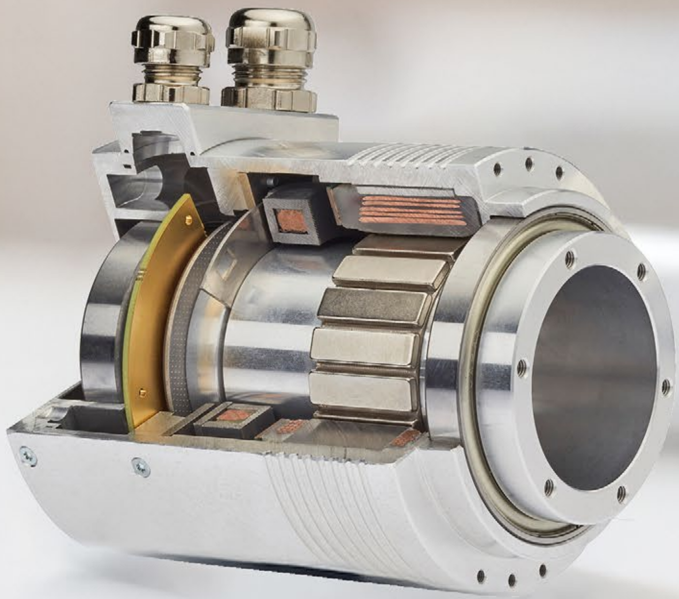
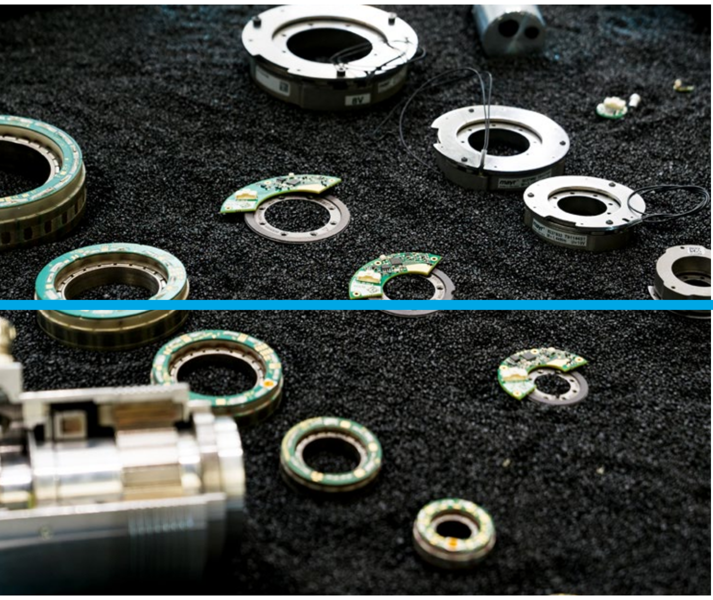


WHITEPAPER

From the frameless servomotor to the complete drive:

Five steps to successful system integration

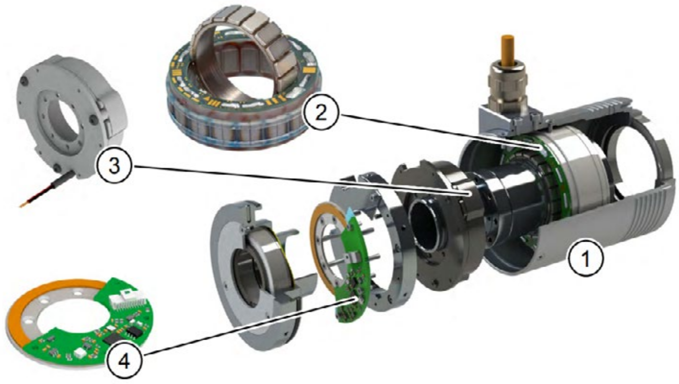


Content

Successful system integration through well thought-out component selection

Frameless servomotors offer decisive advantages over standard servomotors with housings:
They enable more space-saving integration, reduce the overall weight and eliminate superfluous components such as additional housings and mounting structures.

