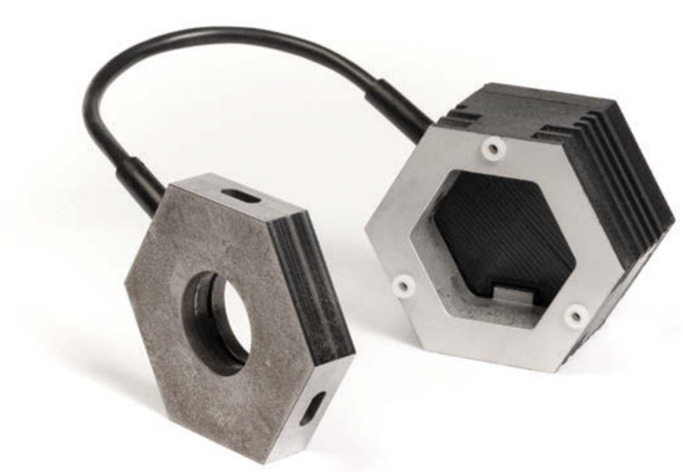
Smart Screw Connection Q-Bo®

**Monitoring of bolted joints –
wireless, self-powered and retrofittable**

The smart screw connection Q-Bo® measures the preload force and transmits it wirelessly and self-powered to a cloud

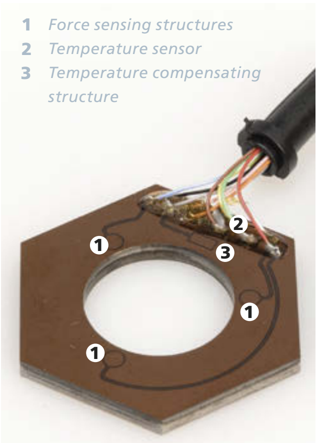
www.cit.fraunhofer.de/q-bo



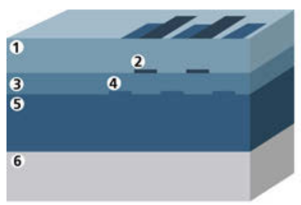
Due to its two-part design, the system can be retrofittable for DIN screws

The smart screw connection Q-Bo® is self-powered through energy harvesting

Smart Screw Connection Q-Bo®



The sensory washer



1 Insulating and wear-protection layer (3 µm)
2 Temperature meander structure (0.2 µm)
3 Insulating and wear protection layer (1 µm)
4 Electrode structure Cr (0.2 µm)
5 DiaForce® (6 µm)
6 Metal base body

A schematic representation of the thin film system

The smart screw connection Q-Bo® is a fully integrated IoT device that provides wireless and self-powered monitoring of bolted joints. It consists of four different technologies: A DiaForce® layer system for determining the preload force and temperature, mioty® for transmitting the sensor data, energy harvesting for self-powered operation and a programming box for tamper-proof programming of the bolted joint.

Thin-film sensor technology

The integration of the sensor technology into the smart screw connection Q-Bo® is carried out at the Fraunhofer IST by applying a thin-film system on the surface of washers. For this purpose the piezoresistive DiaForce® layer developed at the Fraunhofer IST is deposited homogeneously on the washer in a PACVD process (plasma-enhanced chemical vapor deposition). Individual electrode structures are then manufactured from chromium, which form the sensor electrodes for load measurement as well as a structure for temperature compensation. Both conductive paths to the contacting points and a temperature-measuring meander structure made of chromium are structured on a subsequent electrically insulating SICON® intermediate layer. This hydrocarbon layer is modified with silicon and oxygen, which is also deposited by a PACVD process. These structures are protected against wear with a second final SICON® layer.

Data transmission

The mioty® radio protocol from Fraunhofer IIS is used to transmit the sensor data of the smart screw connection Q-Bo®. It is an ETSI-standardized Low Power Wide Area Network (LPWAN), which enables coverage of up to 15 km at 868 MHz thanks to efficient channel coding. Due to the Telegram splitting method, in which the data packets of a message are sent distributed over frequency and time, the transmission is very robust even in difficult environments and has a very low power consumption of <10 µAh. Due to a special error correction, the reception of 50% of the transmitted partial packets is enough to completely recover the message. The low intrinsic interference allows the system to receive up to 3.5 million messages with a single base station. Fraunhofer IIS supports both base station manufacturers and node manufacturers in implementing the radio technology through reference designs and software.

Energy supply

The smart screw connection Q-Bo® uses energy harvesting technologies to cover its power consumption, whereby three options can be applied with the help of an energy management system from Fraunhofer IIS. In the first option, temperature differences between the bolt head and the environment are used to generate electrical energy with a thermoelectric generator. For example, a temperature difference of 25 K is required to provide sufficient energy for a measurement and data transmission every 20 seconds. In the second option, solar cells are located on the screw head. Here, e.g. only 500 Lux (indoor) are necessary to ensure a transmission of the sensor data every 30 minutes. Alternatively, it is also possible to supply the sensor via a 230 mAh battery. Depending on the update frequency, this has a service life of up to 15 years.

