
Digital eBook
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# IoT Design & Development

INSIDE:

TND6221/D

# Challenges of Implementing Industrial IoT Technology


## ABSTRACT

The Internet of Things (IoT) is the culmination of progression that has been made within a number of different interrelated technology disciplines in recent years. Through major advances in wireless connectivity and sensing, as well as support given by processing, control and power management devices, the stage is now set for IoT to start seeing widespread deployment in both consumer and industrial spheres. The purpose of the following white paper is to look specifically at Industrial IoT (IIoT). It will describe the commercial dynamics and market trends that are defining this particular sector. In addition, it will give details of the various design issues being faced by engineers as they look to develop and implement IIoT systems, then explain how these challenges may be overcome.


**Keywords:** IoT, IIoT, IDK, Cloud Data, SaaS, IaaS, PaaS, Sensors, Actuators, Connectivity, IoT Operating System, IoT Protocols, LPWA, SIGFOX.

## INTRODUCTION

Industry analyst firm MarketsandMarkets estimates that by 2022 the global IIoT business will be worth around $195 billion annually. There are many factors that will drive this growth, but the principle ones are for companies to be able to:

1. Gain from more efficient working practices – through access to and subsequent analysis of the large quantities of data derived.
2. Respond quicker to incidents that might occur which could otherwise have costly or dangerous outcomes –such as a fault arising or some deviation in an industrial process.
3. Be notified more quickly for places where maintenance (or other preemptive measures) might be required to prevent faults that could impact operations in the long term.

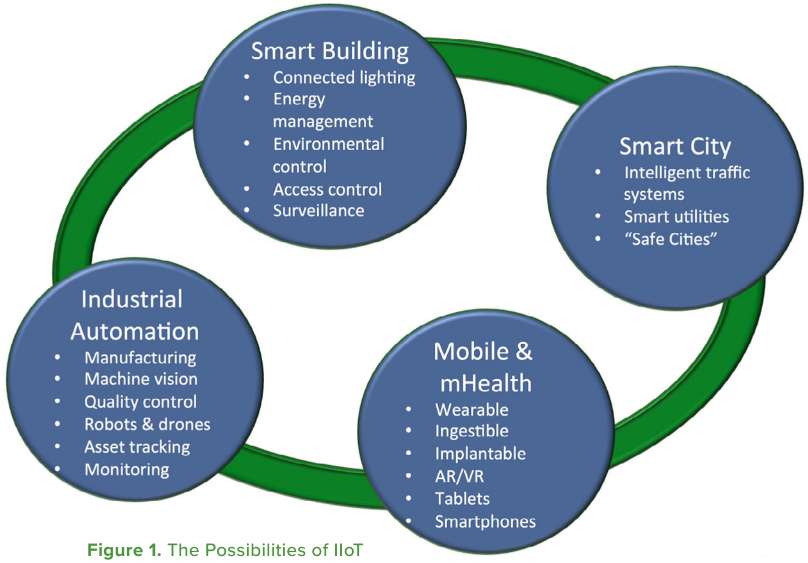


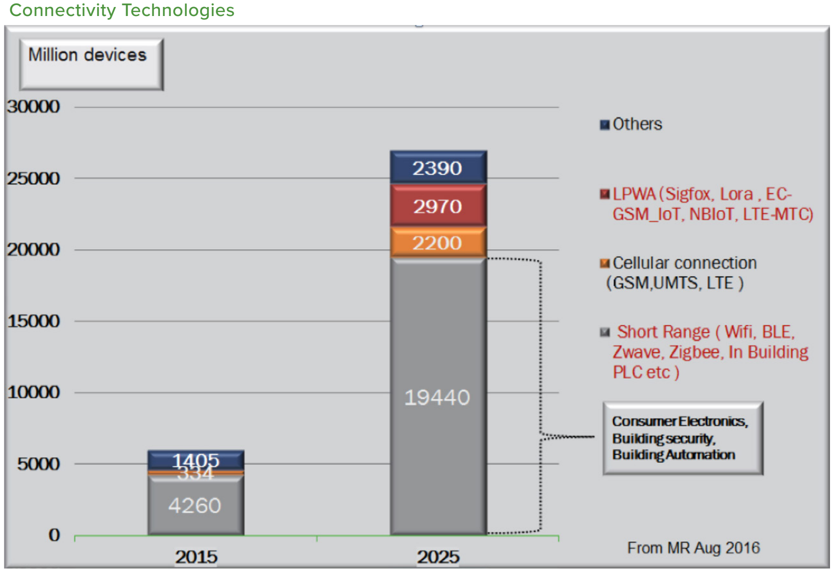

**Figure 1.** The Possibilities of IIoT

# Challenges of Implementing Industrial IoT Technology

continued

IIoT can enable higher degrees of automation and thus raise productivity. It can also help companies to broaden the array of services they can offer, heighten safety, avoid downtime (and the financial expense associated with this), better control their assets and also become more ecologically responsible. As we will see there are fundamental technologies that will form the basis of IIoT implementations – these are connectivity, sensors and actuators.

**Figure 2.** Breakdown in Prevalence of IoT Connectivity Technologies




## CONNECTIVITY

Predictions about the number of connected IoT nodes that will be in operation vary quite considerably. Table 1 gives a detailed summary of the forecasts being made by different organizations. The most ambitious suggest there will be 50 billion by 2020, while others claim 20 to 30 billion is a more realistic figure by that stage (though they expect the 50 billion mark to still be reached or even surpassed, just further into the next decade). What is certain is that there will be tens of billions of objects being connected to the Internet over the course of the next few years and around 50% of these will be for some type of industrial application. There are a multitude of different connectivity technologies offered that will support IIoT. Some of these are already established, while others are still in the process of emerging. They include traditional industrial wireline protocols (such as CAN bus, FieldBus, Hart, KNX, Ethernet, MBUS and PLC), as well as wireless protocols. The wireless connectivity options can be categorized as either cellular-based ones that cover the wide area network (like LTE–M and in the future, 5G) or short-range power-efficient ones (like Wi-Fi®, LoRa, ZigBee®, Z-Wave® and BLE) for 'last mile' implementation.

