The big picture
4 Research robot youBot

News
6 Redefining the kilogram

In focus
8 Full throttle
With Nico Müller at the trial race for the Formula Renault 3.5 in Monza.
15 Made for extreme environments
Zytek's John Manchester on the requirements for motors in racing.
16 "Velocity and environmentalism are not mutually exclusive"
Dominik Stockmann of maxon motor about the future of automobility.
19 Staying on track
Driver assist systems are becoming more and more important. In critical situations they may save lives.
22 Smart head
The FiberCut laser cutting head always keeps the right tool gap to the workplace.

Innovation
24 Power like a manga hero
The robot Kenshiro looks similar to a comic character. However, it is really modeled to resemble humans.

Exploration
26 Earth's hot sister planet
470 °C – maxon motor develops motors to withstand the temperatures on Venus.

Expertise
29 Energy efficiency in microdrives

Column
32 Tomorrow's flying cars are a thing of the past
Patrick J. Gyger

Outlook
34 driven 2/1 // 2014
The multifaceted world of drive technology: Learn more about the next issue of driven.

On the racetrack, every turn counts. The same is true for the road. This is one reason why engineers are developing smarter and smarter assistance systems for us drivers. Be it for efficient engine performance, better aerodynamics, or improved safety. This usually requires small, reliable drives that generate a lot of power without taking too much space. In this issue of driven you can read where maxon motors are used in racing and in passenger cars. We've also prepared some exciting contributions from the field of robotics: Kenshiro, a 1.58 m tall humanoid robot, is an attempt to understand human movement through the robot’s tendon-controlled movements. And youBot, the research robot from KUKA Robotics, is likely to revolutionize industrial research.

Happy reading!

Eugen Elmiger, CEO, maxon motor ag
Dr. Rainer Bischoff, the director of technology development for KUKA, about the youBot:

“We’ve developed youBot for research and teaching. youBot is delivered without proprietary control software. Instead, it comes with a rich pool of open source software, a PC board and an EtherCAT interface to connect to the drive electronics. This gives researchers and students a lot of leeway for the development of new algorithms for robot control.”

Highly focused: Nirmal Giftsun (left) and Alexander Moriarty of Hochschule Bonn-Rhein-Sieg are participating in the Robocup 2013, a robotics competition attended by 2000 researchers and students from all over the world. They are hoping for a win in the discipline “Robocup@work”. Their youBot has to find certain objects in an obstacle course and bring them to the proper place—fully autonomously, using only sensors and algorithms. The joints of the youBot contain flat motors by maxon motor. They are responsible for the precise and powerful movements of the robotic arm.

Learn more:
bigpicture.maxonmotor.com
New motors and gearheads

Our family of configurable products is growing

The configurable DCX product family now includes the two brushed DC motors DCX 16 S (up to 9.5 W continuous output power) and DCX 32 L (up to 110 W continuous output power). This expands the DCX portfolio to a total of seven motors with diameters from 10 to 35 millimeters.

The GPX series of planetary gearheads has also been expanded with two new sizes: the GPX16 (up to 90 percent efficiency, short build) and the GPX 32 (one or two stages, up to 3.6 Nm short-time torque). There is also a version of the GPX 22 with reduced backlash.

Sensorless operation

maxon ESCON 50/4 EC-S module

The ESCON 50/4 EC-S module is designed for efficient control of brushless and sensorless permanent magnet EC motors with Hall sensors up to approx. 200 W. The powerful 4-quadrant PWM servo controller has excellent control characteristics and allows for a wide range of speeds up to 120,000 rpm. Thanks to its rich set of features and with fully configurable digital and analog inputs and outputs, it is the perfect match for dynamic drive solutions with maxon motors. The module is able to operate in closed loop or open loop mode.

All these are ideal prerequisites for use in cost-sensitive applications and applications with high requirements for reliability, e.g. medical devices used in respiratory therapy or handheld surgical or dental tools. The decisive characteristic is lower system complexity through sensorless operation.

The large ranges for input voltage and the operating temperature provide flexibility for many applications.

