RFID & Sensor Technology

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RFID & Sensor Technology

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Document history

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1.0.2	13/12/2022	Final Review
1.0.3	04/01/2023	First published version in German language
1.0.4	27/05/2024	Supplement the document with the working papers reference projects, questions for the sales team, FAQ list to avoid unnecessary support effort
1.1.2	12/09/2024	Final review of the new version - which is now also available in English.
1.1.3	01/10/2024	Final version (also available in English for the first time)

1. About This Document

This document describes the basic structure of an RFID transponder with sensor functionality (sensor transponder), the required peripheral devices (RFID system) and is intended to provide interested parties with assistance in planning, configuring and using the system.

Furthermore, the paper contains application examples and best practices for the use of RFID transponders with sensor functionality and is intended to serve as inspiration for solving problems from many areas of industry and logistics / intralogistics with the help of "RFID with sensor functionality" technology.

2. Target Group

Interested parties, potential users and anyone who would like to utilize the possibilities and advantages of this technology for themselves and their company.

3. Standards And References

ISO/IEC 18000-2

ISO/IEC 18000-3

ISO/IEC 18000-4:2018

ISO/IEC 18000-63

EPCglobal Class 1 Gen 2

ISO/IEC 15693 and ISO/IEC 14443

4. Definition And Scope

This paper explicitly only considers the combination of RFID transponders with sensor technology. Other transmission media and technologies (e.g. battery-supported BLE, LoRaWan, etc.) are characterized by different requirements and boundary conditions and are not considered here. However, similar applications can be realized with these technologies.

5. Standards

RFID applications are operated in several frequency bands which are internationally harmonized. The technical requirements are defined in standards, with different requirements for the LF, HF and UHF ranges.

The air interface and the protocols for transponders in the LF range (120...134 kHz) are described in the ISO/IEC 18000-2 standard. The ISO 11784 and ISO 11785 standards also applicable for animal identification. While the identification function is standardized here, proprietary solutions have so far prevailed for the additional integration of sensors, e.g. for recording the body temperature of animals.

For HF (13.56 MHz), the transmission standards ISO/IEC 15693 and ISO/IEC 14443 and ISO/IEC 18000-3 apply.

The globally valid standard ISO/IEC 18000-63 (last update 11/2021) is available for UHF (840...960 MHz) and in particular for sensor transponders. Chapter 8 of this standard describes the different degrees of complexity of the sensors.

The ISO/IEC 18000-4:2018 standard is available for RFID systems that operate in the 2.4 GHz band (especially for item management).

6. General Intended Use

A sensor transponder is based on a combination of RFID technology (LF, HF or UHF) and connected sensors. The sensor records measured values of physical variables such as pressure or temperature or, in the simplest case, binary signals from (e.g. inductive) sensors or mechanical switches.
The measured values can be stored on the RFID transponder and read out using RFID readers.
The great advantage of this combination is that the basic function of RFID technology, namely item identification, can also be used (multi-use) and offers real added value.
In addition, the memory of the RFID transponder can be used to store device-based information (electronic type plate), calibration data for the sensor technology or a production or maintenance history. Typical areas of application for sensor transponders are manufacturing processes in which process parameters on rotating or mobile components need to be monitored or adverse environmental conditions such as vibration, shock or temperature make wired transmission difficult or even impossible.
In logistics / intralogistics, sensor transponders offer the possibility of monitoring processes, e.g. to ensure consistent quality (e.g. in cooling chain monitoring).

The contactless and non-visible contact transmission of sensor values using RFID is therefore a robust, low-maintenance and durable solution.

7. Naming Convention

Common synonyms for "RFID transponder" are "tag" and "mobile data storage device". RFID read/write devices are also referred to as "transceivers" or "readers". These terms are used interchangeably in this document.

8. Introduction

RFID (**R**adio **F**requency **ID**entification) has become an integral part of modern production in the industrial sector, as well as in logistics / intralogistics and our private everyday lives.

The advantages of RFID are obvious.

The contactless identification technology, which is insensitive to many environmental influences, works without visual contact between an RFID transponder and reader and thus enables the realization of identification even in environments with adverse conditions where, for example, a high degree of soiling, moisture, vibration, etc. exists.

The second major advantage over optical identification technologies such as 1D barcodes, QR codes and data matrix codes is the rewritability of the memory. This allows object-based identification to be combined with object-related, decentralized data storage.

The workpiece therefore not only carries its own identifier, but can also provide additional data such as required production steps, process data or even sensor data.

RFID is therefore THE enabler for IoT / IIoT in industry and logistics.

Sensors are the cornerstone of modern production; they record operating states (condition monitoring), record digital or analog measured values and thus make it possible to quickly adapt process parameters and react to changing requirements as well as avoid system downtime (predictive maintenance).

The intention is to combine contactless RFID technology and sensors in one device and replace the wired data transmission path with a so-called air interface.

This combination allows an object to be linked to an unchangeable number for identification, while the data memory is used for other application scenarios such as storing a maintenance history and simultaneously transmitting the sensor data via the air interface.

9. Functional Principle of Passive Sensor Transponders (Without Their Own Energy Storage)

A sensor transponder without its own energy storage needs the (electro-) magnetic alternating field of the reader to be supplied with energy. The measured values are recorded and transferred to the reader.

It is possible to spatially separate the location of the measured value recording from the location of the measured value transmission. This means that there is a reader at the location where the measured values are recorded, which only provides its (electro)magnetic field to supply the sensor data carrier. The measured values are stored in the memory of the data carrier.

A reader is then available at the point of measured value transfer, which reads out the stored data.

If the application requirements allow, it is recommended that the measured values are recorded using passive sensor transponders. The reasons for this are, for example, the simpler implementation and the more cost-effective and lower-maintenance design of the sensor transponder compared to semi-passive RFID transponders.

10. Functional Principle of Semi-Passive Sensor Transponders (With Their Own Energy Storage)

A sensor transponder with its own energy storage does not require any energy from the reader's transmission field to record measured values (self-sufficient operation). The measured values are recorded, stored and transferred to the reader at a later time.

