ON Semiconductor®

Creating an Energy Harvesting Zigbee® Green Power™ Switch for Smart Homes and Buildings

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Introduction

The Internet of Things (IoT) is at a crossroads in terms of energy consumption and more questions about whether traditional sources of energy are capable of supporting its growth are being raised. As described in the white paper, [Creating a State−of−the−Art, Cost−Effective Energy Harvesting Bluetooth® Low Energy Switch](), using alternative sources of energy combined with low−power connectivity has significant market potential.

One such method for alternative, battery−free energy is to harvest dynamic energy from the movement and force applied to a button operating similarly to an ON/OFF switch.

The benefits provided by wireless, battery−free switches are obvious and address top concerns of IoT manufacturers – ease of implementation and power consumption. These devices offer unparalleled flexibility for deployment within buildings because they do not require any hardwiring. They also remove the maintenance hassles and environmental impact of battery replacement and disposal.

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 fulfill 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 is easy to retrofit. For example, you can install new light switches without having to cut any holes in the wall.
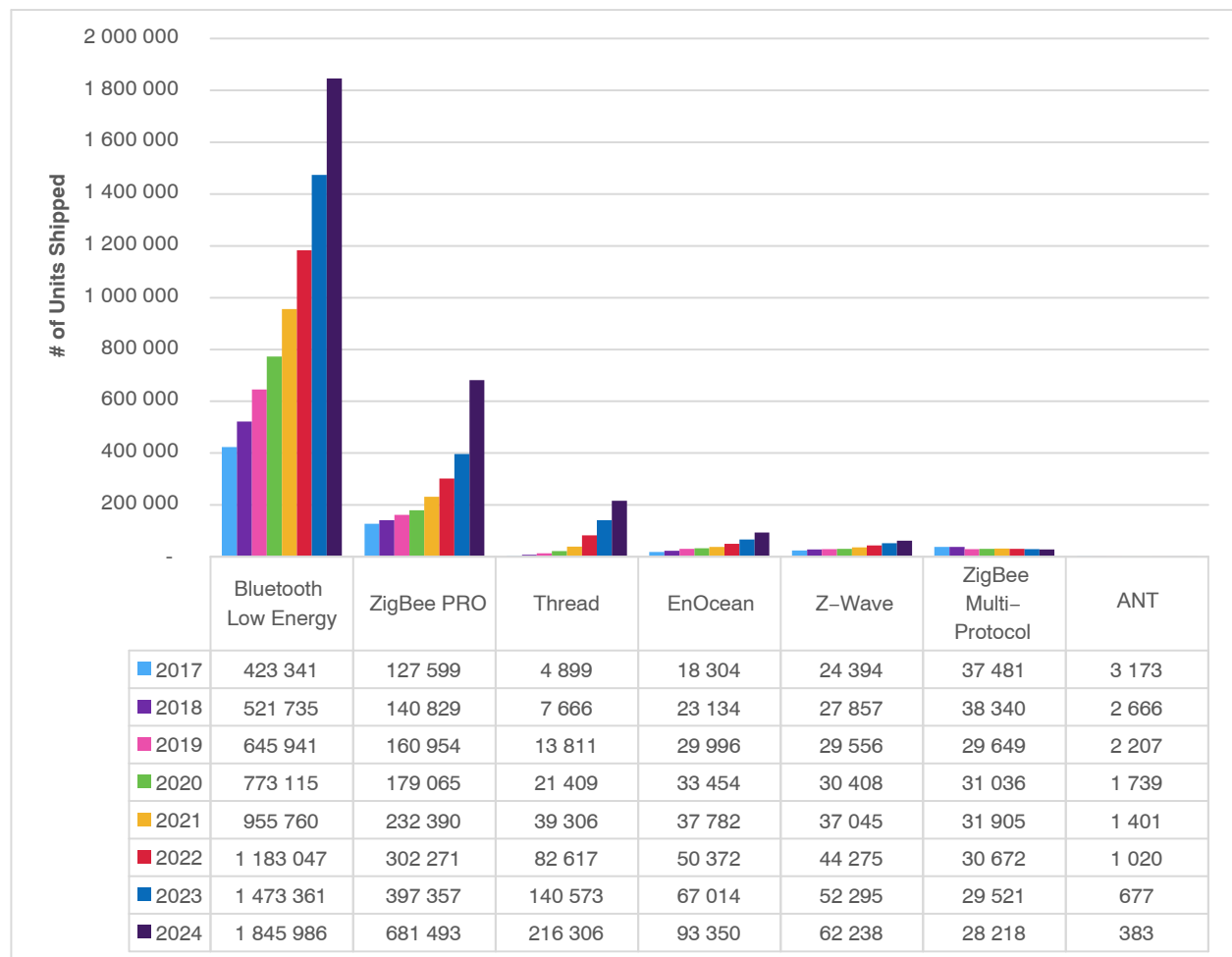
There are also numerous possibilities for use in industrial automation, particularly when the time it takes to lay cables is disproportionate to the application. Here again, the energy harvesting wireless switch serves as a cost effective, battery−less alternative to cable−based micro−switches.

