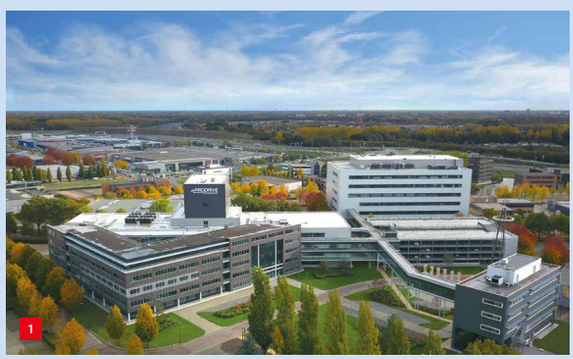
BROAD PORTFOLIO, DEEP INTEGRATION

From a high-tech electronics company, Prodrive Technologies has evolved into a solution provider for mobility, energy, healthcare, semiconductor manufacturing, and industrial automation. Motion & mechatronics has become one of its core competencies, covering the development and manufacturing of customised and off-the-shelf motors, drives and motion controllers, a proprietary motion software platform, and their integration in custom mechatronic systems such as high-precision motion stages. Vertical integration including R&D, engineering, production automation, manufacturing, assembly, testing and service, is a cornerstone of Prodrive's sustained growth.

Prodrive profile

Founded in 1993, Prodrive Technologies, headquartered in the Eindhoven (NL) Brainport region (Figure 1), designs and manufactures high-tech electronics, software, and mechatronic products and systems. It is now one of the fastest growing technology companies in Europe, with over 2.200 employees (40% in R&D and engineering). The company operates four dedicated R&D programmes and three highly automated manufacturing sites as well as sales offices around the world.

Prodrive's business models cover in-house design & manufacturing, manufacturing services, off-the-shelf products, and customisations. These are supported by R&D and engineering competencies in systems engineering, electronics, mechanics, magnetics, software, and optics; performance and lifetime testing expertise and facilities; manufacturing facilities, from machining and injection moulding to coil winding and magnet gluing; and in-house automation capabilities that help to uphold production in the Netherlands.



The Prodrive Technologies campus in Son, near Eindhoven.

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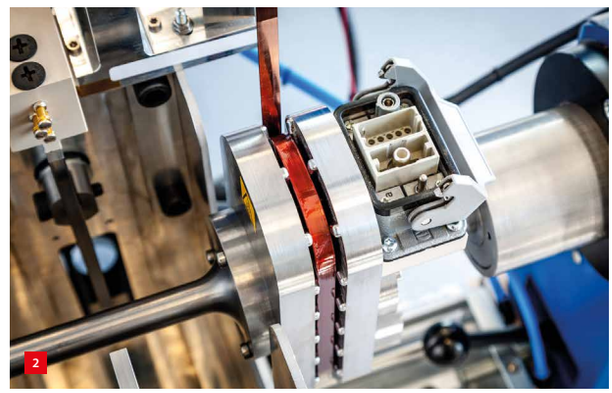


Automation of the coil-winding process.

Started as a high-tech electronics company, Prodrive Technologies has now also built up a strong position in the development and production of custom mechatronic precision solutions, for applications ranging from digital pathology and wafer inspection to PCBA manufacturing and pick & place automation. Over the years, Prodrive has created a comprehensive motion portfolio, including motors, drives and power supplies, motion controllers, and a proprietary software platform.

Motors

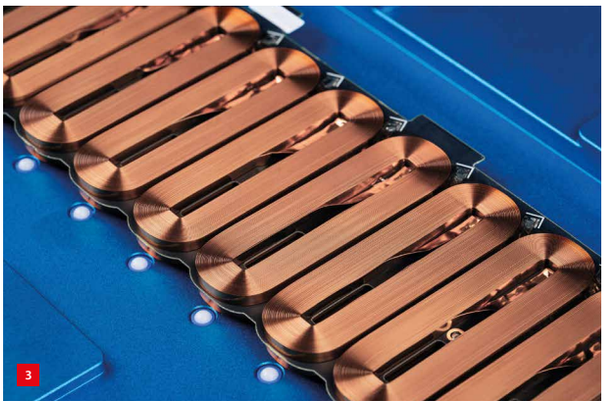
The range of motors includes ironless as well as iron-core linear motors, voice-coil actuators, high-vacuum-compatible motors, and customisations. Automation of the coil-winding process (Figure 2) has been directed at producing motors that achieve high servo performance, high efficiency, and low force ripple.

Vacuum compatibility

For applications in cleanroom manufacturing, e.g. of semiconductors or displays, the vacuum-compatible ironless Gryphon linear motor has been developed. Ironless linear motors have a stationary array of magnets that form

EDITORIAL NOTE

This article was based on an interview with Desmond de Haan (global sales manager), Bart Gysen (product line manager motors & actuators) and Nadia van Sinten-Lanters (marketing manager) at Prodrive Technologies.



Flat-wire technology maximises heat transfer from the coils to the housing.