NEW PRODUCTS

13.63 seconds

2.7 seconds from 0 to 60 mph (97 kph). 5.6 seconds from 0 to 100 mph (160 kph). And even higher speeds are possible: The Hennessey Venom GT which, according to the Guinness Book, is the fastest production car in the world, accelerates from 0 to 300 kph in 13.63 seconds. The current record holder when it comes to top speed is still the Bugatti Veyron Super Sport at 431 kph. Thrust SSC, a rocket-propelled vehicle, even achieved 1190 kph. Anyone who drives fast needs not only special tires and a lot of gas, but also a lot of electronic assistance. maxon drives can be found, for example, in the safety and aerodynamics systems of sports cars and passenger cars.
Fast, competitive, spectacular: The Formula Renault 3.5 is seen as a crucial stepping stone on the way into the premier class, the Formula 1. Ambitious racers do not just bring their talent – they also have maxon motors on board to control the throttle of their 530-HP V8 engines.

Article: Andreas Turner
The racetrack of the Autodromo Nazionale di Monza is technically demanding. Two turns are particularly difficult (see right). They demand extremely precise acceleration and braking. This makes reliable control of the motor’s air intake through the throttle flaps even more important.

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**Curva Parabolica**

**2° Curva di Lesmo**

**Variante del Rettifilo**

**Variante Ascari**

**Curva Biassono**

**Curva del Serraglio**

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**Hot curves**

- Gear lateral acceleration
- Speed (kph)
- Run-out areas
- Maximum braking force
- Elastic: Here, the cars in front are braking while cars in the back are still accelerating.
- Demanding: Staying on the road can be difficult here.

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Download the tablet issue 1/2014 and experience a race from the driver’s point of view.

magazine.maxonmotor.com
Top gear 260 kph… 270… 280… 285… 290… speed pours into the cockpit like hot bathwater. The back of Nico Müller’s neck is pushed against the edge of his bucket seat under the heavy, even pressure almost like a mud pack. Strangely it does not relent even after reaching the top speed of 310 kph. The 21-year-old executes the required steps as if in an oxygen intubation: Inhale, exhale, raise shoulders, drop shoulders, all with exaggerated slowness to ride out the adrenaline rushes.

Exploding fuel vapors
The tachometer shows 9000 rpm as the hammering pistons of the V8 rip a torrent of fresh air through the fully open throttle flaps in a rasping howl. In the cylinders, fuel vapors detonate in controlled explosions, delivering brutal acceleration.
A sharp bend, initiated with a quick dip of the left foot on the brake pedal, causes a centrifugal pull on tires, suspension, chassis, and neck muscles. And yet, like the rotating blade of an edge trimmer, the car cuts smoothly along the track in the midst of a lush green area interspersed with a few trees.
The one seater clings like a barnacle to the smooth gray band winding its way through the Royal Park in Monza, past the Milano Golf Club. The down pressure from wings and diffusers now exceeds the weight of the Formula Renault 3.5 car – strong enough to activate the natural laws of a compressed world. Under the heat of the load, the steering seems to have merged into a unit reaching all the way up into the driver’s shoulders. In the approach to the Parabolica, the carbon brakes are suspended like a guillotine waiting to hurl the young Swiss racer into his harness with a force equal to three times his own weight.

Fine tuning
The pit at Draco International Racing in the Autodromo Nazionale di Monza: “We nailed it this lap, the car felt great on every section of the track,” says Nico Müller most casually. He flashes a relaxed smile. Before the actual lap time was announced, the young man from the Bernese Oberland knew instinctively that he would appear in the upper reaches of the provisional ranking. As he turns to walk off towards the shower, he lets the pit master know where the set-up of the 610 kg Zytek-powered Formula Renault could use some fine tuning.

“We are working on the details of the adjustable rear wing and the pedal mapping, even if we gain less than one tenth of a second per lap in the end,” says Draco team manager Simone Giglio. He explains how the characteristic fields of the accelerator pedal, the so-called pedal maps, affect the performance and driveability of the engine. “It is always about the relationship between speed and accelerator position. Thanks to drive-by-wire, the electronic throttle control, this can be defined in almost any way.” Even some serially manufactured sports cars today are using this technology to provide a more dynamic characteristic as an option. Drivers can choose a more direct, quicker response from the engine, which then feels more like a racing unit.

Butterfly throttles
The Zytek engines used in the Formula Renault 3.5 are equipped with so-called butterfly flaps that are mounted on a rotating axle. At full throttle, the flap is vertical, offering no resistance to the air flowing into the cylinder. To close, it rotates into a horizontal position and interrupts the air flow.

The precise control of the Zytek throttle system is handled by a maxon RE-series DC motor and planetary gearbox. All eight flaps are connected with a single mechanism. They open and close in just 10 to 15 milliseconds, comparable with the flash of a camera. On a high-speed racetrack like Monza, the car is at full throttle about 70 percent of the time. The throttle flaps open and close about 100 times per lap. During a fast lap, such as 1:35 minutes, they change position about every 0.9 seconds.

