Battery-Less NFC Sensor Tag with programmable “On Tag” Data Pre-Processing

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Texas Instruments Deutschland GmbH
MCU Safety & Security
Battery-Less Sensor Data Monitoring

- Sensor patches
- Data measurement and collection
- Data logging
- Reading with a smartphone
Application Example - Temperature Monitor

Temperature Monitoring

Special characteristics for Sensor Networks
- ... passive, autonomous HF to trigger Sensor activities
- ... NFC Technology allows interoperability to other networks
- ... due to RFID technology access to Data Logger Memory even without battery
- ... 13.56 MHz technology allows cheap and small form factor antennas
- ... semi-passive operation possible due to HF energy harvesting

The NFC technology in the cell phones is the “interoperability enabler” – with other applications and networks. (details see http://www.nfcworld.com/nfc-phones-list/)
RF430FRL15xH – Low Power Microcontroller

Features

- Package: VQFN (24), 4 mm x 4 mm
- Fully programmable 16-Bit
  MSP430 microcontroller
- Ultra Low Power Consumption
  - 140 µA/MHz (Active Mode)
  - 16 µA (Standby Mode)
- Data Preprocessing
- Data Logging
- Supply voltage 1.5V
- Powered by RF field or battery

<table>
<thead>
<tr>
<th>Device</th>
<th>RAM(KB)</th>
<th>FRAM(KB)</th>
<th>USCI</th>
<th>SD 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF430FRL151H</td>
<td>1</td>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RF430FRL152H</td>
<td>4</td>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RF430FRL153H</td>
<td>4</td>
<td>2</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>RF430FRL154H</td>
<td>4</td>
<td>2</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Powering the Device

Battery-less – Powered by energy harvesting from the RF field
- The complete device and the connected sensors are powered by the energy harvested from the RF field of the reader/writer device (e.g. smartphone or tablet)
- The device includes also a voltage double to support connected sensors or external circuitry with higher supply voltage requirements

Powering through battery
- 1.5V single cell disposable battery support (e.g. Type 377)
- Battery switch in the device ensures long battery life when device is stored with mounted battery
- Ultra-low leakage of max. 20nA with battery switch open
- Battery switch can be controlled through RF
Passive Radios – High Frequency (HF/NFC)

High Frequency Passive Radio Technology – NFC

The Radio Spectrum for classical passive RFID systems

High Frequency characteristics
• Well defined magnetic field; energy transfer possible
• Rather short read ranges: proximity / vicinity systems
• NFC allows wide interoperability e.g. Cell phones, PC, etc.
“No Power” solutions for RFID Tag – inductive coupling solutions (9kHz … 30MHz)

A Transmitter and Receiver Coil forms a magnetic coupled system. An alternating current generates a magnetic field which induces a voltage in the Receiver Coil. The efficiency of the power transfer depends on the coupling between the inductors and their quality factor.

**Pro**
- Proven technology
- Reasonable power transfer efficiency
  - …no battery required!
- Compatible with many user models
- Can be combined with an UHF data-link

**Con**
- Inductive coupled system ⇒ distance
  - Distance
  - May require tuning
- Energy coupling requirements may limit data rate (Q-factor)
Passive Radios – High Frequency (HF/NFC)

13.56MHz RFID System Overview – NFC / e.g. ISO15693

A battery-less tag gets its energy from the radio waves generated by the reader / NFC cell phone ...

Downlink (Reader ➔ Inlay)
ASK Modulation
Pulse Position Coding
Data-rate 1.6 or 26 kbits/sec

NFC Sensor Node e.g. Intelligent Tag using ISO15693 Tag

Data collector – NFC enabled Cell phone

Data collector - HF Reader

Antenna
Passive Radios – High Frequency (HF/NFC)

13.56MHz RFID System Overview – NFC / e.g. ISO15693

Communication from Inlay to Reader …

Uplink (Inlay ➔ Reader)
FSK or ASK modulation
Manchester coding
Data-rate 6 or 26 kbits/sec

Antenna

Data collector - HF Reader

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The power management of the device supports operation from the RF field only, battery only, as well as RF field and battery together.
Battery Lifetime Calculation

- 1.5V Battery (Type 377): 1.5V / 28mAh
- RF430FRL15xH Active Time per Measurement: 256ms
- RF430FRL15xH Power Consumption: 140μA/MHz (Active Mode), 16μA (Standby Mode)

Battery Lifetime with battery switch open (20nA leakage): multiple years
FRAM Microcontroller - What is FRAM?

Key FRAM Characteristics

**FRAM** = Ferroelectric **Random Access Memory**

Similar to DRAM

- … individual read and write of each bit possible
- … no special write sequence
- … fast write speeds
- … very little current is needed to store data

Information is stored on (Fe-)Capacitor

However:

- … non-volatile
- … no periodic refresh needed
FRAM Microcontroller - What is FRAM?

FRAM - Read and Write Access

Hysteresis Loop of the F-Cap material – PZT (Lead-Zirconate-Titanate)
Key advantages of FRAM

<table>
<thead>
<tr>
<th>Specifications</th>
<th>FRAM</th>
<th>SRAM</th>
<th>EEPROM</th>
<th>Flash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-volatile</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Retains data w/o power</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Write speed (13 KB)</td>
<td>10ms</td>
<td>&lt;10ms</td>
<td>2 secs</td>
<td>1 sec</td>
</tr>
<tr>
<td>Average active Power [µA/MHz]</td>
<td>100</td>
<td>&lt;60</td>
<td>50,000+</td>
<td>230</td>
</tr>
<tr>
<td>16 bit word access by the CPU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Write endurance</td>
<td>10^15</td>
<td>Unlimited</td>
<td>100,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Soft Errors</td>
<td>Below Measurable Limits</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bit-wise programmable</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Unified Memory</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><em>Flexible code and data partitioning</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Write More**
Collect more data over time with 100x faster writes than Flash
Extend product life and ditch the EEPROM with infinite endurance