Sophisticated system integration results in an efficient, lightweight and powerful drive solution. However, in order to design the motor, control unit and mechanical components optimally, it is important to clearly define key parameters as early as the planning phase. The desired application ultimately determines the choice of components and their composition. This white paper shows you how to use these key parameters to select the right drive components, ensure efficient system integration and make your application powerful, reliable and economical.



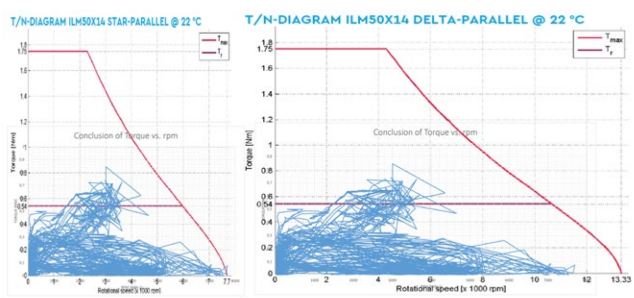
System components of a drive with hollow shaft motor

1 Hollow shaft motor with integrated safety brake
2 ILM servo kit
3 Safety brake
4 Absolute position sensor

Key questions before selecting drive components:

- ✔ What **power** must the drive provide? (torque, speed)
- ✔ Which **input variables** are available? (operating voltage, current, control interfaces)
- ✔ What other **requirements** must be met? (weight, size, inertia)
- ✔ What **requirements does the application have**? (accuracy, speed, safety, brakes)

The actual operating conditions of the application result in a load profile that the drive must fulfill. It describes how the torque and speed change over time, which peak loads occur and which thermal requirements need to be taken into account.

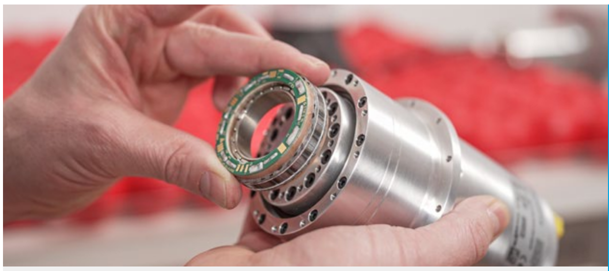


An exemplary load profile of a drive for exoskeletons

The various components of the drive

1 Servo motor

Choosing the right servomotor is crucial for the development of sophisticated drive systems. This is the case when the drive plays a central role in the application and it is essential for the function of the product that it is particularly powerful, but at the same time compact, light and efficient.

