Interactive RFID and NFC Enable New Applications in Electronics

Zero-power technology for late customization, Track&Trace, Bidirectional Communication and easy Bluetooth pairing

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RFID and Electronics are growing together

Radio Frequency Identification (RFID) has penetrated our lives already in a number of fields – be it in access control for entering the office, in libraries for self-check-out, in ski areas for hands-free entry or in fashion retail for easy and quick inventory taking. Passive RFID tags do not need a battery and therefore offer an inexpensive way to identify objects over distances of up to several meters. The RFID chip is completely powered by the RF-field that is generated by the reader. In addition to the widespread High-frequency (HF) or Ultra-high-frequency (UHF) industrial readers, the increasing penetration of Near-field-communication (NFC) technology in smart phones and other mobile devices allows these to be used as HF readers as well and therefore brings RFID more and more into the hands of consumers.

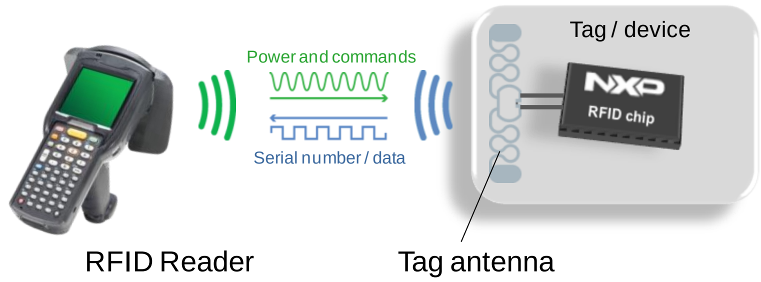


Figure 1 Passive RFID tags are powered by the reader/writer field and do not need a battery or other power supply for communication

In the above mentioned traditional applications, the RFID tags are usually standalone cards, tokens or adhesive labels attached to the product they identify. Also in electronic devices, RFID track&trace is starting to spread and replace the bar codes currently used for the identification of printed circuit boards (PCBs). The first generations of RFID chips for PCB tracking work like a stand-alone tag which just happens to be located on the same PCB – there is no connection between the RFID chip and the circuitry on the board.

A new generation of RFID chips now offers an I²C connection in addition to the antenna port, and can therefore be connected directly to microcontrollers and ASICs. What does this mean for electronics designers, product-, service- and production-managers? It opens completely new possibilities for electronics during production, test and service, and can offer more convenience to the end user.

Completely new applications change the way we interact with electronic devices

The use of passive RFID brings power consumption down to new levels: from **low power** to **zero power,** for example when waking up a device through RFID/NFC with no stand-by current. Or when communicating with a device which is completely switched off (or does not even have a battery inserted), where you can read diagnostic information or write configuration settings to the unpowered device.

This section explores several use cases, showing the benefits and functional implementation.

Late customization

Many electronic devices need to come to the market in variants – different country or language settings, different feature sets, sales channel adaptations or firmware versions. This is the case e.g. in home appliances (washers, dryers, microwaves, coffee machines), cell phones, cordless phones, and many more. In most cases, the hardware of these devices is the same for the whole product family, and the variants are only determined by configuration data which is stored in a memory area on the main board of the device. This creates a dilemma between ease of programming and supply-chain flexibility: The earlier in the manufacturing process the variant is programmed, the easier this programming process is. However, with an early customization, the supply chain flexibility suffers because the manufacturer has to build stocks of all variants and cannot react quickly to changes in demand later on (see Figure 2).

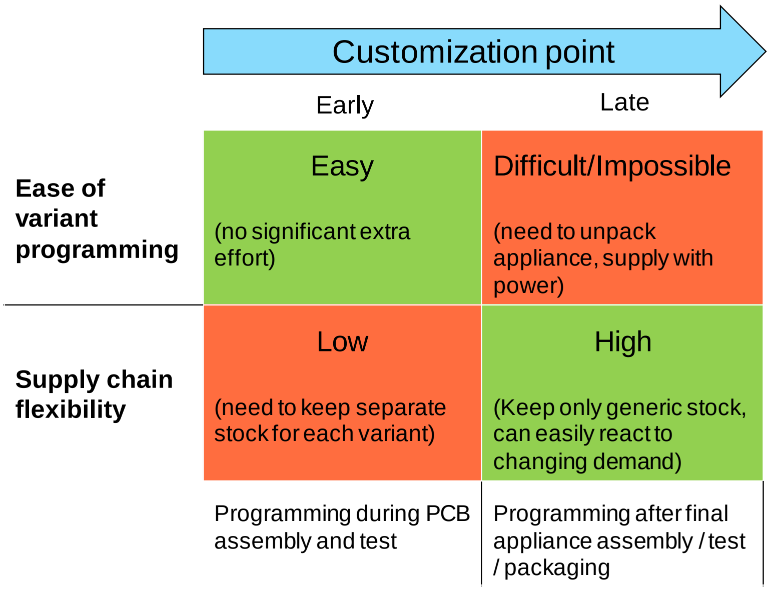


Figure 2 The Variant Dilemma: Contact-based programming of variants can either save programming cost or supply chain cost, but not both.