Depending on the type of energy storage device used to supply a semi-passive sensor transponder (e.g. capacitor, gold cap, accumulator), it can be charged while the sensor transponder is in the detection range of the reader. This method is more common for inductively coupled systems in the LF and HF range, whereas the possible energy transfer of the alternating electromagnetic field is usually too low for UHF.

Other energy sources can also be used to recharge the energy storage unit: using existing, ambient energy such as temperature (differences), movement, pressure or light (energy harvesting).

The type of energy source used to operate the sensor transponder as well as the energy source used for charging determine the duration of the charging process.

11. Basic Structure of an RFID Sensor Transponder

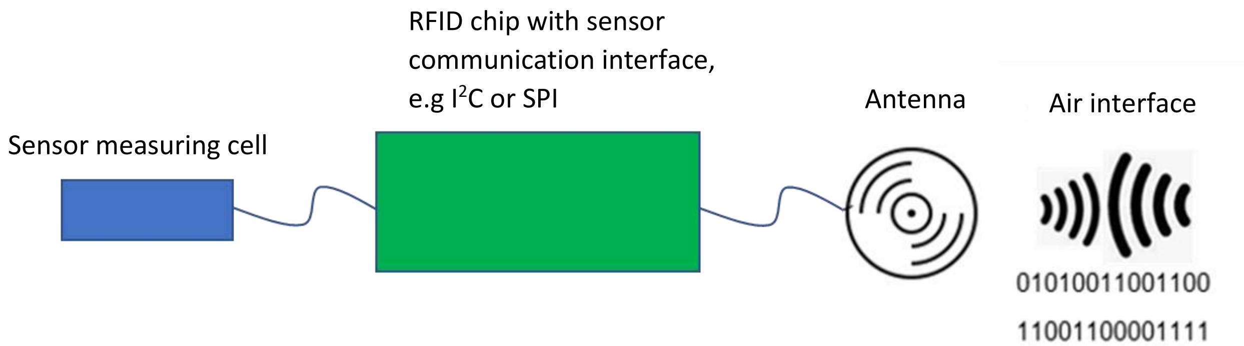


Figure 1 Basic structure of an RFID sensor transponder

The sensor can be a simple binary element (e.g. closing contact, inductive sensor) for detecting "target present" or a measuring cell that detects temperatures or pressures, for example. With UHF, it is also possible to generate measured values by detuning the transponder's antenna.

12. Basic Structure of an RFID System

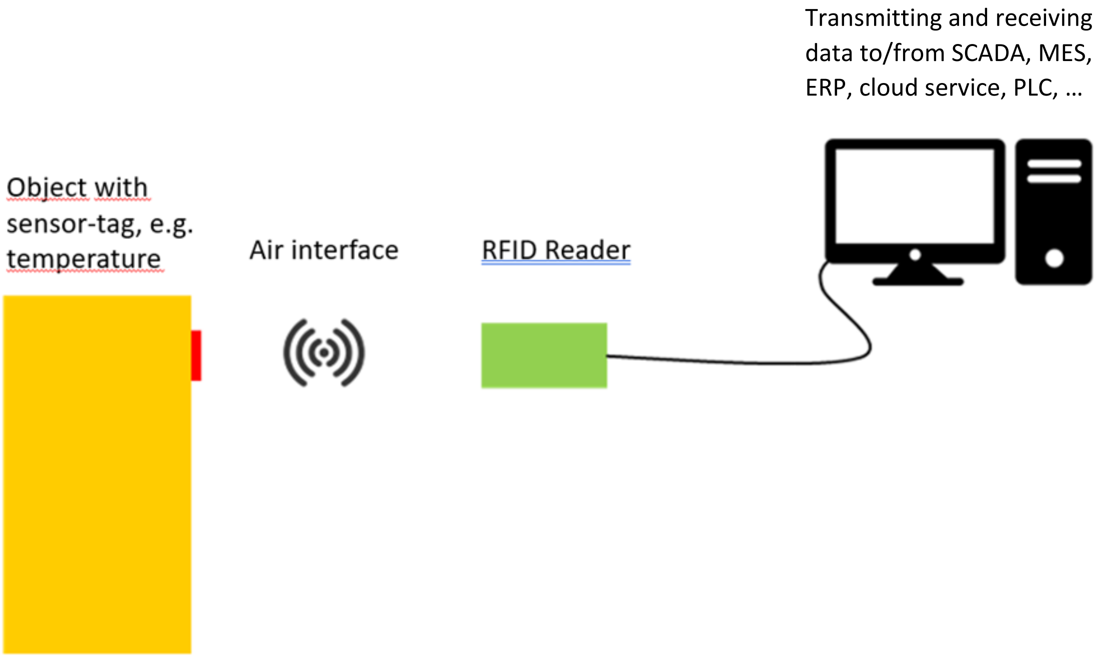


Figure 2 Basic structure of an RFID system

The sensor data carrier records the measured values, which are transmitted to an RFID reader via the air interface. The data are then sent to an application for processing or display.