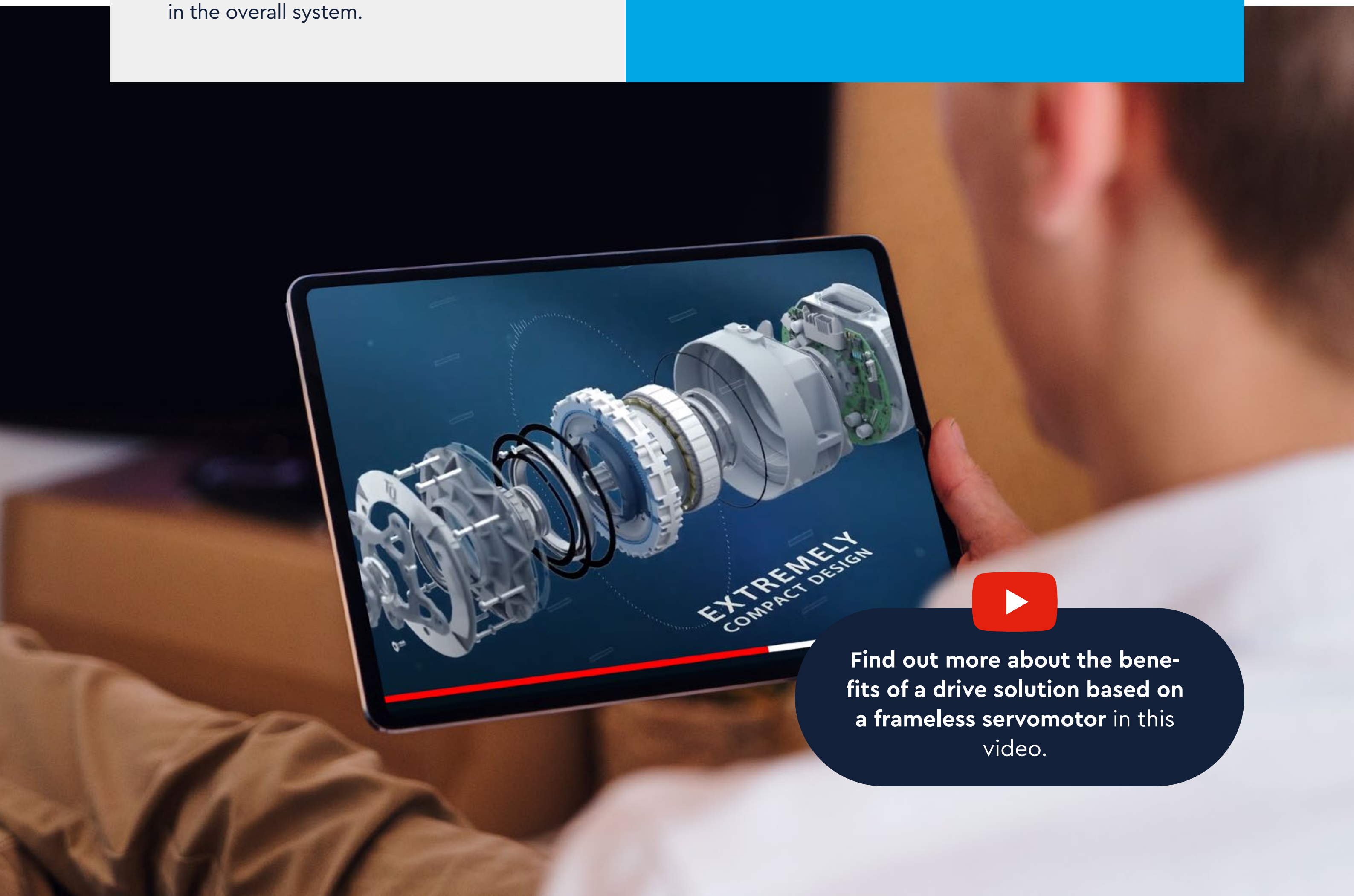


When is a frameless servomotor worthwhile?

When the drive plays a central role in the overall system.

The advantages:

- **More freedom in design -** no restrictions due to standard components that limit further developments
- **Tailor-made solution -** flexibly adaptable Performance tailored to the application
- **Sustainable cost optimization -** more economical in the long term over the entire product life cycle



Find out more about the benefits of a drive solution based on a frameless servomotor in this video.

Main technical criteria for motor selection

Power output

Determines how much energy the motor converts per unit of time (in watts). The power requirement varies depending on the application: a small gripper arm requires significantly less power than an autonomous vehicle drive system.

Torque

Indicates the force exerted by the motor on a rotary movement (in Newton meters - Nm).
A decisive factor for applications in where loads have to be moved or held, e.g. in humanoid robot joints.

Size & weight

The motor must be integrated into the overall design to save space. Especially in mobile robots and drones, weight is crucial for efficiency.

Other decisive selection criteria

Thermal management

How efficiently the motor dissipates heat is crucial for continuous loads and high power requirements. Thanks to their high copper fill factor, TQ motors minimize electrical resistance and reduce ohmic losses to a minimum - for maximum efficiency and lower heat generation.

You can find out more about thermals with electric motors in this video.

Dynamics & speed

High speed and acceleration are essential for fast movements - especially when these have to be able to change abruptly. Crucial for applications that require maximum precision and responsiveness.

Cost-benefit ratio

In addition to performance, production costs, service life and maintenance costs also play a decisive role. Frameless servomotors offer clear advantages here: By dispensing with additional components in the system, they require less maintenance and are more robust and cost-efficient in the long term than conventional servo motors.

