

The maxon motor magazine

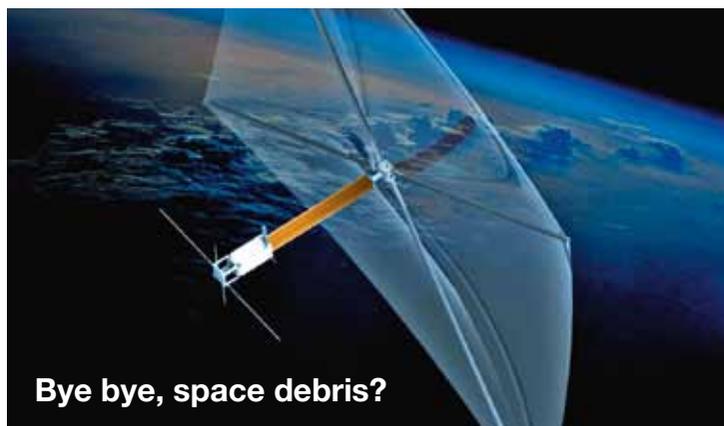
# driven

2 // 2014



## Operating rooms of the future

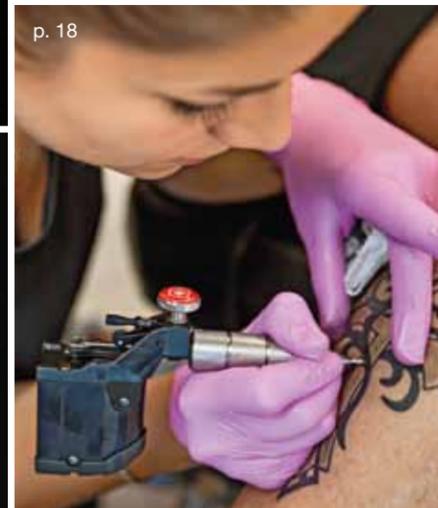
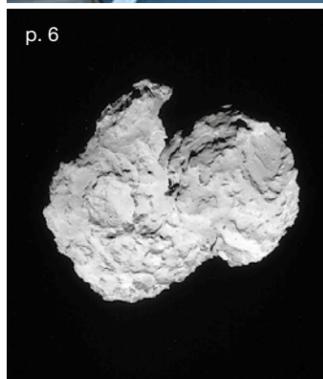
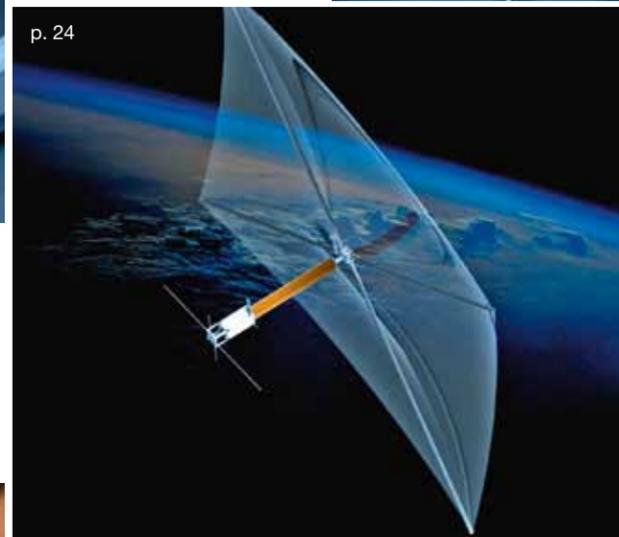
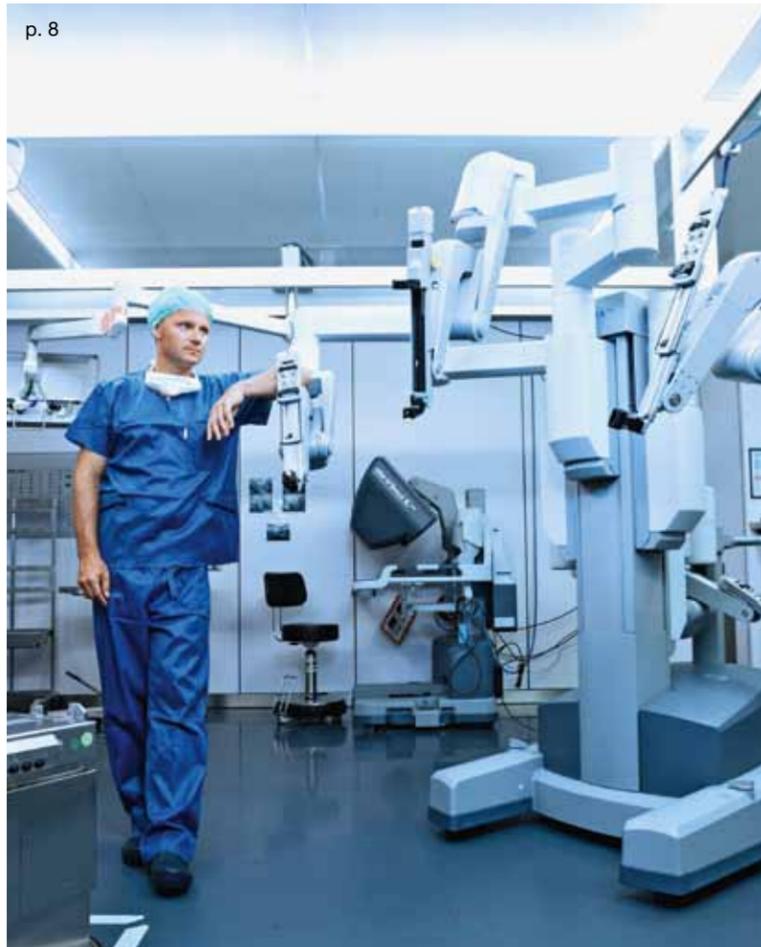
High-tech for health and beauty



Bye bye, space debris?



“Swiss made” tattoo machines



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Photo: maxon motor ag

**Editorial**

# Better quality of life through better electric motors



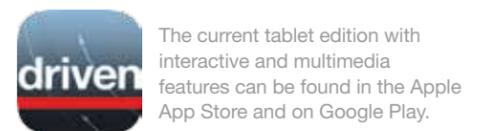
Eugen Elmiger, CEO, maxon motor ag

**P**hysicians have been improving our health, our looks, and our lifespan for centuries. The difference from earlier times is that today, they have state-of-the-art tools at their disposal, such as surgical robots and precision tools for complex operations. Researchers are even developing a miniature pump to support circulation.

High tech has been transforming the operating room for some time now, and as you can read in this issue of driven, maxon motors are playing an important role in this development.

It makes me proud that we have been able to keep abreast with the rising requirements in medical technology and contribute to the health of many people. I am convinced: Technological progress and improved quality of life go hand in hand.

Happy reading!



# Get The Big Picture!

The TU Delft's hydrofoil boat rises from the water after the start, reducing its water resistance to that of a human hand. The hydrofoils were designed using know-how from aerospace engineering. The front hydrofoil has a drive system by maxon motor. Combined with a height sensor, the drive system ensures that the boat remains at the optimal elevation above the water.

Learn more:  
[bigpicture.maxonmotor.ch](http://bigpicture.maxonmotor.ch)



**Gerwin Geukes, Managing Director at maxon motor benelux, talks about the cooperation with the TU Delft team:**

“Being involved in this high-end project gives us an opportunity to gain insight into what’s going on in the heads of the next generation of engineers. Things that may be commonplace for our engineers can be new to the students, and vice versa.”



**maxon RE 25**  
Ø 25 mm, 20 W,  
Graphite brushes

Photos: maxon motor ag, TU Delft Solar Boat Team



The Rosetta space probe

## On the search for primal matter

On August 6 of this year, the time had come: After a journey of more than ten years, the Rosetta space probe reached the comet 67P/Churyumov-Gerasimenko, known as "Chury" for short. For the first time in the history of space travel, a probe rendezvoused with a comet.

The first images have already yielded an astonishing new insight: The comet Chury, with its size of about four kilometers, is not round or oval, as people expected. It looks like two rocks loosely stuck together. At minus 70 °C, the surface is much warmer than predicted. Initial data indicates that it is covered with a layer of black dust.

The most difficult part of the mission will take place in mid-November, when the Philae lander is scheduled to touch down on Chury. It will be the first controlled landing on a comet. A real pioneering feat – and maxon motor is part of it. A Swiss RE-13 motor lowers an alpha particle X-ray

spectrometer from the probe's belly to the comet's surface. The device is going to analyze the chemical composition of the rock and identify individual elements. Philae is equipped with a total of ten measuring devices.