13. Basic Structure of a SAW-based RFID Sensor System

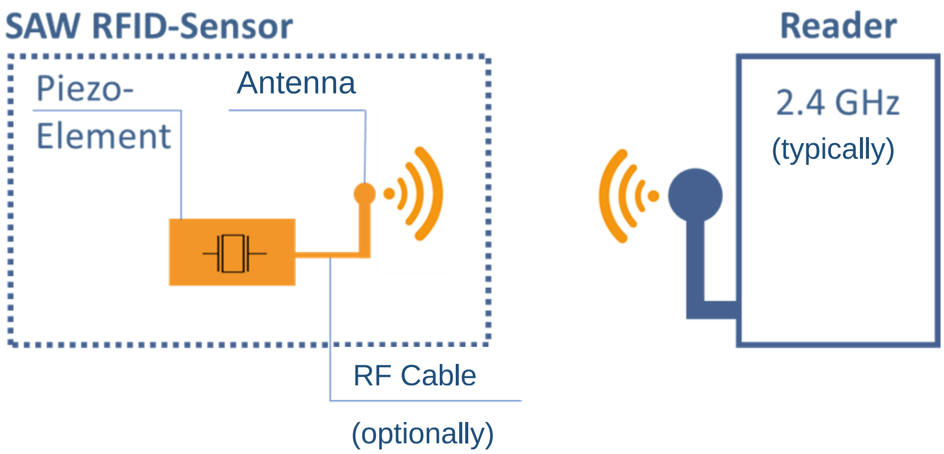


Figure 3 Basic structure of a SAW-based RFID sensor system

A SAW RFID sensor consists of a characteristically vibrating piezo element (also known as an ID tag) that is galvanically connected to an antenna. The electromagnetic reader signal is converted into an acoustic wave (Surface Acoustics Wave: SAW) in the sensor, modulated with the measurement signal and reflected back as an electromagnetic signal. Optionally, an RF cable of variable length can also be connected between the sensor and the antenna. The SAW resonator oscillates depending on temperature, pressure, strain, etc.

This sensor principle is characterized by a very compact and lightweight design. The transponder is robust, passive and analog, i.e. it does not require any circuits. In summary, SAW RFID sensors have the following properties:

- Compact and lightweight
- Passive and analog
- Robust and particularly temperature-stable
- No latency, very fast query
- Coexistence with Bluetooth and WLAN
- Read Only RFID

SAW RFID sensors are typically scanned in the broadband ISM band at 2.4 GHz. There are also SAW sensor systems that operate at 433 MHz or 868 MHz and 960 MHz, whereby only the sensor value is transmitted at these frequencies (without an identification number).

14. Transmission Range

Depending on the power and frequency, the transmission range extends from a few millimeter to less than one meter in the LF and HF bands and up to several meters in the UHF range.

However, component tolerances, the installation situation in the application, ambient conditions and the influence of materials (especially metal and liquids) can cause the achievable distances to vary significantly.

Frequency:	LF (available worldwide, minor national restrictions)	HF (available worldwide, minor national restrictions)	UHF (available worldwide, please note that there are different frequency regulations per region)
Range	up to typ. 10 cm	up to 1 m	up to a few m
Transmission principle	Inductive	Inductive	Far field
Antennas	Coils, often many windings with ferrite	Coils, often air coils with a larger diameter	Depending on application and environment, common antennas (patch, dipole...)
Impact of environment	Rather low	Low to moderate	Moderate to high

15. Protection Class

The ambient conditions have a direct influence on the protection class of the sensor transponder. An application in a dry, clean environment can possibly be achieved with an open or covered flexible antenna structure, such as those used for inlays or labels. An application in a harsh industrial environment requires devices with higher degrees of protection (e.g. IP67, IP69k), which may only be ensured by full encapsulation or encapsulation.

16. Temperature

A distinction may need to be made between the sensor element and the RFID part. It must be taken into account whether the sensor and RFID part are located in one housing or are connected to each other by a cable and can therefore be installed separately from each other.

If the sensor is a passive element (e.g. PT100 for temperature measurement), it can be used at higher temperatures. If the sensor is an active element (digital measuring cell), the maximum permissible temperatures according to the specification must be taken into account, just as with the RFID part. Common limits for microelectronic components are temperatures up to 85°C or 125°C.

SAW RFID sensors can currently be read at temperatures of up to 250°C to 400°C, depending on the design. This applies to both the sensor element and the transmission element.

17. Technical Aspects

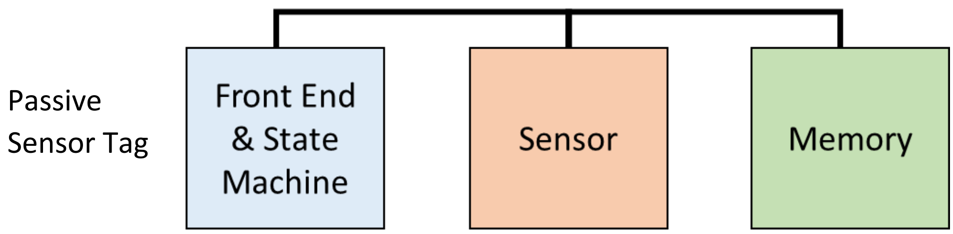


Figure 4 Passive Sensor Tag

The input block (front end) of an RFID transponder is connected to the antenna and converts the alternating electromagnetic field emitted by the RFID reader into a DC voltage to supply the electronics. The electronics also demodulate the information transmitted by the reader via the alternating field and execute the corresponding commands. In the opposite direction, the transponder responds in the LF and HF band with a "load modulation" in which the emitted magnetic field (inductive coupling) of the reader is modulated. In the UHF band with electromagnetic far-field conditions, the transponder response is transmitted in the backscattered signal (backscatter).

With a passive sensor tag, both the transponder block and the connected sensors are powered from the field. There is no energy storage. Only if an RFID reader is present, energy is available to record, store and transmit measured values to the reader. This works well with simple sensors and permanent installations where the sensor tag is constantly in the field generated by the reader. The commands received from the reader are often executed in a special low-power logic unit (state machine).

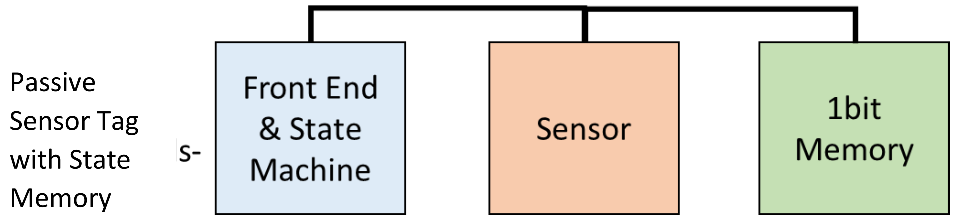


Figure 5 Passive Sensor Tag with State Memory

In many cases, it is only important to record whether certain limit values are violated during a measurement, i.e. whether a defined threshold has been exceeded or not reached. In this case, only one status value needs to be saved. This is also referred to as a retentive sensor.