Perfect coordination for maximum efficiency

The motor selection is not an isolated step - it must harmoniously match the housing, electronics, controller and application. Especially in robotics, a precisely matched drive solution is crucial to optimize energy efficiency, performance and service life.

2 Sensors

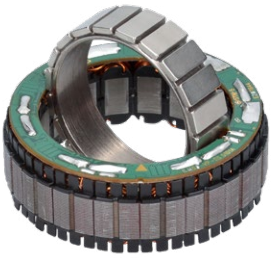
Various sensors are required for reliable and efficient control of drive units.

Sensors in drive technology

- Temperature sensors
- Hall sensors
- Encoders
- Speed sensors
- Torque sensors

Temperature sensors - Monitoring the motor temperature

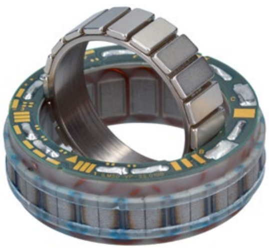
Temperature sensors monitor the winding temperature to ensure that the motor operates within the optimum load range at all times. Additional sensors in the system enable a more precise analysis of the load limits and can be used for the dynamic adjustment of the motor control.



ILM-E: Temperature and reverberation sensors integrated as standard

Hall sensors - rotor position determination

Hall sensors determine the rotor position based on the magnetic field and are essential for the commutation of servomotors (for switching the current flow in the windings) in order to ensure constant torque and continuous rotation. Without Hall sensors, sensorless techniques such as electromotive force (EMF) feedback are required, but these are less accurate at low speeds.



ILM: Optional sensor integration possible

Encoder - incremental or absolute?

An encoder is a sensor that measures the position, speed and direction of rotation of a rotating or linear movement and converts it into an electrical signal.

Incremental encoders

Incremental encoders measure position changes of the motor in small steps (increments). As soon as a movement occurs, they generate pulse signals that are counted to determine the movement or speed Challenge: The absolute motor position is not known after the first switch-on. Therefore, a reference run must first be performed to determine the initial position.

Absolute encoder

An absolute encoder detects the exact position at all times, even after a power failure. Each position is defined by a unique code pattern (e.g. binary or gray code). This means that no reference run is required, as the current position is available immediately after switching on.

	Incremental encoder	Absolute encoder
Advantages	• Simple design • Inexpensive to purchase	• Provides absolute position data immediately • No reference run required • Greater safety and reliability in critical applications
Disadvantages	• Position is lost after a power failure • Requires a reference run for initialization	• More expensive • More complex design
Areas of application	• Conveyor belts • CNC-machines • Printers	• Robotics • Medical devices • Satellite and space technology

