotational speed of the wheels in relation to one another, the

TYPES OF DRIVING			
	Combined	City	Highway
Types of losses	**Energy losses**		
Energy lost in charging battery	16%	16%	16%
Electric-drive-system losses	16%	18%	14%
Parasitic losses	3%	4%	2%
Power to wheels, dissipated as:			
Wind resistance	36%	29%	45%
Rolling resistance	23%	25%	22%
Braking	23%	40%	7%
Types of gains	**Energy gains**		
Regenerative braking	–17%	–32%	–6%

The table shows how energy is lost in a vehicle and the percentage of energy regained from regenerative brakes. *(Source: Argonne National Laboratory data, SAE 2013-01-1462, and presentation)*

brake controller can calculate how much torque is available to generate electricity as well as monitor wheel speed.

The brake controller directs the electricity produced into the batteries or capacitors during braking. This ensures delivery of optimal amounts of electricity, and prevents overloading of the batteries or capacitors. Ultimately, the brake controller decides which brake system to use. If the required braking force is too great for the regenerative brakes, the brake controller activates the friction brake to avoid possible accidents.

IS IT EFFICIENT?

Regenerative brakes work best at specific speeds, particularly in stop-and-go driving situations. The energy lost due to heat through friction is around 80%. Regenerative braking can recapture half that energy lost and reduce fuel consumption by 10% to 25%.

The future of efficient braking lies in hydraulic hybrids and hydraulic-power-assist (HPA) braking. Hydraulic hybrids replace electric motors and batteries with motor-pumps and accumulators. HPA slows down a vehicle by using its kinetic energy to power a reversible pump, which sends hydraulic fluid from a low-pressure accumulator to a high-pressure type. The pressure is achieved by compressing nitrogen gas in the accumulator as the fluid is pumped into the empty space formerly occupied the nitrogen. The decrease in hydraulic pressure in the motor-pump helps slow down the vehicle. Hydraulic hybrids could potentially reduce fuel consumption by 25% to 45%. md

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What's the Difference Between IC, Rotary, and Electric CAR MOTORS?

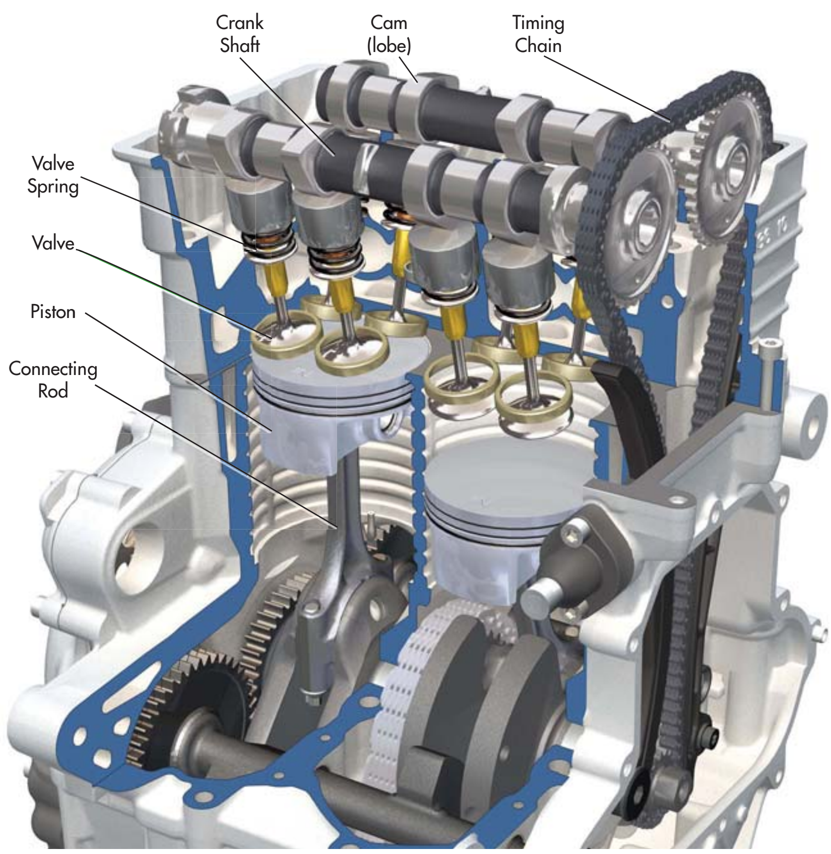
Will the electric motor be the end of the internal combustion engine?

Automotive engineers are concerned with weight-to-power ratios when designing vehicles. While light-weighting is a strong focus within the industry, researchers are also looking at more efficient engine design. The internal-combustion (IC) engine is currently the engine of choice for vehicles, but the growing concern regarding climate change has given electric vehicles increased attention over the years. Understanding the difference between these engines and how they affect resources—not to mention, the weight-to-power ratio—reveals key properties that might indicate when or if the IC engine could be in decline.

PISTON IC ENGINE

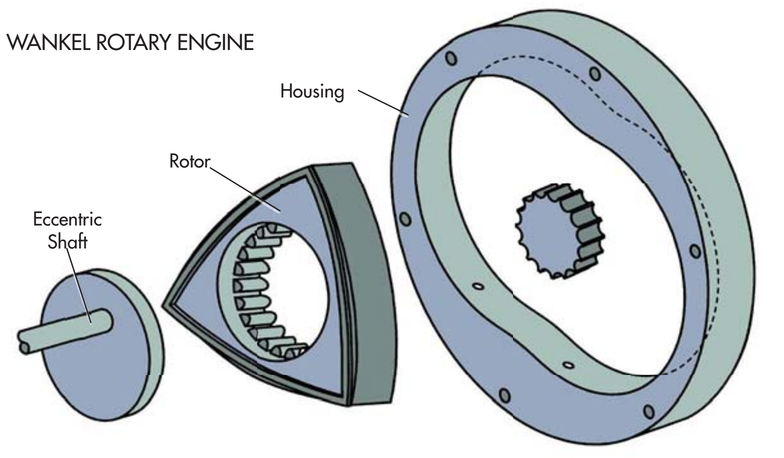
The efficiency of the piston engine, in general, is around 28% to 45%. It can have hundreds of moving parts that can be the source of more maintenance, noise, and energy losses than in rotary or electric engines, which have fewer parts and less complexity. Despite these issues, the weight-to-power ratio is keeping IC piston engines on top—for now.