Table 1.
**NUMBER OF CONNECTED IoT NODES BY 2020**

| ORGANIZATION | IOT NODES |
|---|---|
| Business Insider | 24 billion |
| Gartner | 21 billion |
| IDC | 30 billion |
| Goldman Sachs | 28 billion |
| GSMA | 50 billion |

## ACTUATORS

IIoT presents an opportunity to control different mechanisms remotely via cloud-based automation infrastructures, including activating lighting, driving of motors, opening/closing actions, etc.

# Challenges of Implementing Industrial IoT Technology

continued

The advent of smart lighting and smart motor control will have real tangible benefits to society, in terms of greater convenience and marked energy savings. Li-Fi communication technology, for example, is now permitting the ability to interface with what were previously conventional standalone actuators.

## SENSORS

Likewise, the capture of data through instrumentation will be pivotal to making system deployments effective. Different sensor technologies can be employed in an IIoT context, providing valuable insight – on the temperature at which an industrial process is being conducted (to ensure that it is running correctly), the ambient light and moisture levels in a large commercial greenhouse (to check that conditions are correct to allow maximum crop yield), or nitrogen-oxide content in gas leaving the exhaust flu of an industrial boiler. Outside the industrial engineering sector other types of sensors can be utilized for different tasks that are still categorized under the IIoT umbrella. In building automation, passive infrared devices can be used to provide motion detection, for controlling the lighting/heating or alternatively for security purposes. In healthcare, sensor technologies will allow remote monitoring of parameters, such as blood glucose levels, etc. This will result in significant improvements in the quality of patients' lives, as they will be able to spend less time in hospitals/clinics. For sensor-connected networks, the power consumption of the object is likely be significantly less than will be the case for connected actuators, hence battery-powered objects will represent the vast majority of deployments. This is likely to prove critical to IIoT proliferation, as many applications will rely on sensors that have been deployed in remote locations (and therefore sending engineers out into the field to regularly replace batteries will be uneconomical). The power consumption and connection range of the radio interface will potentially represent a significant impact on the lifespan of the battery (so BLE and other ultra-low power RF protocols will be preferable). In some cases energy harvesting will be employed to take care of the power supply problem, enabling batteries to simply be dispensed with.

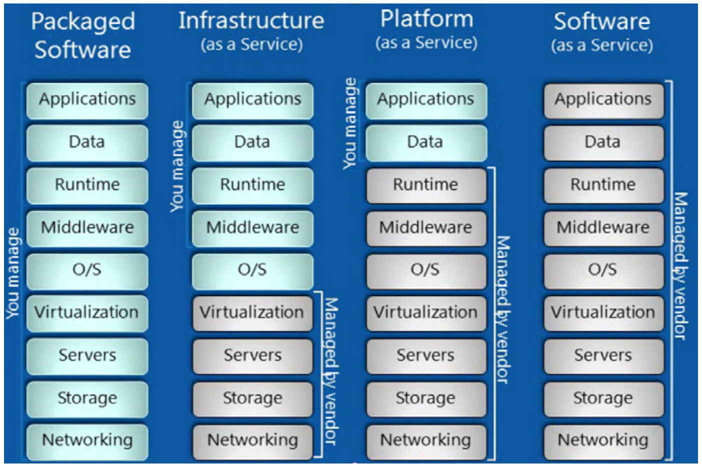



**Figure 3.** Itemization of Service Offered per Category. *Source: VentureBeat*

## PRACTICALITIES OF IIoT DEPLOYMENT

In addition to the limitations placed on IIoT hardware due to battery-powered operation, the electronics located at each node is likely to have other constraints. The large number of nodes deployed could mean that low bill of materials (BOM) costs need

# Challenges of Implementing Industrial IoT Technology

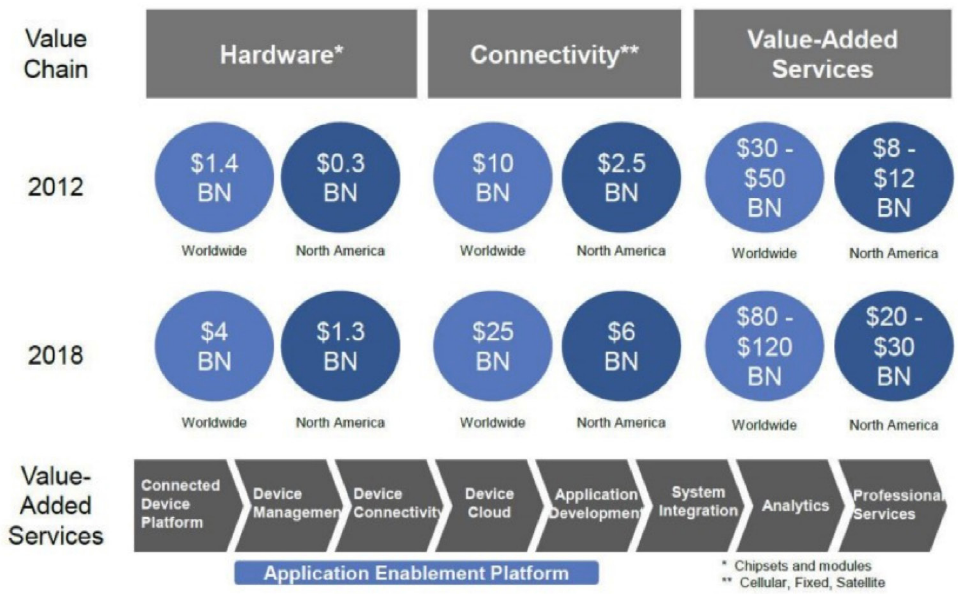
continued

to be adhered to. Furthermore, available space may also be restricted. These factors mean that often IIoT objects will generally have only limited microprocessor and memory resources that they can draw upon. Consequently, their construction must be as sleek as possible, with no excess functionality incorporated.

