HBK
HOTTINGER BRÜEL & KJÆR

WHITE PAPER

Contactless Torque Sensing for E-Mobility

How Contactless Strain Gauge Technology Solves Next Generation E-Mobility and Industrial System Challenges

No-compromise torque sensing

The development of high-performance electromechanical systems, in e-bikes, robotics, electric vehicles (EVs), and Industry 4.0 applications is now hitting the physical and functional limits of conventional torque sensor technologies. Latency, inaccuracy, susceptibility to interference, mechanical wear, and integration complexity force engineers into compromises that degrade final product performance and increase the total cost of ownership (TCO).

To address these challenges, HBK, a global leader in precision measurement with over 60 years of strain gauge expertise, now offers the SG3Q platform for rotational torque measurement. Developed by Sensitivus, the SG3Q platform combines advances in automated manufacturing with the proprietary Sensitivus contactless link and angle sensing technology.

With the SG3Q platform, HBK marks a paradigm shift for in-product torque sensing. Previously, engineers relied on indirect torque measurement and spent significant development time compensating for errors by comparing results to a reference HBK sensor. Now, the HBK reference sensor can be integrated directly into the product, using less space than alternatives while reducing BOM cost and scaling to any production volume.

This white paper is intended for R&D engineers, system architects, and product managers. It provides a technical deep- dive into why this approach outperforms indirect measurement alternatives (magnetostrictive, optical, Hall effect), how it solves the critical issue of zero-point stability, and how it enables OEMs to design better, more reliable products with a faster time-to-market.

The Context: When the Sensor Becomes the Limiting Factor

The growing sophistication of motor control algorithms has exposed an unavoidable truth: the quality of a control system cannot exceed the quality of the data it receives. User expectations for more responsive, safer, and more efficient systems place increasingly stringent demands on sensors:

- **High accuracy (±1 – 2%)**: For proportional assistance, fine energy management, and predictable behaviour
- **Stable zero point (±0.5% of full scale)**: Crucial for immediate and smooth torque response, even at low input
- **Low latency (2 ms)**: For an instantaneous feeling of control and active safety
- **Absolute reliability**: For maintenance-free operation over the entire product life, even in harsh conditions

Traditional technologies struggle to meet these requirements, forcing engineers to spend valuable time compensating for their limitations with complex software filters. In turn, these filters add latency and mask the user's true intent. As a result, performance is bottlenecked at its very source.

Integrated SG3Q torque sensing technology delivers precise, real-time measurement directly within the e-bike drivetrain.

The Secret to Performance: Absolute Zero-Point Stability

At the heart of the torque measurement challenge lies zero-point stability – the baseline from which every measurement is calculated. Any instability, however minor – whether caused by temperature, ageing, or interference – introduces fundamental uncertainty into the system.

HBK's strain gauge technology, by its very nature of measuring a physical deformation, delivers exceptional zero-point stability. Paired with contactless transmission, it preserves signal purity from the source all the way to the controller.

Problem (Unstable Zero-Point)	Consequence for the Engineer	Impact on User Experience
Signal drift at no-load	Forced to implement detection thresholds and frequent re-zeroing routines.	A „dead zone" sensation at startup; the system fails to respond to light inputs.
Measurement uncertainty	Need to apply aggressive signal filtering to smooth the data.	Increased latency, creating a feeling of „lag" between action and system reaction.
Lack of repeatability	System behaviour can vary from one cycle to the next, making fine tuning extremely complex.	Unpredictability, sometimes surprising or uncomfortable behaviour, erosion of user trust.

Comparative Analysis of Torque Sensing Technologies

The choice of sensor technology is a fundamental architectural decision. The table below compares the main technologies available for high-volume OEM applications, focusing on the criteria most critical to the integration engineer.

Characteristic	Contactless Strain Gauge (HBK SG3Q)	Magnetostrictive	Optical	Hall Effect/Magnetic
Measurement principle	Direct (measures shaft deformation)	Indirect (change in magnetic permeability)	Indirect (deflection of a light beam)	Indirect (measures magnetic field deviation)
Typical accuracy	High (±1 – 2%)	Medium (±2 –5%), potential degradation	High (if clean)	Low (±5 –10%), highly non-linear
Zero-point stability	Excellent (± 0.5% FS) – Direct measurement, no compensation	Medium/Poor (changes with rotational angle, hysteresis)	Poor (alignment sensitivity)	Poor (alignment and temperature)
Magnetic interference immunity	None	Very high susceptibility (major issue)	None	Very high susceptibility
Contamination sensitivity	Low (sealed system)	Low	Very high (oil, dust, water)	Low
Calibration complexity	Low (factory calibrated)	High (requires degaussing)	Medium (requires precise alignment)	High (non-linearity compensation)
Impact on mechanical design	Low (PCB integration)	High (requires special shaft treatment)	Medium (precise alignment required)	High (requires magnets and alignment)
Engineer's verdict	The reference solution for high performance, reliability, and integration simplicity.	A risky compromise in environments with motors or variable fields.	Unsuitable for industrial or drivetrain environments.	A low-cost solution for non-critical applications not requiring precision.

