infrasolute
smart infrastructure monitoring

# Sensor Failure Analysis

For assessing the operational lifespan of a sensor system, the following points are important, along with conducting corresponding tests:

- Failure analysis of all electronic components (FIT/MTBF)
- Possibilities for sabotage (EMP)
- Failure probability (Data-Retention) of the storage medium used
- Prevention of water ingress (capillary suction) into the interior of the system
- Mechanical robustness of the sensor
- Susceptibility of transmission
- Data security
- Declaration of conformity

## Failure analysis of all electronic components (FIT/MTBF):

The FIT value (FIT = failure in time) describes the failure rate of technical components, particularly electronic components. Using the FIT values of individual components, the failure probability of complex devices can be calculated. In the absence of redundancies, it is assumed that the failure of any individual component leads to the failure of the entire device. The sum of the failure rates of the individual components thus determines the failure rate of the entire device.

The FIT method yielded the following results for the corrosion sensor/moisture sensor: 23.0.

Converting to the MTTF value (Mean Time To Failure = average operating time until failure) results in a duration of over 200 years for the corrosion sensor/moisture sensor.

To further increase reliability, the following measures have been taken:

- Redundant system across 2 wire levels.

- Prior to data transmission, the signal amplifier is checked, and its functionality is conveyed.

The warranty/guarantee periods are not affected by the values mentioned in this document.

*Source: IMS Fraunhofer Institute*

## Possibilities for sabotage (EMP):

Electronic components can be destroyed by electromagnetic pulses (EMP). Such pulses can be generated by machinery or deliberately.

Tests were conducted without negative results using a power of 5.1 joules in a time period of less than 1 millisecond.

*Source: IMS Fraunhofer Institute*

## Lightning Influence

Electronic components in exposed installation locations (bridges, open decks, marine structures) can either be directly struck by lightning or be affected by voltage increases in the reinforcement area due to a lightning strike on the building. The corrosion and moisture sensors are mounted directly on the reinforcement of the reinforced concrete. A pulse-like current flow through the reinforcement grid generates a rapid buildup and breakdown of the magnetic field around the reinforcement steel, thereby inducing a current in the transponder coil. Due to the lack of normative requirements, testing is conducted according to generally specified limits in the literature. Here, a current surge of 50 kA is applied.

The test was conducted without negative results.

*Source: IMS Fraunhofer Institute*

## Standard Influences (EMC) for the Overall System

Electronic systems are influenced by a variety of interference factors:

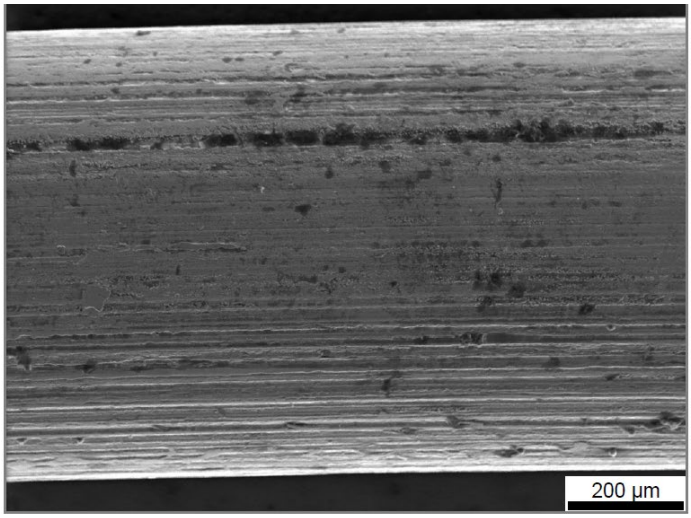
- Inherent immunity (internal EMC), i.e., immunity to internal electrical variables
- External immunity (external EMC), immunity to electromagnetic interference from external devices
- Interference emission level describes the conducted or radiated interference emitted by a device/system.

Tests according to EN 1326-1/EN 61326-1/EN 300330-1-V1.7.1/EN 300330-1-V1.7.1 were conducted without negative results.