## CLOUD SERVICES & SUPPORTING INFRASTRUCTURE

The cloud will be the foundation upon which IIoT data processing and storage activities are reliant. In the realm of consumer IoT, the data that is captured and transported to the cloud may be required for marketing analysis (for example), without any subsequent involvement from the user. In contrast to this, however, IIoT-based data (concerning industrial processes, confidential medical records, etc.), must be managed under extremely strict control procedures and with authorization of the owner of this data. To mitigate the potential threat of industrial espionage, hacking or even acts of terrorism, a fully secured service offering needs to be employed – this can either be software as a service (SaaS) or platform as a service (PaaS) based.

WANT MORE? CLICK HERE for the complete technical note




## WATCH THE VIDEO:

**IoT SYSTEMS AND SOLUTIONS AT A GLANCE PART 1**

In this part 1 webcast, we will discuss the macro market trends we are observing as we work with our partners, customers, and engineering teams.

TND6269/D

# Creating a State-of-the-Art, Cost-Effective Energy Harvesting Bluetooth Low Energy Switch

## INTRODUCTION

As IoT rapidly grows into new markets such as Mhealth, agriculture 4.0, and building automation, new questions are being raised about the energy required to support its growth. Within the industry, we see a broad spectrum of power requirements. On one end, we have (relative to the number of IoT nodes) a small number of cloud servers with very high power requirements. These are running 100% of the time resulting in huge energy budgets. At the opposite end of the IoT ecosystem we have a huge number of end nodes with limited power demands and typically little up-time when they are active and demanding an energy source.

In June 2018, The World Material Forum 2018, held in Nancy, France, had a dedicated session titled: “Big Data/AI for Materials Efficiency”. The paper presented by a Stanford Professor named Reinhold Dauskardt gave the following indicators:

“The Annual power consumption of US-only Data centers is estimated at 90 Billion kWh. This is equivalent to 34 nuclear power plant reactors of 500 MW, or exactly half of the nuclear power plant capacity of France (some 56 Reactors).”

Underlining the power demand of data centers/cloud computing server resources further is the statistic that in 2017 3% of worldwide electricity consumption was accounted for by data centers. That might be perceived by some as a low percentage, but driven by the world’s insatiable hunger for the creation, consumption and movement of data, there is a kind of Moore’s law that can be applied to the energy consumption of data centers, that is that it will double every four years. At this pace, if nothing changes, then theoretically, by 2037, computers will use more electric energy than the current worldwide production. Reinhold Dauskardt continued and then concluded: “A huge challenge ahead of us for the 20 next years, is to reduce the energy footprint of the IoT by designing objects that are connected to the Internet AND disconnected from the electric networks. They must be electric-friendly, autonomous and use any source of energy one could think about such as vibration, heat and light.”

On the end-node side, as previously hinted, predictions give several tens of billions of nodes will be deployed by 2021. Each of them will have very low power consumption and combined with limited up-time, this can result in low individual energy budgets, which is good. But the dramatic proliferation still correlates to potentially very high global power consumption.

# Creating a State-of-the-Art, Cost-Effective Energy Harvesting Bluetooth Low Energy Switch

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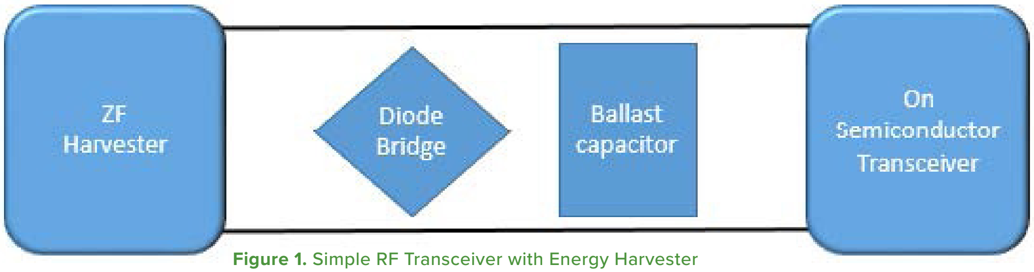



**Figure 1.** Simple RF Transceiver with Energy Harvester

## ENERGY HARVESTING USING BLUETOOTH LOW ENERGY

One source of alternative energy is Bluetooth Low Energy. Application examples which can implement this technology include wall and lighting control, building automation, and asset tracking.

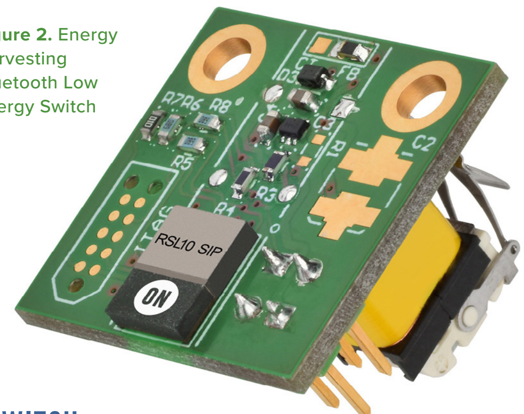
ON Semiconductor's RSL 10 radio is a Bluetooth 5 certified System-on-Chip that supports Bluetooth Low Energy and has been awarded the industry's best EEMBC® ULPMark scores for power efficiency (1090 ULPMark CP @ 3 V; 1260 @ 2.1 V). Together with ZF, we have partnered to produce a Bluetooth Low Energy switch reference design for battery-less IoT applications that is entirely self-powered by a mere 300 J. With the Bluetooth Low Energy frame protocol being as short as 10 ms, a total energy budget of less than 100 Joule is required. The comparison between the harvested 300 J and the required 100 J transmit budget is obvious.