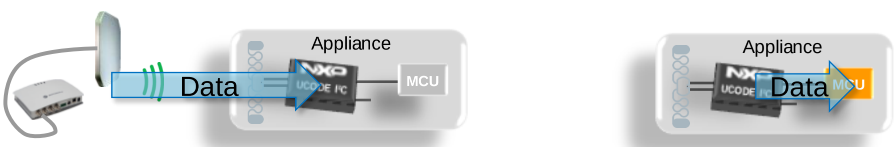
RFID offers a solution to this dilemma: By using a dual-port RFID chip (a chip with an RFID interface and an I²C port) to store the configuration data, late customization becomes much easier. Depending on the antenna size and the chosen RFID frequency, several meters of programming range are possible, as long as there is no significant shielding between the reader antenna and the tag antenna. This enables the customization even when the appliance is already in the sales packaging, and therefore it makes it possible to quickly react to changing demand of one variant or another. As a consequence, this increases the supply chain flexibility (see Figure 3).

	Late customization with RFID
Ease of variant programming	Easy (no contact interface needed, device can be unpowered)
Supply chain flexibility	High (Keep only generic stock, can easily react to changing demand)
	Contactless programming after final assembly or packaging

Figure 3 RFID-based late customization (zero-power configuration) is easy to implement and saves supply chain cost.

Implementing RFID-based late customization is not difficult. All that is needed in the device is a dual interface chip like the UCODE I²C and an antenna structure which is part of the printed circuit board (PCB). Details on the implementation are described in a later section. The frequency of choice for late customization through packaging is UHF (868…915MHz), because only UHF offers read/write ranges of several meters.

The process of the late customization is shown in Figure 4. The key here is that the appliance can be completely unpowered while the RFID reader writes the configuration data into the user memory of the dual-interface EEPROM.



Step 1
- Device is unpowered
- Write data from UHF reader/writer into UCODE I²C user memory

Step 2
- Power-up device
- MCU reads the data from the UCODE I²C user memory

Figure 4 Zero-power write process, using the UCODE I²C dual-interface memory. Here the write process with a stationary UHF reader plus antenna is shown.

Making customer service easier

When an electronic device comes back for service or repair, some basic data has to be collected:

- Product identification (serial number, production date, hardware version…)
- Firmware version
- Service and repair history
- Activity or error log

Also here, RFID offers a convenient way to collect the data directly from the device to be serviced. The zero-power read capability of a dual-interface memory, as shown in Figure 5, creates a significant advantage over currently used methods. Let's have a look at each item:

- **Product identification**: Today this is mostly done by a printed or engraved serial number plus an optional bar code. All other data (production date, hardware version, etc.) can then be retrieved from the database using the serial number as a key. This has some disadvantages: Often the device has to be opened to access the serial number, as aesthetics concerns prohibit the use of serial numbers on the outside of the device. The serial number can be unreadable due to wear or because it was scratched off in an attempt to fraudulently obtain warranty repair after the warranty period.
  Advantage with RFID: The serial number can be read without line-of-sight, i.e. simply by bringing the device close to an RFID reader without opening the device or locating a bar code. This saves valuable time of the service staff. Additionally the RFID tag can hold more information in addition to the serial number, so that production date, hardware version and more can be stored locally on the chip and be retrieved without a connection to the database. Finally it also makes service fraud significantly harder, as the RFID chip is embedded into the device.
- **Firmware version**: In order to identify the firmware version of a device without doubt, the device has to be still functional, has to be powered, and diagnosis hardware has to communicate with the device through a service port (e.g. infrared interface or service plug).
  Advantage with RFID: The microcontroller (MCU) of the device writes the firmware version into the dual-interface user memory at each startup. This way, the firmware version can be read out later with an RFID reader, even without powering the device, and even when the device is not functional anymore.
- **Service and repair history**: This is usually recorded in a database, using the serial number as a key.
  Advantage with RFID: Some service and repair information can be stored offline in the user memory of the dual-interface memory and can therefore be accessed for a basic check even when the database is not available, e.g. due to a missing network connection.
- **Activity or error log**: In order to facilitate diagnosis and to gain usage statistics, a device can implement a log in an internal memory where it records the last successful operation, error codes, or device statistics like an operating time counter. Similar to the firmware version readout, this data can only be retrieved when the device is powered and functional and connected to the diagnosis hardware.