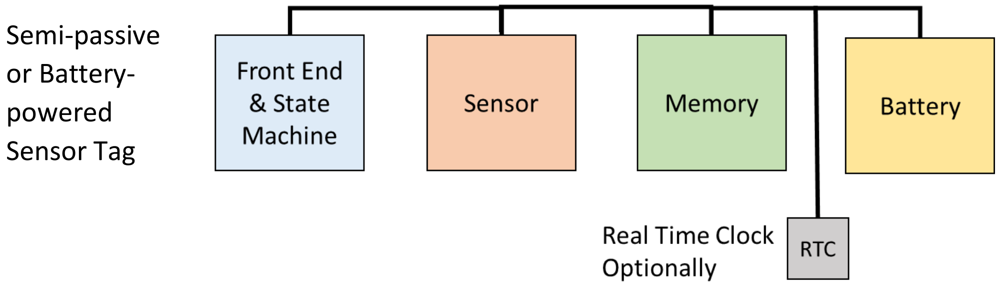


Figure 6 Semi-passive or Battery-powered Sensor Tag

If the demands on the sensor and therefore usually also the energy requirement increase, the possible energy supply from the field is usually no longer sufficient. A sensor transponder with a built-in energy storage unit becomes necessary. If the transponder part continues to draw its energy from the reader field and only other function blocks such as the sensor and memory are supplied from the internal energy storage unit, this is referred to as a semi-passive sensor transponder. Semi-passive transponders are the method of choice when regular measured value recording is required for a mobile application where the transponder is only located in a reader field for reading. An example of this is cooling chain monitoring, where the sensor transponders are only read with readers at individual stations (gates) along the way. However, the measurements must be taken at much shorter and regular intervals. In many cases, a battery is used for the energy storage, which is superior in terms of capacity and reliability to other previously mentioned energy storage systems, especially in extreme environmental conditions and measurements over a longer period of time. In the case of complex and expensive sensor tags, the battery is often replaceable. If it is not, the use of the sensor tag is limited by the service life of the battery.

In semi-passive transponders, in addition to a state machine, the logic unit also uses low-power microcontrollers (µC), which have a wider range of functions and also process the measurement data supplied by the sensor.

Especially when a large number of measurements are carried out over a longer period of time – e.g. in cooling chain monitoring, which typically takes up to 4 weeks - and the measured values need to be saved, the exact time at which each individual measured value was recorded is often of interest. Here, simple clock generators such as RC oscillators are not sufficient in terms of accuracy and a quartz-stabilized time base (Real Time Clock RTC) should be integrated. This would also be fed from the internal power supply of a semi-passive sensor transponder.

The aim is to ensure that sensor transponders can also be operated with standard RFID readers. While the ID function of a transponder is sufficiently standardized, this has only been partially achieved for the sensor function to date. This may be due to the dynamic development of an ever-growing number of sensors for recording mainly physical variables, but also to the extensive data that describes such a transducer. It is usually not sufficient to simply store the digital measured values in raw form without also providing information on the physical quantity (unit), measuring range and time stamp of the measured values.

The validity of the sensor's measured values depends on various factors.
Internal voltage fluctuations, which are particularly common with passive sensor tags, can influence the measurement data or even completely corrupt the validity of the data. Such errors must be intercepted by suitable measures.

In the case of semiconductor sensors in particular, the typical accuracies specified by the manufacturing process are often not sufficient, meaning that the sensors also need to be calibrated. It should be possible to store the corresponding calibration data in the sensor transponder, with the option of carrying out recalibrations, e.g. to counteract ageing of the sensors. If the digital measured values in the memory are provided with a CRC, "bit tippers", for example, can be detected and corrected if necessary. "Outliers" can be detected by comparing them with the permissible measuring range using a plausibility check.

When it comes to security-relevant applications of sensor transponders in the broadest sense, the sensor data should be protected against falsification and the transmission of the data should also be protected. Encrypting the data already in the transponder and transmitting the encrypted data to the reader - if necessary continuously up to the end application - protects the transmission path. Digital signatures can ensure that the measurement data actually originates from the desired sensor transponder. Unauthorized access, e.g. to the calibration data, can be made more difficult by using passwords stored on the transponder.

18. Binary Status Detection

Ring Transponder Clutch with Sensor

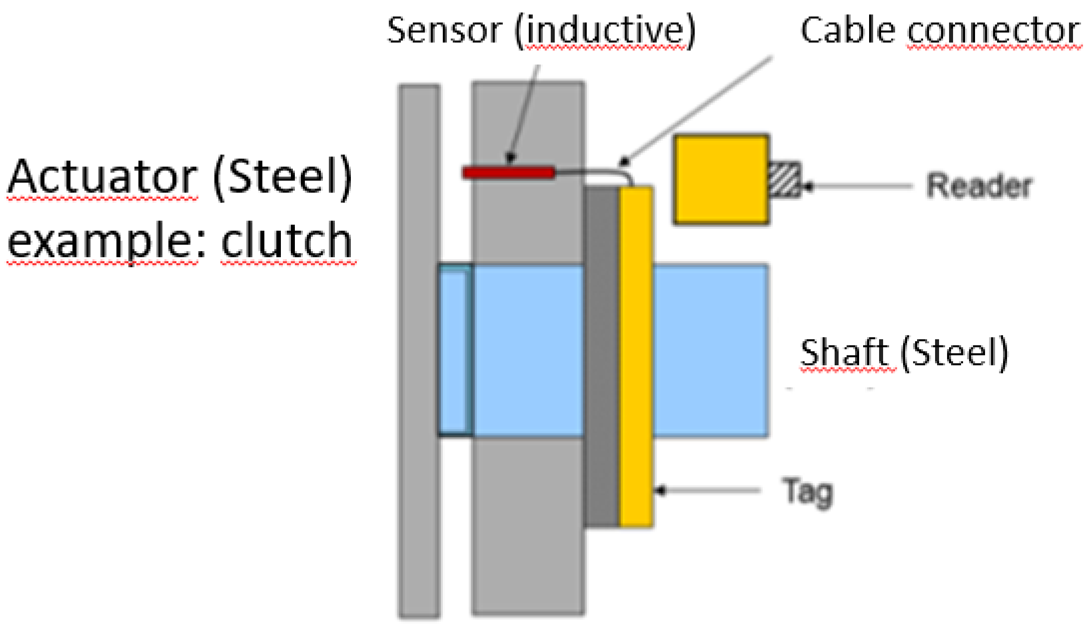


Figure 7 Application Example Binary Sensor Clutch Monitoring

In this example, the inductive sensor detects the actuating plate of a clutch. This 1-bit information is transmitted contactlessly to the reader via the RFID part.