A key factor to making this eco−friendly application a reality is ensuring that the wireless protocol used are conducive to the low−power nature of the switch. Available protocols include Bluetooth® Low Energy and the Green Power™ protocol offered by the Zigbee® Alliance.

Green Power by the ZigBee Alliance

Designed for optimized energy consumption and even energy harvesting, the Green Power protocol from ZigBee Alliance offers tremendous potential within industrial IoT for applications including connected lighting and building automation. The Green Power protocol can be easier to deploy in larger buildings due to its long–range connectivity, provides flexible deployment and reconfiguration options, and is compatible with all new building trends with its eco–friendly and low power design.

The Zigbee protocol is well established and has experienced significant growth across all low–power wireless applications, as shown in Figure 1.

	Bluetooth Low Energy	ZigBee PRO	Thread	EnOcean	Z–Wave	ZigBee Multi–Protocol	ANT
2017	423 341	127 599	4 899	18 304	24 394	37 481	3 173
2018	521 735	140 829	7 666	23 134	27 857	38 340	2 666
2019	645 941	160 954	13 811	29 996	29 556	29 649	2 207
2020	773 115	179 065	21 409	33 454	30 408	31 036	1 739
2021	955 760	232 390	39 306	37 782	37 045	31 905	1 401
2022	1 183 047	302 271	82 617	50 372	44 275	30 672	1 020
2023	1 473 361	397 357	140 573	67 014	52 295	29 521	677
2024	1 845 986	681 493	216 306	93 350	62 238	28 218	383

**Figure 1. Comparison of Wireless Standards/# of
(Source: Omdia 2020)**

As shown in Figure 2 below, Zigbee Green Power is especially popular within smart home, smart building and connected lighting. Zigbee has benefitted from a solid reputation in the B2B arena as well in the DIY field with the availability of IKEA Tradfri and Philipps Hue, and Xiaomi Mi.