The most common engine on the road today is the four-stroke IC piston engine. Each stroke performs a task in a combustion cycle that rotates the crankshaft or driving shaft. With each stroke, the piston



Researchers have found by adjusting a piston engine's valve timing, performance can be greatly improved. Some companies, such as Ferrari, developed dynamic valves. One example boasts a three-dimensional lobe with a sliding camshaft that alters engine timing as demands on the engine changes. *(Credit: Drivingtestsuccess.com)*

travels from top dead center (the top-most position the piston can reach in the cylinder) to bottom dead center (the bottom-most position).



The Wankel rotary engine is modular—as long as there is a crankshaft long enough to accommodate rotors. In 1991, Mazda used a four-rotor engine to become the only Japanese car company to win the 24-hour Le Mans. That will be the only rotary motor ever to win this title, as the race's governing body outlawed rotary motors in 1992.

The first stroke, the intake or induction stroke, draws air and fuel into the cylinder. In diesels, this stroke only draws in air; the fuel is injected just before the power stroke. As the piston returns to the top, it compresses the mixture; a spark plug then ignites it. Diesel engines have higher compression ratios that generate higher temperatures, thus causing combustion when fuel is injected without a sparkplug. Diesel engines have heating elements, called glow-plugs, where the sparkplugs are located that help warm up the combustion chamber for cold starts.

The fuel/air mixture is ignited during the next stroke, the power stroke, and the expanding gases from the small explosion force the piston to bottom dead center. Finally, the fourth stroke, the exhaust stroke, returns the piston to top dead center and pushes gases out of the cylinder.

The pistons' linear moments are translated into rotary motion through connecting rods that turn the crankshaft. In turn, the crankshaft drives the transmission. The crankshaft also connects to the

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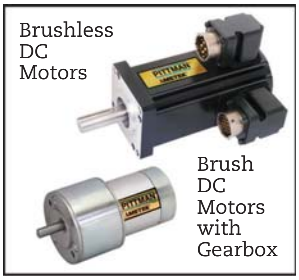

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camshaft(s)—normally with a belt, though sometimes a rolling chain is used. The camshaft rotates the cams to open and close valves, controlling the timing of the intake and exhaust of gases in the cylinders.

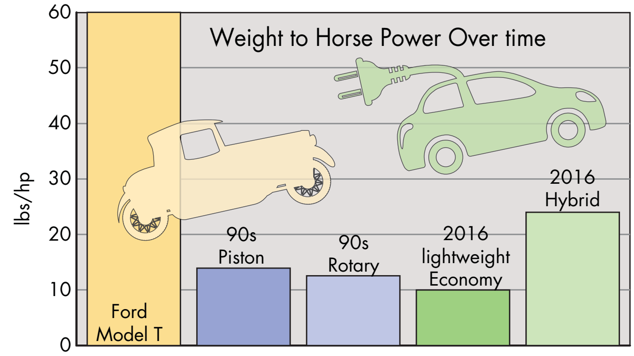
To get the most power out of each stroke, designers focus mainly on the pistons, cams, and valve design. Performance and efficiency improvements often rely on increasing the speed or rpms and pressures on these components. This can be challenging: Something as simple as increasing pressure during compression strokes (e.g., the compression ratio) could require a completely new cylinder head, pistons, and connecting rod made from materials that withstand the higher stresses. Higher stresses also might demand higher octane fuel for proper ignition. Ignoring any of these issues can lead to excessive wear on the engine and inefficient operation.

ROTARY IC ENGINE

A rotary engine—specifically, the Wankel rotary engine—does not have pistons, but rather, a three-lobed triangular rotor. The key differences from a piston engine are the reduction of parts, reduced vibration, and the ability for the motor to perform at high speeds (rpms). The engine comes in a relatively small package with a high power-to-weight ratio. Compared to piston engines, the rotary engine's simple concept and complex geometry has sparked some passionate debates as to why it isn't more popular.

To envision the inside of a rotary engine, it is first necessary to know what an epitrochiod is (also called an epicycloid). Epitrochiods are geometric shapes formed by tracing a point along a radius of a shape that is rolling out or inside another shape. If you ever used a Spirograph, you were playing with epitrochiods. A rotary engine's housing is a simple epitrochiod of two circles. The rotor spins eccentrically inside the housing, changing the volume of three spaces (chambers) formed between the two.

Rotary engines share the same four-stroke sequence of piston engines: intake, compression, power, and exhaust.



The weight-to-power ratio is important, and while EVs and hybrids are more efficient than internal combustion engines, this ratio needs to improve to compete in the transportation market. EVs are not presented, as numbers powered can vary greatly. However, in general, the economy models weighed more than the hybrids. The numbers are used only to give a general idea of vehicle weight-to-power ratios over time.

The rotor's rotation increases the volume of the first chamber drawing in air and fuel—the intake stroke. As the rotor continues to turn, the volume in the chamber shrinks, compressing the contents of the chamber causing the compression stroke. A problem at the next step is the geometry between the housing and rotor separates the chamber into two spaces. This elongated and separated ignition chamber can hinder complete combustion, as some of the air/fuel mixture is cut off from a spark plug. To help, there are either two spark plugs, or one spark plug with an exclusion or divot in the rotor to let the mixture into both spaces of the chamber.

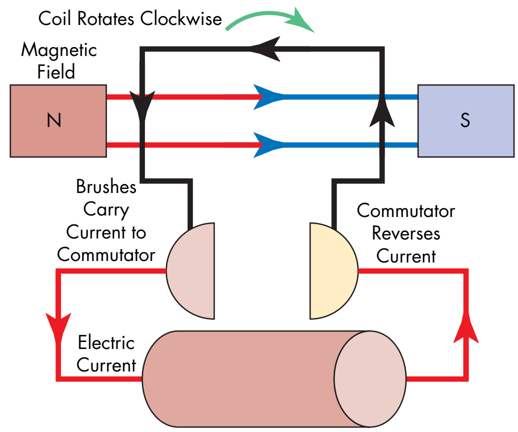
Normally, two spark plugs are used, and Mazda has even used three spark plugs in its racing cars. Expanding gases rotate the rotor further into the expansion or power stroke. Eventually, the expansion drives the rotor around to where there is an exhaust port in the housing. The volume between the housing and rotor shrinks again, pushing exhaust gases out of the chamber—the exhaust stroke.