*Source: IMS Fraunhofer Institute*

## Prevention of Water Intrusion (Capillary Absorption) into the Interior of the System

Moisture and water disrupt or damage all electronic systems. A water molecule has a size of 25 nanometers. To prevent water from penetrating electronic assemblies, they are encapsulated with a resin. Resins (one or two components) are always long-chain molecules. These do not prevent capillary absorption along a wire, as the wire manufacturing process creates grooves of 20 to 100 micrometers. In the "CorroDec 2G" system, the intrusion of water along the individual wire entry into the sensor housing is prevented with the aid of a special nanotechnology acting as a water barrier.




**Probenbehandlung:**

**Probenlage:**

**Hochspannung:**
20 kV

**Detektor:**

**Archiv-Nr.:**
0806A01019

**Abb. 8:** **Probe 3,**
Oberfläche Draht 3

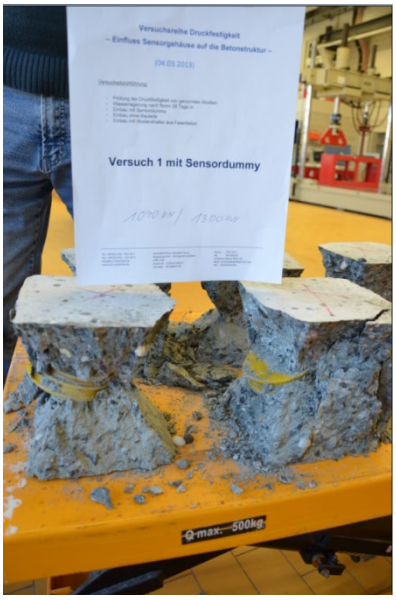
## Mechanical Durability of the Sensor

After installation, sensors are subjected to high mechanical loads, allowing them to withstand direct passage of cars/trucks. The following load assumptions are considered:

Car: 10 kN / 20 cm²

Truck: 96 kN / 40 cm² (contact area of the tire)

Test series with a load of 400 kN/cm² were conducted without damaging the systems. Additionally, the risk to the concrete structure (weakening of statics) was considered. Proper installation of the sensor systems (parallel to the concrete surface) is a prerequisite.




## Data Security

Ensuring the security of data is paramount in any system. Measures are taken to safeguard against unauthorized access, manipulation, or theft of sensitive information. This includes encryption protocols, access control mechanisms, regular security audits, and compliance with relevant data protection regulations. Additionally, continuous monitoring and updates are implemented to address emerging threats and vulnerabilities.

*Source: IMS Fraunhofer Institut*

## Failure Probability (Data-Retention) of the Used Storage Medium

Smart sensor systems, due to their diverse tasks (acquiring and analyzing measurement data, data transmission, internal checks, temperature measurements, etc.), must be controlled by internal software (firmware). Besides the processor, the most important component is the storage unit, as it stores the operating system. To ensure an extremely long lifespan, it must be ensured that even individual occupied memory locations do not lose their information (so-called Data-Retention). The manufacturer conducts tests for this and provides the information to end customers through datasheets.

The data retention warranty is defined by the manufacturer to be over 40 years. This value is multiplied through regular readouts.

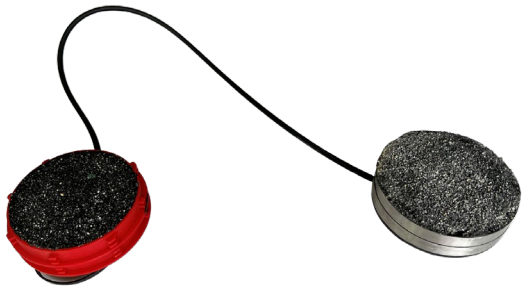
*Source: Texas Instruments*

## Influence on Transmission

The sensor system utilizes an extremely low frequency as its transmission medium. Due to this low frequency and the employed data protocol, susceptibility to interference is very low. The following possibilities have been tested:

| | |
|---|---|
| Steel reinforcement (connection with wire tie) | Low influence |
| Steel reinforcement (welded connection) | High influence |
| Operation underwater | Moderate influence |
| Operation under metal-coated sealing | Limited communication possible |
| Operation adjacent to another RFID Reader | Very high influence |
| Embedded in concrete | No influence |

Note: Susceptibility can be eliminated with special designs (separation of communication part from the sensor).