		2017	2018	2019	2020	2021	2022	2023	2024
⊟ Lighting	ZigBee PRO	20,314	22,096	24,421	28,697	47,524	79,221	134,215	351,665
	Bluetooth Low Energ	747	2,209	6,159	12,524	29,299	60,507	112,427	212,345
	EnOcean	7,141	8,573	11,852	14,284	14,730	23,530	35,753	57,261
	Z-Wave	2,551	3,300	4,432	5,141	7,729	10,280	12,699	15,589
	Thread	-	55	197	446	1,745	4,784	11,523	28,521
	ZigBee Multi-Protoco	-	-	-	-	-	-	-	-
	ANT	-	-	-	-	-	-	-	-
Lighting Total		30752.00118	36232.72785	47060.94289	61092.2206	101026.6686	178321.3133	306616.4579	665381.395
⊟ Home Automation	ZigBee PRO	29,654	37,411	44,516	47,303	59,194	79,042	98,941	132,910
	Thread	4,739	7,035	12,225	17,614	29,363	58,417	95,719	136,862
	Bluetooth Low Energ	1,460	1,926	3,276	5,251	8,638	13,600	20,254	28,826
	Z-Wave	10,326	11,324	11,118	11,150	13,297	15,554	17,885	20,657
	EnOcean	442	645	918	1,245	1,936	2,942	4,276	5,979
	ZigBee Multi-Protoco	1,207	1,541	1,965	2,101	2,591	3,264	4,051	4,942
	ANT	-	-	-	-	-	-	-	-
Home Automation Total		47828.70089	59880.74337	74016.71971	84663.68353	115019.0442	172819.3442	241125.5864	330175.2332
⊟ Building Automation	ZigBee PRO	17,976	23,437	27,027	29,127	39,328	50,134	62,044	70,555
	EnOcean	9,587	12,310	14,994	15,426	17,866	19,806	21,949	24,067
	Bluetooth Low Energ	-	1,036	2,399	4,154	7,578	13,053	18,994	25,950
	Thread	-	115	417	1,340	3,930	9,153	14,050	19,824
	Z-Wave	3,254	3,386	3,436	3,284	3,713	4,122	4,682	5,365
	ZigBee Multi-Protoco	-	-	-	-	-	-	-	-
	ANT	-	-	-	-	-	-	-	-
Building Automation Total		30817.23758	40284.31868	48273.40331	53329.39581	72414.88481	96269.08448	121719.1967	145760.1089
⊟ Other Industrial Applications	Bluetooth Low Energ	25,296	31,996	34,479	34,962	45,193	54,433	64,250	74,321
	ZigBee PRO	6,795	8,015	9,215	9,367	11,033	12,164	12,485	11,931
	EnOcean	1,134	1,606	2,232	2,500	3,250	4,094	5,036	6,043
	ANT	-	-	-	-	-	-	-	-
	Z-Wave	-	-	-	-	-	-	-	-
	ZigBee Multi-Protoco	-	-	-	-	-	-	-	-
	Thread	-	-	-	-	-	-	-	-

Figure 2. Comparison of Wireless Standards Growth by Market Segment (Source: Omdia 2020)

Zigbee Green Power overcomes the challenge of battery life by simplifying the frame structure complexity of the Zigbee PRO native protocol. If one can make a comparison, Zigbee Green Power is to Zigbee 3.0 what Bluetooth Low Energy is to Bluetooth Classic. More detailed information about Zigbee Green Power protocol can be found here.

Strata Enabled Zigbee Green Power Kit
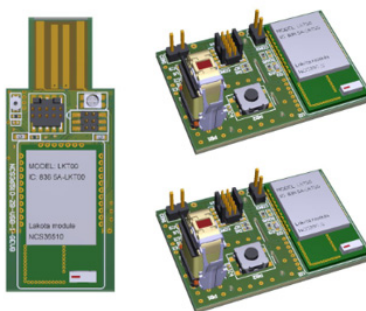
Figure 3. Strata Enabled Zigbee Green Power Kit

The Strata Enabled Zigbee Green Power Kit demonstrates the use of NCS36510 in a battery−free Zigbee Green Power application. The kit consists of one Zigbee Coordinator (ZC) USB device, which interfaces with the Strata Developer Studio™, and two energy harvesting nodes, which act as Zigbee Green Power Devices (ZGPD). By pressing the ZF switch on each of these devices, energy is generated and used to power the NCS36510 module.

The Zigbee Green Power Kit design consists of an energy harvester, simple diode rectifier bridge, a clamp, a small 56 μfarad storage capacitor, as well as the NC36510 transceiver.
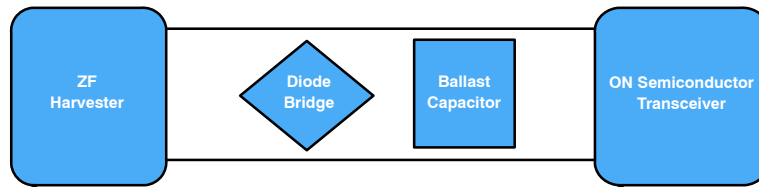
Figure 4. Zigbee Green Power Kit System Overview

ZF Energy Harvesting Switch

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.

