IoT Development Kit (IDK) IDK SmartPassiveSensor_RFID Shield

Quick Start Guide: Bring Up Test of SPS_RFID Shield

INTRODUCTION

This document describes how to use the RFID shield on the IDK Baseboard and shows the good reading range performance of the RFID shield with the attached helical whip antenna

Software and Hardware Preparation

**Software Requirement:**
Windows PC with minimum 1 USB port, installed Java JRE/JDK v.8u101 or higher, Operation system Windows 7, 8 or 10, mini USB cable, Installed IDK IDE v3.6.5 or higher

**Hardware Requirement:**
- IDK Baseboard with Power connection cable (IoT Baseboard to the RFID shield)
- DC Power Supply Adapter, Recommended SMI24–12–V–P6

RFID shield kit is provided with:
- RFID Shield
- 1/4 Wave Whip Antenna for ETSI 866MHz
- Header 1x 10; 2x 8;1x
- Smart Passive Sensor™ (SPS) Tag Samples

Figure 1. RFID Shield Mounted on the IDK Baseboard
**Procedure:**
1. Mount the header and the antenna provided with the SPS_RFID shield kit on the SPS_RFID shield header connector and on the SMA antenna connector respectively.
2. Mount the SPS_RFID shield onto Baseboard over the Arduino header connector.
3. Connect the power cabling between the IDK Baseboard and the SPS_RFID shield. Connect mini−USB cable with the IDK Baseboard and computer.
4. Connect power supply adapter or any other supporting output voltage (7−12 V) to the IDK Baseboard and ensure that the two green LED are on as shown in the left picture in Figure 1.

**Smart Passive Sensor**
ON Semiconductor’s Smart Passive Sensors (SPS) are UHF RFUD wireless sensors that allow the passive sensing of fluid level, temperature and moisture values from the respective tags. The tag digitizes sensed information which can be read by a standard UHF RFID Gen 2 compliant reader. The sensor IC of the SPS, powered by the UHF reader, utilizes the patented self−tuning Chameleon engine which optimizes the detuned antenna condition by internal variable capacitance. The sensor IC has the ability to measure the amount of RF power received referred to as On−Chip RSSI and sends this information to the reader as a digital value.

The detailed information of each Smart Passive Sensors can be found in the respective datasheets which can be downloaded in the ON Semiconductor’s homepage [1].

The following table shows the overview of the SPS family with the operating frequency in UHF band and sensing functionality respectively.

**Table 1. OVERVIEW OF SMART PASSIVE SENSOR FAMILY**

<table>
<thead>
<tr>
<th>Product (old = new Partnumber)</th>
<th>Feature</th>
<th>UHF Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPS1M002A = SPS1M002PET</td>
<td>Moisture</td>
<td>FCC (902–928 MHz)</td>
</tr>
<tr>
<td>SPS1M002B = SPS2M002PET</td>
<td>Moisture</td>
<td>ETSI (860–880 MHz)</td>
</tr>
<tr>
<td>SPS2T001A = SPS1T001PET</td>
<td>Temperature</td>
<td>FCC (902–928 MHz)</td>
</tr>
<tr>
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</tr>
</tbody>
</table>

Partnumber Nomenclature: SPSxYzzzVVV
- SPS = Smart Passive Sensor
- x = Region, 1 = FCC, 2 = ETSI
- Y = Sensing Function
- zzz = unique iterative number
- VVV = Form Factor: FOM = Foam; PET = flexible PET; PCB = Printed Circuit Board; CRM = Ceramic Substrate
UHF RFID Band

EPC Gen 2 RFID tags work in the frequency band from 869 MHz to 950 MHz which covers the main frequency sub-bands used in different geographical regions. The IDK RFID sample program implemented 4 sub-bands covering 4 regions

- Europe, India, Middle East, Africa: 865–868 MHz
- US, South America and some regions of Asia: 902–928 MHz
- Japan: 950–956 MHz
- China: 920.5–924.5 MHz

The UHF RFID sub-bands is implemented in the IDK RFID sample program as following:

```c
const char* getRfidFreqBandName(const FreqBandEnum band)
{
    switch (band)
    {
        case FCC: return "FCC";
        case ETSI: return "ETSI";
        case PRC: return "PRC";
        case JAPAN: return "JAPAN";
        case FCC_center: return "FCC_center";
        case ETSI_center: return "ETSI_center";
        default: return "UNKNOWN";
    }
}
```

And can be set with the API

```c
if (initializeRfid(ETSI) < 0)
```

The attached whip antenna is optimized to cover the ETSI UFH band. Covering all UHF RFID sub-bands above, the LHCP antenna [5] is recommended.

