SESSION 3: THE NFC COCKPIT
THE COMPLETE DESIGN TOOL FOR ENGINEERS
October 2016
Agenda

Design and implement NFC applications

Session I, 7th September
**Product support package for NXP NFC readers**
[https://attendee.gotowebinar.com/rt/2329750067403618817](https://attendee.gotowebinar.com/rt/2329750067403618817)

Session II, 28th September
**Antenna design considerations for NXP NFC reader solutions**
[https://attendee.gotowebinar.com/rt/282682617345186049](https://attendee.gotowebinar.com/rt/282682617345186049)

Session III, 18th October
**The NFC Cockpit - the complete design tool for engineers**
[https://attendee.gotowebinar.com/rt/4665515186055692345](https://attendee.gotowebinar.com/rt/4665515186055692345)

Session IV, 31th October
**NFC Reader Library - SW support for NFC frontend solutions**
[https://attendee.gotowebinar.com/rt/7151741873899128067](https://attendee.gotowebinar.com/rt/7151741873899128067)
Design and implement NFC applications

Session 3, 18th October
The NFC Cockpit: The complete design tool for engineers

- Link with last session
- DPC: Dynamic Power Control
  - Parameters to define DPC
- NFC Cockpit
  - DPC Configuration
  - Correlation test
  - Adjust RRx
  - DPC calibration
  - TX shaping
- Summarize
ANTENNA DESIGN CONSIDERATIONS REVIEW
Antenna Matching

Asymmetric matching

Symmetric matching
Final assembly

Demo board

Matching board

Antenna

- 470nH
- C = 30 μF
- C mode = 1 SRF = 250MHz

- 33pF
- 27pF
- 36pF
- 27pF

- 1R
- 1R
- 0.25R
- 2.3pF

- 600mH
Final antenna tuning measurement results

First matching: \( Z = 21.9 + j1.5\Omega \)

Fine tuned: \( Z = 20.6 + j1.5\Omega \)
Antenna loading & detuning

Metal (smartphone)

\[ Z = 4.2 + j0 \ \Omega \]

Due to symmetric matching, \( Z \) decreases \( \Rightarrow I_{TVDD} \) increases
Antenna loading & detuning

Reference PICC

\[ Z = 4.8 + j2.2\Omega \]

Due to symmetric matching, \( Z \) decreases \( \Rightarrow I_{TVDD} \) increases
DPC: DYNAMIC POWER CONTROL
What is DPC?
Dynamic Power Control

- Allows software controlled transmitter current limitation
- Allows power control
- Allows improved antenna tuning
- Allows increased Q
- Allows smaller antennas
DPC principle

1: Load change
   → Decreases impedance
   → Increases AGC value

2: AGC value change
   → Decreases TVDD setting
   → Decreases ITVDD
   Decreases power

3: New TVDD setting
The PN5180 DPC dynamically measures the AGC value. The default time interval of this measurement is defined in DPC_TIME register. It is recommended to leave this interval as defined by default.
In our example, we start operating at gear 0.

The high threshold defined by Gear 0 is exceeded, DPC shifts to Gear 1.
DPC gears principle

- DPC defines the low threshold (to shift back to Gear 0) due to the first measurement after switching to Gear 1.
- The high threshold defined by Gear 1 is exceeded, DPC shifts to Gear 2.

Field strength

- Gear 0 DPC_THRSH_HIGH
- Gear 1 DPC_THRSH_HIGH
- DPC_AGC_SHIFT_VALUE

Gear 0 Gear 1
DPC gears principle

6. DPC defines the low threshold (to shift back to Gear 1) due to the first measurement after switching to Gear 2

7. The high threshold defined by Gear 2 is exceeded, DPC shifts to Gear 3

Field strength

Gear 0 DPC_THRSH_HIGH
Gear 1 DPC_THRSH_HIGH
Gear 2 DPC_THRSH_HIGH

DPC_AGC_SHIFT_VALUE

Gear 0 Gear 1 Gear 2
DPC gears principle

- **8** DPC defines the low threshold (to shift back to Gear 2) due to the first measurement after switching to Gear 3
- **9** The low threshold defined by Gear 3 is exceeded, DPC shifts back to Gear 2