Reliable under extreme conditions
The challenging application conditions—strong vibration and temperatures up to 130 degrees Celsius—made special adaptations on motor and gearbox necessary. John Manchester, Zytek Operations Director: “The support from maxon motor during the test and evaluation phase has ensured that the motor is working flawlessly and reliably even in difficult conditions.”

In the past, Draco Racing had pilots like Felipe Massa, Pastor Maldonado and Rubens Barrichello under contract. In other

On a high-speed racetrack like Monza, the car is at full throttle about 70 percent of the time.

Nico Müller trades his Formula racer for a car with a roof
A glorious victory in Monaco, another in Budapest, and 9th place in the Formula Renault 3.5. Nico Müller’s resume for the 2013 season has won him much renown in racing circles and helped him to take the next step up on the career ladder. He will spend the 2014 season as a factory driver for the Audi team in the famous Deutsche Tourenwagen Masters (DTM).

The Zytek V8 engine used in Formula Renault 3.5 racing.

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The Zytek V8 engine used in Formula Renault 3.5 racing.

Details of the Zytek RE 35 DC motor and planetary gearbox 4.0–8.0 Nm power for extreme demands.

For racing applications, the maxon RE 35 DC was fitted with custom graphite brushes, a special epoxy resin, and a reinforced commutation system. All motors in the maxon RE series have an ironless rotor and high-power permanent magnets (see here). They achieve more than 90% efficiency. To provide more torque for controlling the throttle of the Zytek engine, the maxon RE 35 is fitted with a GP 32 HP (High Power) planetary gearbox featuring an optimized output shaft. Depending on the reduction ratio, it can deliver up to 12 Nm.

The Zytek 360 CR motor

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The Zytek 360 CR motor
teams, the Formula Renault 3.5 has brought forth drivers like Sebastian Vettel, Fernando Alonso, and Robert Kubica. Vettel is a four-time Formula 1 world champion, Alonso has won the title twice.

Time to go home for Nico Müller. In jeans and a polo shirt, he waves good-bye to the team and says, turning to the reporter: “The only times when you really control a race car is at full throttle and when braking.” While the reporter is still thinking about what he just heard, Nico opens the trunk of his rental car, drops his XXL training bag and gets behind the wheel to drive back to the hotel. His driving is slow, almost conspicuously unobtrusive.

Every optimization is worth the effort, even if it is only to eke out a few tenths of a second.

The World Series FR3.5 vehicles developed by Renault Sport use Zytek engines. Zytek is a British company that produces control systems for the automotive industry, drive technology, engines and hybrid technology. John Manchester, Engineering Operations Director at Zytek, explains in the interview why drives by maxon are suited for the electronic throttle adjustment in the V8 engine of the racing cars.

Interview: Anja Schütz

What is Zytek best known for? And what was the most important development in your company?

Zytek are now universally regarded as world leaders in motorsport for both engine and energy recovery powertrains, and have supplied products to all the major racing series in the world. The most significant development we have made over the years has been with our energy recovery systems. This is ground breaking technology and is set to have a big impact on motorsport over the coming years.

What do you think has been the most important development in the automotive industry in the last 20 years?

The development of hybrid and electric vehicles has made a significant change to the type of vehicles we drive today and will drive in the future. In motorsport you have to continually develop and improve products in a very short time frame and this of course has the added effect of accelerating product development at a greater rate than in main stream production.

This has enabled Zytek to make big steps in technology transfer from motorsport applications into main stream automotive products, which of course enables rapid product improvement.

Does Zytek still have its own racing team? If yes, what are the goals?

Zytek first began working with maxon products in July 2011 and we were extremely impressed with their technical backup and service. The motors used in our drive by wire throttle systems on the Renault FR3.5 engines need to function in a very extreme environment. maxon really understood this problem and made suggestions on how to improve their product to suit this application. Since we started working together Zytek have built up an excellent relationship with maxon and we now use their products in other applications, such as a new clutch control system which will be introduced next season.

What do you think is the future of automotive? (also in motorsports)

I believe the main changes in both automotive and motorsport vehicles will be the development of full electric and hybrid drivetrains, which is going to help create alternative and more efficient powertrains.

Contest

Who is winning?