**Decrease Power**
Extend battery life with 230x lower energy writes vs Flash
Minimize wireless system power by shortening memory update times

**Unified Memory**
Simple to use with unmatched flexibility
Bitwise programmable memory can be used for data or program storage
Outlook

- Monitor health status autonomously
- Share data securely
- Connectivity to health service center
Information & Demo

• Find more information about the Battery-less NFC/RFID Temperature Sensing Patch on http://www.ti.com/tool/TIDM-RF430-TEMPSENSE
  – Description
  – Technical Documents
  – Schematics with BOM
Thank you for your attention ...
Backup Slides
Passive (Battery-Less) NFC Solution

- Fully programmable ultra low power 16-Bit microcontroller **RF430FRL15xH**
- Low Power Consumption: 140 µA/MHz (Active Mode); 16 µA (Standby Mode)
- CPU System Clock: 4 MHz
- Package: VQFN (24), 4 mm x 4 mm
Introducing RF430FRL15xH Sensor Transponder

**ADC**
- Analog sensor interface
- Integrated temp sensor

**NFC**
- Secure proximity pairing
- Secure data transfers

**Serial IF**
- Digital sensor interface
- Connection to a gateway

**FRAM**
- Non-volatile / fast access
- Data & program storage

**CPU**
- Collection setup
- Data processing

**Low power**
- Passive operation
- 1.5V battery

**RF430FRL15xH NFC sensor transponder**

<table>
<thead>
<tr>
<th>Memory</th>
<th>Debug</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 kB FRAM</td>
<td>JTAG</td>
</tr>
<tr>
<td>8 kB ROM</td>
<td>Embedded Emulation</td>
</tr>
<tr>
<td>4 kB SRAM</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clock</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 MHz HF clock</td>
<td>1.5 V Battery</td>
</tr>
<tr>
<td>256 kHz LF clock</td>
<td>13.56 MHz RF field</td>
</tr>
</tbody>
</table>

**Connectivity**
- ISO 15693 (AFE 26 kbps)
- ISO 15693 encode/decode
- 1× USCI B (I²C/SPI)
- 8 General Purpose I/Os

**System**
- 16-bit Timer_A0
- 3 CC Registers
- 16-bit CRC
- Watchdog

**Sensor Interface**
- 14-bit ΣΔ-A/D Converter

**Sensor**
- On-Chip Temp Sensor
NFC (Near Field Communication) Basics

- **NFC**: wireless radio communication
- **Principal**: electromagnetic induction between two loop antennas
- **Radio Frequency**: ISM band of 13.56 MHz (unlicensed, globally available)
- **Modulation**: ASK (Amplitude-shift keying) using Manchester coding
- **Data Rates**: ranging from 106 kbit/s to 424 kbit/s
- **Distance**: 10 cm (3.9 in.) or less
- **Operating Modes**:
  - Active: generates an RF field
  - Passive: retrieves the power from the RF field
- **Communication Protocol**: ISO 15693
- **Typical applications**:
  - Ticketing, micro payment, access control,
  - Device pairing
  - Contactless token (Smart Card, RFID label, key fob)
Active - Passive NFC Communication

Reader emits carrier

Tag charges up

13.56 MHz

Reader sees modulated data (envelope detection)

Tag clocks out data (96-bit unique code)

424 kHz
Ferroelectric RAM (FRAM)

- **Nonvolatile memory**
  - for storage of program code or user data such as calibration and measurement data

- **Low power consumption**
  - Access to the FRAM cell at low voltage
  - Very little current is needed to change the data
  - Low average and peak write power leads to low average and peak power consumption of the MCU

- **Fast Write Speeds**
  - Writes are completed within the instruction cycle time
  - No data buffering required
  - No charge pump needed
  - Fast wake-up time
FRAM Microcontroller – Advantages

FRAM - Write Endurance

1 write per second (same address, no wear leveling):

- Flash: < 3 hours
- FRAM: > 3 million years

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FRAM Microcontroller – Advantages

FRAM – Energy Efficient Non-Volatile Storage

- ... significant faster programming compared to Flash
- ... no pre-erase of the memory required
- ... requires only 1/1000 of the Flash programming energy
- ... individual Byte programming possible, no “sector” programming
- ... FRAM allows re-programming during program execution
- ... FRAM is best suited for “over-the-air” software updates

Flash-based MCU:
Programming of 16 bit:
~100us * 2mA = 200nC / 16 bit

FRAM-based MCU
Programming of 16 bit:
~100ns * 4mA = 400pC / 16 bit
FRAM Microcontroller – Advantages

FRAM – Unified Memory

Application Requirement

“Traditional” Microcontroller

Program

Data (RAM)

Program (Flash)

FRAM Microcontroller

Data

Unified Memory

Program
Application Example

Intelligent Container – IMSAS Uni Bremen
Vernetzte, intelligente Objekte in der Logistik.

http://www.intelligentercontainer.de
Application Example

Medical

- The NFC enabled phones allows consumers to readout information from NFC enabled medical sensors (passive measurement on the spot or battery supported data logging) and transfer data to remote healthcare center for analysis and instruction
  - Blood pressure
  - Temperature
  - Glucose
  - Pulse
  - EKG
  - EMG
Application Example 2

Monitoring of physiological Parameters

- EEG monitor
- ECG monitor
- Pulse-Ox monitor
- Hydration monitor
- Heart rate monitor
- Temperature monitor
- Mental health monitor
- Blood glucose monitor
- Activity (calorie) monitor