The RSL10 Bluetooth Low Energy switch reference design implements a smart and low cost power supply schematic. Conventional transceivers need more than 2.5 V of power, substantially more than what is required using RSL10. Additionally, they require complicated implementation of energy harvesting consisting of expensive Buck/Boost converters, EMC radiating coils, and costly timing generation to limit radio-frequency interactions within tiny form-factor sensor nodes.

The RSL10 switch reference design removes these issues by enabling direct connectivity of the harvester to the transceiver using a low drop diode bridge with filtering capacitor.

With the compact design of the transceiver that we have been able to achieve it becomes easy to integrate every element in a small form-factor battery-less switch while supporting Bluetooth Low Energy (Bluetooth 5) transmission. This smart hardware design provides reduced Bill of Materials (BOM), improved layout flexibility, and easier upgradeability after the application is released to market.

**Figure 2.** Energy Harvesting Bluetooth Low Energy Switch




## ZF SWITCH

In a world where the number of networks is increasing, requirements for information transmission are also changing. Transmission must be mobile and flexible, while using as little energy as possible. The solution is energy harvesting wireless switches from ZF. They are easy and effective to use, without any cables or batteries.

# Creating a State-of-the-Art, Cost-Effective Energy Harvesting Bluetooth Low Energy Switch

continued

Due to its miniature construction, the high efficiency in the functional chain, and its long life expectancy of up to 1,000,000 switching cycles, the ZF wireless switch needs only a small amount of power for operation with no maintenance required – and can be installed in a tight space.

This environmentally friendly system has numerous advantages: You have the flexibility to install a switch without cabling in any location you want, where it will fulfil its function over the entire length of its service life without any maintenance or battery changes. In contrast to information transmission via cables, the self-powered wireless switch is also attractive for building services because it's easy to retrofit. For example, you can install new light switches in a freshly decorated room without having to cut any holes in the wall.

There are also numerous possibilities for use in industrial automation, particularly when the time it takes to lay cables is disproportionate to the application. Here again, the energy harvesting wireless switch serves as a cost effective, battery-less alternative to cable based micro switches.

**Technical Specifications:**

- **Inductive generator:** The energy required for data transmission is created by the mechanical actuation of the switch. Energy generated: 2× min. 0.33 mWs
- Miniature design combined with extremely high energy output
- **Long mechanical life:** minimum 1 million switch operations
- Mono-stable/Momentary design: Switching mechanism returns to starting position after release (pushbutton)
- **Bi-stable/Latching design:** Switching mechanism with two rest positions (e. g. On/Off switch)
- **Dimensions:** 20.1 × 7.3 × 14.3 mm
- **Temperature range:** –40 to + 85°C
- No EMC required due to low energy used by the switch

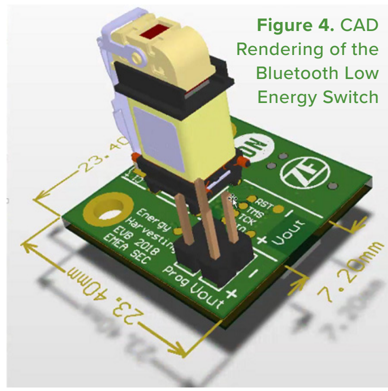


**Figure 4.** CAD Rendering of the Bluetooth Low Energy Switch

## THE EVOLUTION OF ENERGY HARVESTING

As IoT continues to grow, it's clear that manufacturers will continue to seek new ways of improving energy efficiency and alternative sources of energy for entirely battery-less applications which provide lower maintenance, improved wireless range, simpler EMC transmission, and lower

| APPLICATION | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| CONNECTED & SMART HOME | | | | | | |
| HOME AUTOMATION | | | | | | |
| PLUGS/SWITCHES | 14,943 | 23,773 | 38,947 | 65,670 | 97,206 | 143,904 |

**Figure 3.** IHS MARKET Annual Shipment Estimations (Kunits)

# Creating a State-of-the-Art, Cost-Effective Energy Harvesting Bluetooth Low Energy Switch

continued

application cost. IHS Market is projecting a significant growth (CAGR of 57%) of the connected switches for home automation.

Recent introductions by key DIY retail players in the fields of consumer lighting show the mega-trend of wireless switches. But they are battery powered. And they suffer from short lasting life (3 to 6 months), despite all efforts made for improving performance.

Battery-less implementation is definitely removing this restriction.

With an estimated 100 millions switches sold worldwide by 2021, the need for battery-less operations is getting critical for cost and maintenance reasons.

Together with ZF, ON Semiconductor is perfectly positioned to supply the perfect technology fitting the most difficult challenges ahead of us.

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Configure rapid prototyping platform for Industrial IoT, Smart City/ Building, and mHealth application from ON Semiconductor.

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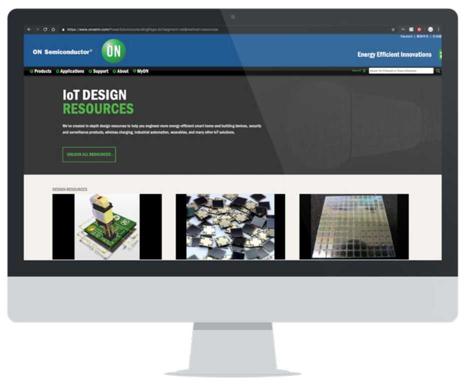


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AND9795-D

# A Brief Introduction to Silicon Photomultiplier (SiPM) Sensors

**The Silicon Photomultiplier (SiPM)** is a low-light sensor that has performance characteristics comparable to a conventional PMT with the practical advantages of a solid-state sensor. The SiPM is well suited to a variety of applications including LiDAR, medical imaging, radiation detection and biosciences.