Figure 5. Energy Harvesting Source from ZF

Technical Specifications:
- Inductive Generator: The energy required for data transmission is created by the mechanical actuation of the switch. Energy generated: 2x min. 0.33 mWs
- Miniature design combined with extremely high energy output
- Long Mechanical Life: Minimum 1 million switch operations
- Monostable/Momentary Design: Switching mechanism returns to starting position after release (pushbutton)
- Bistable/Latching Design: Switching mechanism with two rest positions (e. g., On/Off switch)
- Dimensions: 20.1 x 7.3 x 14.3 mm
- Temperature Range: −40 to +85°C
- No EMC required due to low energy used by the switch

NCS36510 Zigbee System−on−Chip

Figure 6. NCS36510 SoC

The NCS36510 is a low power, fully integrated, System on Chip that integrates a 2.4 GHz IEEE 802.15.4 compliant transceiver, Arm$^®$ Cortex$^®$−M3 microprocessor, RAM and FLASH memory, a true random number generator, and multiple peripherals to support design of a complete and secure wireless network with minimal external components. The NCS36510 offers advanced power management techniques that allow operation down to supply voltages as low as 1 V while minimizing current consumption. The NCS36510 is specifically designed for applications requiring maximum battery life while minimizing cost. The NCS36510 incorporates an industry leading 32 bit Arm Cortex−M3 processor for high performance, low power and low cost processing. The NCS36510 includes 640 kB of embedded FLASH memory for program storage along with 48 kB of RAM for data storage. The NCS36510 uses a hardware−accelerated MAC to minimize processor overhead while maximizing available processor power forerunning application software.

A Zigbee Green Power protocol stack, developed by DSR, is available for the NCS36510.

Zigbee Green Power Protocol Stack from DSR

DSR Corporation (DSR) is a professional software and product development firm headquartered in Denver, Colorado. DSR Corporation has been developing products in wireless technology since 2001, releasing cloud and Internet of Things (IoT) systems since 2006. DSR is the ultimate end−to−end IoT partner for many companies around the world and within different IoT verticals. DSR has delivered solutions in enabling wireless communications in products, embedded software for gateways and sensors, application integration layer, cloud backend, end−user apps (mobile and web), and general technology consulting with niche expertise. DSR is one of a handful of companies around the world that develops solutions covering the entire product spectrum − from the lowest level (hardware layer) to the top−level user apps. DSR is a big supporter of open standards and flexible development, making us technology and vendor agnostic because we understand that not all solutions fit all use cases and business models.

A technology partner of ON Semiconductor, DSR has customized their stack for the NCS36150 platform and the Zigbee Green Power Battery−free Challenge. This has resulted in a unique value proposition, now adopted by significant Zigbee players.
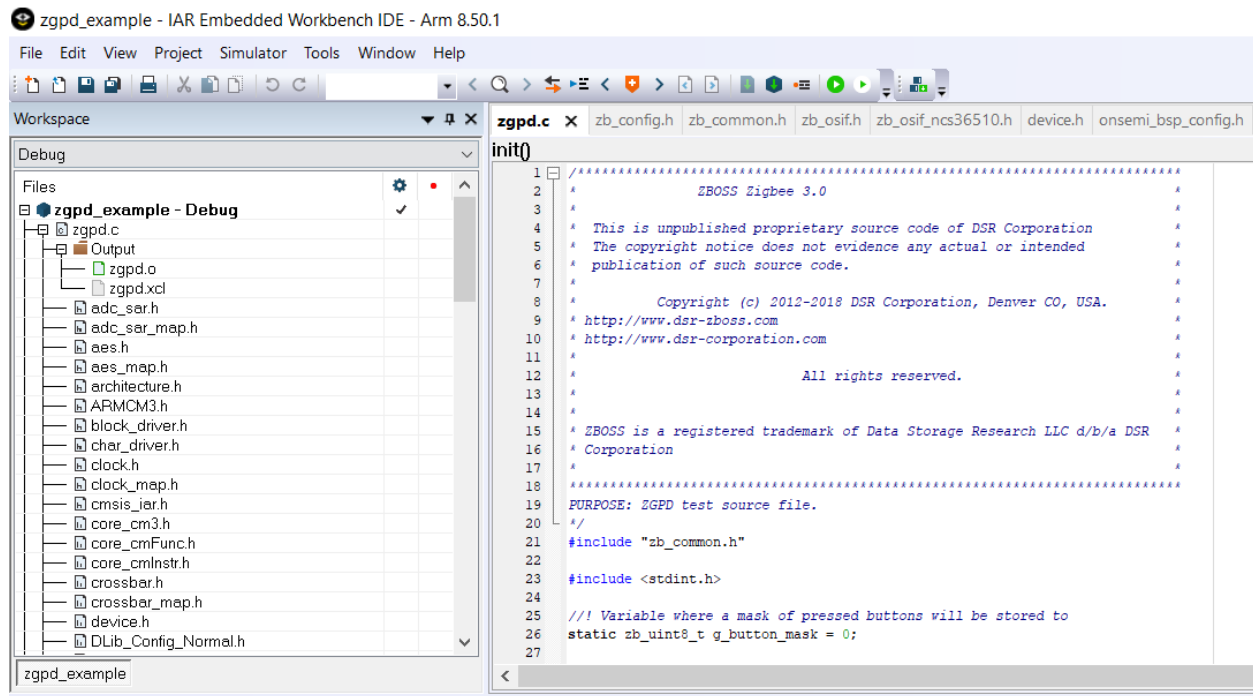
Figure 7. Zigbee Green Power Source Code in IAR SDK Framework