Other examples of binary status detection are

- *Fill level detection on containers*
- *Monitoring of correctly actuated interlocks*
- *"Digital" sealing, tamper proof*

19. Temperature and Pressure Measurement in Agitators / Centrifuges

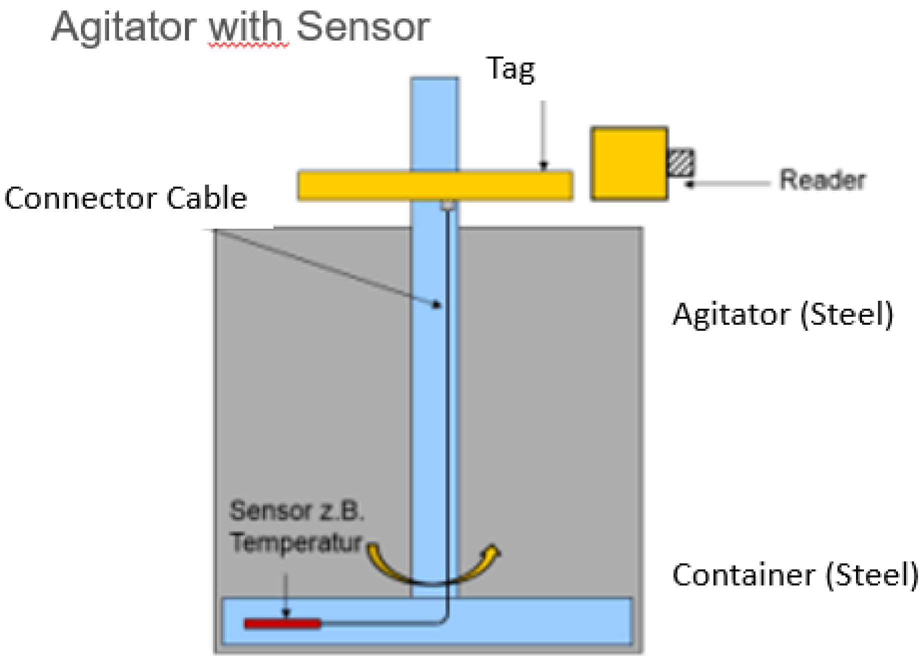


Figure 8 Application Example Agitator

In this example, the sensor detects the temperature or pressure in an agitator / medium.

20. Temperature Measurement on Cooling or Heating Rolls in the Paper and Steel Industry

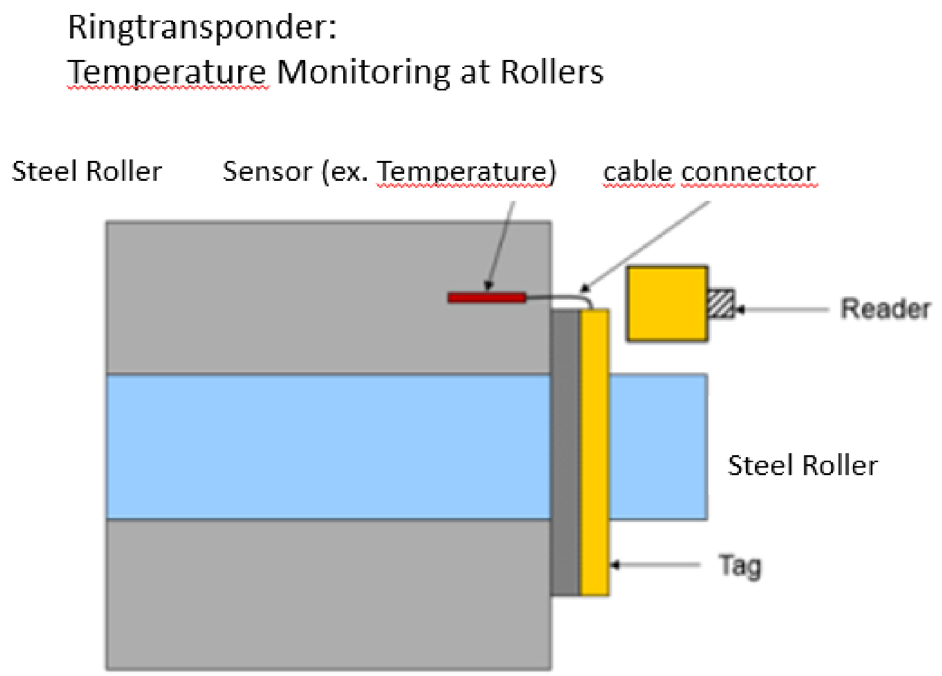


Figure 9 Application Example Roller temperature monitoring

In this example, the temperature sensor measures the temperature of the roller; or more generally, the sensor data carrier replaces expensive and vulnerable slip rings for transmitting any measured values. Maintaining the correct temperature range is extremely important in many applications with cooled or heated rollers.