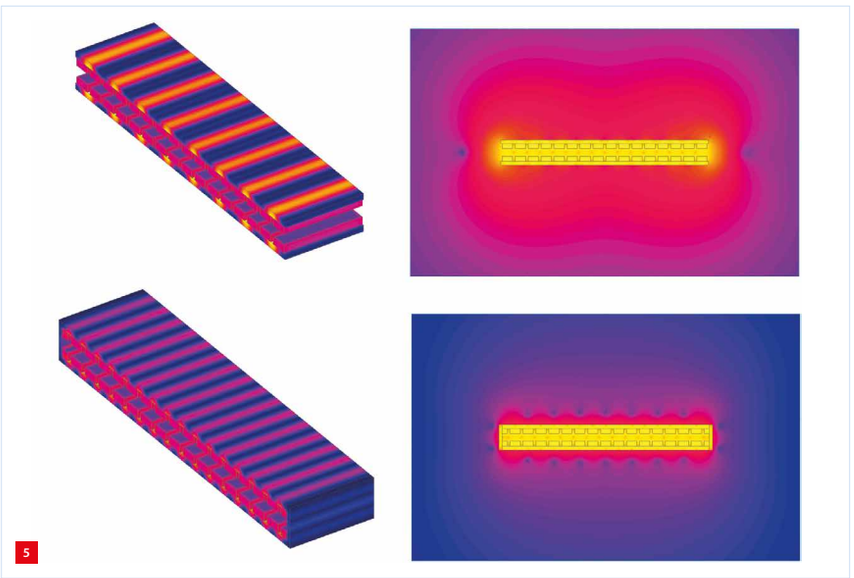
the magnetic yoke, on either side of a movable coil unit that drives the load. Without iron they have a relatively low mass and hence can achieve high accelerations.

The Gryphon is no adaptation of an existing motor, but has been specifically designed for vacuum compatibility, aimed at preventing and mitigating particular and chemical contamination. This started with the mechanical design, for example by ensuring that no (residual) air is trapped by motor components during operation. Motor materials such as potting materials, coatings, and adhesives, have been individually selected for low outgassing. In-house bake-out and cleaning facilities help to ensure cleanliness, which is monitored with RGA (residual gas analysis) and even SEM (scanning electron microscopy) for testing and qualification purposes.

A challenge in vacuum, i.e. low-pressure, environments is heat dissipation, as atmospheric convection is virtually absent. Prodrive utilises flat-wire technology (Figure 3) that maximises heat transfer from the coils to the housing. In addition, minimising the potting clearance and taking care of accurate coil-unit assembly helps to lower heat dissipation, which can already solve part of the problem.

Magnetic shielding

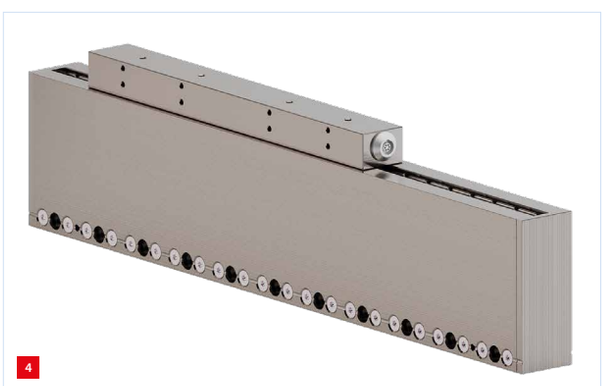
In sensitive applications, such as electron microscopy, magnetic leakage fields are undesired as they can disturb an electron beam. In particular, flux leakage is present at the ends of the magnet yokes. Ending the magnet yokes with a half pole and optionally a shielding plate minimises the phenomenon (Figure 4), making them particularly suited for use around electron beams. Simulations help to optimise the shielding (Figure 5). Prodrive has extensive EMC testing facilities, including anechoic chambers, for testing modules and even complete systems and cabinets for electromagnetic compatibility.

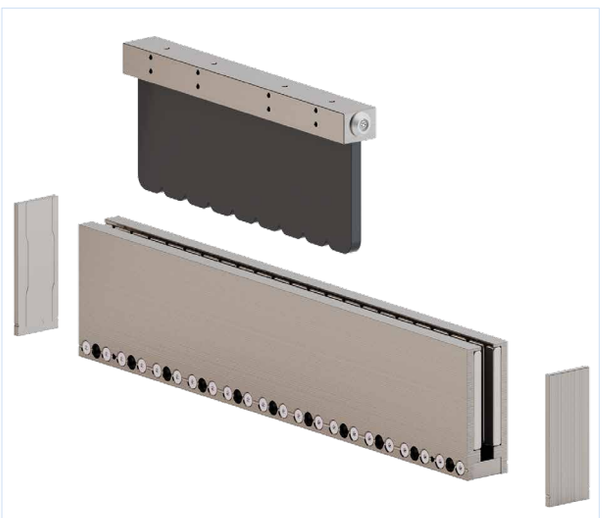


Simulations of a linear motor predict the effect of half-pole and end-plate solutions (shown below) on the magnetic stray field.