The Rosetta project is probably going to take until late 2015. Until then, researchers want to collect as much data as they can about the core and the tail of the comet. This data is evaluated for clues about the condition of the early solar system – and it might even provide an answer for one of the really big questions: Could it have been comets that brought water to Earth, or even the seeds of life, billions of years ago?



### What's next?

On our Twitter channel @maxonmotor, we will keep you up to date with news from the Rosetta mission.



In mid-November, the landing unit Philae (below) is going to touch down on the comet Chury (left).



cosmetic surgeries. According to a study by the International Society of Aesthetic Plastic Surgery (ISAPS), 11.6 million people underwent cosmetic surgery in 2013. Compared with the last survey in 2011, the number has almost doubled. The most popular operations are breast enlargements, liposuction, and tightening the eyelids. However, the most common procedure does not require a scalpel and is therefore recorded in a separate statistic: Botox, a neurotoxin that is injected under the skin. According to expert estimates, this procedure has been performed more than five million times globally, often by means of pistols that provide the correct dosing with the aid of maxon motors. Swiss precision drives can also be found in hand-held devices for liposuction and cellulite treatment.

Photos: ESA/ATG medialab, maxon motor ag, Rubberball / Mark Andersen

## NEW PRODUCTS

More power for hand-held tools

### EC-4pole 30, autoclavable

The EC-4pole motors by maxon are veritable powerhouses. Because their rotors are equipped with two pole pairs, these brushless drives offer high power density and a very high rated torque. The EC-4pole 30 with a diameter of 30 millimeters is designed to withstand more than 1000 autoclave cycles, a feature which makes it ideal for use in medical hand tools. This very strong motor is the right choice for bone saws, drills, and arthroscopic shavers.



The DCX product family



maxon EC-4pole 30  
Ø 30 mm,  
150 W, brushless

This efficient line of motors continues to grow

### DCX motors 14L/16L/22L/26L and GPX planetary gearheads 14/19/26/37

The brushed motors of the DCX series are especially powerful for their size. They are easily configurable online and can be delivered within 11 days. Now four more motors have been added to round out the existing portfolio. Diameters 14, 16, 22 and 26 are also available in a long version (L). At the same time, four new GPX planetary gearheads are being launched in the sizes 14, 19, 26, and 37. The existing GPX 16 and GPX 32 are now also available in different versions (ceramic, reduced noise level, and reduced backlash).

# The future of surgery belongs to **robots**



Photos: intuitive Surgical, maxon motor ag / Philipp Schmid, maxon motor ag



Daniel Seiler graduated from medical school at the University of Zürich and specialized in urological surgery. Today he is a urology specialist at Hirslanden Klinik Zürich.

There is no blood on Daniel Seiler's hands after a surgery. Sitting at a console, he directs the daVinci surgical robot, which performs minimally invasive surgeries with utmost precision. An impression.

**V**ery much unlike his two sons, Daniel Seiler is not a computer gamer. He stays away from such things.

At first glance this may seem surprising, as the urologist sits in front of a console almost daily, operating joysticks in both hands, with his eyes fixed on a computer screen. However, he isn't in it for the fun. Quite the opposite: Every small movement is vitally important, because Daniel Seiler is in the operating room of the Zürich Hirslanden clinic, where he controls a daVinci surgical robot from a few meters away. The robot's four arms are equipped with instruments such as a forceps and miniature scissors, as well as a camera. Its instruments are inserted into the patient's abdomen through small cuts, eight to twelve millimeters in length. In near silence and with extreme precision, Dr. Seiler controls the surgical robot to remove a cancerous prostate gland, an operation that used to be rather risky. State-of-the-art technology has made it routine.

#### The critics are silent

As with any surgery on a human being, there is no one hundred percent guarantee that everything will go well. Daniel Seiler is not unaware of this. However, he has seen the daVinci robot enable huge advances, especially in urology. In over ten years, the Swiss physician has carried out several hundred operations using the robot. This makes him one of the leading specialists in his field. He says,

"Early on there were still critics who doubted the usefulness of such a system. However, almost all of them are silent now."

The daVinci surgical robot was introduced 14 years ago by US company Intuitive Surgical Inc. Since then it has been used in more than 1.5 million operations, half a million in 2013 alone. The trend is clearly upwards. Daniel Seiler of the Zentrum für Urologie Zürich compares the daVinci robot to a sports car: It takes a good driver to control the car and get fast lap times. Accordingly, it took several years for the surgeons to gain the necessary experience to use the surgical robot efficiently. "Today we are able to take full advantage of all the benefits of the daVinci system", Daniel Seiler says.

In urology, the precision of the daVinci system is especially valued because there are so many sensitive blood vessels involved, for example around the prostate. Daniel Seiler: "We are able to offer our patients a very high level of post-operative functionality with respect to continence and sexual potency. This contributes to a higher quality of life."

This high precision is not a matter of chance. The system uses maxon DC motors, which ensure accurate transmission of the operator's movements to the instruments. The daVinci robot has a total of 39 drives.

**There is no stopping the trend towards robot-supported surgery.**



The daVinci surgical robot is controlled manually using two joysticks.



#### For precise arm movements

The daVinci surgical robot boasts several motors from the RE series. These brushed drives are popular with developers especially because of their high efficiency. The high-quality magnets (rare earth) and patented ironless winding provide clean operation with no cogging torques, and more than 90% efficiency.



maxon RE 13  
Ø 13 mm, precious metal brushes, 2.5 W



maxon RE 40  
Ø 40 mm, graphite brushes, 150 W



maxon RE-max 29  
Ø 29 mm, precious  
metal brushes, 9 W



**The slim alternative**  
The RE-max 29 excels with its strong performance at low cost. It is equipped with the same magnets as the RE motors. However, its manufacture is automated. In the daVinci robot, it is used together with an MR encoder.

These include RE 40 motors, RE 13 motors with maxon planetary gearheads and encoders, as well as RE 29 motors.

**maxon motors transmit the operator's movements**

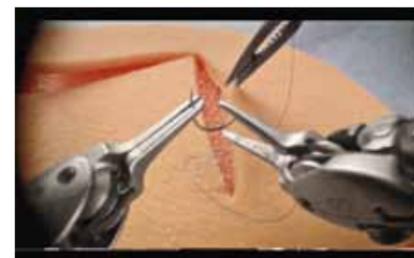
One special feature of this application is that the motors process both input and output signals. Some drives are in the control console, where they forward operator movements as signals to the computer. From there, these signals are forwarded to the motors in the manipulators, which then carry out the relevant movements. Because of their ironless windings, the maxon motors have no cogging torque, which improves positional accuracy.

Another advantage is the excellent dynamics, which make these motors perfect for applications such as the daVinci robot.

The daVinci robot is not only used in urology but also in gynecology, and increasingly in ear, nose and throat surgery. It has even been used in cardiovascular (bypass) surgery. "The possible applications of this system are almost endless", says Dr. Daniel Seiler. He believes that the only limitations are in people's heads. This is why he shares the confidence of other experts: There is no stopping the trend towards robot-supported surgery. Or, to use one more metaphor from motor sports: The fastest lap has yet to be driven. ■

**Advantages offered by the daVinci**

- The instrument heads at the end of each robotic arm can be rotated 540 degrees to reach into any corner. This allows precise work in very constrained spaces. Any hand jitter is compensated electronically.
- The control movements are reduced by a transmission. If the operator moves the joystick by 15 millimeters, this translates to a motion of only 5 millimeters. This reduction ratio can be increased even further at the push of a button.
- 3D imaging with tenfold magnification gives the operator a perfect overview.
- Blood loss is very low with this minimally invasive surgical technique.
- Several small incisions heal faster than the large cut of an open operation. As a result, patients also have a shorter stay in the hospital.
- The operator sits comfortably at a console. This is much less tiring than having to bend over patients day in day out.



Download tablet issue 2 // 2014 and see the daVinci surgical robot in action. [magazine.maxonmotor.com](http://magazine.maxonmotor.com)



The four arms of the daVinci surgical robot are equipped with various instruments, including a forceps and miniature scissors, as well as a camera.

# Hope for cardiac patients

Intra-aortic pump powered by miniature brushless DC motors provides heart failure patients an aid to help hearts rest and heal.

**C**hronic heart failure patients draw hope from a new technology. A team of life science entrepreneurs in Houston, Texas has developed the first catheter-deployed circulatory assist device intended for long-term use. Procyrion, Inc.'s Aortix™ provides a minimally invasive treatment option for the more than two million chronic heart failure patients in the USA alone who are too sick for medication. This pre-clinical cardiologist tool dramatically reduces risks associated with circulatory support devices and enables treatment of younger, healthier patients before progressive damage occurs.