Wireless Transmission Strategy

For low power applications, the Green Power protocol offers numerous advantages that can positively influence communication range:

- Using a spread spectrum instead of Fast Frequency Hopping (FFH) for improved range
- Lower bit rate (250 kb/s) for improved sensitivity performance
- Higher Tx power (8 dBM)
- Using a less crowded wireless spectrum

By implementing the Green Power protocol, the Zigbee Green Power Kit offers the following wireless features and functionalities:

- 8 dBm transmit power for longer range
- Reduce transmission frames to 4
- Conserve energy to listen for incoming replies from the network (Man Machine Interface (MMI) for better user experience) and organize secure commissioning and pairing
- Only using half of the available energy (the switch generates energy on push and release but we are only using the energy from the push)
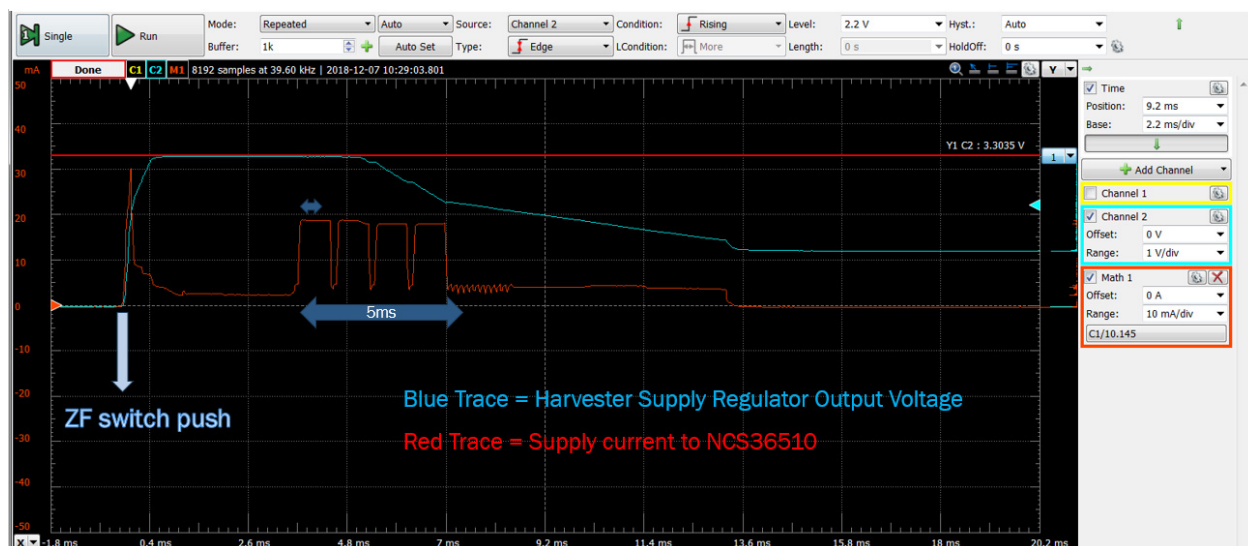
Figure 8. Wireless Transmission Diagram and Energy Spent