---

The low threshold defined by Gear 3 is exceeded, DPC shifts back to Gear 2
DPC gears principle

The low threshold defined by Gear 2 is exceeded, DPC shifts back to Gear 1.
PARAMETERS TO DEFINE DPC
Parameters to define DPC

1. **Number of gears (DPC_AGC_GEAR_LUT_SIZE, 0x81)**
   - Defines the number of gears (1 Byte)
   - Value: 1…15 (decimal)

2. **Tx settings per gear (DPC_AGC_GEAR_LUT, 0x82 … 0x90)**
   - Defines the output power settings per gear
   - Details see next slides

3. **AGC HIGH threshold (DPC_THRSH_HIGH, 0x5F … 0x7C)**
   - One AGC high threshold (2 Bytes) per gear -> DPC_THRSH_HIGH
   - Defines the maximum AGC value per gear
   - The DPC switches to the next gear, as soon as AGC Value > DPC_THRSH_HIGH
NFC COCKPIT
NFC Cockpit
Download

www.nxp.com
NFC Cockpit
Start
BACKUP EEPROM
NFC Cockpit

Start
NFC Cockpit

Start
NFC Cockpit

Start
NFC Cockpit
Start
NFC Cockpit
Start
DPC CONFIGURATION
NFC Cockpit
DPC Configuration

Prerequisites

1. “Symmetrical” antenna tuning (to e.g. 20Ω) [DONE]
2. Ensure a good correlation between AGC & ITVDD
3. Adjust RRx to achieve
   - AGC value = appr. 300dec unloaded (full NFC)
   - AGC value = appr. 600dec unloaded (pure Reader mode)

Define

1. Number of gears (e.g. 5 seems to be good for standard EMVCo POS)
2. Tx settings per gear (DPC_AGC_GEAR_LUT)
3. ITVDD switch (e.g. 205mA)
CORRELATION TEST
Precondition for DPC:
- Linear link between AGC value and ITVDD current
- Requires “symmetric” antenna matching and L0 > Lant/2
NFC Cockpit

Setup

TVDD
5V – 245.2 mA
NFC Cockpit
Start
NFC Cockpit
Correlation test
NFC Cockpit
Correlation test
NFC Cockpit
Correlation test
NFC Cockpit
Correlation test

Load 1: Ref PICC

Target ITVDD = 184 mA + 10 mA
NFC Cockpit
Correlation test

Target ITVDD = 184 mA + 20 mA
NFC Cockpit
Correlation test

Target ITVDD = 184 mA + 30 mA
Target ITVDD = 184 mA + 40 mA
NFC Cockpit
Correlation test
NFC Cockpit
Correlation test
NFC Cockpit
Correlation test
NFC Cockpit
Correlation test

Load 2: Phone

Target ITVDD = 184 mA + 10 mA
NFC Cockpit

Correlation test

Target ITVDD = 184 mA + 20 mA
NFC Cockpit
Correlation test

Target ITVDD = 184 mA + 30 mA
NFC Cockpit
Correlation test

Target ITVDD = 184 mA + 40 mA
## NFC Cockpit

Correlation test

### Correlation Test

<table>
<thead>
<tr>
<th>ITVDOD unloaded</th>
<th>ITVDOD Step Size</th>
<th>ITVDOD Max</th>
<th>Current ITVDOD</th>
<th>Number of Loading Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>184 mA</td>
<td>10 (0 to 20)</td>
<td>230 mA</td>
<td>mA</td>
<td>2</td>
</tr>
</tbody>
</table>