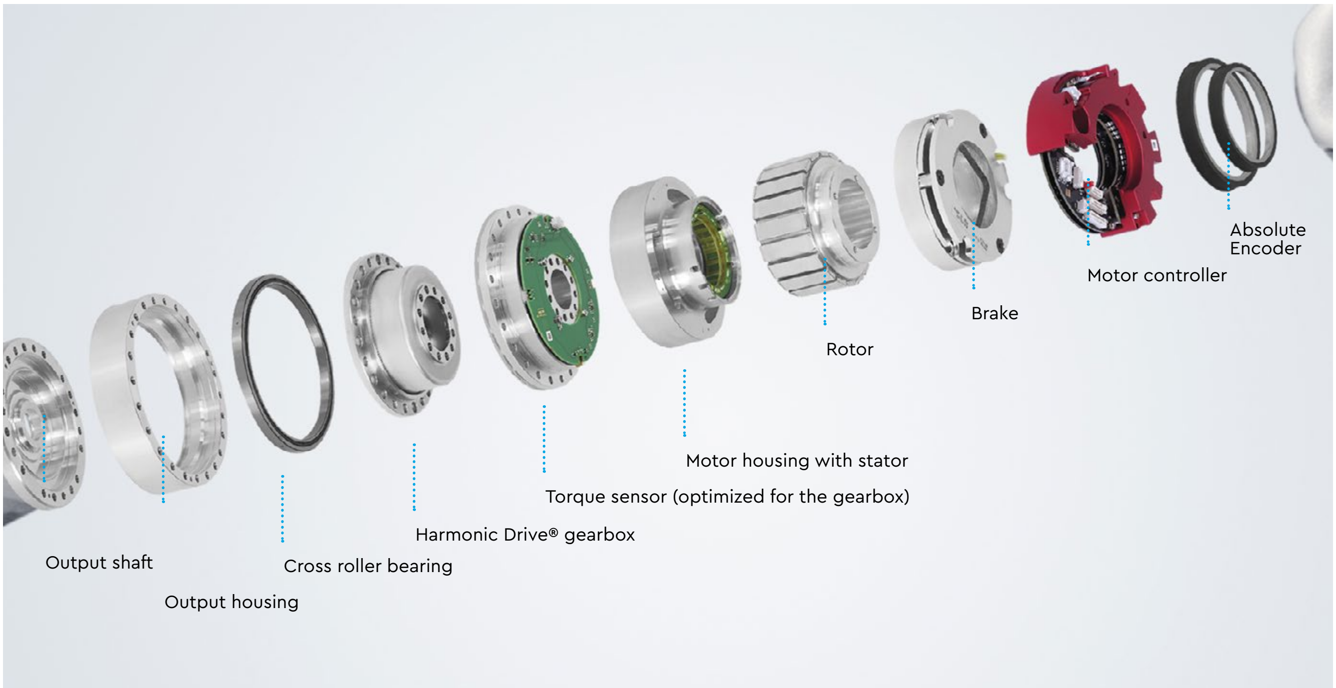
Typical scenarios depending on requirements:

Standard application (1 encoder per axis): An encoder is attached directly to the motor (e.g. on the rotor). It measures the position of the motor, which is sufficient for many applications such as simple industrial robots.

Extended application (2 encoders per axis): One encoder is installed on the motor for controlling the drive movement, an additional encoder on the joint, for more precise position feedback directly on the mechanical axis. This design is often found in high-precision robots, e.g. in collaborative robots (cobots) or in medical technology.

In highly developed robots (such as in humanoid robotics or space travel), encoders and torque sensors are combined to enable precise and force-adaptive control.

An example of this is the complete drive for robotic solutions from Sensodrive.



Structure of a complete drive from Sensodrive. Image source: Sensodrive

3 Gearbox

When putting together the drive system, there is one key question: Does my application need a gearbox at all?

This decision depends on several factors:

- **Torque requirement:** Is the torque generated directly by the motor sufficient or is a gear ratio required?
- **Dynamics:** Should the axis react quickly and perform precise movements?
- **Precision:** How accurate does the positioning need to be?
- **Space requirements:** Is there enough installation space available to install a larger gearbox or a more powerful motor?
- **Weight:** Is a lightweight drive crucial, e.g. for mobile robot systems?

A comparison of drive concepts in robotics

	Direct drive (without gearbox)	Quasi-direct drive (with gearbox, low ratio)	High-ratio gearbox drive (with gearbox, high gear ratio)
Advantages	• Maximum precision • Fastest response times • No gear backlash or wear	• Good ratio between force and dynamics • Compact design • Low gear backlash	• Extremely high torque • Compact solution for high loads • Precise positioning with slow movements
Disadvantages	• Limited torque • Larger motor and more installation space required	• Limited increase in torque • Slight wear under high loads	• Limited dynamics • Possible wear due to continuous load • Higher inertia
Applications areas	• Medical technology • Semiconductor production • High-precision measuring devices	• Humanoid robots • Exoskeletons • Lightweight robots	• Heavy-duty robots • Production systems • Space travel

Direct drives or gearbox solutions - when does which technology make sense?

Direct drive - maximum precision & dynamics
Direct drives do not require gears and transmit power directly. They are ideal when maximum precision, minimum friction and maximum dynamics are required. They are particularly useful whenever the required torque is directly accessible and no additional play is required.