*Source: IMS Fraunhofer Institut*

## Declaration of Conformity

In accordance with EC Decision No. 765/2008 and 768/2008 "General Principles of the CE Marking," the manufacturer or importer declares that the product complies with the applicable requirements set forth in the harmonization regulations of the European Community concerning its affixing.

In particular, for the "Corrosion Sensor" and "Moisture Sensor" products, the following standards apply:

- ESD according to EN 61326-1
- Immunity to interference according to EN 61326-1
- Emission of interference according to EN 300330-1-V1.7.1

*Source: IMS Fraunhofer Institut, Infrasolute*

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| Ihr Zeichen | Ihre Nachricht vom | Unser Zeichen | |
|---|---|---|---|
| | | GvB | Duisburg, 25. September 2014 |

Abschätzung der Lebenserwartung der elektronischen Schaltung "Betontransponder"

Sehr geehrter Herr Seuss,

im Rahmen des ZIM-Projekts „Entwicklung eines technologisch neuen Sicherheits- und Überwachungssystems für Korrosion an Beton- und Schachtbauwerken mit erstmaliger Fernabfrage" (kurz Betontransponder) wurde eine Abschätzung der Lebenserwartung der elektronischen Schaltung durchgeführt. Betrachtet wurde dabei der Teil des Systems, für den Fraunhofer IMS verantwortlich ist: die Leiterplatten des Betontransponders, also die komplette elektronische Schaltung. Nicht betrachtet wurden Einflüsse der Verkapselung, wie Vergussmasse und Gehäuse, die ggfs. durch mechanischen Stress Einfluss ausüben könnten.

Die Untersuchung gliedert sich in 2 Punkte:

- einer Abschätzung der Ausfallrate nach dem FIT-Verfahren (Failure in Time), die die Betriebsbedingungen wie Temperaturwechsel und auftretende Ströme auf Bauteil und Leiterplattenebene berücksichtigt und
- einer Betrachtung des Datenerhalts von Speicherzellen.

**FIT-Verfahren**

Dem FIT-Verfahren liegen die folgenden Normen zugrunde:

- Bauelemente FIT und Applikationsbedingungen: SN_29500
- Leiterplatten FIT: IEC TR 62380

Das FIT-Verfahren wurde mit den folgenden Parametern durchgeführt:

- durchschnittliche Temperaturschwankungen 30 °C
- Anzahl der Temperaturwechsel im Jahr 365
- Durchschnittstemperatur 25 °C
- Spannung der BE (Durchschnitt über Alle) 3,3 V
- Strombelastung der Gesamtschaltung 4 mA

Eine Eigenerwärmung des Systems durch den elektrischen Betrieb wird nicht berücksichtigt, da die auftretenden elektrischen Leistungen minimal sind und zu keiner signifikanten Erwärmung führen.

Das FIT-Verfahren lieferte die folgenden Ergebnisse:
Gesamtausfallrate:

- Feuchtetransponder 17,2
- Korrosionstransponder 23,0

Die Ausfallrate entspricht aufgrund der extrem niedrigen Aktivzeiten dem des Ruhezustandes. Dieser geht von Bauelementen, die in der Norm nicht spezifiziert sind von 0.1 (=Kondensator) aus. Damit ergibt sich insgesamt eine sehr niedrige FIT Rate für das System. Die Umrechnung in den MTTF Wert (Mean Time To Failure = mittlere Betriebsdauer bis zum Ausfall) ergibt für beide Transpondertypen eine Dauer von über 200 Jahren.

**Datenerhalt**
Die Betrachtung des Datenerhalts von Speicherzellen bezieht sich auf die Herstellerangaben des Bausteins, in dem die Speicherzellen enthalten sind. Um auch eine niedrige Ausfallrate zu für die Speicherzellen zu erzielen, wurde die FRAM-Technologie verwendet, die laut Hersteller folgende Zeiten für den Datenerhalt erfüllt:

- Betrieb bei 25 °C Datenerhalt 100 Jahre
- Betrieb bei 70 °C Datenerhalt 40 Jahre

Diese Angaben sind entnommen aus: http://www.ti.com/lit/an/slaa526a/slaa526a.pdf

Somit kann aufgrund der statistischen Angaben eine Gesamtlebenserwartung von über 40 Jahren abgeschätzt werden.

Mit freundlichen Grüßen

Dr. Gerd vom Bögel

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