Rotary engines do not have to transfer linear to rotary motion, eliminating violent changes in direction that have to be made by pistons/ Therefore, rotary engines generate much lower vibrations. The rotary design also lets the power stroke operate over a longer rotation of the shaft, thus reducing sporadic torque on the crankshaft (from ignition to exhaust there is about 270 deg. of rotation, versus 180 deg. on piston engines). Ultimately, a single rotor in a rotary engine is comparable to the three pistons in reciprocating engine. Rotary engines often have two rotors for smooth operation and are comparable to V6 engines.

As early as the 1960s, some auto executives and observers thought rotary designs would become the design of choice for cars and trucks. But Mazda, the first company to mass-produce rotary engines, stopped production after 2012. Mazda said unless the company could justify annual production of 100,000 units, the Wankel engine would not be manufactured again. However, research to improve the engine is still underway.

With so many benefits, what happened to the rotary engine? A rotary engine can operate with as little as three moving parts, making it simple and easy to maintain. Basic piston engines have at least 40 moving parts. This led to some conspiracy theories questioning how a car with so few parts would cause the loss of millions to car-part companies. But a better argument for piston over rotary engines is made with the complex seals, low-end torque, and thermal efficiency.

Although Mazda addressed some problems, there was still some cross-chamber contamination and unintentional oil consumption that led to emission and efficiency problems. As regulation for emissions got tighter, the rotary vehicles suffered. In addition, the crankshaft rotates three times per single rotation of the rotor. This 3:1 ratio does not deliver competitive low-end torque (compared to a piston engine). This is why rotary engines are great for mid to high-end applications, such as planes, marine, and race cars, but not for daily commuters.



The basic dc motor changes the flow of electricity to keep the coil out of phase with the magnetic field so that it rotates continuously.

(Credit: explainthatstuff.com)

Thermal efficiency of rotary designs is reduced due to the larger surface area (compared to piston engines) in the combustion chamber. This lets heat escape into the housing and rotor. It should also be noted that about a third of a rotary engine's cooling is done with oil; hence, oil cooling is mandatory. Emissions are another problem with rotary engines. For example, the last production RX-8 engine cannot meet current emission standards, so current design wouldn't be able to be made today without emission improvements.

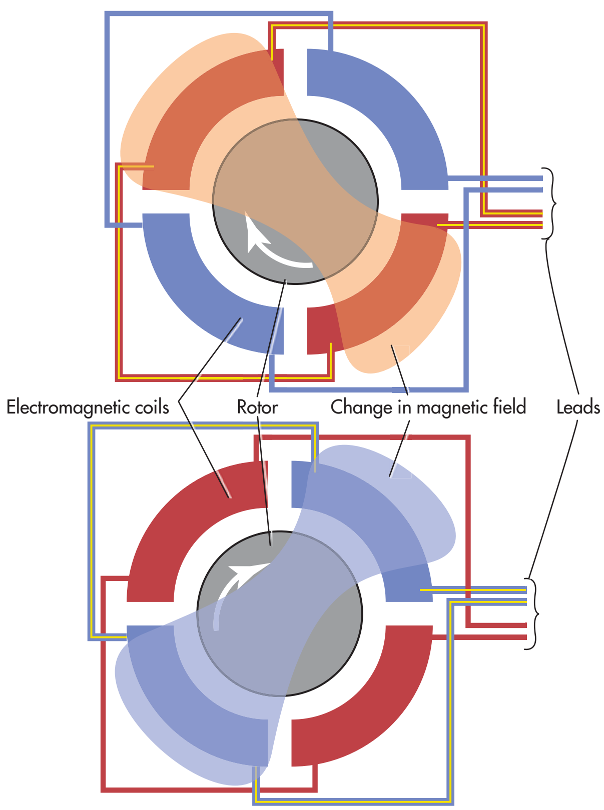
The benefits of the rotary engines—reduction of parts and vibrations—may have been what led some companies to research opposed-piston/opposed-cylinder (OPOC) engines. These are piston engines with pistons along the same plane, but in opposing cylinders. With four pistons operating in two opposing cylinders and in direct opposition, vibrations are lowered by balancing the reciprocating forces with the adjacent piston. This also increases the combustion stroke to once every rotation of the crank shaft, rather than every other rotation, as seen in traditional piston engines.

In 2010, Ecomotors said it could get four times the power from an OPOC two-stroke engine as a four-stroke engine of the same mass. One way this was accomplished was by reducing the number of parts. A 300-hp OPOC engine consists of 62 moving parts. A conventional engine with similar power has around 385 moving parts. Also, the opposing forces mean there is no (or nominal) forces on the main crankshaft bearings. And with lower forces, designers could make the housing out of lightweight magnesium.

ELECTRIC ENGINES

It can be hard to find accurate efficiency ratings for electric vehicles (EVs). While the motor can be 85% to 95% efficient, once the power goes through the inverter, battery, and charger, EV efficiency is closer to 70%. However, electric engines and

HOW AN AC MOTOR WORKS



There are two pairs of electromagnetic coils that are energized in turn by an ac current. The pairs are set out of phase with each other so that the rise and fall of the ac current will alter the magnetic field between them. This change induces an electric current in the rotor that produces its own magnetic field. The rotor will try to oppose the magnetic field from the coils, but since the field is changing with the ac current, the rotor will turn.

> "In general, the limited driving range, battery-charging time, and higher prices keep EVs just out of the grasp of the average person. From a technology standpoint, the main flaw in EVs is the battery. Lithium-ion batteries are powerful, but they are also heavy, expensive, and have the ability to overheat to the point of thermal runaway."

batteries can be relatively sensitive to hilly terrain, and temperature changes that could reduce the efficiency even father. So with higher efficiencies than IC engine, essentially no moving parts in the engine, zero emissions, and the ability to use regenerative braking to increase efficiencies by 9% to 16% (as published in the study), why are EV sales lower than some auto analysts thought they would be?

In general, the limited driving range, battery-charging time, and higher prices keep EVs just out of the grasp of the average person. From a technology standpoint, the main flaw in EVs is the battery. Lithium-ion batteries are the most powerful mass-produced battery. But they are heavy, expensive, and have the ability to overheat to the point of thermal runaway (catching on fire). Most new battery technologies are geared toward lower voltages common in AA batteries. These innovations are not scalable for vehicles applications.

There are two types of electric engines used in EVs: brushless dc motors and three-phase induction ac motors.

DC motors operate off a coil or loop suspended between the poles of a magnet. A direct current of electricity generates a temporary magnetic field, causing it to turn and align with the polarity. An electrical switch (commutator) then reverses the current, which changes the polarity. This will keep the coil rotating indefinitely.