The 802.15.4 Mac Acknowledge with LED on the Switch

We added a Man Machine Interface (MMI) capable to acknowledge with a LED blink upon receiving a MAC frame. This feature is important when the device to be controlled is out of the user's line of sight. Since the communication distance is up to 50 meters indoors, a user may not always be able to see what is happening. So, if the wall switch can provide a visible acknowledgement that their command has been received and processed, that is a fantastic value proposition, system wise.
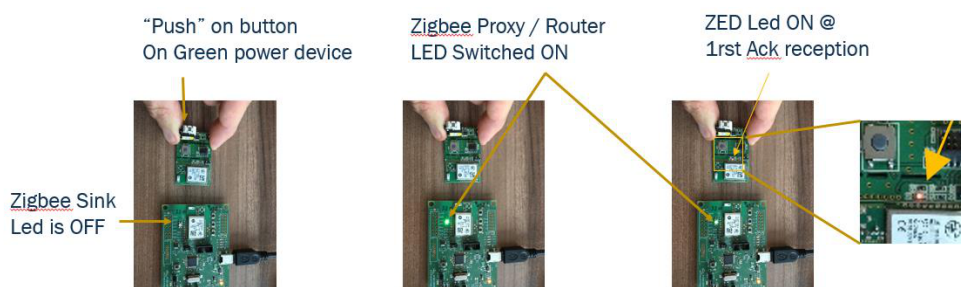
Figure 9. Time Lapse of the Mac Acknowledge LED Blink, Button Side

Time lapse of a network acknowledge reception on the Battery−free button. The green LED emulates a light bulb, while the red blink on the right is the proxy activity acknowledge on the button side.

The Zigbee Green Power Kit Layout

Below, is a close−up view of the kit layout where you can see the harvester and circuitry on the left, the NC36510 on the right, and the programming header in the middle.
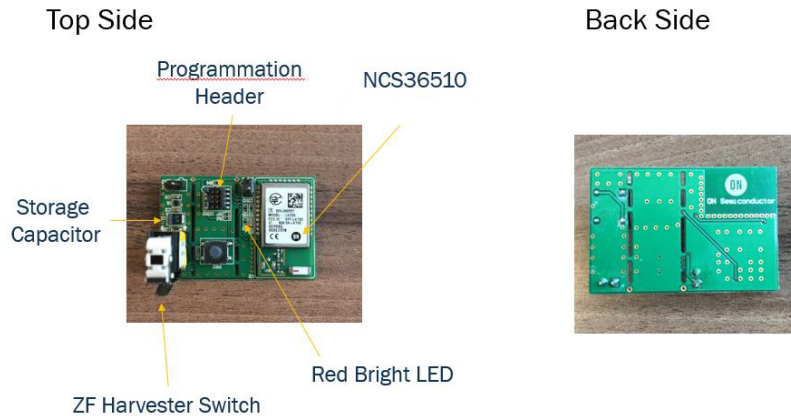
Figure 10. Zigbee Green Power Switch Layout and Components

Note that the central area is pre−punched through with two pre−cutting strips in order to enable integration of the hardware into off−the−shelf plastic buttons.

Strata Developer Studio™

The Strata Developer Studio is a secured, cloud−connected development software to evaluate reference designs, development kits, and evaluation boards with automatic updates and alerts.

Benefits:

- Out of the box experience
- Plug & play system, Strata automatically downloads all necessary hardware design files
- Ability to measure and control different design parameters for customized evaluation
- Complete platforms collateral such as, schematics, layouts, block diagrams, user guides, test reports, data sheets, etc.