### Anchors hold the pump inside the aorta

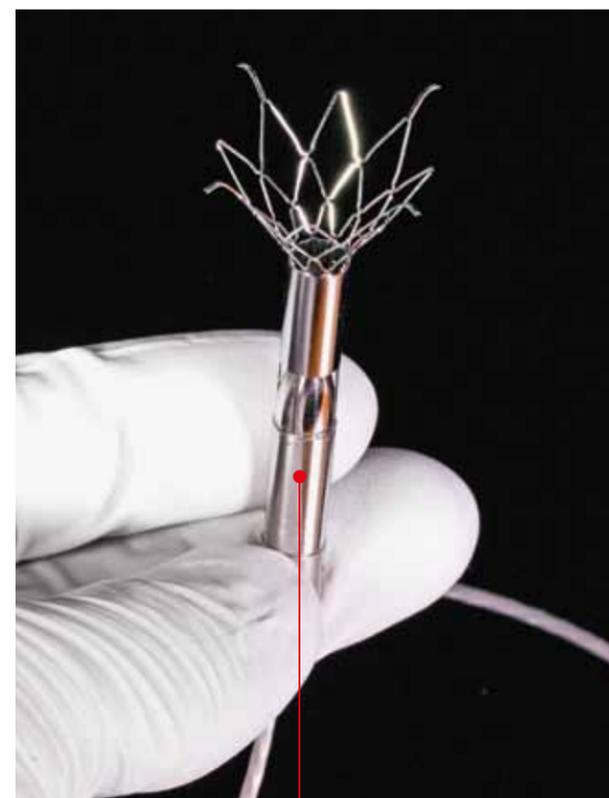
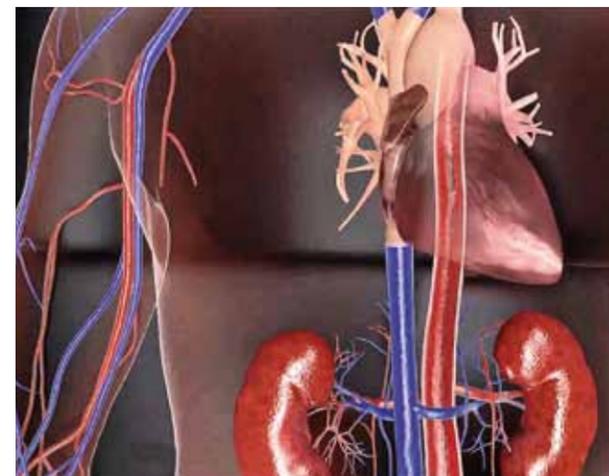
Assisting the natural function of the heart, the intra-aortic pump has been thoughtfully designed as an alternative to large, cumbersome surgical devices currently providing full circulatory support. Unlike these devices, Aortix provides minimal procedural risk. Measuring approximately 6 mm in diameter and 6.5 cm long, a cardiologist can deliver Aortix via a catheter in the femoral artery to the descend-

ing thoracic aorta. Once the catheter sheath is retracted, the self-expanding nickel-titanium anchors deploy to affix the pump to the aortic wall.

Aortix accelerates a portion of the body's native blood flow within the pump and pushes it through fluid entrainment ports directed downstream. The jets entrain native aortic flow, transferring energy to the cardiovascular system and increasing blood flow to vital organs such as the kidneys. Additionally, in a model of chronic heart failure, Aortix decreased energy consumption of the heart by 39 percent, allowing the heart to operate more efficiently, encouraging cardiac rehabilitation and recovery.

### Organs receive better circulation

Procyrion has been working with maxon for almost two years to develop a motor for this unique and demanding application. The basis for the Aortix device is a maxon EC6 motor with some customization including the electrical lead, shaft length, and bearing assemblies - all designed to make the pump durable and biocompatible. maxon also designed



maxon EC 6  
Ø 6 mm, brushless

**Small and strong**  
The brushless DC motor is the second smallest drive in the maxon family.

The cardiac pump is a mere 6 millimeters and 6.5 centimeters long.

Photos: maxon motor ag, Procyrion

a high efficiency motor core for this application, which extends battery life and produces less heat so it doesn't adversely affect the circulating blood. In addition, maxon is working closely with Procyrion to implement a magnetic torque drive, so the motor could be mounted inside a hermetically sealed chamber. This configuration eliminates the possibility of blood entering the motor core. The magnetically coupled pump arrangement is a method sometimes used for giant pumps in the oil field, but because of maxon's breadth of experience across multiple industries, the company was able to help the Procyrion team successfully transfer this technology to a miniature scale medical application.

### Technology from oil drilling applied to medical technology

Each Aortix device consists of a small, continuous flow pump mounted within a self-expanding anchoring system. The anchored pump attaches to a flexible power lead, which can be tunneled to a desired transdermal exit site or to a Transcutaneous Energy Transfer (TET) system for subcutaneous implantation without an indwelling power lead. Presently, the device can operate for over eight hours on a single battery pack. The external battery pack and control unit have been designed to be "hot swappable", meaning the battery can be changed without needing to stop the device. A variety of charging devices can be used. The Procyrion team has also built a TET charging system that enables the battery to be charged wirelessly. This design has the potential to significantly reduce the risk of infection, common with other implantable heart pumps.

Because traditional assist devices replace heart function rather than support it, device failure can be fatal. With Aortix, a partial support device which doesn't obstruct native blood flow, failure is not life threatening. Should the pump fail, the device can easily be retrieved and replaced in another minimally invasive, catheter-based procedure.

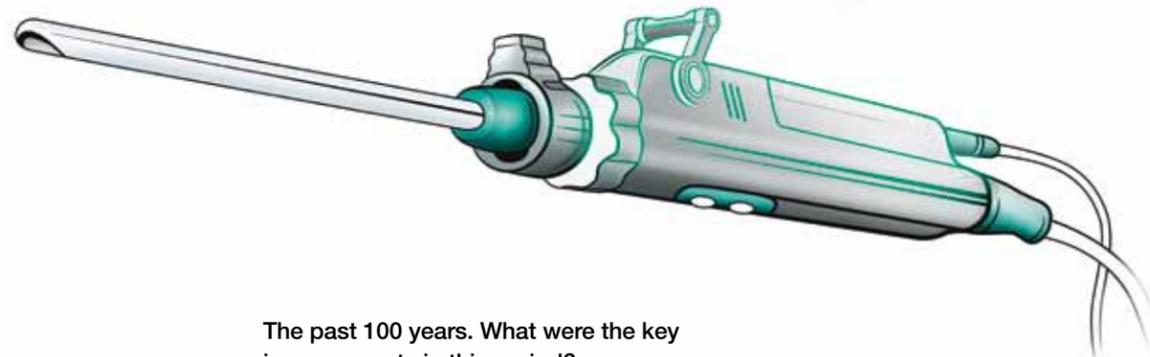
**Aortix reduces the heart's energy consumption by 39 percent.**

# “The operating conditions for the motors are brutal.”

DC motors can be found in any operating room, and they must comply with the highest quality requirements. But what exactly does that mean? We asked Anthony Mayr, Senior Project Leader at maxon motor.



Applications of surgical hand tools include removing tissue and cartilage (left) and drilling holes (below).



## The past 100 years. What were the key improvements in this period?

Before 1900, orthopedic surgery – which deals with conditions of the muscular and skeletal system – was very limited and focused almost exclusively on congenital defects in children. This changed a few years later, due to technological improvements during the war. The increasing number and complexity of the operations created a demand for instruments that permitted such operations to

be performed more quickly and efficiently. Tools like saws, hand drills, and files were upgraded with pneumatic drives, which gave surgeons unprecedented new options. Later on, innovation in electric motors (low noise, higher torque, simpler control) led to a transition from pneumatic to electric drives – a typical phenomenon that was also observable in other industries.

**“The drives have to resist very high vibration levels.”**

Anthony Mayr

## Orthopedic surgery and improvements in quality of life go hand in hand – would you agree?

Absolutely. The development of surgical techniques has significantly changed the methods of treatment. Emergency or trauma surgery is a good example. Surgeons today have tools and methods at their disposal that permit the repair and reconstruction of even the most severe injuries – even those that in earlier times would have necessitated the amputation of the affected limb. Modern orthopedic methods and tools are designed with the goal of making surgeries less invasive. Tissue damage and post-operative pain are minimized, and the recovery is quicker. These are



Anthony Mayr did his PhD in material sciences at Monash University in Melbourne, Australia. He is a Senior Project Leader at maxon and specializes in the development of customer specific drive systems for medical technology.

clear examples of how modern surgery significantly improves the post-operative quality of life for patients.