GETTING STARTED

- Open the IDK SW by clicking onto IDK icon in start menu or via IDK reference icon on your desktop

![Figure 2.](image)

- When the IDK environment is opened, click with left mouse button on Examples → Simple and select the simple example RFID to run a simple application
• Code structure of the example appears on left window under Project Explorer, named AS3993_RFID. It usually happens there is a small red cross visible close to the name of the project. This is due to indexing that has to be rebuilt. In order to remove the red cross, right click on the AS3993_RFID, go to Index and left click on Rebuild. It disappears after few seconds.

![Figure 3. IDE](image)

• Go to Device Manager and identify the USB Port number. In this example COM3 was recognized and the value in file “config.cfg” was modified with the COM3. Save the modified file

![Figure 4. USB Port Configuration](image)

• Left click on the project AS3993_RFID to highlight the selected project and press the ON icon in the menu bar as depicted in the Figure 5 below. A console window opens with the prompt to reset the board and starts the time count–down immediately.
• Once the RESET button on the IoT Baseboard is pushed, the flash programming starts as illustrated in the console window below.

Now you can start to run the RFID application in the console window by adding a sample tag near the antenna and pressing the RESET button on the IDK Baseboard.

The example below shows the RFID reading process of three sample tags: 2 temperature and one moisture tag identified by the RFID Reader.
RFID READER READING RANGE AREA

The maximum distance or the reading area of the RFID shield to the tag position depends on the reader antenna type and the tag orientation itself regarding to the reader antenna position. Due to different environment conditions, like the reflection of the nearby objects causing multipath interference as well as influence of the human body holding the tag in the proximity of the reader antenna, the maximum read range can vary and cannot be precisely predicted in advance.

The following chapter illustrates the different RFID reader range areas based on the evaluation results in an ordinary environment.

The IDK RFID shield kit is provided with the helical whip antenna [3] with the omni-directional radiation pattern characteristics.

The whip antenna is mounted on the left corner edge of the RFID shield as shown in the picture below which effects the radiation pattern directivity due to the ground plane of the RFID shield itself.

Within the optimum reader reading range, up to 10 SPS tags can be detected as shown below.

![Figure 8. Reading of 10 SPS Tags Simultaneously](image)

The commonly used mounting position of the whip antenna are in horizontal and vertical plane with regard to the ground plane.

In H–plane position, the antenna is mounted with the pointing position parallel to the earth ground floor as shown in the Figure 8.
The second generally used antenna mounting position is in vertical plane, in following referred as V–plane, whereby the whip antenna is pointing to the ceiling and perpendicular to the shield and ground plane. To mount the whip antenna vertically on the RFID shield, an additional right angle adaptor [4] has been used as shown in picture below.

![Whip Antenna in Vertical Mounting Position](image)

To get flexible antenna position, a RF coaxial cable can be used to connect the antenna far away from the RFID shield, for example a RF cable length of 1 m with the attenuation of about ~ 0.5 dB in UHF range can be used without a significant RF power degradation.
RFID Reader Antenna in H−Plane

The Figure 10 illustrates the RFID shield reading area with the attached whip antenna and measured in an ordinary environment. The baseboard with the RFID shield is placed on the desk with the height of table to ground about 78 cm and the tag is placed in the horizontal polarized position whereby the height of antenna to the tag at reference position is 7 cm.

At the reference position, the RSSI is about 30. The tag is moved to the different position on the same place to characterize the tag reading area. In this measurement setup, the optimum reading position is right side of the RFID shield where the maximum reading distance up to 60 cm has been achieved. The second reading area in red with an omni-directional radiation characteristics can be observed when the tag is in the vertical position to the earth ground plane.

Figure 10. Top View of Tag Reading Area in H−Plane Position
**RFID Reader Antenna in V–Plane**

The picture below shows the optimum tag reading area with the vertical mounted whip antenna.

The first blue area the tag is positioned in the horizontal plane that means orthogonal to the vertical mounted whip antenna, the second reading area in red, the tag is in the vertical position as the mounted whip antenna.

In this setup, the max reading distance of the tag is about 60 cm in x–axis direction.

The blue reading area shows similar shape as in the horizontal mounted whip antenna above while the tag in the vertical position shows omni–directional shape. The tag position in the y–axis with max 42 cm is better than x–axis direction.

![Figure 11. Top View of Tag Reading Area in V–Plane Position](image-url)
**Left Hand Circular Polarized Antenna**

The following tag reading measurement is performed with the antenna[5] provided with the SensorRFA–GEVB[2]. The reading distance about 135 cm can be achieved, in front of the antenna with the tag in the horizontal plane as shown in the picture below. The blue reading area as reference shows the max distance with the whip antenna about 60 cm.

![Antenna Type: Reading Area with Tag Distance(cm)](image)

**Figure 12. Reading Distance with Circular Antenna vs. Whip Antenna**

Optimum reader range area and maximum reading distance can be selected depending on the application with the reader antenna type and tag position/orientation respectively. If the tag position is mostly in front of the antenna and higher reading distance is required, the circular polarized antenna[5] can be used but at the expense of higher price and size. But even with a small sized and cheap whip antenna [3], a decent reading performance can be achieved if the position and orientation for both antenna and tag are selected carefully.