SIMPLY EXPLAINED

Some of the advantages of dc motors include immediate high torque and the fact they are relatively cost-effective. On the downside, they should not be run without a load, as it could damage the motor. That is why running a dc motor to turn a belt could be a poor design. If the belt brakes, there is no load and the motor could spin into a catastrophic failure.

Such dc motors are also are not ideal for maintaining speed over varying load conditions—e.g., an EV with this motor might not perform well in hilly terrain. And while adjusting the voltage can control dc motor speed, the motor has a maximum rpm rating beyond which it cannot go, so speed is inherently limited.

A ring of laminated metals is used in ac motors to generate a magnetic field when ac current is applied. The electromagnets encircle a rotor. The ac causes the strength the electromagnets' magnetic field to rise and fall, creating a shifting magnetic field that generates torque.

Compared to dc, ac motors offer higher torque and speeds. They are more adaptable to variable speed and loads, so it works better for hills. And they accept energy from regenerative braking easier than a dc motor. But the coil winding can be heavy, and an inverter is necessary when using batteries. In general, an ac motor's overall cost is higher than that of a comparable dc motor.

Overall, there are automotive and off-road applications for ac and dc motors. But to make electric motors and EVs viable, it will take major advances in battery technology. The current energy storage necessary to power EVs adds too much weight, making the weight-to-power ratio too high. There are also the problems of slow recharging and environmentally clean disposal.

A cradle-to-grave analysis published by the Union of Concerned Scientists shows that an EV with an 84-mile range creates about 15% more emissions to manufacture than a conventional car. This difference could be recouped in a year of driving, and the car will emit half as many pollutants over its lifetime—including manufacturing. So as deals, such as the Paris Accord, get passed and move toward a carbon-neutral society over the coming years, we might see more EVs on the road.

However, like many technologies, a multiple of them are needed to achieve optimal efficiency. Due to the current state of batteries, smaller IC engines are pairing with electric-drive technologies that are making even the emission standards of 2025 (54.5 mpg) sound easier to hit than some may have initially thought. If hybrid innovations for the IC engine design are not improving the performance and growth of the piston engine, it is at least increasing the slope of its diminishing return and extending the IC engines existence—at least, for the time being. md

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The Future of Robots

—and the Motors and Drives Leading the Way

Machine Design takes a look at the world of modern and future robotics and the components being used to drive them.

The Delta 3 is a result of the Pac-Drive product line from Schneider Electric. It has a minimum of three degrees of freedom and can be used in the pharmaceutical or food industries.

Robots are everywhere! In modern automation, they are an essential tool on most plant floors. In our homes, they have become cleaning tools and personal assistance/entertainment devices. This current trend is not dying down as robot manufacturers find new ways to fine-tune their design, creating nimbler and faster robots. In a recent study from Tractica, 6.5 million robots were sold in 2015. Per their predictions, 100 million robots will be sold worldwide within the next five years. Currently, the types of robots sold are split 50/50 between industrial and non-industrial. Robots such as placement robotic arms and XY gantry robots are prevalent in manufacturing and packaging, but the future of robotic sales looks to be for personal assistance robots. These robots will help us in everyday tasks as well as assisting the elderly and helping educate children.

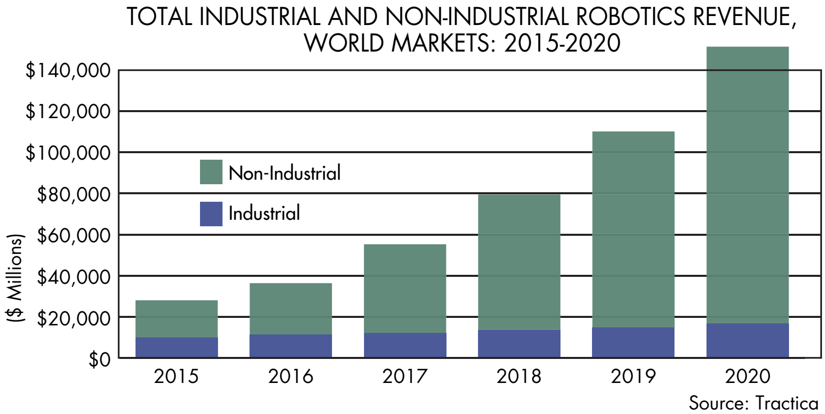
MODERN ROBOTS

The current trend for robotic design is small and lightweight. Modern engineering design stresses how important it is to focus on envelope size, lightweight design, and energy efficiency. Parker Hannifin has introduced a series of motors that help cut down on weight and envelope size. Its frameless motor K-Series does away with the main housing and shaft to cut down on weight. It's ideal for

The frameless motor design from Parker Hannifin provides high torque ranges and space-savings options by not including a housing or shaft.

machine designs that require high performance in small spaces. The motors allow for direct integration with the mechanical transmission device. This eliminates parts that add size, allows for minimum motor size per application, and gives designers the advantage of reducing cost. The frameless motors contain a motor stator and rotor and come in different outer diameter sizes: 32, 44, 64, 89, and 178 mm. They benefit from peak torque values of 0.26 Nm up to a max of 81.74 Nm and speeds of up to 5,000 revolutions per minute (RPM), with a higher speed windings of 30,000 rpm if needed. The K-motors have a pre-installed integral commutation board; the motor and feedback are an integrated unit. The use of rare earth magnets provides high resistance to thermal demagnetizing and high-flux in a small volume. They are Class-H insulated for up to 155°C temperature operation, meeting UL requirements. Lastly, they use high-density copper winding for low thermal resistance and consistent performance. Weight range on the series is a minimum 0.15 lb to a max of 13.98 lb.

While the K-Series provides customization for specific designs, Parker Hannifin's P-Series of motors and drives provide flexibility. For Gantry and Cartesian robots, motors and drives need to have general-purpose utility and be flexible so that one prevents the constant switching out of drives. The P-Series drives and motors operate in a variety of machine-controlled architectures. The drives have EtherCAT connectivity for high-speed motion bus, USB communications for convenient setup, and 8 inputs/4 outputs with EtherCAT models. The Safe Torque Off feature for the EtherCAT models immediately cuts power to the motor, then dynamic braking quickly brings the motor to a stop. The line of drives from Parker Hannifin also has auto-tuning features. In real time, the drives can apply tuning via adaptive resonant filters and



The graph above shows the predicted robot trends for the next five years based on research from Tractica.

The P-series drives and motors are designed for flexibility to accommodate several motors and prevent the constant switching out of drives.