## What are the challenges for maxon in the field of medical technology, in particular motors for surgical applications?

The operating conditions for motors in surgical hand tools are brutal. Because of various oscillating processes (sawing, drilling, widening), drives are subjected to very high vibration. This is compounded by high temperatures in overload conditions (torque or speed), as well as contact with fluids and alkaline solutions due to the strict cleaning and sterilization requirements. I am fortunate

in that our maxon motors and transmission work exceedingly well under these conditions. This makes my job a lot easier!

## You mention sterilization. Why is it so important?

Like all medical instruments that come into contact with the patient during an operation, electrical surgical tools have to be sterile. Usually sterilization is performed using steam. The device is heated to 134 degrees for 20 minutes at 2.3 bar and 100 percent humidity. This is a great challenge for electrical components. Motors in surgical tools are no exception. Current tests however show that with careful material selection and by pro-

tecting critical components – for example by hermetically sealing the rotor – we can build motors that survive more than 2000 steam cycles in the autoclave.

## Medical products for the global market are subject to extremely strict regulations. Doesn't that make the development of such products rather difficult?

It is true that medical standards are very strict. However, if one considers the value of a human life then it's easy to see that high standards are an indispensable part of the business. Fortunately we have great experience in the development of medical products, and we clearly understand the wishes of our customers. This allows us to provide innovative custom solutions that fulfill and exceed even the strictest customer requirements. Close cooperation with customers to achieve their goals is one of the great challenges in my job as Project Leader – and it's a lot of fun, too.

## How do you think medical technology is going to develop in the future?

Systems will become smaller, lighter, and stronger. This also includes electric motors in orthopedic surgery, where more compact, less noisy and more powerful tools are making invasive surgeries even more precise and effective.

Regarding the future of surgical procedures, I believe that robotized and computer-supported methods will be more advanced and widespread. The benefits of such systems are impressive: Miniaturized precision methods with smaller and smaller incisions and less tissue trauma enable faster healing processes that require less painkillers and shorter hospital stays – and cost less. Another great benefit is that the surgeon does not have to be in the same room as the patient – the beginning of an era of completely new possibilities for remote surgery.

In any case, the primary goal of surgeons is to help their patients recover as quickly as possible so that their quality of life is the same as before the surgery – or higher. We are proud to support surgeons worldwide in attaining this goal. ■■■

# Inked to precision

The tattoo scene is driven by younger artists who have little in common with the old stereotypes. They create true masterworks using the latest technology. And they all know the «Swiss Motor» by maxon.

**T**he age of rockers and sailors is over. The tattoo scene has developed, away from ill-lit chambers with burly, bearded men scratching hearts into biceps, to well illuminated studios where young and talented artists create their works. Like the Swiss Alena Lizier, who, at 24, is already the owner of a tattoo studio in St. Gallen. 'Please take off your shoes when you come in,' she says as we're entering. Hygiene is a must.

Kitsch reigns supreme in Alena Lizier's studio. Colorful decorations are everywhere, like an old metal cash register, a large statue of St. Mary, or a gold-colored sofa with blue velvet upholstery. The large windows offer a view of the city. Everybody comes here – policemen, hairdressers, bankers. Tattoos have become socially accepted and are regarded as hip and cool. Pop stars and athletes led the way, and the masses followed. That's fine with Alena Lizier. She is a part of the new tattoo era, where the drawings are finer and more detailed than they used to be, and look much more like

works of art. In part, this is thanks to modern technology. Traditional coil machines are increasingly being replaced with rotary devices driven by small electric motors. They make it easier to draw fine lines. They are also lighter and much less noisy than earlier models. maxon motors are setting the standard. Tattoo machine manufacturers worldwide like to list the «Swiss Motor» by maxon in their specifications. It is synonymous with longevity and reliability, very important factors for tattoo artists who use their tools daily and demand that they perform reliably for many years.

#### maxon motors make the difference

Enrico Friedli of Swisstattoomachine was among the first in the industry who discovered the benefits of maxon motors. His tattoo machines have been in the market since 1998 and enjoy a very good reputation. Friedli relied on quality motors by maxon right from the start. It turned out to be a good decision. 'The motor made the big difference from the other manufacturers' machines,' he says. 'It allowed us to stand out from the competition.'

**“I am merging my art with real people every day.”**

*Alena Lizier, tattoo artist*

Alena Lizier graduated from the graphics class at art school and became a typography designer.

**Rugged and durable**  
For the world's first cordless tattoo machine, Swisstattoomachine relies on maxon's RE 13 motor with 2.5 W. The motor is equipped with precious metal brushes and offers excellent energy efficiency and dynamics. Like all RE-series motors, it has an ironless rotor (no cogging torque) and high-power rare-earth permanent magnets. Its efficiency is over 90 percent.



**maxon RE 13**  
Ø 13 mm, precious metal brushes, 2.5 W

Photos: Interfoto/Alinari, maxon motor ag / Philipp Schmid, maxon motor ag



Alena Lizier in her studio (left) and Enrico Friedli, managing director of Swisstattoomachine, in his workshop.

Today, customers are still sending him first-generation machines that need only a small inspection before going back to the tattoo studio.

Swisstattoomachine supplies devices worldwide, to China and the US. And even though other manufacturers have also started to use maxon motors, Enrico Friedli still stands out from the crowd: After three and a half years of development, he introduced the first battery-powered tattoo machine this summer, a spectacular innovation that had been awaited for a long time. The «Unchained» is equipped with a maxon RE 13 motor. This DC drive with precious metal brushes has a power of 2.5 W and is perfectly suited for battery operation thanks to its energy efficiency. It hardly makes any noise and has very low vibrations. And it is lightweight, a very important point with tattoo machines that artists need to hold in their hands for hours on end. At 140 gram, the «Unchained» is only 20 gram heavier than its predecessor model, «Heidi», which has a power cord. The number of strokes per minute can be adjusted at the device, ranging from 3000 to 6000.

**More freedom of movement for tattoo artists**

Alena Lizier is excited when she picks up the new machine for the first time. 'Awesome! I have a lot more freedom of movement and don't have to be careful about the power cord.' Hygiene is another benefit, as the cord of a tattoo machine has to be wrapped in a plastic hose before each work step. The tattoo artist turns her attention back to her customer, on whose leg she is completing an image. She dips the needle into black ink and carefully draws a fine line. The needle carries the ink into the middle layer of the skin, where it will stay for the remainder of the customer's life - to the satisfaction of everybody involved, hopefully. At any rate, Alena Lizier has realized her dream: 'I am merging my art with real people every day. What could be better?'

**“The motor allowed us to stand out from the competition.”**

Enrico Friedli, Swisstattoomachine

# ‘We simply had the best motor.’

An increasing number of tattoo machines are using electric motors, including those made by Swisstattoomachine. The Swiss manufacturer now uses innovation to consolidate its leading position in the global market.

Enrico Friedli, Swisstattoomachine has been producing machines with maxon motors since 1998. What has changed since then?

Well, we are still building our machines by hand. «Heidi», our original, is still a hot seller. We are offering it in all kinds of colors and versions nowadays. But the tattoo scene really has changed. Twenty years ago, tattoos weren't enjoying the best reputation. By now they have reached mainstream society. This certainly has something to do with the fact that the scene has become more professional and young, talented people with a background in the arts have taken over. It's really amazing what some of these people can do.

Who buys your machines, and where do you deliver?

Our products are preferred mainly by the younger generation of tattoo artists. Our customers come from all over the world. Europe, the US, China, Russia – we supply all markets.

An increasing number of tattoo machines are using electric motors. What is the advantage over the older magnetic coil models?

By their nature, rotary machines are much less noisy and produce less vibration than coil machines. This makes them an ideal choice for liners, machines used for outlines and black ink drawings. They are also reliable, durable, and low maintenance. However, I think that coil machines will always find buyers, if only out of pure nostalgia, similar to vinyl records.

What role does the electric motor play in a tattoo machine?

A quality motor is very important. It has to run smoothly, efficiently, and quietly. And it has to be light. Weight is a key factor in tattoo machines. We used maxon motors right from the start. This allowed us to stand out from the competition – we simply had the best motor.

Your new product, the cordless tattoo machine, is really groundbreaking. What made you go that way?

The development was a natural step that I'd wanted to take for a long time. However, the realization took some investment, and a lot of persistence. My initial estimate for the development time was two years. In the end it was three and a half years of testing and tweaking. But now I'm even more happy to present my innovation to our customers.