21. Temperature Monitoring of a Sealing Jaw

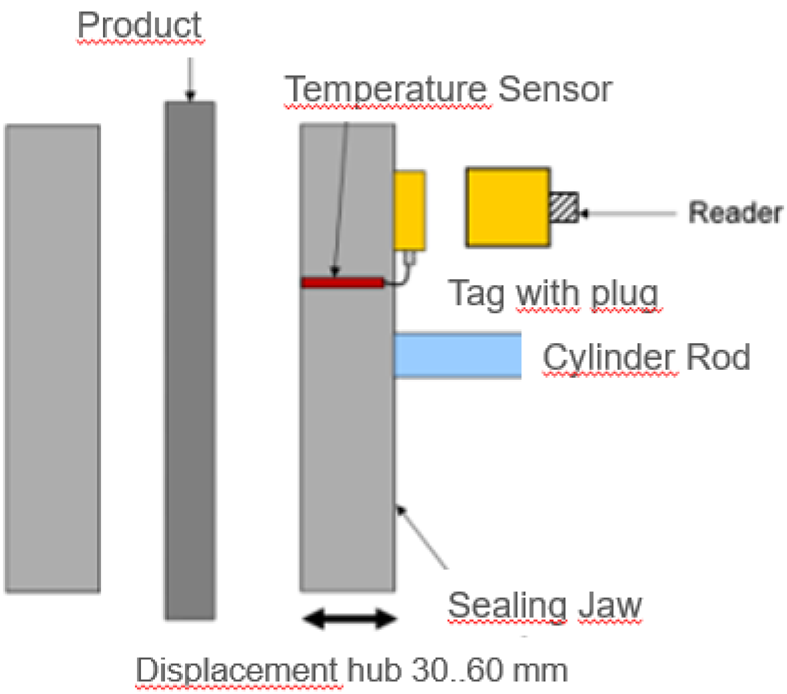


Figure 10 Application Example Sealing Jaw

In this example, the sensor data carrier records the temperature of a sealing jaw. This application is characterized by a high failure rate when using standard sensors (cable based). This is due to the stroke and the load on the cable connection.

22. Vacuum Feed-Through

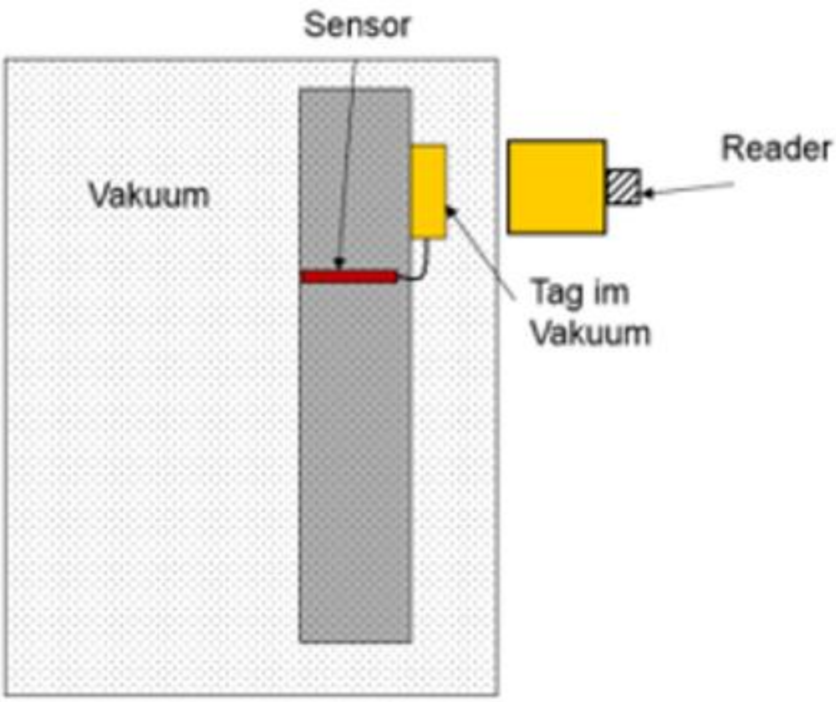


Figure 11 Application Example Vacuum Feed-Through

In this example, the sensor data carrier detects any physical variable (e.g. pressure, temperature) within a closed, inaccessible space. This can also be a room / container that is no longer accessible after loading and sealing (e.g. autoclaves, vacuum casting systems).

