WHITEPAPER

Build battery-free smart locks with NFC energy harvesting technology

Say goodbye to battery life concerns!

By Qi Zhu, Director, Power and Sensor Solutions, Infineon Technologies

Edition: v1.0
Date: 12/2023

www.infineon.com

Table of contents

1 Abstract

Today, battery-powered smart locks with shared access capabilities have become increasingly popular in both consumer and industrial access control applications. However, battery-related issues frequently arise in many use cases. For outdoor applications, fluctuating temperatures and extremes can significantly reduce battery life. Indoor applications, on the other hand, can incur high battery replacement costs – particularly when dealing with a large number of locks. Additionally, safety concerns in industries such as oil, gas, mining, and aviation prohibit the use of lithium (Li) batteries.

Eliminating the need for batteries in smart lock applications can be achieved through energy-harvesting technologies. However, choosing the right technology can be challenging when it comes to ensuring 24/7 serviceability. Photovoltaic technology, for instance, relies on the availability of sunlight. Piezoelectric and thermoelectric technologies, on the other hand, deliver power in the µW range, which means that the required harvesting time for 24/7 serviceability is too long.

To address these issues, a Near-Field Communication (NFC) energy-harvesting solution was chosen for two reasons:
– NFC technology is widely available on mobile phones, making it a practical choice for users.
– NFC energy harvesting can provide the necessary milliwatt range of power needed to ensure serviceability.
Infineon's latest solution for NFC locks can harvest 20 to 50 mW from the NFC field, depending on the type of mobile phone in use. The single-chip, highly integrated solution provides designers with the flexibility to create miniaturized, battery-free, mobile phone-controlled smart lock systems.

2 Smart locks today

Smart, keyless-entry locks, including deadbolt, lever handles, padlocks, and more, are poised for continued growth due to three key factors: the megatrend of digitalization, the adoption of new smart-phone-centric lifestyles, and the increasing need for shared access management. According to a recent report, the global smart lock market, currently valued at 1.95 billion US dollars in 2022, is expected to grow at a CAGR of 19.6% from 2023 to 2030.

Today's smart lock solutions are primarily battery-powered, microcontroller systems that offer connectivity options such as BLE, NFC, or Wi-Fi. Smart lock vendors are constantly adding new features to their products to stay competitive and differentiate themselves from others. Some of the modern features that smart locks now offer include distance sensing and face recognition, which work together to create a seamless door access experience for the user. Besides, improving battery life remains a challenging topic that all vendors are still working on. This is because battery life is a critical factor that customers consider when selecting a smart lock.

In many outdoor applications, battery-powered smart locks cannot be used due to the reliability issues of batteries in hazardous outdoor environments. To overcome this problem, battery-in-key solutions are used, where the lock's electronic circuit is powered by a battery within the key when the key is inserted into the lock. This solves the outdoor battery problem. However, this is not considered a true smart lock solution as a physical key is still required to operate the lock.

In certain areas, a suitable smart lock solution is not available for various reasons. For instance, organizations with a large number of locks, both industrial and consumer-focused, are hesitant to adopt smart lock solutions due to the cost and effort required for regular battery replacement. In industries such as oil and aviation, the use of smart locks with Li-batteries is forbidden due to safety requirements. Similarly, in consumer products such as outdoor mailboxes, indoor cabinets, and bicycles, battery-powered solutions are not suitable due to battery-related issues, size limitations, or cost constraints. Hence, achieving a truly “keyless” life is still a distant possibility, and more innovation is required in the field.

Infineon's recently launched battery-free NFC smart lock solution [3] eliminates the requirement for batteries and enables the use of the mobile phone as a key. This solution complements the battery-powered version, expanding the coverage of smart lock use cases and bringing us one step closer to achieving the “keyless” goal.

3 NFC lock solution

NFC is a mature technology for contactless exchange of data over short distances. Besides the data exchange, NFC technology can also transfer power using the electromagnetic field. The combination of data exchange and energy transfer in one interface and its availability in billions of mobile phones and other NFC-reader-enabled devices make NFC an exciting enabler for battery-free smart locks.