How do you rate the cooperation with maxon motor?

The people at maxon have always been a great support and helped us to adapt their DC motors to our needs. The cooperation was really great, even in the early stages, when we needed only a few motors.

Where does the road lead for tattoo machines?

Machines will become even smaller, maybe until they are only about the size of a pencil. However, this will mean externalizing the controls. I can easily image tattoo artists using smartphones to set the desired number of strokes per minute on their irons.



Enrico Friedli, CEO of Swisstattoomachine 55-year-old Enrico Friedli's first contact with the tattoo scene was in 1998, when he was living in the US for a while and met his countryman Pele Brunner. Pele, a tattoo artist, was developing a tattoo machine for himself and his friends, the Swisstattoomachine. However, he did not have the time for proper sales. Enrico Friedli took over the business and began to commercially manufacture and sell the machines.

**Tattoos – a millennia-old tradition**

The practice of tattooing dates back far into prehistory. Researchers have discovered drawings in the skins of 7000 year-old mummies in Chile. Egypt and Polynesia also practiced tattooing very early. Tattoos usually had ritual significance, and the procedure was very painful. Sailors later introduced the practice to Europe.



# The maxon motor magazine driven

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# The big spring cleaning in space

They are used in communications, weather forecasting, or research: Satellites improve our quality of life. However, there will soon be too many of them, and disposal is difficult. In the future they might simply sail away.

**29 000**  
of these pieces are larger  
than ten centimeters



**1300**  
active satellites are in  
orbit around Earth

**3000 t**  
of debris is orbiting Earth

Space is getting crowded. An ever increasing number of satellites are in near-Earth orbits, accompanied by thousands of fragments of their defunct predecessors, as well as of rockets. The risk of collision, and damage going into the millions, is rapidly increasing. At a conference about space debris, the European Space Agency (ESA) set itself the goal of clearing the skies and to support research into the deorbiting of satellites.

A possible solution was conceived at the Surrey Space Centre (SCC) at the University of Surrey, England. The idea is simple: Future satellites will be equipped with large sails. Within 25 years after the end of a satellite's mission, the sail will pull it down to burn up in the Earth's atmosphere. The sail utilizes the resistance of the residual atmosphere, which exists in altitudes of up to 600 kilometers.

## Carbon outriggers stabilize the sail

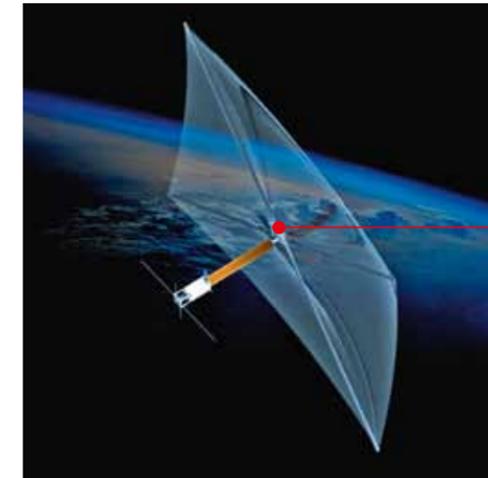
The sail developed in Surrey is called Inflatesail. It measures five by five meters and consists of a high-performance plastic foil. The sail module is smaller than a shoebox and weighs only two kilograms. However, the technology has to be not only lightweight, but also robust – and cheap. After all, it is not a part of the satellite's main mission objective. The Inflatesail won't be used before the satellite's service life has expired, i.e. after ten to twenty years. Then the following happens: First a small, inflatable mast folds out. Then the sail is extended by means of four carbon outriggers that provide stability. Once it has expanded, the sail slowly drags the satellite closer and closer to Earth, until it crashes and burns up in the atmosphere. Engineers believe this technology to be capable of bringing objects with a weight of up to 700 kilograms down from the skies.

## Long years of experience in space

The sail is unfolded by a brushless EC-max motor by maxon. The motor is combined with a GP 16 planetary gearhead, equipped with ceramic components for a long life span and to protect against corrosion. The drive has a diameter of 16 millimeters. It is built

according to extremely high standards and works even in space. maxon motor is using its long years of experience in the aerospace industry, for example in the Mars missions or the SpaceX program.

Andrew Viquerat, Research Fellow at SCC: 'We have been working with maxon motor for



The Inflatesail pulls a satellite closer to Earth, until it finally burns up in the atmosphere.

years and will continue to do so – because of the reliability of their products if nothing else. The folks at maxon have always shown interest and been really helpful, even when our wishes were slightly unusual.'

## First test next year

Very soon it will be seen whether the Inflatesail stands up to practical testing. Next year, it will be fired into space as a part of the QB50 nanosatellite project. There it will first serve to propel the satellite, using the solar winds. After one year, a maneuver will be initiated that is intended to result in a safe crash and burn-up in the atmosphere. The mission's success could soon lead to a commercial application of the development and help to keep the skies above us clean. ■

maxon EC-max 16  
16 mm brushless  
DC motor



maxon GP 16 C  
16 mm, ceramic  
reinforced



## Efficient and cost-effective

With the EC-max 16, maxon motor offers a high-quality brushless drive with excellent value for money. The motor comes with a robust steel housing and, like the majority of brushless motors in the maxon portfolio, a rotating permanent magnet made of neodymium. The Inflatesail also uses maxon's compact planetary GP 16 gearhead, which is especially suitable for transmitting high torque. Thanks to its ceramic components, this gearhead offers an especially long service life.

Technical article series, part 2

# Energy efficiency in microdrives

## Controlled mechanics

A suitable controller is not the only requirement for driving small motors efficiently. Mechanical components play a key role in keeping losses low.

by Jan Braun



Jan Braun received his degree in electrical engineering from the University of Applied Sciences (HTL) in Biel, Switzerland. He started his career programming and commissioning roller coasters and large drives on a Kilowatt scale. For more than eleven years now, he has been working with microdrives at maxon motor ag. In the sales department, he works as technical sales support for Germany and the Northern European countries. He now provides acclaimed technical training for the worldwide sales network, as well as training seminars for customers.

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Durability and reliability of microdrives are especially important in surgical tools.



Photos: Fotolia, maxon motor ag, Sequana Medical GmbH

In the first part of the technical article about microdrives, I focused on the motors (see driven, issue 1/14). What are the losses in idle or standstill operation? How do I optimize a winding for minimum current consumption and maximum battery life? In the second part, I will explain why a suitable control and efficient mechanics are important for the energy consumption of a drive, and what measures can be taken to reduce heat build-up.

### Suitable control

Brushed DC motors need control electronics only to control the current, speed, or position. For brushless DC motors (EC motors), the controller handles primarily the commuta-

tion and, if required, also the current, speed or position control. The power loss of the control electronics depends on the type of the power stage and is determined by transmission losses and the controller's own consumption.

### Controllers with a linear power stage

Controllers with a linear power stage regulate the speed via the motor voltage, using the voltage divider principle. A variable resistor is wired in series with the motor. The benefits of linear controllers used with brushed DC motors include simple control, cost-effective design, and lack of interference. The power consumption depends on the processor and is usually very low – typically around 1 W, not



A configurable GPX rotary drive as well as a spindle drive, by maxon motor.

counting any auxiliary consumers like additional inputs or outputs. Transmission losses however should not be underestimated. These are Ohmic losses in the variable serial resistor, in fuses, MOSFETs, and measuring shunts. They can become very large, especially for high motor currents or lower voltages (low required speeds). They are calculated using the formula

$$P_{VCu} = R \cdot I^2$$

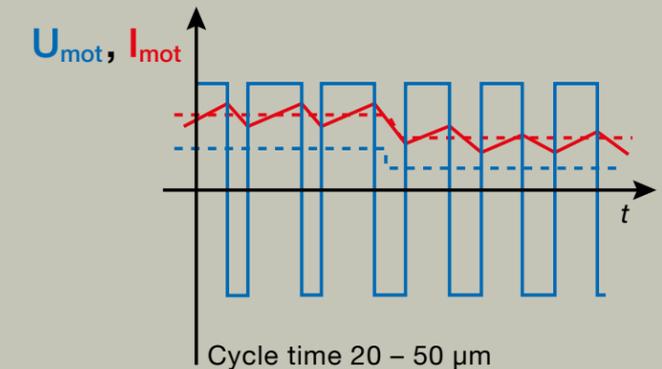
For this reason, linear controllers are suitable only for relatively low-power motors up to 100 W and rarely used today.