Hector has three EC 45 flat motors on each of its legs, delivering 50 watts of power per motor to the robotic movements. *(Image courtesy of Maxon Precision Motors)*

Hector can walk independently and respond to obstacles via complex sensors collecting data of the surrounding environment. *(Image courtesy of Bielefeld University)*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detecting vibration peaks to dial in inertia and tuning gains. The P-Series motors need to be flexible, which is why they follow the BiSS-C standard for open-source absolute-encoder design. Absolute encoders are becoming the norm for drives due to their cost-saving benefits.

Schneider Electric offers all-in-one robotic solutions. They are add-ons to the PacDrive product line geared toward providing fast and easy-to-integrate robotic solutions. The motors, drives, and robotic assembly designed by Schneider Electric ease installation. Included in the PacDrive portfolio are the Delta 2 and Delta 3 picker mechanisms, which are available with installed motors of the Lexium SH3 or Lexium 62 ILM families. The PacDrive Delta 2 has a max load capacity of 55 lb and the Delta 3 is capable of 33.1 lb. The PacDrive Delta 3 has three or four degrees of freedom and is IP65 rated for pharmaceutical and food application. The SH3 servo

motors are available in five flange sizes: 55, 70, 100, 140, and 205 mm. They have a nominal torque range of 0.5 to 50.7 Nm, peak torque values of 1.5 Nm to a max of 330 Nm., and speed of 1,500 RPM to a max of 8,000 RPM. The Lexium SH3 servo motors are equipped with integrated encoders that have a single-turn (131,072 points/turn) (2) or multi-turn (131,072 points/turn × 4,096 turns) integrated encoders. A stainless-steel version of the SH3 motors, the SHS family, is also available in three flange sizes: 55, 70, and 100 mm.

The Lexium 62 ILM integrated drive and motor bundle is compact and offers quick interconnects and hybrid cables for signal and power level. When connected, they provide automatic network configuration and has diagnostic capabilities. The LXM62 ILM is considered plug-and-play technology due to the ease of installation. It is capable of a nominal torque range of 0.5 Nm to 12.5 Nm, a peak torque of 3.5 to 55 Nm,

The RE 40 motors used in Romeo have iron-less Maxon winding, which ensures precise control and current that is proportional to torque. This allows the controller to use current measurements to determine when Romeo has encountered an obstacle or has collided. *(Image courtesy of Maxon Precision Motors)*

Romeo comes from a family of robots designed by Aldebaran. The other two are Pepper, which uses wheels to roll around, and Nao, the smallest. *(Image courtesy of Aldebaran Robotics)* and speed of 1,500 RPM to a max of 6,000 RPM. They are available in flange sizes of 70, 100, and 140 mm. The ILM integrated drive and motors take up to 90% less cabinet space, up to 90% less wiring time, and up to 70% less cabling. Due to their fast installation time and cost-saving cable handling, the ILM integrated drives are frequently used for rotary-capping applications.

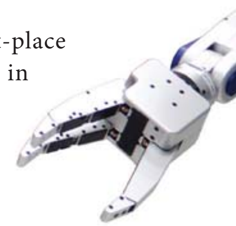
THE FUTURE OF ROBOTICS

As mentioned earlier, robots are leaning away from assembly and automation, and shifting focus toward entertainment and personal assistance. The robot in the image on p. 60 is called "Hector" and was developed by the Biomechatronics Research Group at Bielefeld University. The robot is about 3 feet tall and weighs 26.5 lb. The exoskeleton consists of carbon fiber-reinforced plastic, which makes it extremely lightweight. The purpose of the project is to achieve better control of underlying coordination principles as well as to investigate the fundamental concepts of how to elastically control actuated driven robotic systems.

Each individual leg of the robot contains an EC 45 flat Maxon motor, with a total of 18 motors. The EC 45 flat is a brushless motor delivering 50 watts of power at a diameter of 45 mm. The motors for this particularly design are custom built by Maxon, as the elastomer couplings were integrated directly into the drives.

The next phase of robotics will introduce personal assistants. "Romeo," designed by French robotics company Aldebaran, aims to be the perfect assistant for the elderly. Romeo is almost 5 feet tall and weighs 81.6 lb. The researchers at Aldebaran are currently testing to see how far they can push Romeo's limits. The goal is to maximize its walking ability, navigation, and human-robot interaction. Eventually Romeo will be able to respond to human body and facial expressions.

Romeo uses 37 Maxon RE 40 motors. The RE 40 motor uses graphite brushes at 150 watts of power. The RE 40 has a 40 mm diameter and has nominal torque ranges of 94.9 mNm to 190 mNm. The motors come with iron-less Maxon winding, ensuring excellent control behavior.



The DRC-Hubo robot was one of the first-place finalists of the DARPA Robotics Challenge in 2015. The DARPA Robotics challenge consists of realistic scenarios such as driving a car, cutting holes into walls, opening doors, and negotiating difficult and uneven terrain. The Korea Advanced Institute of Science and the Rainbow Company built the robot in conjunction using 33 Maxon motors, mainly the EC-4pole 30 brushless

The EC-4pole 30 brushless motor from Maxon achieves maximum power in Hubo by being operated in overload conditions in conjunction with cooling fans. *(Image courtesy of Maxon Precision Motors)*

motor. The robot operates on two legs, but benefits from being able to utilize rollers built into the knees. This helped Hubo complete the required competition tasks in the shortest time. The robot has an aluminum casing instead of plastic, stands 6 feet tall and weighs 176.4 lb.

The EC-4pole 30 brushless motors deliver significant power at 200 watts per motor. The Hubo uses 25 of these motors, which operate at overload conditions. The robot was equipped with cooling fans so that the motors could operate safely even in overload conditions. Hubo demonstrates the closest example of how technology of today can be used to advanced and push the capabilities of modern robotics. md

DRC-Hubo won the 2015 DARPA Robotics Challenge and the KAIST (Korea Advanced Institute of Science and Technology) and the Rainbow Co. were awarded $2 million in prize money. *(Image courtesy of KAIST and Rainbow Co.)*

Distribution

VICTORIA FRAZA KICKHAM | Distribution Editor

Image courtesy of Thinkstock

AVNET, IBM Partner to Accelerate IoT Development

Technology companies join forces to bring new Internet of Things solutions to OEMs and other customers in the United States, Europe, and Canada.

Global technology distributor Avnet announced a new collaboration with IBM designed to accelerate the development of Internet of Things applications in the United States, Europe, and Canada.