Win two weekend tickets for the Formula 1 “Großer Preis Santander von Deutschland” from July 18 to 20, 2014 on the Hockenheim Ring. Download the tablet issue 1/2014 and join the contest. The deadline for participation is June 30, 2014. magazine.maxonmotor.com

Join now!
Three theories

Battery-powered cars for everybody, cars without drivers, and energy efficiency in motor sports – Dominik Stockmann talks about three visionary theses.

Prediction no. 1
People are slowly coming to realize that petroleum is too precious to burn. In 2025, developed countries will have more electric cars than cars with a combustion engine. They will be powered by on-board batteries or hydrogen fuel cells.

Energy storage remains the critical factor in electric mobility. Lithium-ion batteries are the most advanced batteries currently used in electric cars. However, these batteries are still a long way from reaching the energy density of fuels like diesel or gasoline. Gasoline has an energy density of about 10,000 watt-hours per kilogram (Wh/kg). The modern lithium-ion cells used in top-of-the-range electric vehicles have an energy density of about 120 watt-hours per kilogram, about 80 percent less. Researchers have some hope for the potential of zinc-air batteries, which are expected to deliver 10 times the energy density.

Battery efficiency has improved in recent years. In 2020, the Tesla Model S earned a certification for an energy efficiency of 80 percent. But the old-fashioned combustion engine is still much more efficient. Automakers will have to rely on electrical drivetrains more than on batteries. The current challenge is to make the battery as energy efficient as possible.

If we are to become independent of fossil fuels, new battery technologies need to be researched and developed until they are ready for serial production. These technologies also need to be affordable in order to become applicable in mass-produced vehicles. It is likely that the battery will prevail as an energy storage device compared with the fuel cell. Fuel cells would need far greater technological breakthroughs to become competitive.

It remains to be seen whether the majority of people in industrialized countries will be driving electric cars by 2025. One thing however is certain: Sooner or later, electromobility will become the rule.

Prediction no. 2
By 2030, the automobile will finally live up to its name: It will accelerate, brake, and find its way all by itself. We will take the steering wheel only for fun.

Autonomous vehicles are being tested even today. Google’s autonomous car has already traveled 600,000 kilometers on public roads in California. Many leading carmakers are also developing such vehicles. The biggest challenge is the cost. According to expert estimates, a typical test vehicle is equipped with CHF 80,000 worth of sensors, software, and hardware. This is of course far too much for a normal car.

Many of these systems however are already installed in luxury cars today, for example to recognize lane demarcation lines. If the vehicle unintentionally approaches the demarcation line, the system assists the driver to stay on track with discreet steering support, or warns him by gently vibrating the steering wheel. Some cars are already capable of keeping a constant distance from the vehicle ahead, initiating emergency brake maneuvers, or parking automatically.

As early as 2010, Audi sent an unmanned vehicle to the legendary Pikes Peak mountain race in the US. The car completed the just 4301 meter high peak in the Rocky Mountains in 27 minutes without any human intervention. This was an acceptable time, even though it was far from the winning time of about 10 minutes.

One day, autonomous vehicles will revolutionize road traffic. The majority of traffic accidents are caused by human error. Com-
Staying on track

Driver assist systems can save lives, for example by waking a driver from microsleep.

Driver assist systems in cars are instruments that can save lives. Examples include adaptive cruise control (ACC), brake assist systems, or lane departure warning systems (LDW). The latter warn the driver when he is about to leave the lane unintentionally. This is accomplished with various systems and computers that determine the vehicle’s position in the lane. When the car is in danger of leaving the road, the system activates an electric motor in the steering wheel that causes the wheel to vibrate, warning the driver. maxon motor is supplying a luxury car manufacturer with motors for this application. The base motor is the brushed A-max 16 (precious metal brushes, 2 W), modified for the application with an eccentric weight and a specified bearing. In order to prevent the other vehicle systems from being affected by the electromagnetic fields of the motor, it is equipped with special EMI suppression for automotive applications. The requirements for the small drive system are high: It needs to be low-noise, dynamic, compact, and feature high power density. The small A-max 16 was able to fulfill these requirements without any problem.

Autonomous cars by Google are equipped with laser, radar, GPS, and cameras.

The maxon motor magazine 1 // 2014
All the facets of drive technology in interactive multimedia. Tablet editions of driven are available for free download in the Apple App Store and on Google Play.

More information at: magazine.maxonmotor.com
The FiberCut laser cutting head by Laser Mechanisms cuts metal like butter, accurately and fast. The gap between laser head and workpiece is controlled by maxon DC motors and planetary gearheads.