The SiPM is operated in Geiger-mode which enables high gain ($1x10^6$) at moderate bias (~30 V). This is achieved by creating a high field region in the diode that generates a self-perpetuating charge avalanche when a photon is absorbed. Once a current is flowing through the diode, it should then be stopped or 'quenched'. Passive quenching (i.e. no active circuitry), is achieved through the use of a series resistor which limits the current drawn by the diode during breakdown. This lowers the reverse voltage seen by the diode to a value below its breakdown voltage, thus halting the avalanche. The diode then recharges back to the bias voltage, and is available to detect subsequent photons.

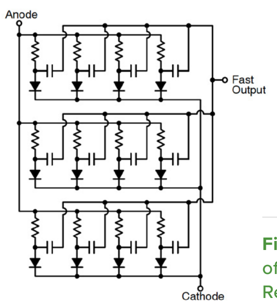



**Figure 1.** A SiPM Consists of an Array of Microcells (SPAD Plus Quench Resistor) with Summed Output

In this way, a single photodiode device operated in Geiger-mode functions as a photon-triggered switch, in either an 'on' or 'off' state. Proportional information on the magnitude of an instantaneous photon flux is not available. A photodiode operated in the Geiger mode is referred to as a SPAD (Single Photon Avalanche Diode).

The SiPM is formed of a dense array of small, independent SPAD sensors, each with its own quenching resistor, as shown schematically in Figure 1. Each independently operating unit of SPAD and quench resistor is referred to as a "microcell". When a microcell in the SiPM fires in response to an absorbed photon, a Geiger avalanche is initiated causing a photocurrent to flow through the microcell.

## VIDEO:

**IOT SYSTEMS AND SOLUTIONS AT A GLANCE PART 2**

In this part 2 webcast, we will introduce the discuss the different market and system requirements needed for an IoT system, and solutions offered by ON Semiconductor that can help you achieve these market and system requirements.

# A Brief Introduction to Silicon Photomultiplier (SiPM) Sensors

continued

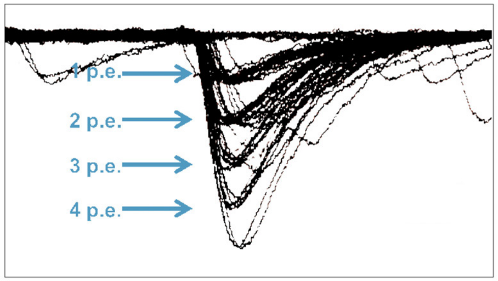



**Figure 2.** SiPM Output when Illuminated by Brief Pulses of Low-level Light, Showing the Discrete Photon Levels

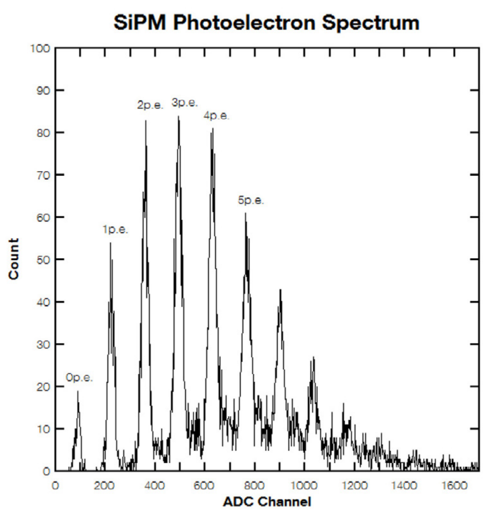


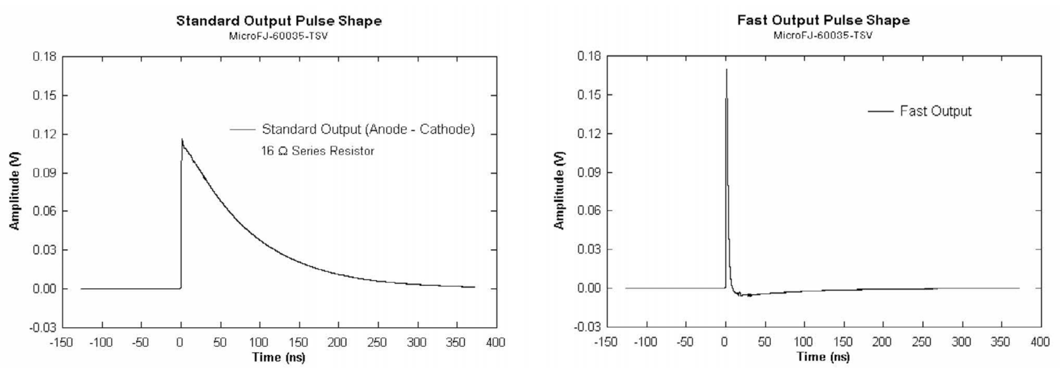

**Figure 3.** Charge Spectrum Showing the Well Defined Single and Multiple Photon Peaks

It is important to note that the Geiger avalanche will be confined to the single microcell it was initiated in. During the avalanche process, all other microcells will remain fully charged and ready to detect photons. The sum of the photocurrents from each of these individual microcells combines to form a quasi-anlog output, and is thus capable of giving information on the magnitude of an instantaneous photon flux. The response to low-level light pulses is shown in Figure 2, and a charge spectrum of these pulses is shown in Figure 3.

## SIPM RESPONSE

The SiPM output pulses are shown in Figure 4. Reading out from the anode or cathode is referred to as the standard output. The recovery time of the sensor is determined by the microcell recharge time constant. This is dependent upon the various capacitances and resistances in the sensor system. Since the capacitance of the microcell will depend upon its area, the reset time will vary for different microcell sizes.