### Pulsed power stage (PWM)

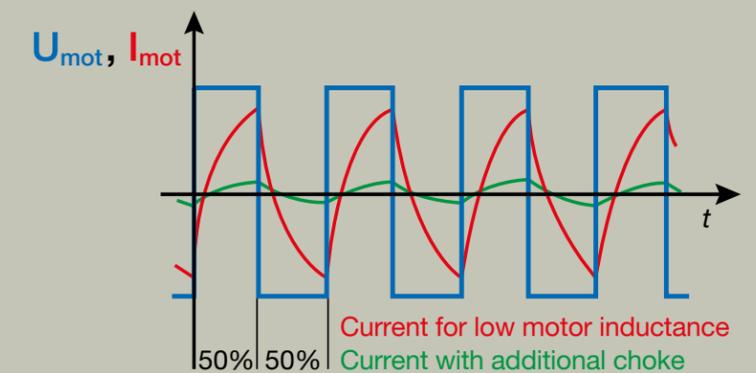
Most controllers for both DC and EC motors use a pulsed power stage. The efficiency of pulsed controllers typically is between 90 and 98 percent. The voltage supplied to the motor is switched at a very high rate (typically from 20 kHz to 60 kHz) between two or three levels (usually +VCC, 0, and -VCC). Due to the motor's relatively large mechanical time constant, it is effectively supplied with a mean voltage that can be adjusted by manipulating the relative duration of the voltages (pulse width modulation, PWM). The main benefit of pulse width modulation is that losses remain very low. These losses consist of transmission losses (Ohmic losses in fuses, MOSFETs and measuring shunts), the controller's own power consumption (depending on the processor, typically around 1 W, not counting auxiliary consumers),

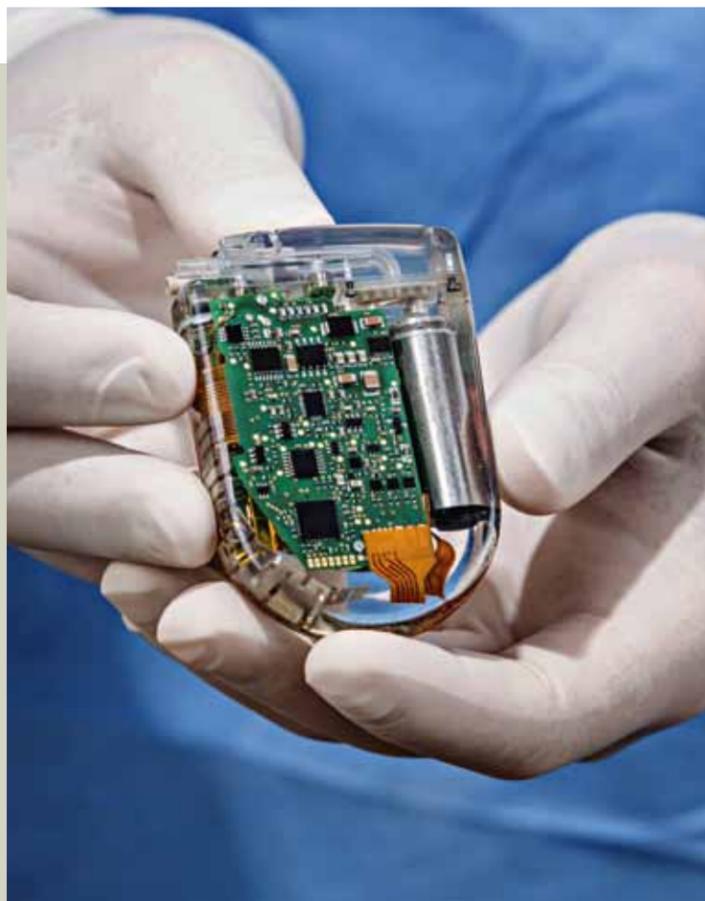
### 2-level PWM

Voltage and current curve. The hatched lines show the mean values for current and voltage.



Reduction of the current ripple by using an auxiliary choke.





Microdrives by maxon motor are used in many medical applications such as the Alfapump, which removes fluid from the abdominal cavity.

### Motor choke to control heat build-up

For motors with very low inductance, such as motors that do not have an iron core, the current fluctuates very fast. There may be large current peaks within a PWM cycle, and the resulting high RMS value (effective current) heats up the motor. To protect the motor and prevent the efficiency gains from being at the cost of the motor's lifespan, additional inductance is needed. A so-called choke is wired in series with the motor to attenuate current peaks. The motor's behavior does not change, because torque is proportional to the current's arithmetic mean. Improved control stability is another positive effect of the added inductance. This is why most maxon controllers come with built-in chokes, making additional inductance unnecessary. However, this is not always the case – for example when maxon motors are operated with third-party or customer-supplied controllers.

The formula for approximating the maximum peak current  $\Delta I_{max}$  in a 2-level PWM cycle is:

$$\Delta I_{max} = \frac{V_{cc}}{4 \cdot f_S \cdot (L_{mot} + L_{choke})}$$

Peak currents can be curbed with the following measures:

- Lowering the supply voltage VCC, if possible.
- Increasing the PWM frequency  $f_{PWM}$  (at least 20 kHz, better 50 kHz and up). Frequencies lower than 10 kHz should not be used.
- Selecting a winding with high inductance, or increasing inductance by wiring a choke ( $L_{add}$ ) in series with the motor.

### Efficient gearhead mechanics

The efficiency of a planetary gearhead is about 90 percent per stage. Worm gears have less

than 40 percent. For spindle drives, ball screws reach 80 to 90 percent, trapezoidal screws only 40. When one considers these differences, it becomes clear why the selection of efficient mechanical components offers much potential for minimizing losses. Mechanical losses are caused by friction between teeth, the bearings, at disks and seals, as well as by churning losses in lubricants.

Losses in mechanical drives or gearheads can be described using a model similar to that for the motor. However, it is important to distinguish between idle losses and load-dependent losses. As a rule, these aspects are considered as part of the overall efficiency and loss calculation.

### Low load decreases efficiency

Measurements show that the efficiency of any gear is independent of the load across a wide range (see graphic). Only when the load is low, the idle losses become significant relative to the transmitted torque. This lowers the efficiency.

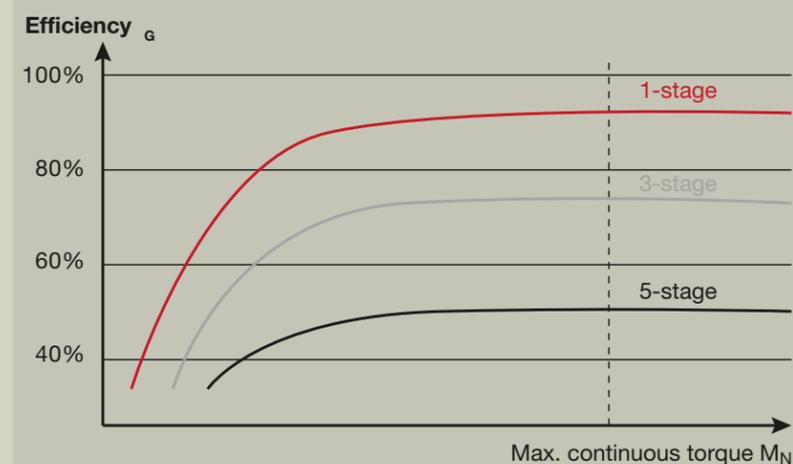
Gearheads should therefore be loaded with at least 50 percent of their continuous torque in order to achieve acceptable efficiency. Efficiency should be included in the calculation of the motor torque. It is a good and accurate method for considering losses in gearheads.

### Conclusion

High efficiency and lower power losses are not the only considerations for battery-driven applications like golf carts, medical power tools, insulin pumps, or packaging machines. Good utilization of the available voltage, low power consumption, low heat build-up, high power density, suitable controllers, and efficient mechanical components are key factors. The objective is to optimize all components so that that the drive consumes a minimal amount of current, in order to achieve the longest battery life possible. ■

### Gearhead torque curve, in principle

The graphic shows how efficiency loss occurs in a motor. This assumes that the power conversion itself is loss-free.



The ESCON 50/5 servo controller by maxon.



# There is action in the game

The SMS Lab of ETH Zürich is all about human motion sequences. Now the scientists are planning a competition between electro-mechanically supported parathletes.



**Arm robots** Motors of the RE series are used both in the ARMin arm robot and in the children's version, ChARMin. Each motor controls one axis. The two primary axes in the children's version are each driven by one maxon RE-40. Because of the patented ironless winding and the advanced magnet, these motors achieve an efficiency of over 90 percent.