**Article: Deb Setters**

**Smart head**

**Precision at high speeds**

There are three FiberCut heads in the series: the Straight Head SH, Right Angle RA, and Right Angle Compact RAc. All three use a maxon produced GP22 (19:1) planetary gearhead. According to Gerry Hermann, Senior Electrical Engineer at Laser Mechanisms, “Speed is the most important feature we needed and high speed automation forces the need for accuracy at those speeds.”

The heads attach to most robot arms used in the manufacturing lines of the automotive industry. The lasers are used to cut out large body panels for cars and trucks, as well as smaller support components such as undercarriage mounts and structural components designed for overall strength and safety of the final automobile.

To keep up with production lines, the creation of components such as undercarriage mounts needs to be efficient. Furthermore, accuracy is key for assembly purposes.

The maxon RE-max 29 brushed motor offers high performance density for its size, which is the main reason Laser Mechanisms selected it. Additional benefits included durability and long life. Due to maxon’s ironless core design, which results in low electrical erosion between the brushes and commutator segments, the motor lasts longer.

**200 mm per second, 24/7**

The speed of the FiberCut head can reach 200 mm per second even though the maximum travel of the head – in an up and down motion – is only 25 mm. How this works is that the lower part of the head moves up and down to maintain a constant standoff distance between the laser and the metal being cut. Springs are used to push the head out, while the motor is used to pick the head up.

Some additional features of the FiberCut laser cutting head include an adjustable focus lens for focus-to-tip adjustment and a cam-operated drive system with axial crash protection. The heads work with all leading fiber-delivered laser systems up to 4 kW with wavelengths of 1064/1080 nm. All the wiring and assist gas lines are internally plumbed to avoid snags and breaks when working around structural automotive components.

Each head in the series includes a sealed beam path and a design that is engineered for the factory floor environment associated with automotive manufacturing, which is essential for the 24/7 operations of the automotive industry. The main enclosure is purged with a dry air source to keep the inside clean. This is important so that debris doesn’t get into the optics or into the motor chamber. Along those lines, the maxon motors used in the device produce no particles that could damage the optics or cause a maladjustment to the tip standoff control. Additional motor features include quiet operation.

Advanced laser beam solutions are used in all aspects of industrial automotive applications, including cutting, welding, drilling, scribing, surface treatment, and other processes. Plus, these solutions can be used with every type of laser, such as CO2, Nd:YAG, and fiber lasers.

Laser Mechanisms (Novi, Michigan) is a regular innovator in this industry, producing components that enhance performance, increase safety, and provide flexible capabilities while maintaining ease of use, reasonable costs, and greater overall effectiveness. One of the company’s recent innovations is the FiberCut” series of laser cutting heads.

The FiberCut laser cutting head collimates and focuses a laser beam to provide a clean cut along metal surfaces. This three-dimensional cutter is light weight to minimize the inertia seen by the supporting robotic arm. The FiberCut nozzle also senses the required tip standoff distance from the workpiece (using Laser Mechanisms’ patented sensing technology) and automatically maintains that distance, providing a high accuracy cut as the cutter moves around the 3 dimensional metal part.

**Millimeter precision**

Laser cutting heads of the FiberCut series use RE-max 29 brushed motor as the key components for controlling the gap. Each system also uses a GP22 planetary gearhead manufactured by maxon. The brushed RE-max 29 motor by maxon is very high-powered for its size. Other advantages include durability and a long service life. The ironless core of the maxon design reduces electrical erosion between the brushes and the commutation segments, increasing motor lifespan. Thanks to maxon’s drives, the laser cutting heads excel through low-noise operation, extremely fast response, long life, and consistently high quality.

**Photos: Laser Mechanisms, maxon motor ag**

The laser cutting head is primarily used in the automotive industry, for example for cutting chassis beams.

“High speed was our main consideration.”

Gerry Hermann, Laser Mechanisms
The 1.58 meter tall robot answers to the name of Kenshiro. It was brought into being by Tokyo University and has 160 muscles which are controlled via tendons by 93 brushless maxon motors.

The humanoid robot is the impressive result of many years of research.

Article: Anja Schütz

As powerful as a manga hero

The 1.58 meter tall robot answers to the name of Kenshiro. It was brought into being by Tokyo University and has 160 muscles which are controlled via tendons by 93 brushless maxon motors. The humanoid robot is the impressive result of many years of research.