When a mobile phone with an active NFC is put close to the NFC antenna of the smart lock, the mobile phone will detect the NFC device and start to build an NFC communication (see Figure 1). Spontaneously, the 13.56 MHz NFC carrier signal transfers a certain amount of energy to the receiver antenna. The received AC signal is converted to DC current by the rectifier and used to charge the capacitor. As long as the NFC connection is available, energy is transferred from the mobile phone to the capacitor. The energy stored in the capacitor is controlled by an H-Bridge to drive the motor.

The ubiquitous mobile phone, supported by both iOS and Android devices, provides access to the lock. Smart lock functions of access sharing, key management, and others are enabled with mobile apps. On the lock side, it can be as simple as an NFC actuation controller, a PCB antenna, a capacitor, and a DC motor – it is simple, small, and cost-effective. This design approach provides high-level digital security – native security with short-distance NFC and encrypted NFC data frame.

The use of battery-free NFC technology could provide an even greater momentum for future smart lock growth.

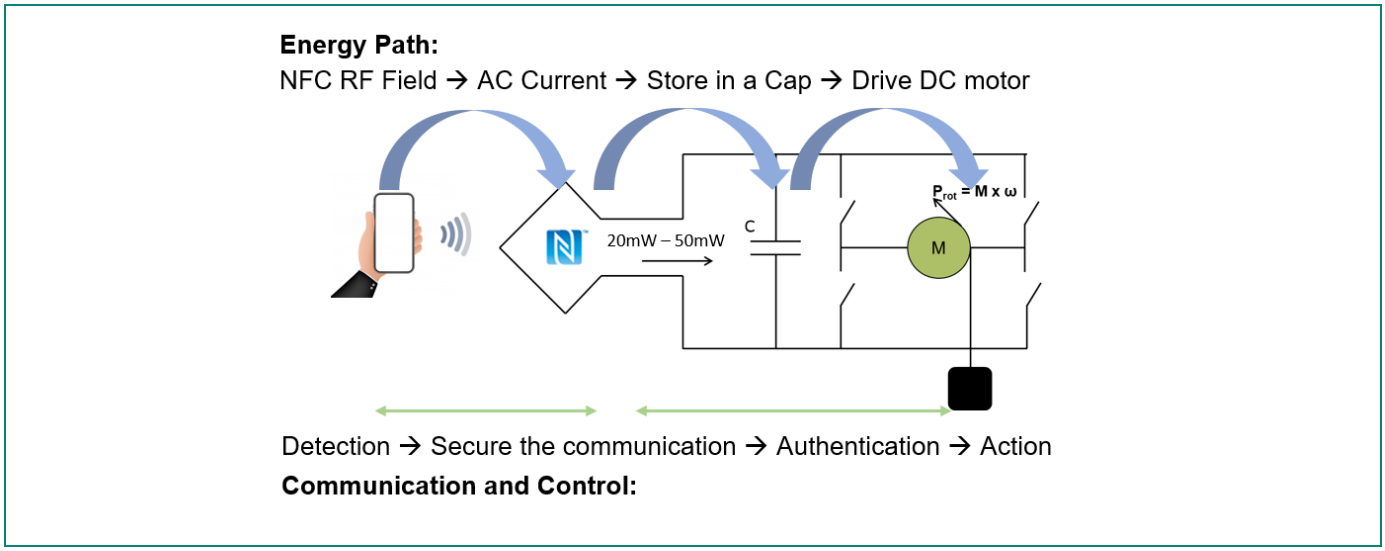

Figure 1 The NFC lock system concept

4 Infineon NAC1080: An NFC actuation controller

Infineon NAC1080 [3] is a programmable 32-bit Arm® Cortex®-M0 microcontroller with an NFC front end. It is designed to enable cost-effective development of smart actuators, especially battery-free devices such as battery-less smart locks. It is also a unique NFC tag-side controller in the market with an integrated motor-driver and energy-harvesting modules. With NAC1080, a smart lock can be implemented using a single chip with a minimum BOM.

Figure 2 shows the highlights of NAC1080's functions. NAC1080 has an integrated NFC interface compliant with ISO-14443 Type A for connection with a mobile phone. As soon as the NFC connection with a mobile phone is established, the IC starts to harvest energy from the NFC RF field. The harvested energy will first be used to power the IC and the remaining energy is redirected to the external capacitor via the energy-harvesting pin (Vcc_HB).

The integrated H-bridge enables control of the DC motor according to the embedded software. To ensure that the energy reserve is sufficient to achieve the required motor rotation, NAC1080 has a built-in function to check whether the Vcc-HB voltage has reached the targeted threshold value.