23. Moisture Detection

Figure 12 Application Example Moisture Detection

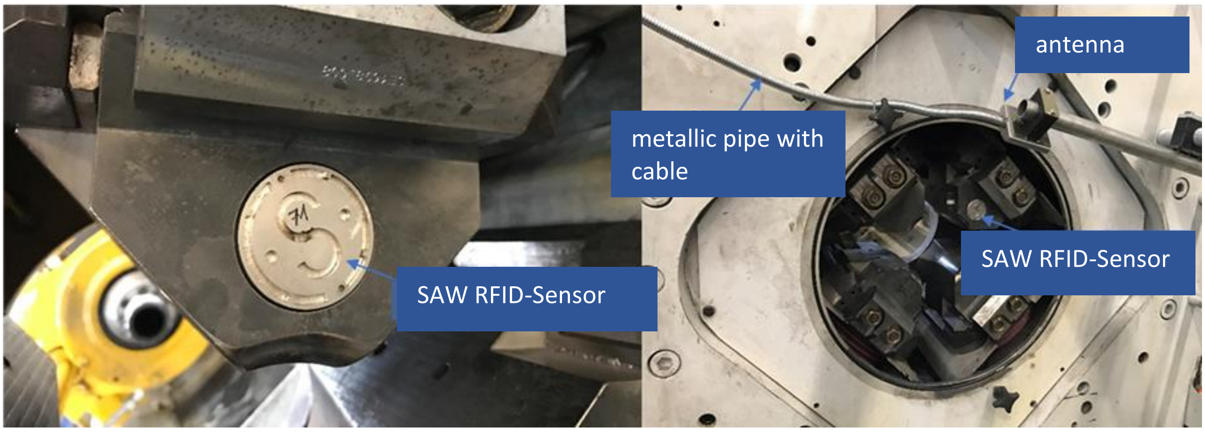
Picture: Avery-Dennison

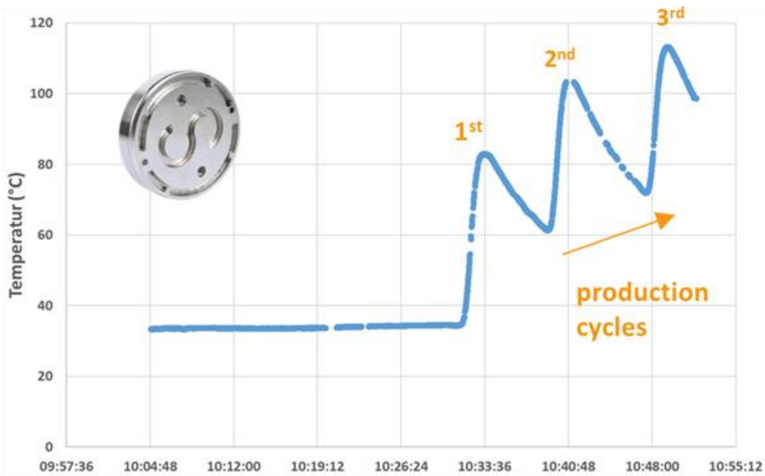
In this example, a passive UHF data carrier detects moisture by resistive measurement via the tag's antenna or capacitive detuning.
Application examples:

- *Leak testing in the automotive sector (bodywork)*
- *Building condition monitoring (e.g. roofs)*

24. Application example for SAW RFID sensor systems

SAW-RFID: Application example Rotational Forging





Characteristics:

- Enables IoT in heavy duty industry
- Condition Monitoring
- Predictive Maintenance

Application areas:

- Forges and foundries
- Reflow and soldering ovens
- Hardening of electronic components

Figure 13 Application Example SAW Temperature Monitoring

In this example, the temperature of rotating forging tools (rotary forge) is measured in situ using a SAW-based RFID sensor.

25. Attachment

I. Reference Projects RFID Sensor Data Carriers

The following section presents some reference projects that have been categorized according to the following criteria:

1. Classification / Market segment
2. HF/UHF?
3. Radio and protocol standard (e.g. ISO15693, ISO 18000-63 EPC global Gen 2)
4. Which physical quantity is recorded (e.g. pressure, temperature, binary state)?
5. Application description
6. Which technologies have been used so far?
7. Concept, Proof of Concept (PoC)?
8. What problem is solved by using wireless transmission?
9. Software effort / integration into existing / to be created systems / infrastructure

Reference Project 1: Seed Quality Monitoring

1. Industry / manufacturing / seed producers
2. HF
3. ISO15693
4. Temperature
5. A sensitive product, in this case seeds, is temporarily stored in stainless steel containers in a chaotic and dynamic high-bay warehouse. To ensure high quality standards, the seeds must be stored under safe climatic conditions. A key criterion here is the temperature inside the stainless steel containers. For this purpose, the temperature of the seed must be measured directly in the containers.
6. Previously, the sensor values were transmitted using contact pins of the sensor on the container and a contact pad located at the storage location. However, due to the corresponding mechanical wear, reliable permanent transmission was not possible. Furthermore, if the container was not 100% positioned, no contact was made and no measured values could be transmitted. If the contacts were dirty, there was also no functional reliability.
7. Contactless and visual contact-free identification of the objects with simultaneous measured value transmission was required.
8. The sensor data carrier guarantees high availability of identification without manual intervention and, thanks to the contactless transmission of energy and measured values, permanent and traceable quality assurance. In addition, the product can be identified using the RFID sensor data carrier, thus supporting chaotic warehousing. The shortest route within the fully automated warehouse can always be selected.
9. In addition to maximum availability, data security is also required. After all, if a controller including the database fails, the seed may no longer be usable. For this reason, a second controller is used to provide Profinet S2 system redundancy. If a PLC fails, the second controller automatically takes over control of the process.

The sensor data carriers are supplied pre-configured to initialize the measurements and read out temperature values using standardized write and read commands in the memory area of the RFID data carrier.

Reference Project 2: Leakage Measurement in a Vehicle

1. Industry / manufacturing industry / automobile manufacturers
2. UHF
3. ISO 18000-63 EPC global Gen 2
4. Moisture detection
5. After the final assembly of a vehicle in automotive production, a so-called rain test is carried out. This is to detect any leaks in the vehicle.
For this purpose, the car body is fitted with self-adhesive data carriers that react to moisture at relevant points during the production process. The moisture is detected by a change in the relative impedance of the data carrier.
Before the vehicle enters the sprinkling chamber as part of the final inspection, it first passes through an RFID gate that detects all data carriers. After irrigation, the vehicle exits through a second RFID gate, which again reads all data carriers. If moisture has penetrated at any point, the system detects a discrepancy between the two readings and sends a corresponding error message to the user's MES system. Affected car bodies can thus be directly ejected and reworked.
6. Until now, a worker has carried out measurements with a suitable hand-held device. Here, measuring tips are pressed into the carpet at the lowest points in the foot area/floor area to detect moisture. This manual process required the worker to have the relevant experience of where water could accumulate in the bodywork.
7. Automated recording ensures unambiguous and reproducible results. For this purpose, a defined number of sensor data carriers are affixed to the lowest points in the footwell before the carpet is laid.
8. The automated process guarantees a consistent result in terms of the evaluability of the result and a high level of repeatability. The manual process was too uncertain to allow further conclusions to be drawn about production defects. By using the sensor data carriers, the quality measures carried out could be clearly verified.
9. The reproducibility was first checked using handheld readers, i.e. without integration into higher-level systems. The PoC was then carried out using permanently installed UHF readers (gate) to detect the moisture.