Article: Anja Schütz

“We wanted to understand the movements and appearance of humans and replicate them as closely as possible in Kenshiro,” explains Prof. Kei Okada. With a size of 1.58 m and a weight of 50 kg, the robot is modelled on a 12-year old boy.

The name Kenshiro is known in Japan through a hero in a well-known manga comic series from the 80s. To imitate the human anatomy as closely as possible, the scientists equipped Kenshiro with the most important human muscles. In the legs, 50 drives are used as artificial muscles. There are 76 in the torso, 12 in the shoulder and 22 in the neck. The robot has the largest number of muscles ever installed in a humanoid robot.

The researchers at the Jouhou System Kougaku Laboratory (JSK) of Tokyo University decided upon maxon motor for the drive system. Kenshiro’s 160 artificial muscles are contracted by 93 brushless maxon EC (BLDC) motors.

High dynamics, an extremely wide speed range, and their very long service life. Powerful BLDC motors are required for the muscle contractions, therefore 60 W to 100 W maxon motors are used. Another important criterion for the motor selection was the heat generated by the motor. It is not possible to install a cooling system in the robot. Low heat generation is therefore of critical importance.

Photos: maxon motor ag

The picture shows the team at Tokyo University and the responsible maxon employees (from left to right above): Yoshihito Ito, Hironori Mizoguchi, Prof. Kei Okada, Kenshiro, Takuma Shira, Toseki Maazuki, Marc Gottenkieny (maxon motor ag). Below: Yoarco Motegi, Oliver Camenzind (maxon motor ag), Yuki Asano.
Venus has almost the same size, mass, density, consistency and gravity as the earth. But this scorched world has temperatures hot enough to melt lead. Venus is surrounded by a thick, toxic atmosphere which covers a burned surface with temperatures around 470 °C and has a pressure that is ninety times higher than on Earth’s surface – the same kind of pressure that exists a kilometer underneath the surface of our oceans. The atmosphere consists mainly of carbon dioxide, with clouds of sulfuric acid. Glimpses below the clouds reveal volcanoes and deformed mountains. Venus spins slowly in the opposite direction of the other planets. This means that on Venus, the sun rises in the west and sets in the east.

We might think a planet this hot with such extreme temperature and pressure would be impossible to explore. But it is not: More than 40 spacecraft have already explored Venus. The Magellan mission in the early 1990s for example mapped 98 percent of the planet’s surface. So why not build a motor for Venus? The request came from Jet Propulsion Laboratory (JPL), which builds satellites and space probes for NASA.

maxon motor and Venus
To be able to go to Venus one day, maxon motor came up with the following solution: The UHT, an ultra-high temperature motor made of special materials that are resistant to 500 °C and higher. maxon used only stainless steel and ceramic components; the maxon winding for example was stabilized with a ceramic part. The first benchmark was operation above 400 °C. In September 2012, we successfully reached 420 °C. In further tests, our motor ran at 450 °C for one hour. This type of motor can be used in any application with particularly high temperature requirements, such as extinguishing robots, deep drilling, or in space.

In this photo entitled “Crater Farm” taken in 1991 by the NASA Magellan satellite, one can see the bizarre craters on Venus. These are evidence of enormous volcanic activity on the planet.

Tough guys for all occasions: the maxon HD Series motors.
Motors for extreme conditions

The Venus motor is based on maxon’s existing Heavy Duty (HD) motor. Some new components were designed, and our engineers were able to draw upon existing knowledge to build a highly heat-resistant version. With the brushless EC 22 HD and the electronically commutated EC-4pole 32 HD, maxon motor launched standard motors for very harsh operating conditions. The electronically commutated version was developed for the exceptionally high requirements in deep drilling technology and stands up to even the most extreme conditions. The different variants of the EC 22 HD are designed for operation in air or submerged in oil. Power ratings depend on the surrounding medium and average to 80 Watt in air (220 Watt EC-4pole 32 HD) and, due to the much better heat dissipation, 240 Watt in oil (480 Watt EC-4pole 32 HD). They are designed to resist ambient temperatures of more than 200 °C (390 °F) and pressures up to 1,700 bar (25,000 psi).

The 22 mm diameter motors are also capable of withstanding vibration up to 25g rms, as well as shocks and impacts up to 100g – that is 100 times the gravitational acceleration. For comparison, a Formula 1 race car encounters about 2g, a fighter jet about 13g. These motors are highly efficient and therefore offer the best prerequisites for battery-operated applications. Thanks to their detent-free running characteristic, they possess outstanding regulation behavior and are especially suitable for high-precision positioning tasks, even at low speeds.