The companies' efforts will help customers develop IoT solutions built on the IBM Watson IoT Platform. The collaboration is designed to help Avnet's wide-ranging customer base capitalize on the opportunities in the rapidly growing IoT market, which is estimated to account for more than $921 billion in technology spending in 2016, the companies said.

The partnership builds on Avnet's growing IoT development business, according to the distributor, pointing to its recent work with SPICA Technologies to help create a smart cities IoT solution to improve water safety. The solution reduces the risk of contracting Legionnaires' disease by using connected devices attached to water pipes that provide real-time information and analysis on water temperature and flow, improving accuracy, and reducing monitoring costs by up to 60%. Avnet helped build the solution by bringing together the sensor components, IBM Core Middleware, IBM Enterprise analytics, and an IBM Cloud deployment to manage the data.

"Developing an IoT solution is incredibly complex and requires deep technical knowledge from a semiconductor level to advanced data analytics running in a data center," Patrick Zammit, president, Avnet Technology Solutions, Global, said in a statement announcing the IBM partnership. "Avnet and IBM joined together to simplify the development cycle at every stage and give our customers the power to unlock the potential of IoT."

Such comments echo those of Avnet's Gerry Fay, president of Avnet Electronics Marketing Global, the company's electronic components division. Fay emphasized Avnet's focus on IoT solutions following the release of the company's quarterly earnings statement in February.

"We have been in IoT always," said Fay, pointing to the company's expertise in sensors, processing, communication protocol devices, and similar products and systems. Avnet took this to the next level recently with the hiring of Eric Williams as vice president of IoT. Such moves will help the distributor further develop its IoT business.

"We believe that finding IoT customers early in the process and asking them the right questions" will ensure success in the competitive IoT space, added Fay. "And we believe that there is more growth and margin opportunity than the market is providing us today."

Avnet and IBM said they will provide customers with a wide range of resources to develop IoT solutions that "effectively gather information, connect to the Internet, and securely manage and analyze data." Those solutions include:

- Availability of IBM applications critical to designing and managing IoT solutions, including IBM Watson IoT Platform, IBM Watson, and IBM Cloud;
- IoT development platforms and kits that accelerate the ability to prototype IBM Bluemix-enabled IoT solutions;
- Create proof-of-concept solutions with Avnet's highly experienced team, enabling Avnet's 100,000 customers to deploy connected devices;
- Avnet data-center and cloud solutions based on an IBM Watson IoT Platform that provide analytics engines, asset management, data management tools, IoT Platform-as-a-Service (PaaS) capabilities, and security;
- Access to the Avnet Cloud Marketplace, which features IBM Cloud infrastructure; IBM Software-as-a Service (SaaS) solutions related to cloud, analytics, mobile, social and security applications; and the ability to create branded storefronts;
- Solutions design, integration, and assembly support services at its solutions centers in the Americas and EMEA;

- In-depth technical education and training through Avnet Academy on IBM Bluemix and IBM Watson IoT Platform.

Customers also will be able to leverage the Avnet Visible Things evaluation and development reference platform. This initiative, driven by Avnet in EMEA, is a platform built on the IBM Watson IoT Platform, designed for edge-to-enterprise IoT projects. It delivers hardware and embedded software to connect smart sensors to the Avnet Devicepoint service, which adds context to sensor information and loads it to an enterprise-strength core system. It then presents a set of business and integration services focused on analytics, cloud, and mobile.

"IBM, alongside its vast network of clients and partners, is ushering in a new era of computing, extending the power of cognitive computing to the billions of connected devices, sensors, and systems that comprise the Internet of Things," said Harriet Green, general manager, Watson IoT, Education and Commerce, IBM. "Working together, Avnet and IBM can help clients further embrace the full promise of IoT using innovative technologies to uncover hidden patterns in data and act on them, to transform business and society alike." ■

DIGI-KEY, ARM UNIVERSITY
Extend Partnership

GLOBAL ELECTRONIC COMPONENTS distributor Digi-Key Electronics announced the extension of its partnership with the ARM University Program to distribute ARM Education Kit hardware components to higher educational institutions.

Digi-Key will provide Education Kit hardware that supports design courses covering embedded systems, system-on-chip (SoC) development, and Internet of Things (IoT) technologies. The full education kits contain ARM-based hardware and software components, in addition to teaching and training materials from the ARM University Program.

"The ARM University Program enables electronics and computer engineering courses all around the world, and last year tens of thousands of students took modules based on our technology," says Khaled Benkrid, director, education and research, ARM. "The collaboration with Digi-Key will provide access to high quality ARM-based hardware, software, and teaching tools to support an even greater number of academics, students, and engineers. Together, we will be equipping a new wave of developers with the knowledge and skills that will underpin their professional careers."

The Program includes technologies provided by key Digi-Key suppliers such as STMicroelectronics, NXP, Cypress, and Nordic Semiconductor. ■

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Miniature Proportional Valves Target Medical Apps

VSO LowPro miniature proportional valves reliably control the flow rate of inert gases in medical equipment. Measuring 16 mm by 14 mm with a mere weight of 12 g, the valves can be implemented in small portable devices. They can be used for pressure control, volumetric-flow control, and pulse-dose control in devices such as portable oxygen concentrators, ventilators, and patient monitors. They are qualified for up to 25-million cycles and offer flow rates up to 50 SLPM with maximum power of 1.5 W at room temperature.

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MEDICALLY CERTIFIED DTM65-C8 external power supplies offer class II input, which eliminates the need for an earth-ground connection and meets Level VI DoE standards for efficiency. They are also certified to IEC 60601-1 and 60601-1-11 medical standards for use in diagnostic and monitoring equipment. Housed in a vent-free, IP21-rated enclosure, the power supplies measure 106 x 60 x 31 mm and can be powered with alternating or direct current via a standard IEC60320-C8 cable and four-pin Power-DIN connector, respectively. They also offer overvoltage and overcurrent protection and accept

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inputs between 90 to 264 V ac. Adapters with power ratings from 40 to 65 W are available with 5-, 12-, 15-, 19-, 24-, 28- and 48-V outputs. They can operate in ambient temperatures ranging from 0 to 60°C.