Three Easy Steps to Obtain Strata Developer Studio:

1. Download Strata from Strata landing page or any released Strata board's webpage.
2. Register and Login.
3. Immediate access to all of Strata hardware platforms design files and User Interface control when any of Strata enabled boards are connected with a USB cable. Figure 11 below shows the Zigbee Green Power Kit automatically displayed in the Strata.
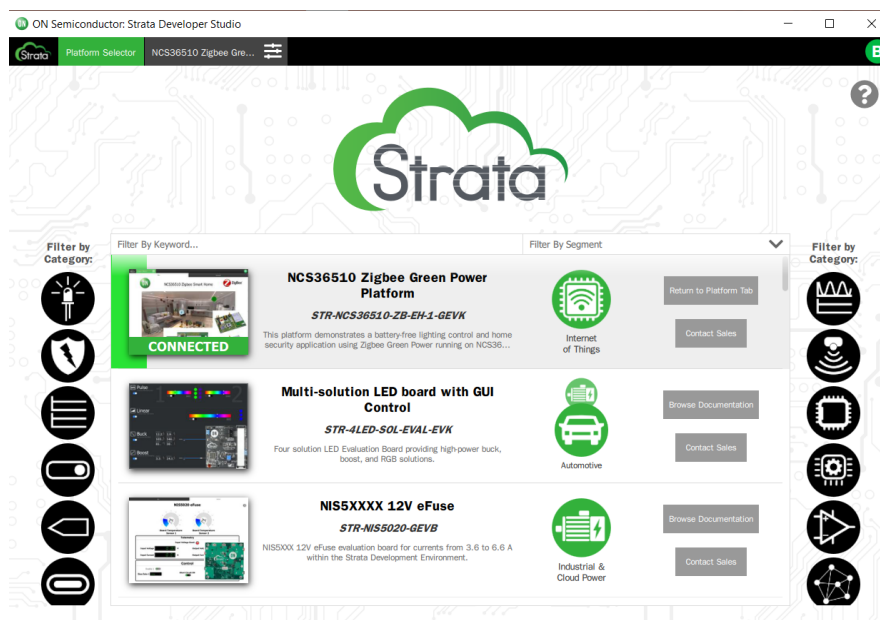
Figure 11. Strata Developer Studio Home Page

Within Strata, a Zigbee Smart Home virtual environment is available for testing device performance.
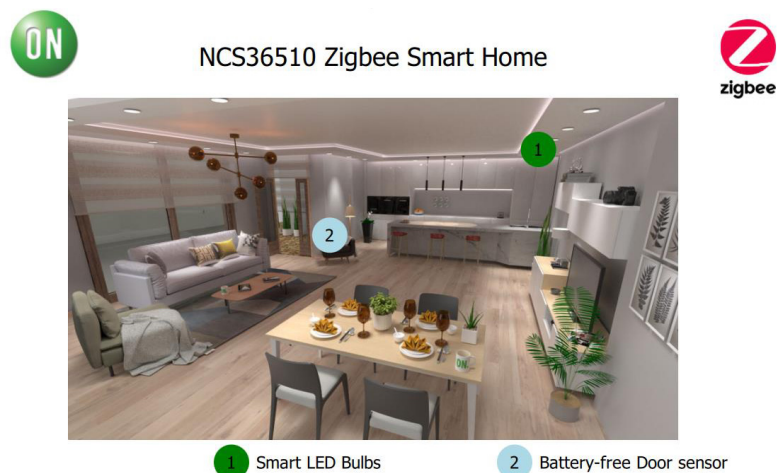
Figure 12. Strata Developer Studio Zigbee Smart Home Environment

Conclusion

We described how a combination of a low−power Zigbee SoC (NCS36510), new design resources (DSR Stack, Strata Developer Studio) and appropriate energy source (ZF) can be used to create an innovative battery free Zigbee Green Power Switch.

The Switch is complementary to the Energy Harvesting Bluetooth Low Energy Switch, and other RSL10 energy−efficient innovations for smart homes and buildings such as the RSL10 Mesh Platform and Connected Lighting Platform.

Continue Reading

- [Creating a State−of−the−Art, Cost−Effective Energy Harvesting Bluetooth® Low Energy Switch](#)
- [Continuous Harvesters and ON Semiconductor's Low−Power RF Technology Close the Gap in Environmental and Accelerometer Sensors for IoT](#)

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