The EC-4pole 32 HD for example is ideal for use in environments where it is exposed to extreme temperatures, high vibration, or ultra-high vacuum. This means the motors can also be used in aerospace applications including gas turbine starters, the generators of jet engines, regulating combustion engines, or exploration robots. To use the motor in conjunction with a gearhead, maxon offers the GP 32 HD, a powerful and robust planetary gearhead.

In the ultra-high temperature motor from maxon motor only materials are used that can withstand temperatures above 500 °C without damage.

The brushless EC 4-pole 32 HD is designed for operation in air or in oil.
Energy efficiency in microdrives

Low energy consumption. Heat. Power density. For microdrives in particular, these factors play an important role when energy-efficient operation is the goal.

Article: Jan Braun

Energy efficiency is an important factor not only in automotive applications, but also for many smaller sized motors. Typical applications include battery-powered devices as well as aerospace applications. The following are only a few examples: laser leveling devices, motorized golf caddies, medical power tools, insulin pumps, robots, packaging machines, and fuel cell powered vehicles.

With all these applications, it is critical to use available power as efficiently as possible. This also means that only a minimal amount of power should be lost as heat. The rise in temperature should be kept to a minimum.

A drive component's efficiency describes these losses in terms of the ratio of output power (input power minus losses) to input power. Typically, the optimal efficiency is 80 to 90 percent for DC motors, 90 to 98 percent for pulsed power stage controllers, around 90 percent per stage for planetary gearheads, and below 40 percent for worm gears.

Aspects of a motor's energy efficiency

Energy conversion is described by the torque constant $k_M$ and the speed constant $k_n$. It should be noted that the speed constant $k_n$ is the inverse of the torque constant $k_M$. Conversion can therefore be expressed completely as $k_M$.

Not all of the electrical input power is converted into mechanical power. After subtracting the voltage drop due to electrical resistance, we are left with the induced voltage $U_i$. Similarly, not all of the generated mechanical power is available to the motor shaft.

Electrical power loss is the part of the electrical power that is not converted into mechanical power. It is given by the losses due to the load current, or in other words, due to Joule power and copper loss. Electrical power loss is proportional to the square of the current (load). The mechanical power loss after power conversion comprises friction in bearings and brushes as well as iron loss. Mathematically, these can be treated similarly to speed-determined friction. Eddy current losses occur with brushless DC motors, also known as EC motors. The rotating magnet in an EC motor induces eddy currents in the magnetic return of the stator. The advantages
Modeling losses in the motor

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

The graphic shows how loss occurs in a motor.

Efficiency graph of a motor

For better illustration, all parameters have been normalized and are given as a percentage of the maximum value. It is assumed that the input voltage is held constant for all curves.

1. At a standstill, when the speed is zero, the efficiency is thus also the output power is zero. However, torque is at the maximum level.

2. In the case of high torques compared to friction, efficiency is proportional to the motor speed at a constant voltage – this can be seen by comparing the speed/torque gradient with the efficiency gradient, which overtop.

3. At lower output torques, friction plays an increasingly important role, until it becomes the dominant factor. As a result, efficiency decreases.

4. When operating at no-load, efficiency is zero since no torque is being delivered. The motor absorbs the entire power in order to overcome friction and iron loss. The no-load current, $I_0$, describes this no-load loss.

Motors operated in the no-load range

For applications where the motor is mainly operated in or near the no-load range – for instance, the mirror drives of laser leveling instruments – it is essential to minimize mechanical friction and iron loss. This reduction can be achieved by selecting smaller bearings, which means the smallest possible motor, and by using precious metal brushes instead of graphite brushes. At low speeds, the use of a controller and sensor instead of a mechanical help to further reduce mechanical frac-

Very low iron losses can be achieved through maxon DC motors with an ironless winding or small 2-pole EC motors, also known as brushless DC motors.

Motors at standstill

If the motor is operated at a standstill – where the motor is at maximum torque – the power loss is given by the electrical losses. This is be-

cause when speed is equal to zero, the output power is also equal to zero. By means of copper losses, the entire input power is converted into heat, which turns a motor at standstill into a large heater. This is illustrated by the vertical red line on the far right of the motor diagram. There are neither friction nor iron losses, as the motor does not turn.