Quasi-direct drive - minimal gear ratio for more power
A slightly reduced gearbox bridges minor differences in speed or torque without significantly impairing dynamics and precision. Example: The TQ-HPR50 e-bike drive, which works with a low gear ratio when the motor needs a little more torque.

High-ratio gear drive
(High-Ratio Gear Drive) - Maximum torque
A high gear ratio is useful for applications that require high torque at low speeds. The focus here is on power transmission; dynamics and efficiency must be optimally coordinated.

TQ-HPR50: The e-bike drive has a gearbox with a low gear ratio.

4 Motor controller

A **motor controller** controls the voltage, current, speed and direction of rotation of a servomotor. The choice of controller is crucial for the **performance and precision** of a robot system - especially in **humanoid robotics** or in highly dynamic applications.

Criteria for selecting a motor controller:

Performance requirements

Maximum voltage and current matching the motor specification.

Control options

- **Speed control:** Precise speed (e.g. conveyor belts).
- **Position control:** Precise movements (e.g. robot axes).
- **Torque control:** Sensitive force control (e.g. cobots, grippers).

Interfaces

- **Communication:** CAN, EtherCAT, RS485 – depending on the system architecture.
- **Encoder interfaces:** Incremental or absolute, depending on precision.
- **Sensor integration:** Connection of external sensors such as torque sensors.

Real-time capability & response time

Important prerequisite for smooth movements, especially for humanoid robots.

Safety functions

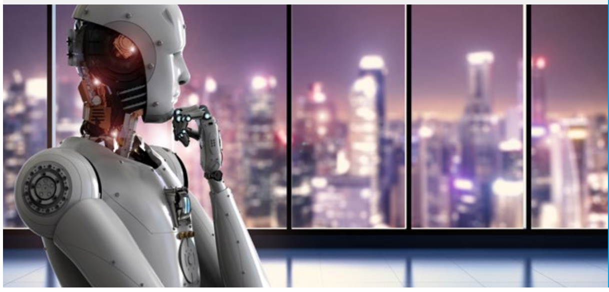
Various safety functions are defined in the functional safety of motor controllers to ensure the safe operation of machines and systems. Here are a few examples:

- **STO (Safe Torque Off):** This function interrupts the power supply to the motor, preventing it from generating torque. It prevents the motor from starting unexpectedly.
- **SS1 (Safe Stop 1):** Here, the drive is brought to a controlled standstill before the STO function is activated. This corresponds to stop category 1 and ensures that the motor stops in a controlled manner before the torque is switched off.
- **SP (Safe Position):** Provides safe position data of the drive via a safe bus, which can be used by a safety controller to monitor end positions or activate position-dependent safety functions, for example.

Programmability & adaptability

Individual control algorithms, compatibility with the flexible open source framework **Robot Operating System (ROS)** for the development of robot software.

Practical example: Humanoid robotic arm



- ✓ **Combined position & torque control** for precise, adaptive movements.
- ✓ **EtherCAT interface** for real-time control.
- ✓ **Torque sensors** for sensitive force control during gripping movements.

A powerful motor controller is the key to **precise, efficient and safe robot systems.**

5 Integration of the overall system

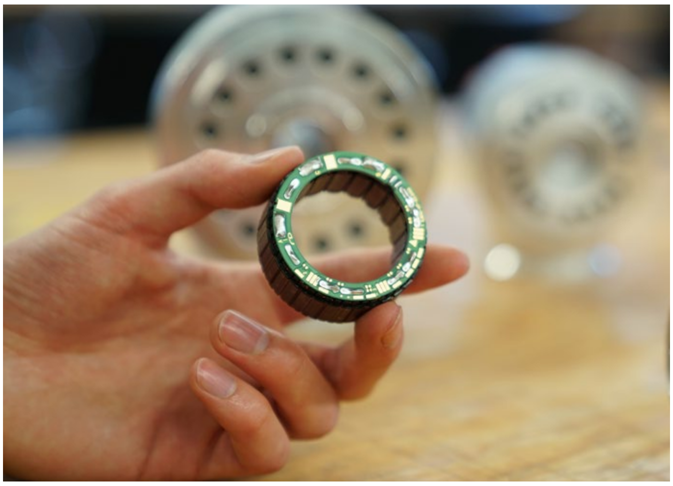
Choosing the right components is not enough - the motor, sensors, gearbox and controller must interact optimally. Efficient integration is crucial for the performance, reliability and service life of the entire system.