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# Battery–Free Wireless Sensor Measurements

## INTRODUCTION

ON Semiconductor's Battery-Free Wireless Sensor tags powered by a Magnus®–S integrated circuit (IC) produce a Sensor Code which gives information about the sensor tag's environment. To maximize the precision of sensor measurements, the user should understand and account for effects related to the reader transmission frequency and the amount of power received by the sensor tag. This note describes those effects and discusses strategies for addressing them.

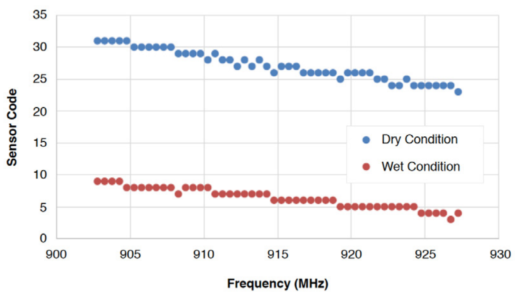


Figure 1. Sample Sensor Code Results for a Moisture Sensor in Dry and Wet Conditions

## FREQUENCY EFFECTS

Legal regulations governing ISO 18000–6C communication forbid readers to transmit on a single frequency for an unlimited time. Before a specified maximum period of time elapses, readers must either turn off or – more commonly – switch to a different frequency within a predefined set of frequencies. Readers can transmit again at the initial frequency after a specified minimum time. When frequency-hopping, readers move between channels in a non-sequential, random-looking order. A Magnus–S IC detects changes in antenna impedance, which can be caused by factors the sensor tag is designed to sense, such as moisture, or the proximity of something metallic. But impedance also depends on frequency, which means that Magnus–S can report different Sensor Codes when it is read repeatedly, as the reader changes its transmission frequency.
Typically, the Sensor Code will vary approximately linearly with frequency, and the line will shift up or down in response to a change in the sensing stimulus. For example, Figure 1 plots the measured Sensor Code as a function of frequency for a battery-free wireless sensor tag designed to sense moisture.

It is possible for Sensor Codes to saturate at their extreme values of 0 or 31. It is a good idea to ignore readings at these extremes to ensure that only data within the dynamic range of the sensor are used in the measurement. Saturation is more likely for sensor tags which exhibit a Sensor Code vs. frequency plot with a large slope (Figure 2). Sensor tags designed to be placed on metal

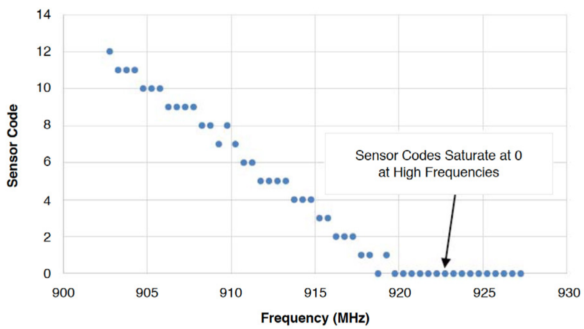


Figure 2. Example Sensor Code Results Showing Saturation at High Frequencies

# Battery-Free Wireless Sensor Measurements

continued

often have this feature.

## SUMMARIZING A SET OF MEASUREMENTS

When the Sensor Code is plotted against frequency, it is straightforward to visually recognize a change in sensor condition. However, it is often preferable to condense the data to a single number which eliminates frequency dependence and focuses entirely on the sensor environment.

Combining results from different frequencies can also average out random noise and improve precision. Table 1 describes three possible approaches to dealing with frequency-dependence and reducing a series of readings to a single number.

Table 1.
TECHNIQUES FOR DEALING WITH FREQUENCY DEPENDANCE

| TECHNIQUE | PROS | CONS |
| --- | --- | --- |
| Use Sensor Code value from one frequency only | • Simplest to implement | • Regulatory requirements prevent continuous transmission at a single frequency; compliance will limit the sample rate<br>• Lack of averaging reduces precision |
| Use the average Sensor Code value over the entire frequency band | • Simplest to implement<br>• Averaging over frequency improves precision and reduces numerical noise | • Must collect enough data to ensure that the frequency range is adequately and evenly sampled to avoid biasing the results |
| Use regression analysis to fit the Sensor Codes to a line, then take the value of the line at some fixed frequency. (See Appendix for details) | • Regression process improves precision and reduces numerical noise<br>• Can achieve good results even when sampling only a fraction of the frequencies in the band | • More complex to implement |

Note that different regulatory regimes have significantly different numbers of frequency channels in them. For example, in North America there are 50 frequency channels, each 500 kHz apart, between 902 and 928 MHz. Under the European ETSI EN 302 208 specification, there are only 4 channels between 865 MHz and 868 MHz. So the time required – and precision gained – by reading the Sensor Code at every channel before producing a result depends significantly on regulatory requirements.

## RECEIVED POWER EFFECTS

When a Magnus–S IC is receiving a low amount of power, the Sensor Code it generates is fairly independent of the precise power level. Once the received power increases beyond a certain threshold, the Sensor Code tends to show an inverse relationship with received power: higher power levels produce lower Sensor Code

# Battery-Free Wireless Sensor Measurements

continued

values. Figure 3 shows a sample plot of the relationship between power and the Sensor Code value, averaged over frequency. Keep in mind that power received by the sensor tag depends on many factors such as distance and antenna gain, not just reader output power.

For applications using low-gain antennas, low-power readers, large minimum separations between sensor tag and reader, or when high sensor precision is not needed, this effect may not be a concern. But in some cases, it will be desirable to ensure that the sensor tag does not receive enough power to significantly affect the Sensor Code. This can be achieved readily by making use of the On-Die RSSI Code.