### AGC Values in Hex and Dec for each Loading Case

<table>
<thead>
<tr>
<th>ITVDOD</th>
<th>RefPCICCA</th>
<th>RefPCICCA</th>
<th>PhoneAp</th>
<th>PhoneAp</th>
</tr>
</thead>
<tbody>
<tr>
<td>184</td>
<td>328</td>
<td>321</td>
<td></td>
<td></td>
</tr>
<tr>
<td>194</td>
<td>338</td>
<td>331</td>
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<tr>
<td>204</td>
<td>352</td>
<td>348</td>
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<td></td>
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<tr>
<td>214</td>
<td>360</td>
<td>364</td>
<td></td>
<td></td>
</tr>
<tr>
<td>224</td>
<td>380</td>
<td>383</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: ITVDOD and ITVDODMax value ranges from 0 to 250
NFC Cockpit
Correlation test

Correlation Tests

<table>
<thead>
<tr>
<th>ITVD</th>
<th>Ref PICC AGC in Dec</th>
<th>Ref PICC AGC in Hex</th>
<th>Phone AGC in Dec</th>
<th>Phone AGC in Hex</th>
</tr>
</thead>
<tbody>
<tr>
<td>184</td>
<td>326 0x146</td>
<td></td>
<td>321 0x141</td>
<td></td>
</tr>
<tr>
<td>194</td>
<td>338 0x152</td>
<td></td>
<td>331 0x14B</td>
<td></td>
</tr>
<tr>
<td>204</td>
<td>352 0x160</td>
<td></td>
<td>348 0x15C</td>
<td></td>
</tr>
<tr>
<td>214</td>
<td>365 0x16D</td>
<td></td>
<td>364 0x16C</td>
<td></td>
</tr>
<tr>
<td>224</td>
<td>380 0x17C</td>
<td></td>
<td>383 0x17F</td>
<td></td>
</tr>
</tbody>
</table>

OK
NFC Cockpit
DPC Configuration

Prerequisites
1. “Symmetrical” antenna tuning (to e.g. 20Ω) DONE
2. Ensure a good correlation between AGC & ITVDD DONE
3. Adjust RRx to achieve
   • AGC value = appr. 300dec unloaded (full NFC)
   • AGC value = appr. 600dec unloaded (pure Reader mode)

Define
1. Number of gears (e.g. 5 seems to be good for standard EMVCo POS)
2. Tx settings per gear (DPC_AGC_GEAR_LUT)
3. ITVDD switch (e.g. 205mA)
ADJUST RRX
NFC Cockpit
Adjust RRx
NFC Cockpit
DPC Configuration

Prerequisites
1. “Symmetrical” antenna tuning (to e.g. 20Ω) DONE
2. Ensure a good correlation between AGC & ITVDD DONE
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   • AGC value = appr. 300dec unloaded (full NFC) DONE
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3. ITVDD switch (e.g. 205mA)
NFC Cockpit
DPC Configuration

Prerequisites
1. “Symmetrical” antenna tuning (to e.g. 20Ω)  DONE
2. Ensure a good correlation between AGC & ITVDD  DONE
3. Adjust RRx to achieve
   • AGC value = appr. 300dec unloaded (full NFC)  DONE
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1. Number of gears (e.g. 5 seems to be good for standard EMVCo POS)
2. Tx settings per gear (DPC_AGC_GEAR_LUT)
3. ITVDD switch (e.g. 205mA)
DPC CALIBRATION
### NFC Cockpit