**AUTOPOWER AND TX ATTENUATOR**

After successful reading of the SPS tag, the console window output following data e.g. for temperature sensor:

```
Found Tag (type = TEMP, label = 55c97, temp = 23.8, rssi = 13, tx_att = 6)
```

whereby

- **Label** = Last 5 hex digits of tag Tag Identification Data (TID)
- **Temp** = Temperature of the tag
- **RSSI** = Received Signal Strength Indicator (RSSI) value from 0–31 whereby 0 is the weakest and 31 is the strongest signal
- **TX Attenuator** used for the reading the tag and can be set from 0 to 19 whereby the value 0 dB is set with highest RF power and 19 dB results in the lowest RF power

The loaded sample program is using the pre-compiled library instanced with `AS3993_RFID rfid` in the main.c file. In order to be able to change the TX attenuator or switch on/off the Autopower parameter within the AS3993_RFID library, following steps are recommended to import the library into the workspace:
Go to the IDK installation path, in this example the IDK installation directory is C:\OnSemiconductor

Go to the folder C:\OnSemiconductor\samples\AS3993_RFID and copy two files AS3993_RFID.cpp and AS3993_RFID.h into your working directory within the workspace and rename the files in order not to confuse with the pre-compiled library, in this example renamed to: myAS3993_RFID.cpp and myAS3993_RFID.h

Press within the IDE F5 button to make the copied files visible

Now the project explorer window lists the copied file, double click on the file myAS3993_RFID.cpp and press Ctrl-F

In the find/replace window enter AS3993_RFID in the “find” field and myAS3993_RFID in the “replace” field as shown in the Figure below and press “Replace All” button

Figure 13. AS3993 class

Do the same steps for the files AS3993_RFID.h;main.cpp; Shield.h;header.h

Rebuild the project AS3993_RFID again

Now you can modify the parameter like TX attenuation and Autopower on/off in the myAS3993_RFID library.

By default, the TX attenuation is set to 6 and Autopower = off

To change the TX Attenuator value go to myAS3993_RFID.h and set the values of your interest and rebuild, in the example below TX Attenuator value is 6 dB

```
#define TEMP_MIN_TX_ATTENUATION 6
#define MOIST_MIN_TX_ATTENUATION 6
```

The Autopower functionality can be switched on or off in the myAS3993_RFID.cpp file with the parameter “tempAutoPower”. Press Ctrl-F and type tempAutoPower in the file myAS3993_RFID.cpp and set the value of the tempAutoPower to “true” if you want to switch on the Autopower parameter and rebuild the project.

```
Int mzAS3993_RFID::measureTempTags()
{
    TempAutoPower = true; //false by default;
    //Do the same modification for the member function myAS3993_RFID::measureMoistTags() in the same file.
    //If Autopower is switched on, the TX attenuation value will be varied automatically from set value to max 19 dB according to the strength of the reflected signal from the tag.
```

```
RFID SHIELD BOARD TEMPERATURE MEASUREMENT

**Measurement Setup:**
- RFID Shield Rev2.0 on IDK Baseboard
- FLIR A655sc IR camera with software Flir ResearchIR Max
  - Emissivity = 0.95
  - Refl. Temperature = 24 °C
- HP 34401A Multimeter for Power Supply Current Measurement
- Keithly DC Power Supply to Baseboard
- RFID Tags: 2x Temperature Tag (SPS2T001B) + 1x Moisture Tag (SPS1M002B)
- RFID Operation Frequency: ETSI (860–880 MHz)

**Table 2.**

<table>
<thead>
<tr>
<th>Measurement Condition</th>
<th>Max RF Output Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>12 V</td>
</tr>
<tr>
<td>Average Supply Current</td>
<td>295 mA</td>
</tr>
<tr>
<td>Peak Supply Current</td>
<td>598 mA</td>
</tr>
<tr>
<td>Max Temp at PA</td>
<td>55.8 °C</td>
</tr>
<tr>
<td>Max Temp at LDO</td>
<td>38.9 °C</td>
</tr>
<tr>
<td>Max Temp at U10: MMIC Amplifier</td>
<td>44.3 °C</td>
</tr>
<tr>
<td>Max Temp at U6: LDO</td>
<td>44.4 °C</td>
</tr>
<tr>
<td>Max Temp at U7: LDO</td>
<td>45 °C</td>
</tr>
<tr>
<td>Max Temp at L6.7: RF inductor</td>
<td>44.6 °C</td>
</tr>
</tbody>
</table>

**Figure 14.**
REFERENCES

[2] EVBUM2508−D.PDF
[4] Linx Conssma010
[5] ATLAS_MTI_MT−242025_TRH_A_RHCP_Outdoor_RFID_Antenna_865−956_MHz; Part Number: MT−242025/NRH