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PLC Integrates HMI Interface

THE UNISTREAM 7-in. panel is a low-cost programmable logic controller that incorporates a powerful dual CPU, sleek HMI touch panels, a variety of I/O options, and UniLogic software. As a result, users can code Ladder, design HMI screens and Web pages, configure hardware, and set up and implement communications. Users can create an all-in-one controller by snapping on a CPU and I/O module to the HMI, giving OEMs and system integrators the ability to customize their PLC with any HMI. It can be configured with RS-485, CANopen, UniCAN, and serial and Ethernet Modbus communications. It supports Ethernet/IP and can be adapted to other third-party protocols. Its USB and serial ports support external devices such as modems, printers, and barcode readers.

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Joysticks Come in a Range of Configurations

THE JS1 PLATFORM for joysticks in the JS1-H family is well-suited for heavy-duty applications. Customers can choose from a standard portfolio of joysticks that consists of three base options—single-axis with spring return, friction hold,

Motion Controller Features Easy-to-Use Interface

THE XPS-RL motion controller is capable of working with up to four axes. Based on the XPS platform, its graphical user interface and single-click stage configuration makes it easy to operate. ESP plug-and-play compatibility recognizes when an ESP-compatible stage is connected to the controller. All parameters are determined automatically to avoid misconfigurations and ensure safe operation. It also includes pre-configured and user-definable motion profiles to help optimize performance and simplify the use of advanced features, including line-arc trajectories, splines, contouring, and complex PVT trajectories.

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and dual-axis with spring return—five grip types, and push-buttons, rollers and other controls that are able to be custom-positioned.

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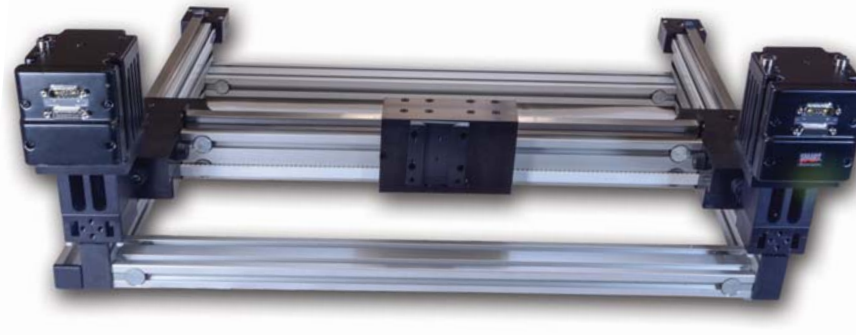

Belt Actuators Simplify Motor Control

THE ROT1 rotary actuator, PSC/M6S actuator, and HBOT1/TBOT1 belt system are all included in a new actuator lineup that is rated with precise motion, long life, minimal maintenance, and compactness. The actuators are designed to be used in conjunction with the Smartmotor line of motors.

The HBOT1/TBOT1 belt system (shown above) implements a combination of belt actuators for motion along two axes. It does not require expensive cable tracks or high-flex cabling, because the motors remain stationary during operation. Meanwhile, the SmartMotor directly interprets Cartesian coordinates during movement and performs transforms on-the-fly to produce the required motion and positioning.

MOOG INC. Animatics, 1421 McCarthy Blvd., Milpitas, CA 95035, (408) 965-3320; www.moog.com

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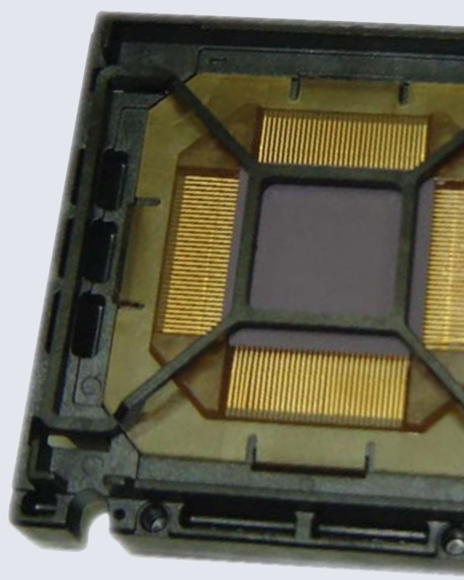
ISOPAK TEST and Burn-In Carriers



Contactless Position Sensors Work in High Operating Temperatures

THE LDI-127 Series of linear variable inductive transducers (LVITs) are contactless position sensors featuring high accuracy and low linearity error. Built with a radial cable exit with swivel rod-eye ends, they operate under high temperatures, vibration, shock, and humidity. They target applications in factory automation, as well as industrial and commercial applications like solar-cell positioners, wind-turbine propellers and brakes, chute or gate positioning, agriculture vehicles, and packing equipment.
OMEGA INC., 1 Omega Dr., Stamford, CT 06907, (888) 826-6342; www.omega.com

feature a unique dual-material design to provide protection from electrostatic discharge in semiconductor devices, and eliminate false failures caused by conductive carriers during testing. In addition, the device leads are electrically isolated to ensure carrier conductivity instead of leakage during testing. Custom carriers are available to mate with a range of sockets. Constructed out of standard NoStat ESD-safe polymers, the carriers also withstand temperatures up to 180°C.

R.H. MURPHY COMPANY INC.,
3 Howe Dr., Amherst, NH 03031, (603) 889-2255; www.rhmurphy.com

Motion-Control Servos Suit Multiple Motor Apps

DIGIFLEX PERFORMANCE digital motion-control servos include positioning-drive features for ac and dc brushless servo motors. They also cater to dc brush-type servo motors, linear and rotary servo motors, closed-loop vector motors, voice coils, inductive loads, and actuators. Products are available with network connections for CANopen, RS-232, RS-485, EtherCAT, EPL, Ethernet PowerLink, and SynqNet. They also may be ordered to support DeviceNet, Ethernet TCP/IP, FireWire, Profibus, USB, Universal Serial Bus, and Sercos interfaces.

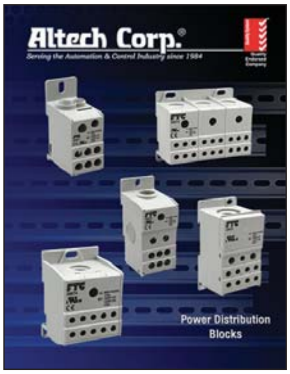
ADVANCED MOTION CONTROLS, 3805 Calle Tecate, Camarillo, CA 93012, (805) 389-1935; www.a-m-c.com

DC-DC Converters Install Easily

THE RHINO PSE series of encapsulated dc-dc converters delivers reliable power sources for sensitive loads. The converters support two ranges of input voltages: 9.5 to 36 V dc and 18 to 75 V dc, and supply output voltages ranging from 5.1 to 48 V dc. They can be controlled remotely and provide input-polarity and overload protection. Installation is made easy with chassis or DIN-rail mounting. Plastic slim-line case converters are also available in 25- and 60-W models.