#### DPC Calibration

<table>
<thead>
<tr>
<th>Gear #</th>
<th>EEPROM (hex)</th>
<th>TX power setting (hex)</th>
<th>Driver voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0x82</td>
<td>F9</td>
<td>5.0</td>
</tr>
<tr>
<td>1</td>
<td>0x83</td>
<td>F1</td>
<td>4.85</td>
</tr>
<tr>
<td>2</td>
<td>0x84</td>
<td>F3</td>
<td>4.75</td>
</tr>
<tr>
<td>3</td>
<td>0x85</td>
<td>F5</td>
<td>4.5</td>
</tr>
<tr>
<td>4</td>
<td>0x86</td>
<td>F7</td>
<td>4.0</td>
</tr>
<tr>
<td>5</td>
<td>0x87</td>
<td>F0</td>
<td>2.85</td>
</tr>
<tr>
<td>6</td>
<td>0x88</td>
<td>F2</td>
<td>2.75</td>
</tr>
<tr>
<td>7</td>
<td>0x89</td>
<td>F4</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>0x8A</td>
<td>F5</td>
<td>2.0</td>
</tr>
<tr>
<td>9</td>
<td>0x8B</td>
<td>95</td>
<td>2.0</td>
</tr>
<tr>
<td>10</td>
<td>0x8C</td>
<td>66</td>
<td>2.0</td>
</tr>
<tr>
<td>11</td>
<td>0x8D</td>
<td>45</td>
<td>2.0</td>
</tr>
<tr>
<td>12</td>
<td>0x8E</td>
<td>36</td>
<td>2.0</td>
</tr>
<tr>
<td>13</td>
<td>0x8F</td>
<td>26</td>
<td>2.0</td>
</tr>
<tr>
<td>14</td>
<td>0x90</td>
<td>15</td>
<td>2.0</td>
</tr>
</tbody>
</table>

- **DPC_AGC_GEAR_LUT_SIZE, 0x81**
- **Tx settings per gear (DPC_AGC_GEAR_LUT, 0x82 ... 0x90)**
Add load until $\text{ITVDD} = 210 \text{ mA}$
NFC Cockpit
DPC Calibration

Up to ITVDD = 210 mA
NFC Cockpit
DPC Calibration
NFC Cockpit
DPC Calibration

Up to ITVDD = 210 mA
NFC Cockpit
DPC Calibration

Up to ITVDD = 210 mA
NFC Cockpit
DPC Calibration
NFC Cockpit
DPC Calibration

Gear 3

Up to ITVDD = 210 mA
NFC Cockpit
DPC Calibration

Up to ITVDD = 210 mA
NFC Cockpit
DPC Calibration
NFC Cockpit
DPC Calibration

AGC HIGH threshold (DPC_THRSH_HIGH, 0x5F ... 0x7C)
NFC Cockpit

DPC Calibration
NFC Cockpit
DPC Configuration

Prerequisites
1. “Symmetrical” antenna tuning (to e.g. 20Ω)  DONE
2. Ensure a good correlation between AGC & ITVDD  DONE
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   • AGC value = appr. 300dec unloaded (full NFC)  DONE
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Define
1. Number of gears (e.g. 5 seems to be good for standard EMVCo POS)
2. Tx settings per gear (DPC_AGC_GEAR_LUT)  DONE
3. ITVDD switch (e.g. 205mA)
TX SHAPING
NFC Cockpit
TX shaping

Reference PICC

Variable operating distance

PN5180 antenna

Wave shape test signal

TX1 or TX2 output

Tx envelope (optional)
NFC Cockpit
TX shaping
NFC Cockpit
TX shaping
NFC Cockpit

TX shaping
NFC Cockpit
TX shaping

- Ref PICC
- TX envelope
- TX

Table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lower Limit</th>
<th>Measured Value</th>
<th>Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>t1 [μs]</td>
<td>2.06</td>
<td>0.06</td>
<td>2.99</td>
</tr>
<tr>
<td>t2 [μs]</td>
<td>0.52</td>
<td>2.18</td>
<td>2.66</td>
</tr>
<tr>
<td>t3 [μs]</td>
<td>0</td>
<td>0.51</td>
<td>1.18</td>
</tr>
<tr>
<td>t4 [μs]</td>
<td>0</td>
<td>0.31</td>
<td>0.34</td>
</tr>
<tr>
<td>Overshoot [%]</td>
<td>0</td>
<td>7.81</td>
<td>10</td>
</tr>
<tr>
<td>Undershoot [%]</td>
<td>0</td>
<td>0.53</td>
<td>10</td>
</tr>
<tr>
<td>ASK Mod. Depth [%]</td>
<td>95</td>
<td>99.30</td>
<td>100</td>
</tr>
<tr>
<td>Monotony</td>
<td>Fail</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NFC Cockpit
TX shaping