Reference Project 3: Temperature Measurement at a Moving Object

1. Industry / Plant engineering
2. SAW 2.4 GHz
3. ETSI EN 300 328
4. Temperature
5. The sensors are connected to rotating slides inside PVD plasma chambers and scanned wirelessly. The very compact and modular design allows the use in any type and geometry of plasma chambers, even as a retrofit in existing systems. In contrast to conventional temperature markers, the temperature information is obtained directly during the process so that the process can be monitored and controlled.
6. Previously, the temperature of the process was checked retrospectively using temperature markers. Some system manufacturers also use slip ring systems to pick up the sensor signal on the rotating part in the system. However, this can only be used to measure systems with one axis of rotation (single rotation).
7. The system is based on SAW sensor technology at 2.4 GHz. The passive and analog technology offers maximum reliability and precision. The measuring system is extremely robust, it is protected against electrostatic discharge (ESD) and has excellent electromagnetic compatibility (EMC).
8. Until now, it has not been possible to measure the temperature of the multiple rotating parts to be coated in-situ, i.e. during the process. A retrospective check requires many experimental tests for process development. Measurement on the external carousel is inaccurate. With the wireless sensor system, the temperature of the object to be coated can be recorded precisely and accurately for the first time. This allows the process to be monitored, optimized and controlled.
9. Parameters must be set, especially for monitoring the signal strength and filtering the data. Success factors are also the correct positioning of the sensor antenna, the read antenna and a good thermal connection of the sensor to the object to be coated. The necessary components are a rod sensor with sensor antenna, optionally designed as a module with cable adapter, a reading antenna, an SMA vacuum feed-through as well as a SAW reader for 2.4 GHz and an SMA cable. The connection to the control system is made using Modbus, for example.

II. Questions for the Sales Team

Explanation:
If an initial meeting is held with a potential user, then this procedure should be followed and important information should be collected for the project manager.

This table is intended as a guideline and can be modified or extended as required.

Question	**Yes / No**	**Comment**
Do you already have an application that works wired?		Yes: Would you like to implement this wirelessly now? No: What data would you like to collect? Highlight the advantages of wireless use
What does the application look like?		
Do you know the ranges of the various wireless technologies?		Technology has physical limits. Classification of the ranges per technology (sensor transmission can significantly reduce the specified ranges): LF < ~0.15 m HF < ~1.0 m SAW (2.4 GHz) < ~15 m UHF / BLE < ~30 m
What data would you like to record?		Solutions currently in use: Temperature, pressure, humidity, torque. Further sensors on request
What is the range of these data (min/max)?		Depending on the respective sensor
What accuracy do you need for data acquisition?		Product-specific - information from the customer is important for product selection.
How often should the data be recorded?		The higher the measurement rate and/or the transmission frequency, the higher the energy requirement.
What reach should be achieved?		Limit sensible ranges. Longer distances, over 10 meters, probably require other technologies.

How much data should be recorded, how many sensors are available?		Several tens of sensors can be detected simultaneously with one receiving antenna = "bulk detection". Do you want to detect several sensors simultaneously?
Is there metal nearby?		Radio waves have limitations/distortions in the vicinity of metal. Narrowing down the physically possible use cases
What service life is planned?		10 years is a reasonable value at “normal” temperatures. Take into account aspects like: Service life of the sensor, the battery, the overall system. Is recalibration necessary?
What is the added value of a wireless solution compared to a wired solution?		Ideally, the wireless solution should provide added value, e.g. recording sensor values on rotating, moving or difficult-to-access parts. Greater flexibility and expandability of the sensors is another advantage. If a wired solution is possible, it is probably more cost-efficient.
Is a solution without an external power supply possible?		Not every sensor system requires an additional power supply. Depending on the type, the complete sensor system can also be supplied by the UHF / HF energy via the air interface. The runtime of systems with additional power supply depends on many factors, e.g. transmission cycles, measurement cycles, ambient conditions, etc.
Cost framework?		Business case validation!

III. FAQ List to Avoid Unnecessary Support Effort

It has been shown that in an initial meeting with a potential future user, questions are asked that always go in the same direction. Therefore, the typical questions were collected and provided with the recommended answers.

1. Question: How accurate is the sensor technology?
Answer: As with any sensor application, whether wired or not, it depends on the sensor product. The details can be found in the product specification.

2. Question: Does the sensor data carrier have to be in the area of the read zone to transmit the sensor value?
Answer: Yes, for transmission on the air interface, the sensor data carrier must be located in the area of the read zone, the antenna field. Depending on the design, the actual sensor, possibly connected to the sensor data carrier with a cable, may be located somewhere else.

3. Question: What is the maximum distance between the sensor system and the antenna?
Answer: In general, it can be assumed that the transmission ranges of BLE, UHF RFID and SAW systems are greater than those of HF RFID systems. Typically, distances for BLE, UHF and SAW applications will be in the single-digit meter range. HF applications are typically in the centimeter range.

4. Question: How many measured values can the sensor system buffer / store?
Answer: This depends on several factors, such as: resolution / type of sensor system, power supply, number of measurement cycles, memory size, etc.

5. Question: Can several sensors be read out in bulk?
Answer: Yes, in principle this is possible. The final number of sensor data carriers that can be read simultaneously with one reader depends on the final application. Typically, such bulk reading can be realized well with UHF RFID. In the HF RFID sector, this is the exception rather than the rule.

6. Question: How fast can measured values be read out and how fast is the repetition rate?
Answer: The transmission rate on the air interface is limited depending on the technology. A repetition rate in the single-digit millisecond range is typically not possible in practice.

7. Question: Can I connect several sensors to one RFID transponder?
Answer: Yes, depending on the type and design, there are corresponding solutions on the market.

8. Question: How long does the power supply of the sensor system last?
Answer: Not every sensor system requires an additional power supply. Depending on the type, the complete sensor system can also be supplied by the UHF/ HF energy via the air interface. The runtime of systems with an additional power supply depends on many factors, e.g. transmission cycles, measurement cycles, ambient conditions, etc.

9. Question: Do I need a line of sight between the sensor / transponder and the antenna?
Answer: Visual contact is not necessary. However, depending on the technology, various materials can have an influence on the transmission range. Typically, metallic / HF-conductive materials and, in the UHF range, liquids also significantly restrict transmission.

10. Question: Does the sensor system work with every reader or is this a manufacturer-specific solution?
Answer: In general, UHF and HF technology is standardized by international standards regardless of the manufacturer. However, the interaction of different sensor data carriers and readers (including antennas) depends on several application-specific parameters and should therefore be clarified with the manufacturer in each individual case.