Voice-coil actuators

Active vibration-isolation systems require a balanced interplay of passive and active damping with voice-coil actuators. Prodrive has developed them for short-stroke applications that can still achieve relatively large displacements, in up to six degrees of freedom. They are controlled in feedback and feedforward mode.





Linear motor, with shielding and a half pole at the end of the magnet yoke (see the exploded view) for minimising magnetic leakage.

The Proton Wafer Stage, a demonstrator for metrology and inspection purposes.

Drives

At the heart of the drives and power supplies is the high-end electronics upon which Prodrive built its reputation. Its Apogee and Kepler drives are designed for low noise and output current ripple, and high linearity. One of the key components is an innovative current sensor that is indispensable for generating and controlling current with high precision.

From custom to off-the-shelf

Drive development is one of the examples of how custom designs can evolve into off-the-shelf (OTS) products. Prodrive works with leading customers to develop special products. When successful, these specials can be transformed into OTS products that can be manufactured and integrated efficiently. In turn, these standard products offer an accessible platform for customisation with minimum effort. This is enabled by the vertical integration that Prodrive pursues, from R&D and engineering to manufacturing and testing. This prevents handover problems and margin stacking, while facilitating system integration.

Motion control and integration

The Prodrive Motion Platform completes the motion portfolio. It features software, Simulink® integration and a simulation environment, as well as integration and debugging tools. Control design can be performed at a high level of abstraction with automatic EtherCAT® configuration and scaling to readable SI units. The platform features third- and fourth-order trajectory planning and is optimised for high sample rate and low latency operation to allow for centralised control. The Simulink integration combined with the in-built simulation environment enables model-based design and verification, when standard control algorithms do not suffice.

This approach helps to minimise physical prototyping and speed up integration. In 2021, Prodrive launched the Proton Wafer Stage (Figure 6), a demonstrator for metrology and inspection purposes, as an example of its integration capabilities.

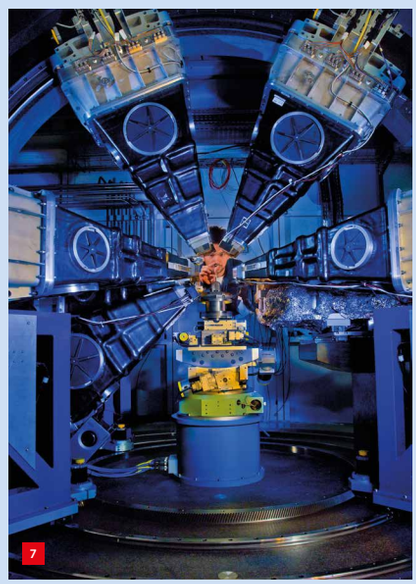
Case study: improving sample positioning at ESRF

The European Synchrotron Radiation Facility (ESRF) in Grenoble (France) was upgraded in a long-lasting project (2015-2022). This made the 'huge microscope' the world's first fourth-generation particle accelerator, which now produces X-ray light some 10,000 billion times more powerful than medical X-rays. ESRF is also upgrading its beamline instrumentation, and in particular nano-positioning end-stations, which are used to precisely position samples with respect to the X-ray beam.

There are around 10,000 axes (mainly stepper motors and piezoelectric actuators) for positioning purposes, usually part of a complex multi-axis system (Figure 7). For the most demanding applications, single- and three-phase linear motors are planned to be used. The major challenge was to find a high-end servo drive flexible enough to work seamlessly in all the highly demanding instrument applications. This is where Prodrive Technologies came in. The Simulink integration in its PMP (Prodrive Motion Platform) real-time software allows ESRF engineers to design any control architecture they need to match their application, while PMP's Python APIs help integrate Prodrive's versatile servo drives into their existing control system.

The design challenge was positioning within 10-15 nm for negligible-jitter scanning. The existing piezoelectric stack actuators can achieve this but have a stroke limited to around 0.1 mm. The new positioning needs involve larger strokes and continuous vibration-free and low-jitter scanning. To tackle these new positioning needs, single- and three-phase linear motors are being used more and more at the ESRF.

Given the relatively low individual motor and drive quantities, ESRF needed a flexible off-the-shelf solution that could be modified for each implementation. That means standardising on a common, versatile drive for as many applications as possible. For accurate scanning applications, ESRF is considering Prodrive's Apogee S3 servo drives. These connect to motors from different manufacturers and have excellent linearity, 24-bit current sensing for accurate control, ultra-low noise outputs with very low output current ripple improving jitter, and 200 kHz PWM output frequency and filtering. These drives work with Prodrive's Arcas motion controller, which can synchronise up to 12 axes at 10 kHz and connect to other EtherCAT subdevices.



A complex multi-axis sample positioning system inside one of ESRF's beamlines. (Image credits: ESRF/McBride)

In this way, ESRF established a platform for universal implementation using Prodrive's PMP software. The requirement of very low drive current ripple to ensure accuracy was fulfilled by this choice, according to an ESRF spokesperson. "Prodrive's drives give us better performance, better accuracy, and very low jitter."

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