Data security

During commissioning, the smart screw connection Q-Bo® is protected against any kind of threat, manipulation, unauthorized access or knowledge. Configuration and secure commissioning with calibration data via UHF RFID can be carried out in a radio-shielded box directly on site, a development by Fraunhofer AISEC. Individual cryptographic keys are also distributed to secure the radio communication, which then protect the LPWAN communication against manipulation and attacks.

Mechanics concept

The underlying mechanical concept for using the smart screw connection Q-Bo® with commercially available DIN screws is based on FEM simulations by Fraunhofer LBF, in which the local stress distributions of the mechanical parts were analyzed and then design optimized based on the requirements of the sensors. The reliability in terms of tightening behavior as well as fatigue strength was experimentally validated to ensure the assembly and operational use of the smart screw connection Q-Bo®. Resistance-force curves were determined to characterize the sensors and used in an experimental investigation to validate the smart screw connection Q-Bo®, taking into account all system components.

The technology was developed in a joint research project by the Fraunhofer Institute for Integrated Circuits IIS, the Fraunhofer Institute for Surface Engineering and Thin Film IST, the Fraunhofer Institute for Structural Durability and System Reliability LBF and the Fraunhofer Institute for Applied and Integrated Security AISEC, coordinated by the **Fraunhofer Cluster of Excellence Cognitive Internet Technologies CCIT**.

15
kilometers range

15
years battery life

Technical Data

Sensors on washer

Pressure		
Number	3	120° offset on washer radius
Range	0 … 150 kN	M18, 10.8
Accuracy	5-10 %	
Temperature		
Number	1	
Range	tbc to +100 °C	
Accuracy	1-2 K	
Acceleration (Vibration monitoring, RMS values)		
Max. Data Rate	3.200 Hz	
Max. Recording Time	2.8 sec. (3 axis)	Optional: 800 Hz, 11 sec. (3-axis)
Max. Acceleration	16 g	

Communication

LPWAN		
Protocol	mioty®	
Coverage	15 km	
Transmit power	Max. 12.5 dBm	
Transmit frequency	868 MHz	
UHF-RFID		
Frequency	868 MHz	Read/write access for configuration without energy supply by means of energy harvesting possible
NFC (optional)		
Frequency	13.56 MHz	Read/write access for configuration without energy supply by means of energy harvesting possible

Power supply

Solar module		
Illumination	500 Lux (Indoor)	Update frequency 30 min.
	18.000 Lux (Outdoor)	Update frequency 30 sec.
Thermoelectric generator		
Thermal gradient (thread to ambient)	25 K	Update frequency 20 sec.
	33 K	Update frequency 15 sec.
Battery		
Capacity	230 mAh (CR2032)	Optional CR2450 for longer operation time
Operation time	2.6 years	Update frequency 60 min.
	3.2 years	Update frequency 24 hours
	15 years	Update frequency 30 days

Commissioning

See RFID		

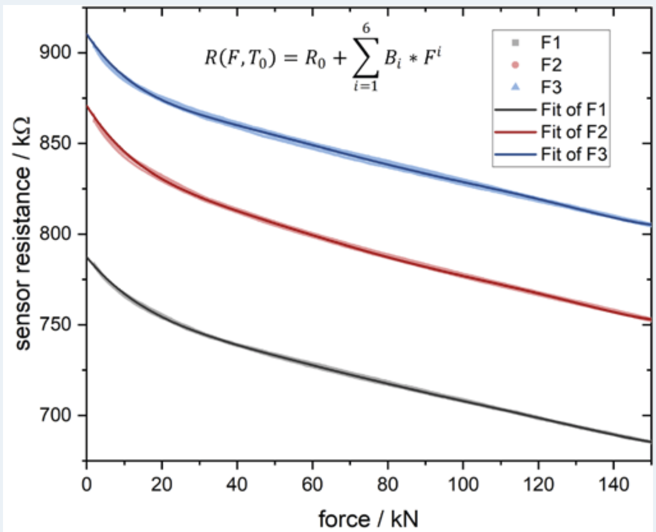
Physical dimensions (add-on version)

Washer		
46 x 10 mm		AF* x height (hexagon)
Electronic module		
46 x 37 mm		AF x height (hexagon)

Physical dimensions (full screw)

46 x 61.5 mm		AF x washer bottom side to heat sink top side
46 x 44.3 mm		AF x washer bottom side to antenna top side
M18		thread

* AF = width across flats



Resistance [kΩ] of three pressure sensors (F1, F2, F3) on the washer as a function of the force [kN]

Contact

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