Advantage with RFID: The MCU writes the log information directly into the dual-interface memory during operation, and the service technician reads the memory out with an RFID reader. This saves time and effort, as the activity and error log can be read out without powering, connecting or opening the device.

Step 1

- MCU writes data into UCODE I²C user memory

Step 2

- Data can be read anytime by a UHF reader even when the device is unpowered

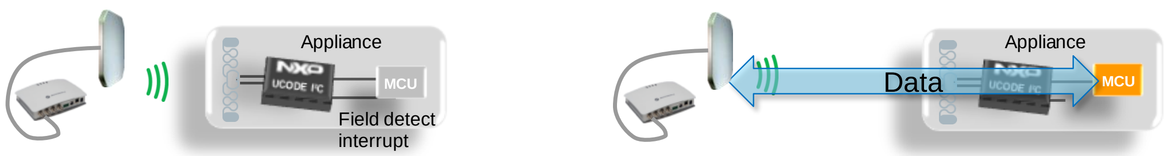
Figure 5 Zero-power read process using the UCODE I²C dual-interface memory. Here the read process with a hand-held UHF reader is shown.

Bidirectional communication

With some dual-interface memories, even direct bidirectional communication between an RFID reader/writer and the MCU is possible. For example, the UCODE I²C supports a bridge mode, in which data is exchanged between the RFID side and the MCU through buffer registers. The bridge mode has three advantages:

- Data is not limited to the user memory size of the RFID tag (user memory is a few kbits usually)
- No limitation on write cycles
- Higher transfer speed due to faster writes to registers and an interrupt mechanism which alerts the MCU once data is available
- No need to make a physical connection (that could influence the measurements)

It is even possible to wake up a device by approaching it with an RFID reader. This creates an interrupt signal upon a first register write from the UHF reader/writer even when the device is in sleep mode, thereby conserving energy during the inactive time. The principle of bridge mode operation is shown in Figure 6.



Step 1

- Bring a UHF reader/writer to the device (powered or unpowered)
- The field-detect function wakes up the device

Step 2

- The device is now powered
- Exchange data between the UHF reader/writer and MCU directly through buffer registers

Figure 6 Bridge-mode operation of a dual-interface memory at the example of the UHF chip UCODE I²C

The following is a non-exhaustive list of applications which can benefit from bidirectional RFID communication:

- **Reading out current measurement data**: Sensor devices
- **Reading out current internal status information** by a service technician: Household appliances, industrial appliances
- **Reading out error log files** which exceed the space of the RFID chip user memory (example UCODE I²C: 3.3kbit): Household appliances, industrial appliances
- Contactless firmware update
- **Write a larger amount of settings** to the appliance, which exceeds the space of the RFID chip user memory
- **Using the RFID reader as an external user interface**, to more easily control the appliance. This is especially of advantage in consumer environments when choosing an NFC compliant solution. In this case any NFC phone can be used as an external user interface. Due to the high and growing number of NFC phones in the hands of consumers, the infrastructure is already present in the market. For details, please refer to the companion paper (1).

Track & Trace in production and beyond

Some electronics companies have started to switch their PCB identification from bar code to RFID – and are experiencing already the benefits this brings:

- Process optimization (removal of bottlenecks)
- Reduction of manual scanning
- Bulk scanning possibility
- Clear identification of boards even if embedded/molded

Cisco and Jabil report an 80% efficiency increase in their production after introducing RFID for track&trace (2). Several properties of passive RFID technology create the benefits mentioned above:

- **No line of sight necessary** – the PCB identifier can be read also through the housing as long as it is not completely shielded.
- **Full item-level serialization** – every PCB has a different, unique number
- **Read/write access** – in addition to the serial number, more information can be stored in the user memory of the RFID chip step-by-step throughout the production process.

In order to help electronics companies implement track&trace in their products and production system, a consortium with six member companies was founded, the RFID Value Creators (www.rfid-valuecreators.com). Beta LAYOUT, Brooks, Enso Detego, Kathrein, Murata and NXP Semiconductors are working together to support a quick and easy implementation of RFID in electronics productions.

Simple Bluetooth Pairing with NFC

Most people today experience challenges when pairing a Bluetooth accessory with a phone. Several buttons have to be pressed, menus to be selected, scan mode to be activated to search devices, access codes need to be entered. All these steps make it a complicated and time consuming process.