**M**achines that let people move again: This is the bread and butter for the 30 employees at the Labor für Sensomotorische Systeme (SMS Lab) at the ETH Zurich, Switzerland. Visitors to the laboratory find their attention drawn to several interesting devices. One of them is ARMin, an arm robot with seven moving axes that is used in the therapy of stroke victims and other patients with neurological conditions. The affected patients have sustained damage to important regions of their brain or spinal cord, which frequently results in paralysis. Simply put, the brain has forgotten how to move the limbs. Patients have to undergo a lengthy therapy that teaches the remaining operational parts of the brain to perform the lost functions. This is where ARMin comes in.

### Virtually buying a bus ticket

The robot performs the movements alone at first. Later on, it only lends occasional support to the person who operates it. All movements are displayed on the screen. In the simulation, the patient can buy a ticket at a vending machine or pour water into a glass – without actually doing these things. This playful training yields huge therapeutic benefits, as a study showed recently. Moreover, the robot lets the patient perform a much larger number of repetitions for each motion sequence than conventional physiotherapy – a therapists tires earlier and cannot perform such complex movements over a long time. “Especially patients with severe paralysis are making much better progress with the arm robot than in a

### The six disciplines of the Cyathlon



**Leg Prosthetics Race:** completing an obstacle course



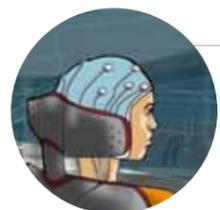
**Prosthetic arms:** performing movements as quickly and efficiently as possible



**Powered Exoskeleton Race:** completing an obstacle course



**Powered Wheelchair Race:** completing an obstacle course



**BCI Race:** controlling an avatar through a brain-computer interface (BCI)



**Bike Race:** competing in a cycling race as fully paraplegic athlete with the aid of electric muscle stimulation

Fotos: SMS-Lab ETH Zürich, maxon motor ag.

conventional therapy”, says Robert Riener, the head of the laboratory. However, his team has no intentions of resting on its laurels. A smaller version of the robot is being developed especially for the therapy of children: ChARMin.

The researchers at the ETH laboratory rely on drive systems by maxon for both arm robots, large and small. The current versions have six maxon DC motors each, including a gearhead and encoder. The drives used are brushed motors from the RE series, as well as a DXC motor that is known for its excellent power to size ratio.

### The human-machine interface is the challenge

Another project of the SMS lab focuses on teaching leg amputees to walk again with the aid of an active prosthesis. The ETH team developed a prototype that can be worn both by the patients as well as by the staff. This allows the researchers to get on the treadmill themselves and test their device. A powerful EC-30 4pole motor by maxon is used to bend and straighten the prosthesis's knee joint. The 200 W drive can be overloaded briefly. This is especially important when climbing stairs, an activity where the knee joint is exposed to high torques.

However, it takes more than power and torque alone to make a good prosthesis. The ETH researchers want to find the best way to control a prosthetic leg in order to optimally support the walking function. The goal is to improve the interface between human and machine. “How do we transmit the patient's intention to move from the body to the prosthesis? And, equally important, how does the wearer receive sensory information about the movement status of the prosthesis?” These are the key questions, according to professor Robert Riener. By now, developers have managed to send vibration signals as a tactile feedback so that the wearer can feel the position their artificial foot is in.

Science is only at the beginnings here, and there remain many challenges. Once these are overcome, wearers of prostheses will be able to execute all movement patterns like walking, climbing stairs, or running, using only a single device. Some first impressions can be gleaned at the Cyathlon, which was initiated by Professor Riener and will take place

in summer 2016. The Cyathlon is a competition where people with disabilities compete against each other with the aid of technology. The event is intended to encourage scientists worldwide to make another step forward in the fields of sensorimotor research, prosthetics, and robotics. The goal of these efforts is to give people with disabilities devices with better motor functions. This will improve not only their general quality of life, but also the acceptance for new technologies.



**Prosthesis** When real power is required, the EC-4pole 30 enters the stage. Its two pole pairs give it an extremely high power density and considerable nominal torque. The motor is also quite robust and resistant to repetitive temporary overload.



A configurable DCX-22 minimotor together with a GPX 22 planetary gearhead, as they are used in ChARMin.

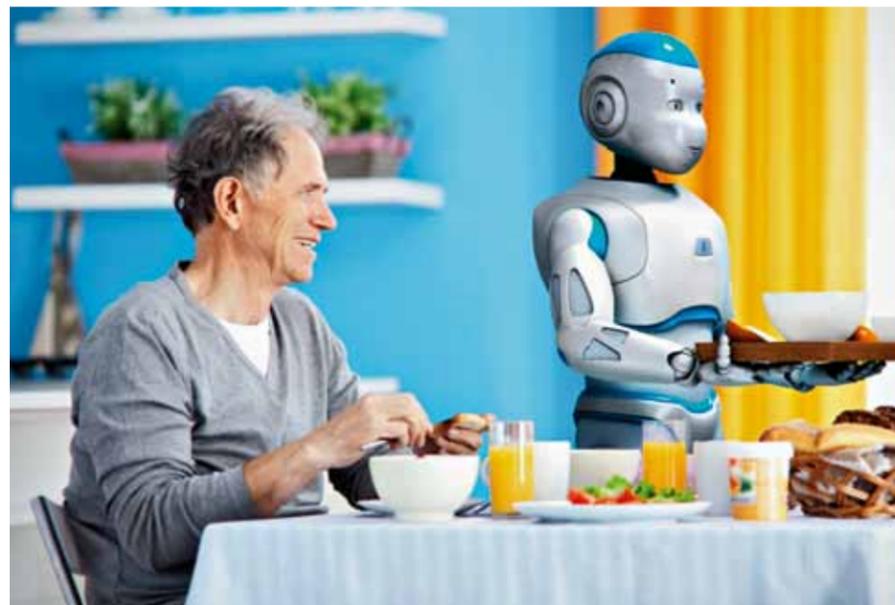
# What capabilities should a future **personal robotic assistant** have?

By Frank Wallhoff



**Prof. Dr.-Ing. Frank Wallhoff** is the head of the Institut für technische Assistenzsysteme at the Jade Hochschule in Wilhelmshaven, Germany, as well as of the Transferzentrum für anwenderorientierte Assistenzsysteme at the Fraunhofer Institute for Digital Media Technology. He is also the coordinator of the international Alias project, which is developing robots to support the elderly.

The Romeo assistance robot is a pilot project of the French company Aldebaran. The robot is driven by 39 maxon motors.



**S**ince the global population is aging, any possibility to close the imminent care gap deserves some consideration.

The interdisciplinary research project Ambient Assisted Living is experimenting with domestic assistance robots. Even today, this field is more advanced than many may think. The first robots, albeit with a very focused application spectrum, have made it into the catalogs of hardware stores: Robotic lawnmowers and vacuum cleaners, as well as mopping robots, have become off-the-shelf mass products.

However, what about more complex robotic assistants? As of yet, the functional capabilities of current prototypes are not quite ready for commercial applications. Their robustness for example is not up to user expectations. However, the potential benefits – and risks – of the coming generation of service robots are being discussed in an ever wider public. Key questions are: What is possible? What is legitimate? What is desirable? Often the argument is made that technology cannot and must not be used as a substitute for interpersonal contact. However, if it cannot be guaranteed in the future that elderly or single persons with a mild or moderate need for assistance are physically attended to, would it not be ethically permissible to provide technical assistance solutions for prevention and to support an otherwise largely autonomous lifestyle?

There is of course a broad spectrum of complex and interdisciplinary, non-trivial, non-technical questions to be discussed. This is why current research project increasingly embed the consideration of ethical, legal and social impacts (ELSI), as well as attempts to estimate the consequences of technology use.

Besides research into the purely technical aspects, initial social studies have been

conducted to collect information about the real-life needs of (senior) users. As part of the ALIAS research project, respondents were asked which functions and capabilities a domestic assistance robot should have. The results show: User expectations are quite pragmatic. Respondents asked for physical assistance in the household, for walking, and for shopping. Robotic assistants should also be communications portals, read letters, function as calendars with a reminder function, as well as an interface to control lighting, blinds, and household appliances.

Another key aspect is telemedicine: Robots record biometric signals with their integrated sensors and transmit them to a physician, who can discuss the results with the patient online. Also on the wishlist is an expanded emergency call device to improve the safety of senior individuals who live alone. Regarding the operation, respondents expect a robotic assistant to behave similar to a faithful butler, i.e. mostly reactive. It should be unobtrusive and respond to speech and gestures in a friendly way. Respondents clearly rejected complex, unpredictable or even authoritative communication behavior.