Option 1: change the antenna tuning
• Hardware change: quite a lot of effort
• Reduce Q-factor: reduces operating distance

Option 2: use Tx Shaping
• EEPROM change: low effort
• No change of antenna tuning: same operating distance

Typically the only option for standard antenna tuning.
NFC Cockpit

TX shaping

TX_UNDERSHOOT_CONFIG (0x0014)
TX_OVERSHOOT_CONFIG (0x0015)
RF_CONTROL_TX (0x0020)
RF_CONTROL_TX_CLK (0x0021)
NFC Cockpit

TX shaping

- **TX_UNDERSHOOT_CONFIG** (0x0014)
  - TX_UNDERSHOOT_PATTERN_LEN
  - TX_UNDERSHOOT_PROT_ENABLE

- **RF_CONTROL_TX** (0x0020)
  - TX_RESIDUAL_CARRIER
  - TX_SET_BYPASS_SC_SHAPING
  - TX_SET_TAU_MOD_FALLING
  - TX_SET_TAU_MOD_RISING

- **RF_CONTROL_TX_CLK** (0x0021)
  - TX_CLK_MODE_OVUN_PREV
  - TX_CLK_MODE_RM → for type A it is typically 001, for type B it must be 111
NFC Cockpit

TX shaping
NFC Cockpit

TX shaping

- Ref PICC
- TX envelope
- TX
NFC Cockpit
TX shaping
NFC Cockpit
TX shaping
NFC Cockpit

TX shaping

No TX shaping

TX shaping

Ref PICC
TX envelope
TX

Ref PICC
TX envelope
TX
SUMMARIZE
• **DPC Configuration**

  - **Prerequisites**
    1. “Symmetrical” antenna tuning (to e.g. 20Ω)
    2. Ensure a good correlation between AGC & ITVDD
    3. Adjust RRx to achieve
      - AGC value = appr. 300dec unloaded (full NFC)
      - AGC value = appr. 600dec unloaded (pure Reader mode)
    4. Ensure wave shapes are ok.

  - **Define**
    1. Number of gears (e.g. 5 seems to be good for standard EMVCo POS)
    2. Tx settings per gear (DPC_AGC_GEAR_LUT)
    3. ITVDD switch (e.g. 205mA)

• **TX shaping**
Summarize

• DPC Configuration
  - Prerequisites
    1. “Symmetrical” antenna tuning (to e.g. 20Ω)
    2. Ensure a good correlation between AGC & ITVDD
    3. Adjust RRx to achieve
      • AGC value = appr. 300dec unloaded (full NFC)
      • AGC value = appr. 600dec unloaded (pure Reader mode)
    4. Ensure wave shapes are ok.
  - Define
    1. Number of gears (e.g. 5 seems to be good for standard EMVCo POS)
    2. Tx settings per gear (DPC_AGC_GEAR_LUT)
    3. ITVDD switch (e.g. 205mA)

• TX shaping
Coming sessions

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Software development in Android and iOS
Embedded software for MCUs
JCOP, Java Card operating Systems
Hardware design and development
Digital, analog, sensor acquisition, power management
Wireless communications WiFi, ZigBee, Bluetooth, BLE
Contactless antenna RF design, evaluation and testing

MIFARE applications
End-to-end systems, readers and card-related designs
EMVco applications
Readers, cards, design for test compliancy (including PCI)
Secure Element management
GlobalPlatform compliant backend solutions
Secure services provisioning OTA, TSM services

We help companies leverage the mobile and contactless revolution
Design and implement NFC applications
Session 3: The NFC Cockpit – the complete design tool for engineers
Cristina Llabrés (Speaker)
Angela Gemio (Host)

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