Mechanical & electrical integration

- **Mechanical fit:** The motor-gearbox unit must fit into the overall structure of the system in the best possible way.
- **Alignment & assembly:** Precise connection of motor, gearbox and sensors ensures efficient power transmission and minimizes vibrations and noise.
- **Electrical connection:** The motor controller must be compatible with the power supply as well as the encoders, mSensors and safety functions. A continuous power and signal connection is crucial for multi-axis applications - a large hollow shaft in the motor makes clean cable routing and integration much easier.

Software & control

- **Communication & interfaces:** CAN, EtherCAT, RS485 for seamless integration.
- **Signal transmission & feedback:** Encoders and torque sensors ensure precise control and monitoring.
- **Real-time capability**: Especially in humanoid robotics, low latencies are crucial for smooth movements.
- **Monitoring & maintenance**: Record operating data, detect errors, enable predictive maintenance.



Thermal management

- **Heat dissipation**: Heat sink, fan or housing design to prevent overheating.
- **Even heat distribution**: Protection of sensitive components through targeted dissipation.
- **Material selection & insulation**: Reduction of thermal loads for maximum service life.

Synchronization & system tuning

- **Perfect coordination of motor, gearbox and sensors** to avoid torsional vibrations and uneven movements.
- **Feedback loop**: Sensors and motors communicate continuously to ensure maximum efficiency and precision.

The aim: maximum performance, precision and efficiency - with a reliable, durable and optimally coordinated drive system.

Ready-made joints & highly integrated axes

In addition to customized system integrations, there are ready-made joints from suppliers such as Sensodrive, Synapticon, Sumitomo or Robotis as well as application-specific actuators - for example from Servoneering.

Application-specific design

For specific applications, it makes sense to develop highly integrated axes individually. The motor, gearbox, encoder and sensors are then tailored exactly to the requirements in order to ensure maximum performance and precision. This requires close cooperation between the manufacturer and customer and is particularly common in industrial robotics, medical technology, automation and vehicle technology, where standard solutions are often not sufficient.

Stand-alone products for versatile applications

Highly integrated axes are also increasingly being developed as directly usable standard products that can be integrated into various systems for different applications in industry without complex adaptations. These offer a high level of compatibility, making them ideal for companies that require fast and cost-efficient solutions.

Advantages of stand-alone, highly integrated axes

- **Faster time to market:** Ready to use immediately, without long development times.
- **Cost efficiency:** No expensive individual adaptations required.
- **Modularity:** Wide range of variants for different applications.
- **High performance & efficiency:** Comparable with customized solutions.

Highly integrated axes are available both as specific special solutions and as ready-to-use stand-alone products. This provides companies with a powerful, economical and time-saving drive solution that can be easily integrated into existing systems.

Conclusion

Successful integration through clear requirements

Optimum system integration not only requires mechanical accuracy of fit, reliable electrical connection, efficient thermal management and precise synchronization of all components - it starts with a clear definition of the requirements.

The key to success: The performance, size, costs and importance of the drive unit for the overall application must be analysed in detail as early as the planning phase. Particularly in areas such as robotics, measurement technology or for positioning systems, where the drive performs a core function, the right selection and integration are crucial for the efficiency and performance of the end product.

About the author

Robert Vogel is Sales & Business Development Manager at TQ-RoboDrive, which develops and produces customized drive systems for demanding applications. Robert Vogel is an industrial engineer and has been working in the automation and robotics sectors for over 20 years.

TQ location in Inning am Ammersee

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