Technology Deep Dive: The SG3Q Platform

The SG3Q platform is the result of merging two fields of expertise: the physics of measurement and the electronics of communication.

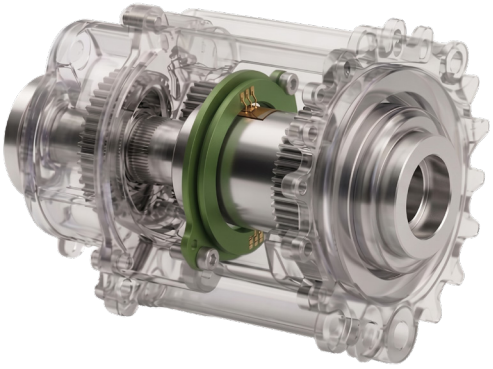
System Architecture:

Rotor

- Strain gauge application: Decades of expertise allow HBK to apply and protect gauge bridges directly onto the customer's mechanical part (shaft, disc, etc.), ensuring the measurement of "true" torque
- Rotating electronics: A compact printed circuit board (PCB), mounted on the rotating part, contains the signal conditioning electronics, analogue-to-digital converter, and digital wireless transceiver

Stator

- Power and data transfer: A stationary antenna, positioned a few millimetres from the rotating part, serves a dual function:
  - Power: Transmits energy via inductive coupling to the rotating electronics, eliminating the need for a battery
  - Communication: Receives real-time torque, angle, and cadence data via a robust, proprietary Sensitivus telemetry protocol
- Stationary interface: The stationary electronics decode the signal and make it available to the customer's main controller via a standard interface (CAN, SPI, analogue, etc.).



The SG3Q architecture combines precision strain measurement with wireless telemetry in a compact, maintenance-free design.

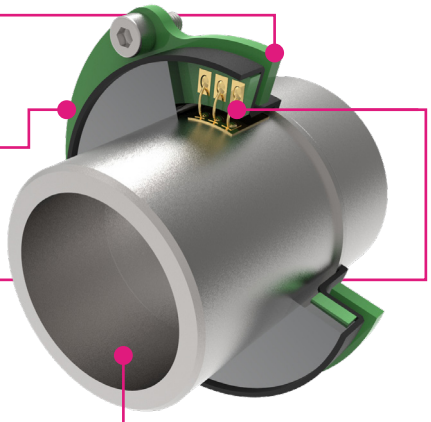
> This architecture provides immunity to interference and eliminates all friction and wear components, ensuring stable performance over millions of cycles.

Stator PCB
Mounted to customer product (stationary)

Rotor PCB
Rotates with the shaft (inner)

Strain gauge
Directly measures torsional strain for accurate and repeatable results

Customer metal integration
The metal shown is only an example – SG3Q is designed to integrate into the customer's metal part, which is typically much larger. The sensor taks up minimal space within the product



SG3Q – 25 mm Example : Anatomy of the sensor

Performance and Technical Specifications

The specifications below represent a typical configuration of the SG3Q platform. Each parameter can be adapted in collaboration with HBK's engineering teams to meet the specific requirements of an application.

Category	Parameter	Typical Value/Range	Benefit for the Engineer
Torque measurement	Measurement range full scale	±1 to ±1000,000 Nm	Fully customisable to the application
	Accuracy (including non-linearity)	< ±1.5% of full scale	Reliable data for precise control loops
	Zero point stability	< ±0.5% of full scale	Enabling fine torque response
	Resolution	0.1% of full scale	Detection of the smallest torque variations
	Frequency response	~500 Hz	Captures fast, dynamic events
Angle measurement	Absolute angle resolution	16-bit (typical ENOB = 13.5)	Position information for control algorithms
	Absolute angle periods	1 to 16 (configurable)	Option space for engineer depending on application
	Absolute angle accuracy	1 period: ±3 deg 2 period: ±1.5 deg 8 period: ±0.5 deg¨(typical)	Higher periods give more accuracy but lower max RPM measurements
	Cadence	± Up to 1000 RPM (derived from angle)	Integrated speed data without additional sensor
Electrical performance	Internal + output sample rate	1000 Sa/s	High-fidelity signal before any processing
	Latency (measurement to output)	2 ms	Near-instantaneous information for maximum responsiveness
	Supply voltage	3.3 – 13.5 Vdc (higher voltage optional)	Flexible integration into the customer's electrical architecture
	Power consumption	< 50 mA	Low impact on the overall power budget
Interface	Protocol – standard	UART 230 k Baud (standard)	Standard UART allows for quick evaluation via a PC interface
	Protocol – configurable	UART, SPI, CAN, I2C (configurable)	Protocol is fully customisable to customer specification
	Analogue outputs	Analogue/PWM modulated cos/sin outputs of angle sensor (option)	Analogue output of angle cos + sin optional for motor commutation or functional safety
	Firmware update	Standard: 16-bit checksum Optional: ECDSA-P256	Flexible firmware update options and fast customisation
Reliability and environment	Operating temperature	–20°C to +85°C (extended optional)	Reliability across a wide range of operating conditions
	Protection	Up to IP67+ (via potting)	Robustness against water, dust, oil, and grease
	Wear components	None	Zero maintenance, maximum service life