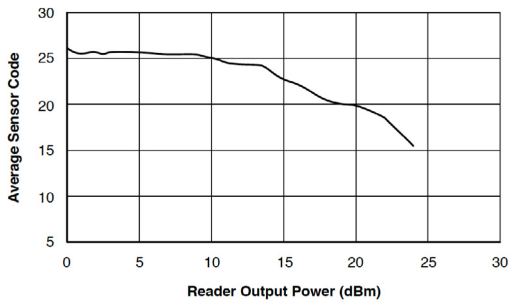


**Figure 2.** Sample Sensor Code vs. Reader Output Power Plot for a Magnus–S2 IC

The On-Die RSSI Code is a 5-bit value (0–31) which can be read from Magnus–S and gives an indication of the amount of power it is receiving. Larger values correspond to higher power. If the On-Die RSSI Code is above the recommended upper threshold given in Table 2, the reader power should be reduced to avoid affecting the Sensor Code.

Table 2.
RECOMMENDED RANGES FOR MEASURED ON-DIE RSSI CODE

| RECOMMENDED ON-DIE RSSI VALUES | MAGNUS-S2 | MAGNUS S-3 |
|---|---|---|
| Upper Threshold (to avoid affecting Sensor Code) | 21 | TBD |
| Lower Threshold, if Achievable (to reduce the chance of missed reads) | 16 | TBD |

It is also desirable to avoid delivering very low amounts of power to Magnus–S, mainly because this increases the chance of reading at some frequencies but not others. This is more likely to occur with readers and/or antennas which exhibit non-uniform radiated power across frequency. In some cases, very low power may also pull the Sensor Code lower, but by a maximum of only about 1 code value. If the On-Die RSSI Code is below the recommended lower threshold given in Table 2, the reader power should be increased, if possible.

In some applications, the power received by the sensor tag can be kept fairly constant (by fixing the placement of the sensor tag and reader and controlling interference in the transmission path). In those cases, the reader power can be preset to a level which achieves the codes in Table 2 and held constant. But often, the reader will be programmed to search automatically for a desirable power level and periodically adjust itself to account for changes in the environment that affect received power.

As noted earlier, higher On-Die RSSI Codes correspond to more received power, up to a maximum code of 31. However, if Magnus–S is receiving very large amounts of power, the power-detection circuitry can become overwhelmed, resulting in unpredictable On Die RSSI values. This should only occur when the reader is transmitting near the upper EIRP limit allowed by regulations, and only when the sensor tag is within a few feet of the reader. But for this reason, when searching for a desirable power level, the reader should start at a lower power and increase if necessary, rather than beginning at maximum power.

# Battery-Free Wireless Sensor Measurements
continued

## APPENDIX

### Review of Linear Regression Analysis

Linear regression analysis offers a straightforward way of summarizing a series of Sensor Code readings taken at different frequencies. Linear regression finds the slope and y-intercept of the line that best fits the measured data, and does not require calculating anything more complicated than an average.

Consider a set of N readings, where $f_i$ indicates the $i^{th}$ measurement frequency $s_i$ and indicates the $i^{th}$ Sensor Code value. Simply calculate the following set of averages:

$$\bar{f} = \frac{1}{N}\sum_{i=1}^{N} f_i \qquad \bar{s} = \frac{1}{N}\sum_{i=1}^{N} s_i$$

$$\overline{fs} = \frac{1}{N}\sum_{i=1}^{N} f_i s_i \qquad \overline{f^2} = \frac{1}{N}\sum_{i=1}^{N} f_i^2$$

The line which fits the data points is given by

$$s = mf + b$$

$$m = \frac{\overline{fs} - (\bar{f})(\bar{s})}{\overline{f^2} - (\bar{f})^2} \qquad b = \bar{s} - m\bar{f}$$

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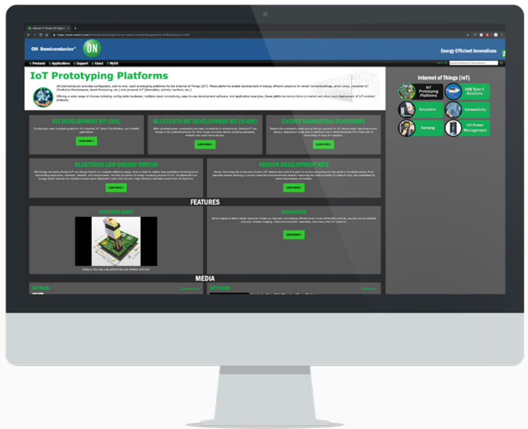
Once the slope (m) and y-intercept (b) of the line are calculated, the value of the fitted line at some fixed frequency (such as the center of the band) can be used to represent the overall measurement.




## IoT Prototyping Platforms

ON Semiconductor provides configurable, end-to-end, rapid prototyping platforms for the Internet of Things (IoT). These platforms enable development of energy efficient solutions for smart homes/buildings, smart cities, industrial IoT (Predictive Maintenance, Asset Monitoring, etc.) and personal IoT (Wearables, activity monitors, etc.)

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# Workflow for an IoT Product

## Detailed Example of a Development Process for a Wireless Alarm System based on Sigfox® Protocol

### INTRODUCTION

In this application note a complete list of process steps is described in order to develop a specific system in the IoT environment. In order to make the description more practical the PIR sensor alarm example is used.

The PIR motion sensor alarm is a product demo developed by ON Semiconductor for detecting movement events and sending messages on a cloud by means of Sigfox network. The following picture shows the finished product. The alarm system is built around two main ON Semiconductor devices: the AX–SFxx–API–y RF microcontroller (Sigfox API stack SW version, xx representing the Sigfox Radio Configuration Zone) and the NCS36000 passive infrared (PIR) detector controller.