Motor efficiency

High efficiency at nominal voltage is, above all, a persuasive selling point. However, it is important to keep in mind that efficiency de-

pends on the respective supply voltage of the motor. Because the ratio of starting current to no-load current increases sharply with higher voltage, the efficiency is also higher. Furthermore, the efficiency curve for lower supply voltages depends more strongly on the motor torque than for higher voltages. To estimate and take into account losses in the motor, it is better to look at the no-load current rather than the efficiency.

Battery-operated applications like mo-
torized golf carts, it is not just a small power loss that counts. The efficient use of available voltage and minimum current consumption are equally important. The objective is to optimize the winding so that it consumes a minimal amount of current, in order to achieve the longest batter-
ty life possible.

For applications in hand-held devices such as medical power tools, the power loss, namely heating, should be kept as low as possible. To humans, temperatures as low as 50 °C seem very hot. Other applications require accommodating a very limited supply of power – one such example is the Mars rover. Such applications require drives with high power or torque density, low weight, and small dimensions.

Conclusion

Scaling down a drive doesn’t mean the chal-

 lenges become smaller. They only become different. Even for microdrives, energy ef-

 ciency matters. However, the focus is less on saving energy and more on low current consumption, low heating, and high power density.

The next section of the technical article "Energy efficiency in microdrives" provides a detailed explanation of why suitable motor controllers and efficient mechanical drives are important for the energy consumption of a drive.
Tomorrow’s flying cars are a thing of the past

Article: Patrick J. Gyger

“The world is as we know it now to be, and always has been: everyone forgets that it could be, or ever was, other than the way it is now.” – John Crowley

One of the drawbacks of living in a city center is the long journey you might have to endure to reach the nearest airport, which will usually be located in the outskirts. No wonder the City of Tomorrow often tries to solve that inconvenience. Take Aerotropolis, for instance: the author of the concept wants to promote a “new urban form placing airports in the center with cities growing around them.”

But the Aerotropolis name rings with a quaint retrofuturistic tone, and brings to mind 1930s pulp imagery (as for instance seen in Frank R. Paul or Arthur C. Radebaugh): massive tower blocks looming over suspended highways. And indeed, having flying machines inside cities is far from a new idea. Few remember today that one could alight in central Manhattan in the mid-1930s: the Downtown Skyport was reserved for an elite, but hinted that aviation would soon be within the reach of everyone.

Throughout the 20th century, inventors filled with industrial-age dreams and nourished by visions of science fiction imagined personal airplanes en masse and how they would shape the city. Before WWII, magazines started promoting the idea of a flying car in each garage. Mr. and Mrs. Smith could expect to conquer airspace just as easily as they had the highway. And so it seemed when the first true flying automobile appeared in 1937: Waldo Waterman’s Arrowbile. In the booming post-war economy, several inventors successfully took on the challenge. The most striking examples were Robert Fulton’s Airphibian (1946), Theodore Hall’s ConvAirCar 118 (1947) and Moulton Taylor’s Aerocar (1949). But these projects were seen as simply too risky technically, financially, and legally, to succeed. Their makers wanted to bring into reality machines that society mistook for suburban fantasies.

Today, the use of composite materials and information technologies might allow new projects to take off – several of which will no doubt claim to be the first proper flying car. Paul Moller’s Skycar has been in the works for decades, and Terrafugia’s Transition is supposed to go into production in 2014, while the vertical take-off and landing TF-X model should be ready around 2020. NASA has also been toying with the idea of Personal Air Vehicles as a solution to the problems of saturation at aerial hubs and highways. Still, financiers and the public will need to be convinced, and the American passion for automobiles never spread to personal airplanes. No matter what happens, the flying car of the future will either have to be piloted by a professional, or be fully automated. You won’t just be guided: you’ll be overseen or even directed. It will also be horrendously expensive. It is not quite the dream of absolute freedom of movement imagined in the mid-20th century by visionary engineers and science fiction artists.

The flying car as a device of personal liberation, freeing us from timetables and traffic jams, fueled by atomic energy, radically transforming our urban landscapes, will remain a symbol of a future that we were once promised, but that will never be. It will keep filling the skies between powerful skyscrapers, above automated food processors, moving sidewalks and armies of robot servants, landing in the backyards of our imagination.

Patrick J. Gyger is a Swiss historian. He is the director of le lieu unique, national center for arts in Nantes, France. From 1999 to 2010, he was the director of Maison d’Ailleurs in Switzerland, a museum for science fiction and utopia, where he curated more than thirty exhibitions (most of which where shown internationally) and published extensively. He is the author of Flying Cars: The Extraordinary History of Cars Designed for Tomorrow’s World (Haynes, 2011).
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