AUTOMATION DIRECT, (800) 633-0405; www.automationdirect.com

ALTECH POWER DISTRIBUTION BLOCKS



Altech has a full line of Power Distribution Blocks in Aluminum or Brass. They are available in one and three phase. Save up to 20% with the new aluminum body.

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Solid State Relays (SSR) are fully electronic, there is no moving parts inside SSR; they have no audible noise, withstand significant vibration without operating problems, have fast response time, but most of all they have higher life-time expectancy.

Used in appropriate operating conditions, SSRs have nearly unlimited life versus 100K cycles for Electro Mechanical Relays (EMR). SSRs don't require any maintenance and prevent manufacturers from unforeseen machines/production stop, which is a great advantage with 24h/24 industrial activity.

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ALTECH DC-UPS SOLUTIONS

Altech has a full line of DC-UPS solutions which include the All-In-One DC-UPS for battery based systems and Ultra Capacitor DC-UPS (no battery).

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- Available in 12VDC, 24VDC and 48VDC
- Adjustable charging current up to 35A
- Easy battery diagnosis and fault identification

Ultra Capacitor DC-UPS:

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ALTECH NON-CONTACT SAFETY SWITCHES

Non-Contact safety switches ensure that safety doors and protective guards remain closed when danger is present. The two technologies offered are safety sensors on magnetic basis (MAK) and safety sensors on RFID basis (CSMS). MAK are dual channel; a safety evaluation unit must be attached. The evaluation unit monitors the correct switching of the two MAK channels and a defined time window in which the two channels must switch. The CSMS can be directly connected to contactors or to an evaluation unit.

The Advantages:

- Wear-free actuating
- Easy to clean
- No actuator so no mechanical damage possible and no hazards or restrictions caused by protruding actuator
- Switching function not affected by contaminants

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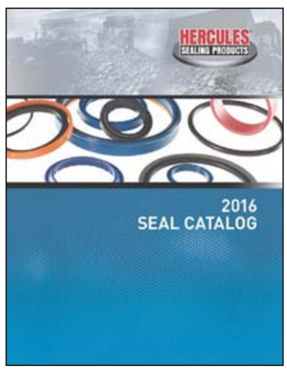

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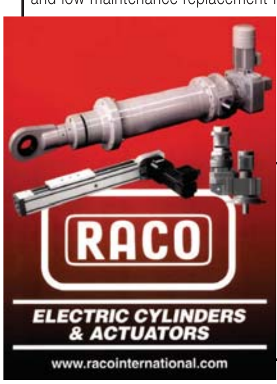

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BRADFORD L. GOLDENSE | Contributing Technical Expert

Top 12 Trends In The Science of Managing R&D and Product Development: Perspectives

Twelve trends affecting the science of managing R&D and product development are described in my January and February articles. In this "bonus" installment, we look at what these trends mean to the evolution of product creation and commercialization.

"Big data" is a macro trend influencing each trend. First coined around 1970, "Moore's Law" describes the doubling of computing capability every two years. Forty-five years later, that doubling is reaching epic proportions. While the cost of data storage was once immense, today it's among the smallest of considerations. The challenge now lies in culling-out real information from the myriad data.

We now have amazing computational and communication tools we wear or carry around. Since 1980, the number of bits per second sent through optical fibers has increased 10 million-fold. We no longer have to be in the same house or office to provide or access needed information. From this perspective, companies do not differ much from individuals or families. They are just entities with larger domains, albeit the same basic needs and wants.

So how do we cull out the needed information from amongst all the data? The solution to that question can be found in the Internet of Things (IoT), where seemingly everything is headed. Just about every past and future product will be designed or redesigned to facilitate the IoT endgame. In the future, products will be second-class unless they propagate information into and pull information out of a networked information repository few currently comprehend—a giant and universally accessible data bank.

Quick access to information lets people manage strategy in VUCA times (Trend 2). It is the reason for Web 3.0. Once in place, it will facilitate improved Organic Innovation (Trend 4) and Open Innovation (Trend 11). In the case of Organic, companies that master it will out-invent their competitors. Companies that don't will Openly Innovate from those that do. Measurement and Correlation (Trend 10) will be achieved because of the "infinite size" of the data set. These factors, in turn, will continue to drive the refinement and understanding of the ownership of Intellectual Property (Trend 12). And issues regarding the efficiencies of Physical Versus Virtual Work (Trend 9), will disappear as geographic location becomes increasingly less important.

Moore's Law also describes a geometric shrinking of size. Computing industry knowledge continues to spill into every other industry from motors to health care. Everyone wants more capabilities occupying less space, Micro-Nano Effects (Trend 8). This trend, coupled with the long-held manufacturing goal of producing low-cost lot sizes of one unit at a time, will keep Engineering and Development Automation (Trend 7) on a tear for years to come. Low-cost lot sizes of one are not possible if humans touch the product. Rapid Prototyping (Trend 1) is one solution. Eventually, it will evolve to deposit atoms versus molecules and the Micro-Nano journey will come full circle.

The management of Core and Functional Competencies (Trend 6) will become extremely sophisticated. Companies will have to stay focused on inventing the things they do best, and where they are protected by Intellectual Property. Functional Competencies will be the most severely impacted as sensors, software, data management and analysis, and communications technologies become part of every product and add differentiable value to the IoT. There will be a progressive "Death of Operations" as lot sizes of one are gradually achieved, and as material sciences replace production and manufacturing sciences.

Where does that leave us? Amazingly, we are back to square one. The most expensive product errors today will still be the most expensive product errors in the future, developing products that don't sell. Product Definition (Trend 2), the remaining trend, will be done physiologically using the aforementioned technologies, thereby eliminating large errors associated with focus groups and surveys. This too, just like other transformational trends described in this article, will become an everyday norm as we get closer and closer to the IoT. md

BRADFORD L. GOLDENSE, NPDP, CMfgE, CPIM, CCP, president of **Goldense Group Inc.** (GGI) (*www.goldensegroupinc.com*), has advised over 300 manufacturing companies on four continents in product management, R&D, engineering, product development, and metrics. GGI is a consulting, market research, and executive education firm founded in 1986.

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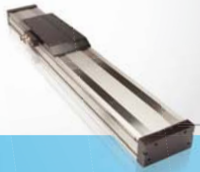

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