Passive NFC tags in the accessory make this significantly easier: All a user has to do now is tap this accessory with his NFC phone. The accessory will switch on automatically thanks to the built-in field-detect function of the NFC tag chip, the phone reads the Bluetooth ID and pairing information which is stored in the NFC tag and then it pairs automatically with the accessory without having to go through Bluetooth scanning mode, as shown in Figure 7.

Many recent product releases of Bluetooth headsets, media streaming devices and speakers, as well as a mouse are using this technology based on the NTAG203F chip and show that a passive NFC tag embedded in the accessory really makes Bluetooth pairing with smartphones easier.

This function is standardized as “Bluetooth Secure Simple Pairing” by the NFC forum, and details can be found at (3).

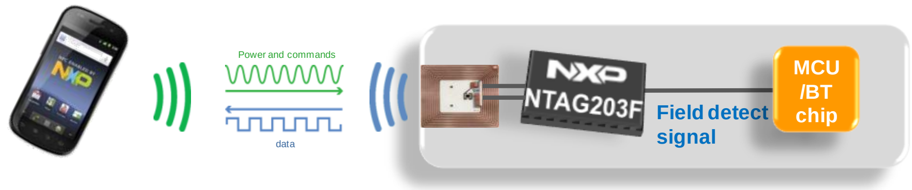


Figure 7 Bluetooth pairing solution with NTAG203F

Implementation Considerations

Frequency selection

When implementing RFID for an electronic device, the choice of the right frequency inevitably comes up. Several frequencies and standards are available, and each one has its own set of advantages and restrictions.

The two main relevant frequencies and technologies for electronics are:

- **UHF (868…915 MHz, EPCglobal Gen2):** long range (several meters), widely used in item-level inventory management. Ideal for manufacturing and industrial applications. A broad range of dedicated stationary and hand-held readers is available.
- **HF/NFC (13.56MHz, ISO14443):** short range (some centimeters). In addition to dedicated stationary and hand-held readers, NFC phones can read and write these tags. There are more than 100 Million phones with NFC functionality already on the market (4), which makes NFC the ideal choice when consumers are supposed to interact with the RFID tag in the electronic device.

Application	Additional conditions	Suggested frequency band	Chip example
Late Customization	Long write range, customization of device through sales package	UHF	UCODE I²C
Easier customer service	Long read range, reading through the appliance housing	UHF	UCODE I²C, UCODE G2iM+
Bi-directional communication	Long communication range, read/write through the appliance housing	UHF	UCODE I²C
	Consumer should be able to communicate with the tag	HF (NFC)	CLRC663
Track&Trace	Long read/write range, Bulk reading, reading through the housing	UHF	UCODE G2iL, UCODE G2iM+
Bluetooth pairing	Compatibility with NFC phones (need “NFC Forum Tag Type” tags)	HF (NFC)	NTAG203F, NTAG216F

More information on the mentioned ICs is available through the references (5) and (6).

How to implement the RFID function in the device

There are three main possibilities how to implement the RFID functionality in an electronic device:

- RFID chip as a surface mounted device (SMD) mounted on the PCB through normal surface mount technology
- RFID chip embedded in the PCB
- An adhesive RFID label (“sticker”) applied somewhere in the device (only for track&trace applications)

For the first two options, the antenna is formed by an appropriately designed copper plane as part of the PCB. The read and write range depends on the antenna size. In UHF, even small antenna sizes between 5x5mm and 10x10mm already offer good ranges as long as there is no significant shielding. More information on the UHF antenna design can be found in (7). For HF (NFC) antennas, please refer to (8).

A special form of an SMD component, the Murata Magic Strap is a module which contains in addition to an RFID chip also an internal short-range antenna. This allows to read and write the chip even before it is soldered to the board’s secondary antenna and therefore enables track&trace of a PCB from the first component on.

Embedding of the RFID chip in the PCB (the second possibility) comes with additional cost, but has the advantage that even the PCB raw material can be tracked.

The third option, the RFID label, offloads the antenna design work to the label/inlay manufacturer and is therefore the least effort from a design point-of-view, and the most flexible when it comes to selecting the location of the RFID tag. The draw-back is that RFID labels usually do not survive soldering temperatures and therefore can only be applied to the PCB or the housing at a later stage.

Conclusion

Passive RFID tags open up new possibilities in designing, manufacturing and servicing electronic devices. So, what's your next step? NXP's global customer support team and our qualified partners are ready to help you determine the optimal methods for embedding UCODE and NTAG chips into your electronics products. NXP provides assistance from concept and design to compliance and production, insuring quick and trouble free implementations to maximize your ROI and time to market. For more information, contact the author at Richard.Schmidmaier@nxp.com or visit our web site www.nxp.com or our RFID specific website at www.nxp-rfid.com.

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