This alarm system is only intended for showing capabilities of ON Semiconductor devices and cannot be considered as real monitoring system for smart home applications. It has some limitations that will be discussed in more details in the concept analysis paragraph.

### PROCESS FLOW

The main steps of the process followed for the development of the PIR sensor alarm system are here summarized:

- From Concept Analysis to “System Requirements”, Specification for HW and SW, included Mechanical Constraints
- HW/SW Development and First Prototype Development
- Testing. HW and SW Bug Tracking and Corrective Action for Fixing Potential Issue

# Workflow for an IoT Product

continued

- SW Development for Certification Approval
- Product Prototype Testing
- CE–ETSI regulatory certification
- Sigfox Ready and Sigfox Verified Certification
- Final Production

Most of the steps are practical then they will not be discussed in the document. The main part that will be treated are HW and SW development and certification procedure.

## CONCEPT ANALYSIS

### Scope and Behavior

The alarm system is used for monitoring limited environment, like rooms, detecting movement events. In order to be fully working, it should be placed in an area covered by Sigfox network.
When an event is recognized, a Sigfox message is sent on the cloud and it can be read back by the user accessing the Sigfox backend or, could be read developing a web or mobile application getting access to the SIGFOX backend server.

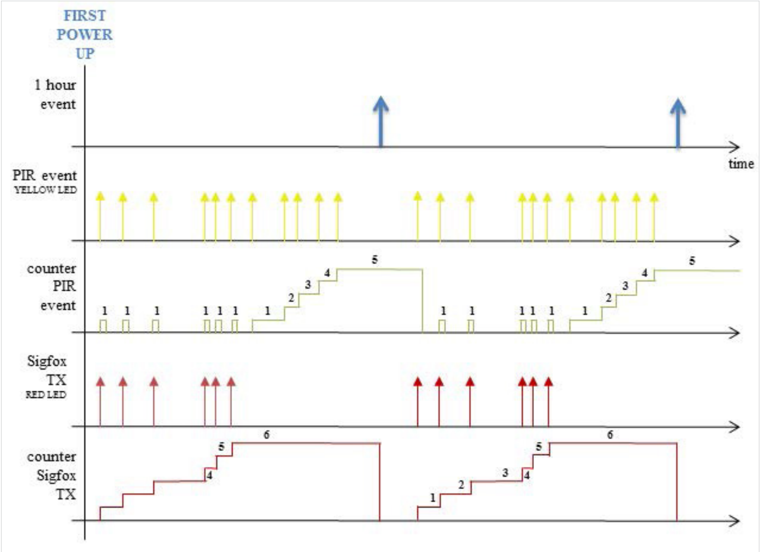
Visual feedbacks are provided to the user in order to understand the system activity by means of LEDs: yellow, red and green.

- Yellow is turning ON whenever the PIR sensor detects a movement.
- Red is turning ON when a radio communication is performed.
- Green is turning ON as result of the Sigfox communication: blinking when error, hold on for a while when no error.

### Sigfox Transmission Specification

Since Sigfox contracts provides up to 140 messages per day in uplink and since the PIR sensor could detect a much higher number of events per day, a rule for avoiding transmission saturation has been considered. Thus the SW will send up to 6 messages per hour where the message content is slightly different according to the timing. In fact, the number of events detected by the PIR sensor during the silent period will be recorded and when the one hour time event is triggered and a further movement is detected, a Sigfox communication with the PIR events' counter is sent out on the cloud (always 1st message of the next hour). Only after the first message of the new hour the event counter is reset.

For sake of simplicity the following picture will show the concept.




### Power Management, Supply Voltage and Battery Life

In order to maximize the lifetime of the Alarm system, the power consumption has

# Workflow for an IoT Product

continued

to be minimized as much as possible. Therefore the RF microcontroller is kept in sleep mode when no PIR events are detected. To entering the low power consumption stage, the management of the event has to be successfully completed. The selection of sleep mode, instead of deep sleep, is preferred because important functionalities are running during low power stage, and they can issue a wake up event to the CPU.

System supply voltage is driven by the most demanding device, in this case the PIR sensor, where the minimum supply voltage required is 3 V, therefore a good trade–off for meeting both voltage level with enough energy capability and minimizing mechanical occupancy is 2 AAA batteries. By using a boost regulator, the battery life time can be extended by regulation of the voltage at 3 V while the battery is being discharged. Even if it is out of the scope of this document, it would be possible to reduce the system power consumption removing all the LEDs since a feedback on Sigfox is always available.

Here a quick calculation of battery life is proposed considering the Sigfox transmission need.

Table 1.

| | VALUE | UNIT |
|---|---|---|
| Sigfox transmission | 51 | mA |
| System in sleep mode | 91 | µA |
| Battery capability | 1500 | mAh |
| Time for a transmission | 6 | sec |
| Number of Sigfox messages | 140 | Msg per day |

Considering the worst case scenario (see Table 2):

Table 2.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 AAA Alkaline Capacity | 1500 | mAh | 3600 | s/h | 5400.00 | C |
| Sigfox TX (140 messages) | 51 | mA | 6 | s | 42.84 | C/day |
| Sleep Charge per day | 91 | µA | 85560 | s | 7.79 | C/day |
| OOB frame transmission | | | | | 0.28 | C/day |
| Total Charge Consumpition | | | | | 50.91 | C/day |
| Battery Life | | | | | 106.08 | day |

### Mechanical Aspects

The selection of the mechanical enclosure is another critical point that will drive next phases. A very basic housing has been selected for this project: rectangular section with enough height to host AAA batteries, lens and PCB thickness. Moreover PCB thickness is a constraint coming from the Sigfox reference design. The housing length is selected in order to host the battery and the antenna length.

As soon as a box has been selected, its drawing will drive the PCB shaping on which the HW design has to properly fit.

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