In the battery-less NFC lock use case, NAC1080 is operated in a so-called passive mode – powered by the energy harvested from the mobile phone. However, NAC1080 can also be powered by a Vcc supply, like a battery. In this case, the energy harvesting function is disabled.

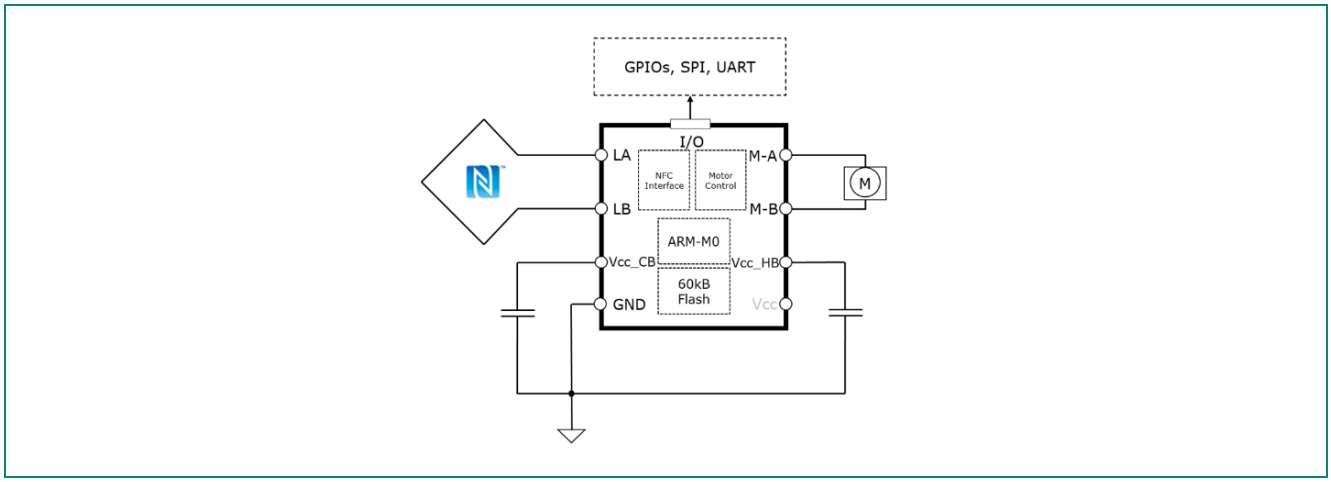

Figure 2 Infineon NAC1080's integrated connectivity, energy harvesting, actuating, and security aspects

For an application like a smart lock, the encrypted communication between the mobile phone and the lock is desired. NFC1080 provides a 128-bit Advanced Encryption Standard (AES) accelerator and a true random number generator to enable data encryption/decryption in an ultra-low-power environment. Secure area in the flash and disabling of the debugging interface are a part of the hardware security functions. In addition, If required, a separate secure element can be connected via the digital interface on demand. The flexible IC architecture and smart partitioning between hardware and software enable customers to maximize the utilization of software-defined functions.

5 NFC lock design

Designing a battery-free NFC lock poses a significant challenge of creating an electromechanical system that can reliably complete the lock's actuations within the specified energy budget. The energy budget, in turn, is determined by the harvesting power and total harvesting time. Harvesting time is equivalent to the time that it takes to open the lock, which is a crucial user experience parameter. Generally, a wait time of 2 to 5 seconds is acceptable, but the faster the better. The amount of power harvested depends on several factors:

- The type of mobile phone being used affects the amount of power received because the NFC antenna design inside the phone and its field strength are not standardized.
- The positioning of the mobile phone's antenna relative to the lock's NFC antenna affects power transfer. A shorter distance and less misalignment improve power transfer.
- The design and tuning of the lock's NFC antenna are important. Because of the variations in NFC antenna design among different mobile phones, a design in the shape of a circle with a diameter of 3 to 5 cm or a rectangle is suggested instead of a specific design optimized for a specific mobile phone.
- The presence of metal objects around the antenna can distort and reduce the magnetic field, negatively affecting received power. To mitigate this issue, ferrite sheets or soft magnetic sheets are typically added.