Technical Specifications Table (SG3Q Platform)

Application Areas and Integration Flexibility

The scalability of the SG3Q platform makes it ideal for a wide range of high-volume OEM applications:

E-mobility:

- E-bikes: Integration into bottom bracket spindles (mid-drive) or hubs (hub-drive) for natural and efficient pedal assistance
- Light electric vehicles (LEVs) and motorcycles: Drivetrain torque measurement for optimised control and enhanced safety

Industrial and Robotics:

- Collaborative robots: Joint torque sensing for collision detection and safe human interaction
- Smart actuators: Precise torque control for assembly processes (for example, tightening) and predictive maintenance

Automotive:

- Steering columns: Measurement of driver-applied torque for electric power steering (EPS) systems
- Drivetrains: Torque monitoring for optimising shift strategies and protecting components

The SG3Q platform adapts to your needs.
From compact, low-torque applications to large, high-torque systems, the SG3Q platform scales seamlessly, with consistent performance and customization.

> HBK's true strength lies in its ability to co-develop custom solutions, adapting to each customer's mechanical geometry (solid or hollow shaft, disc, etc.) and communication protocols

HBK Partnership: From Engineering Vision to High-Volume Manufacturing

Choosing HBK is not just about acquiring a sensor; it is about securing a strategic partner with complete mastery of the value chain, from initial design to global mass production. This partnership ensures that the vision developed during the engineering phase is realised with flawless execution at any scale.

A Foundation of Co-Development

Our commitment to our OEM partners is built on deep collaboration:

- Application expertise: Our engineers work closely with you to understand your application and its unique constraints, helping to define the optimal specifications to achieve your performance and cost targets
- Predictive engineering: We leverage advanced simulation tools (FEA) to optimise the mechanical design and validate sensor performance before the first prototypes are built, accelerating development cycles
- Seamless integration: Every solution is rigorously tested and validated against industry standards. We deliver the sensor pre-mounted on your mechanical component, fully calibrated and ready for immediate integrationinto your production line

Scalable Production for Global Programmes

The SG3Q Torque Sensor Platform combines industry-leading strain gauge technology with manufacturing processes engineered specifically for high-volume environments. From premium e-bike systems to large-scale OEM programmes, HBK delivers the quality, consistency, and scalability required to support global product launches and long-term production growth.

Automated Manufacturing for Repeatable Performance

HBK has made significant investments in advanced automation to ensure every SG3Q sensor performs consistently – from the first prototype to the millionth unit. By minimising operator variability and tightly controlling key production parameters, we achieve highly repeatable performance at scale.

Our production capabilities include:

- Automated strain gauge placement and bonding
- Precision-controlled adhesive application and curing
- Fully automated calibration and sensor characterisation
- In-line functional verification throughout the entire process
- Complete digital traceability for every sensor produced
- Statistical process control (SPC) monitoring across all critical parameters

Quality as a Core Principle

As a global leader in measurement technology, HBK applies decades of sensor manufacturing expertise to every SG3Q solution. This rigorous, data-driven approach guarantees reliable torque measurement throughout the demanding life of an e-bike drivetrain.

Our quality systems include:

- 100% end-of-line functional testing and automated calibration verification
- Extensive environmental and durability validation
- Continuous process capability monitoring (Cpk)
- Full lot traceability and manufacturing data retention
- Continuous improvement programmes driven by production analytics

Engineered for OEM Volume Requirements

Whether supporting a new product introduction (NPI) or a mature, high-volume platform, HBK provides the manufacturing capacity and operational discipline required for large-scale deployment.

Key advantages for our partners:

- Global manufacturing expertise and footprint
- Fully automated, high-volume production lines
- Unmatched sensor-to-sensor performance consistency
- Robust and resilient supply chain management
- Proven, scalable production ramp-up capabilities
- Dedicated engineering and manufacturing support teams

Engineering the Future of Motion Control, Together

As electrified systems demand everhigher levels of performance, the importance of accurate, reliable, and low-latency torque sensing is becoming paramount. The compromises of the past are no longer acceptable.

HBK's contactless strain gauge solution, powered by Sensitivus technology, finally offers a truly no-compromise approach:

- The precision that control engineers demand
- The reliability that quality managers and end customers expect
- The scalability that high-volume markets require
- The integration simplicity that accelerates time to market

We invite you to challenge our experts with your most complex applications.

Contact HBK today to schedule a technical workshop and discover how the SG3Q platform can become your next competitive advantage.

HBK – Hottinger Brüel & Kjær
www.hbkworld.com
info@hbkworld.com