The expectations of the users are therefore quite clear. It remains to be seen how the requirements for robustness and artificial intelligence will be compatible with social demands. Maybe these future robotic assistants will be as well accepted as the already popular cleaning aids. ■



Robotic assistants are already common, in the form of automatic lawnmowers or vacuum cleaners.

Photos: Aldebaran, Avenue Images/Maciej Frolow, Fraunhofer IDMT, Honda Power Equipment



# Outlook 1 // 2015 Aerospace

Discover exciting new applications and interesting stories from the world of drive technology. The upcoming issue of driven – the maxon motor magazine – will be available starting April 13, 2015.



What aspect of this topic do you find particularly interesting? Let us know on our Twitter channel @maxonmotor.

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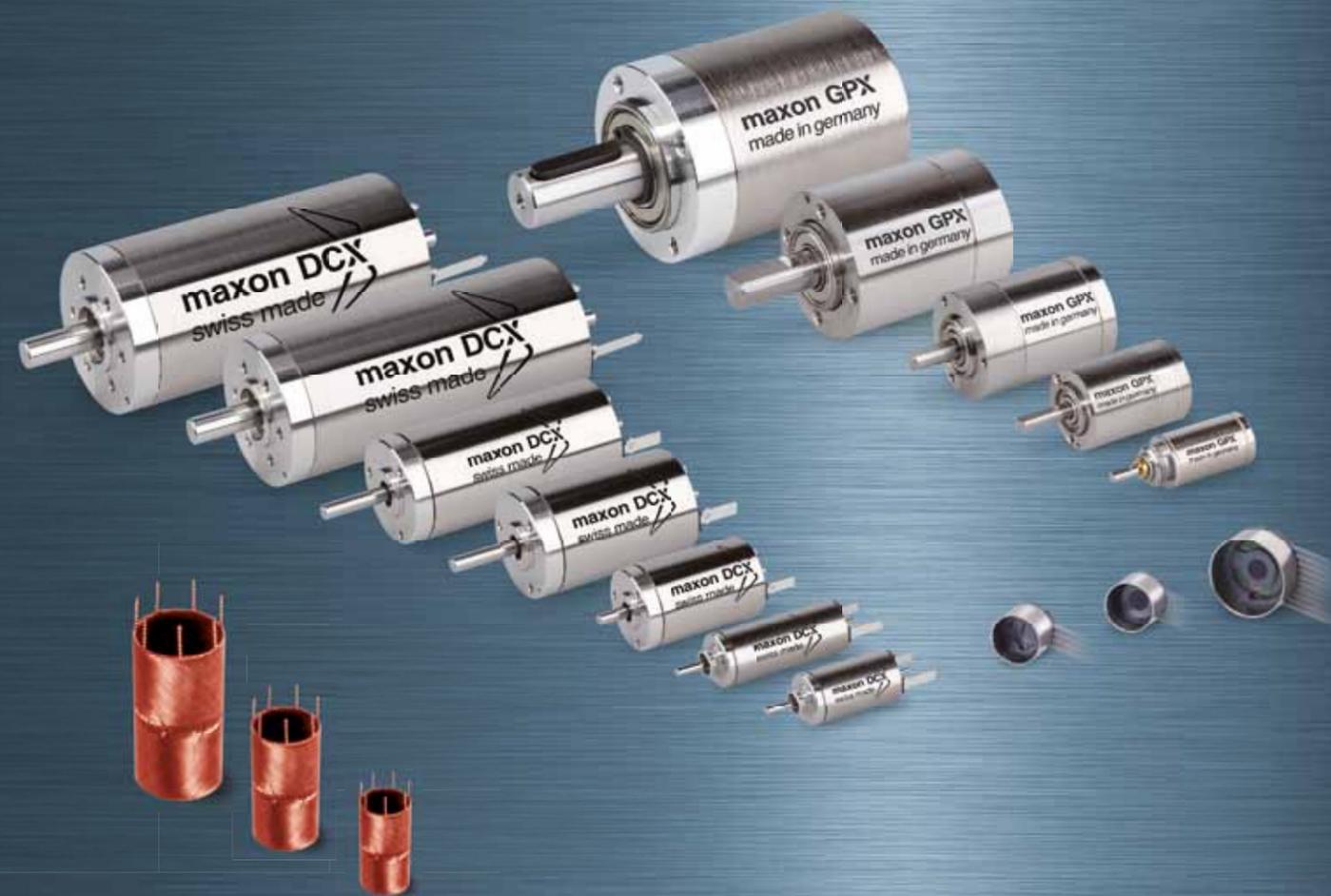
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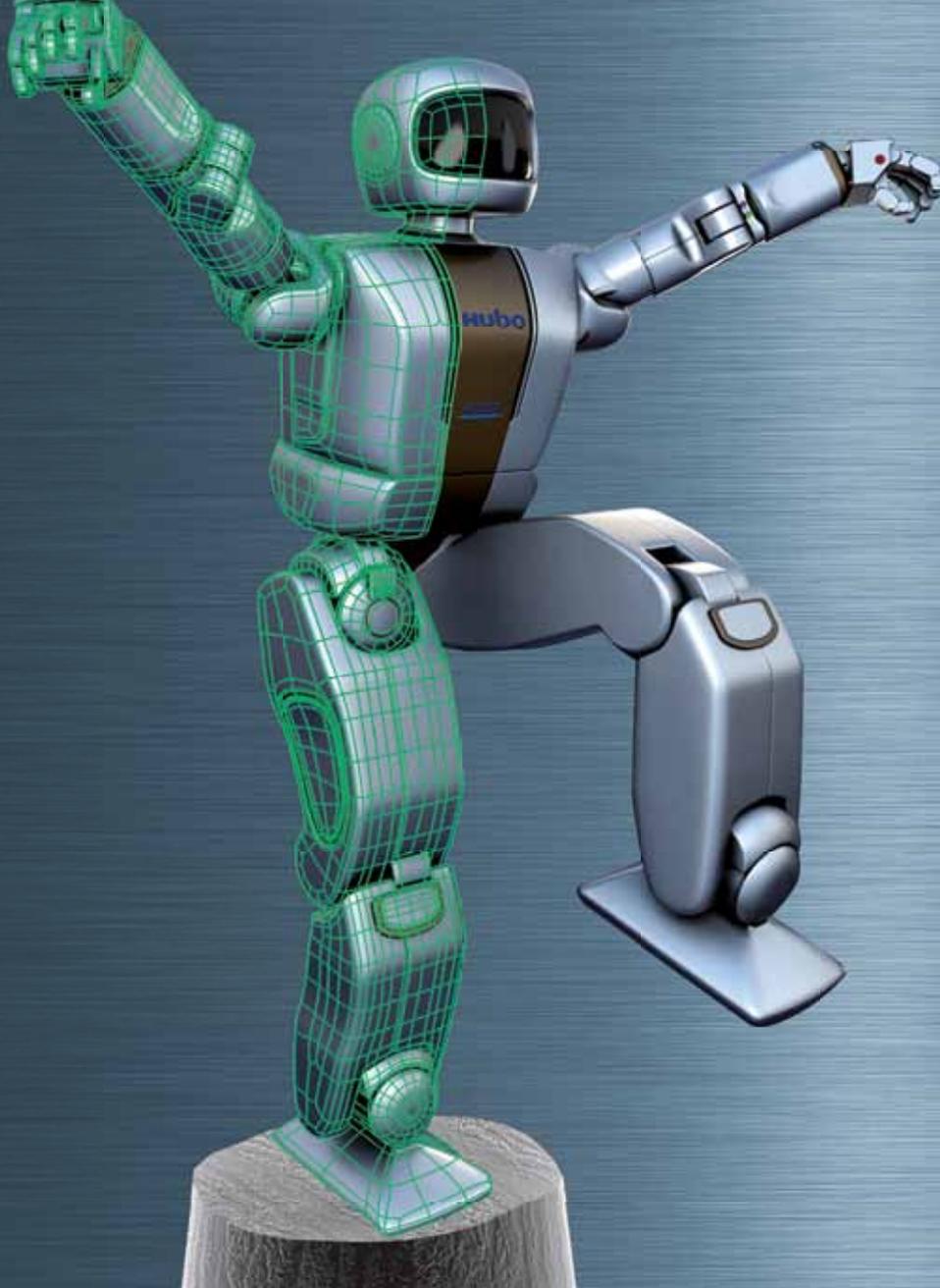
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# When it really matters.

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Androids like HUBO 2 engineered at KAIST (Korea Advanced Institute of Science and Technology) are becoming more agile. They are able to gesture, shake hands, walk and even run. Therefore androids have to rely on energy efficient and dynamic DC drives.

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