During tests made using different mobile phones, NAC1080 was observed to harvest 20 to 50 mW (in addition to ~10 mW to power the IC) when using the reference antenna. It is recommended to use 20 mW as a basis for calculating the energy budget.

In the case of battery-free NFC locks, energy consumption is mostly determined by the actuation component, such as the rotation of the mini DC motor. Therefore, it is crucial to focus on designing this component to reduce the energy consumption. The following two aspects are essential to consider:

- DC motor selection is critical in designing a battery-free NFC lock. It is important to choose a low-power motor with the right level of torque. However, in the lock’s use case, the motor operates for a very short period and so the peak efficiency value in the data sheet is not the parameter for the motor selection. A significant part of the energy is consumed to start the motor rotation. Therefore, a motor with a high start-up acceleration rate is ideal for the lock application. For this reason, the cordless DC motor is suggested.
- The total motor rotation angle is a crucial factor to consider when designing a battery-free NFC lock. The less motor rotation required, the less energy is consumed from both the motor and the IC due to the reduced operation of the IC. Therefore, minimizing the total motor rotation angle is an effective strategy to conserve energy in the lock system.

In many cases, merely replacing the electronic part of an existing battery-powered smart lock may not be sufficient to create a good battery-free NFC smart lock. A smart mechanical design plays an essential role in achieving optimal performance. The electronic platform provided by Infineon [2] creates an opportunity for traditional and new lock vendors to showcase their mechanical design expertise and build excellent battery-free smart locks. This enables vendors to collaborate and integrate the electronic and mechanical components more effectively, leading to a better overall product performance.

6 Typical use cases

The integrated NFC controller is especially suitable for locks that require little mechanical effort. Typical use cases include:

- Indoor furniture/cabinet locks in shared offices, fitness centers, shopping centers, schools, hospitals, airports, train stations, etc.
- Outdoor padlocks for trucks, containers, construction areas, infrastructure equipment/machines, etc.
- Consumer products for mailboxes, parcel boxes, bicycles, scooters, luggage, safe boxes, etc.

One of the more intriguing applications for NAC1080 is the emergency power supply for smart door locks. In this instance, the built-in NFC energy harvesting interface provides an emergency solution when the batteries in door locks are out of power (see Figure 3). Energy is harvested from the mobile phone to the lock system to enable the unlocking action. The use of this interface avoids the need to call an expensive locksmith service to open the lock.

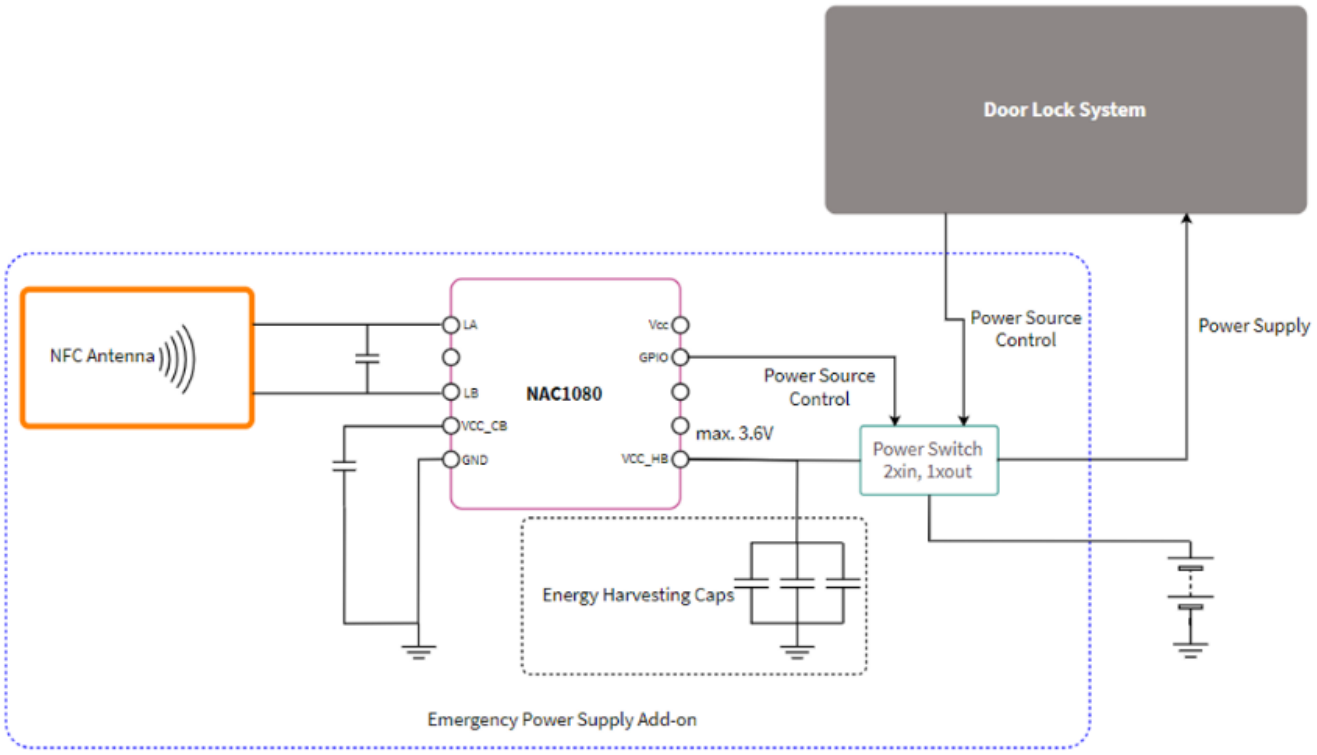

Figure 3 Emergency power-supply function for smart door lock

7 Transitioning to battery-free operation: Tools, software, and design support

To expedite the acceptance of this new design approach to smart locks, development boards, evaluation kits, and design tools are available and regional marketing partners provide additional support. As shown in Figure 4, DEV_KIT_NAC1080 includes a development board, demo software to operate the lock, and the SDK for both firmware and mobile app development. The source code developed for the Infineon NFC lock demo includes firmware and a mobile app, and can be purchased as a reference to accelerate software development.

Figure 4 Design-in support tools for NAC1080

In certain instances, customers may desire to integrate a battery-free lock into their product or service but may lack the necessary resources to develop a complete lock. To address this issue, Infineon has developed a reference design, and is adding to its network partners that offers various levels of support – from antenna and circuit design to complete lock design and even original design manufacturing (ODM) services. Partner examples include:

– IH technology, China, offers a total lock system design service for customers.
– One2Touch, Norway, offers lock module and total lock system design and ODM service.

For the most recent partners visit [4].

8 Unlocking the future

Implementing NFC technology in smart locks not only eliminates the inconvenience of battery replacements, but also promotes sustainability and reduces waste. As more people continue to embrace smart technology in homes and businesses, NFC-enabled smart locks have the potential to make lives easier and more eco-friendly.

9 References

[1] Grand View Research: *Smart Lock Market Size, Share & Trends Analysis Report*, https://www.grandviewresearch.com/industry-analysis/smart-lock-market

[2] Infineon website: *Contactless power sensing*, https://www.infineon.com/cms/en/product/power/contactless-power-sensing-ics/nfc-tag-side-controllers/

[3] Infineon website: *NAC1080 product details*, https://www.infineon.com/cms/en/product/power/contactless-power-sensing-ics/nfc-tag-side-controllers/nac1080/

[4] Infineon website: *Partners for NAC1080 support*, https://www.infineon.com/cms/en/product/power/contactless-power-sensing-ics/nfc-tag-side-controllers/#!partners

www.infineon.com

Published by
Infineon Technologies AG
Am Campeon 1-15, 85579 Neubiberg
Germany

Public

Date: 12/2023

Please note

This Document is for information purposes only and any information given herein shall in no event be regarded as a warranty, guarantee or description of any functionality, conditions and/or quality of our products or any suitability for a particular purpose. With regard to the technical specifications of our products, we kindly ask you to refer to the relevant product data sheets provided by us. Our customers and their technical departments are required to evaluate the suitability of our products for the intended application.

We reserve the right to change this document and/or the information given herein at any time.

Additional information

For further information on technologies, our products, the application of our products, delivery terms and conditions and/or prices, please contact your nearest Infineon Technologies office (www.infineon.com).

Warnings

Due to technical requirements, our products may contain dangerous substances. For information on the types in question, please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by us in a written document signed by authorized representatives of Infineon Technologies, our products may not be used in any life-endangering applications, including but not limited to medical, nuclear, military, life-critical or any other applications where a failure of the product or any consequences of the use thereof can result in personal injury.