AN11314

Multiple Antennas on Single Reader IC

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Application note
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Abstract	This application note describes different design concepts using multiple antennas on a single reader IC.

Revision history

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1.0	20130109	First release

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1. Introduction

This application note describes different design concepts using multiple antennas on a single reader IC.

2. Basic concepts

2.1 Introduction to multiple antennas

A contactless reader/NFC design might require multiple tap points for credentials and/or phones. In order to keep the system cost as low as possible, this functionality can be achieved using multiple antennas with a single contactless reader IC. The host controller can enable/disable each antenna individually to determine on which antenna the card was presented.

This application note describes two different approaches for achieving the required functionality, depending on the system requirements and chipset used:

1. Single ended designs as described in section 3: Single ended design (RC632 and PN512 family)
2. Designs with external switching circuitry as described in section 4: Differential design with external circuitry (RC663, RC632 or PN512 family)

This application note does not cover applications where all the antennas are turned on at the same time. The focus of this document is to describe the use cases where selective powering of different antennas is required.

2.2 Need to enable/disable each antenna individually

The need to enable and disable each antenna individually is often required because the device needs to know on which antenna a card was presented. There might be other designs, however, where it is not required to enable/disable each antenna individually. In this case the design can possibly be a bit simpler, two antennas can just be connected in parallel and enabled/disabled at the same time. This use case would be when there are multiple tap points on the reader that are some distance apart, but it is not practical to just put one large antenna.

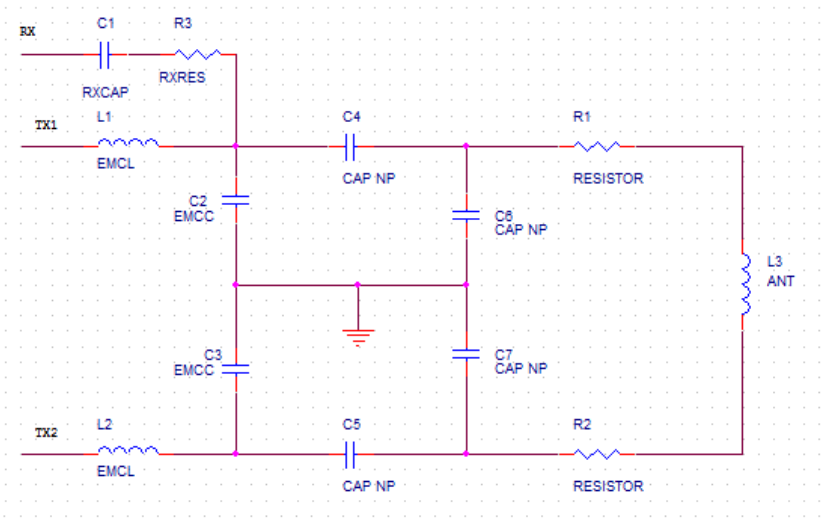

Fig 1. Typical external circuitry for one antenna

Additional antenna(s) can be added in parallel if there is no need to enable/disable each antenna individually. Also this concept can only work properly if both antennas are exactly the same layout (if antennas are different then would need different tuning for each). Note that when two antennas are added in parallel only half of the power will be available on each which will affect the contactless performance.

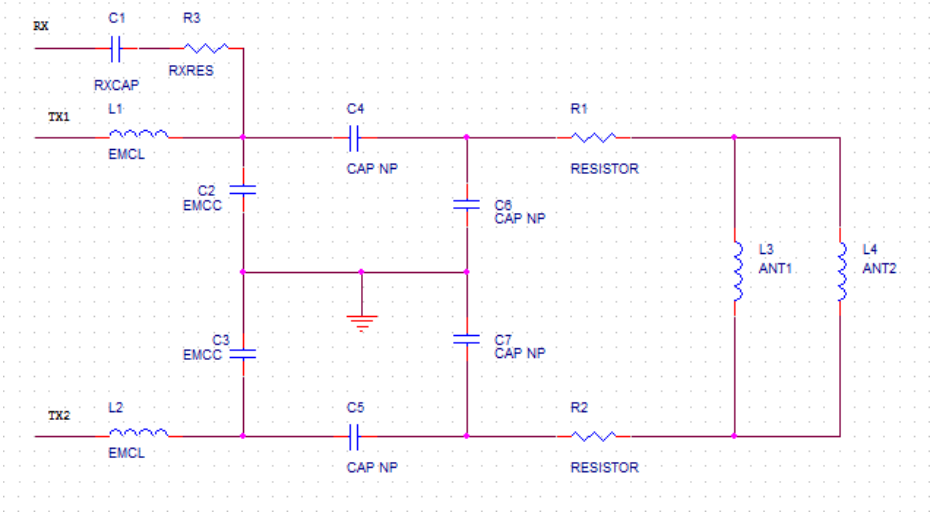

Fig 2. Two antennas in parallel

2.3 Product family members

This document refers to product families for explanation of applicable antenna concepts. The product numbers of families used in this document are listed below.

2.3.1 RC632 family

MFRC500, MFRC530, MFRC531, SLRC400, and CLRC632

2.3.2 PN512 family

MFRC522, MFRC523 and PN512

2.3.3 RC663 family

MFRC630, MFRC631, SLRC610, and CLRC663

3. Single ended design (RC632 and PN512 families)

3.1 Introduction to concept

On RC632 and PN512 family devices TX1 and TX2 can be enabled individually using register settings. When using these reader ICs with two antennas one single ended antenna is connected to TX1 and the other single ended antenna to TX2. The host controller can then enable/disable each antenna by setting or clearing bits in the driver register of the IC. Note that the host can also enable both antennas at the same time if needed.

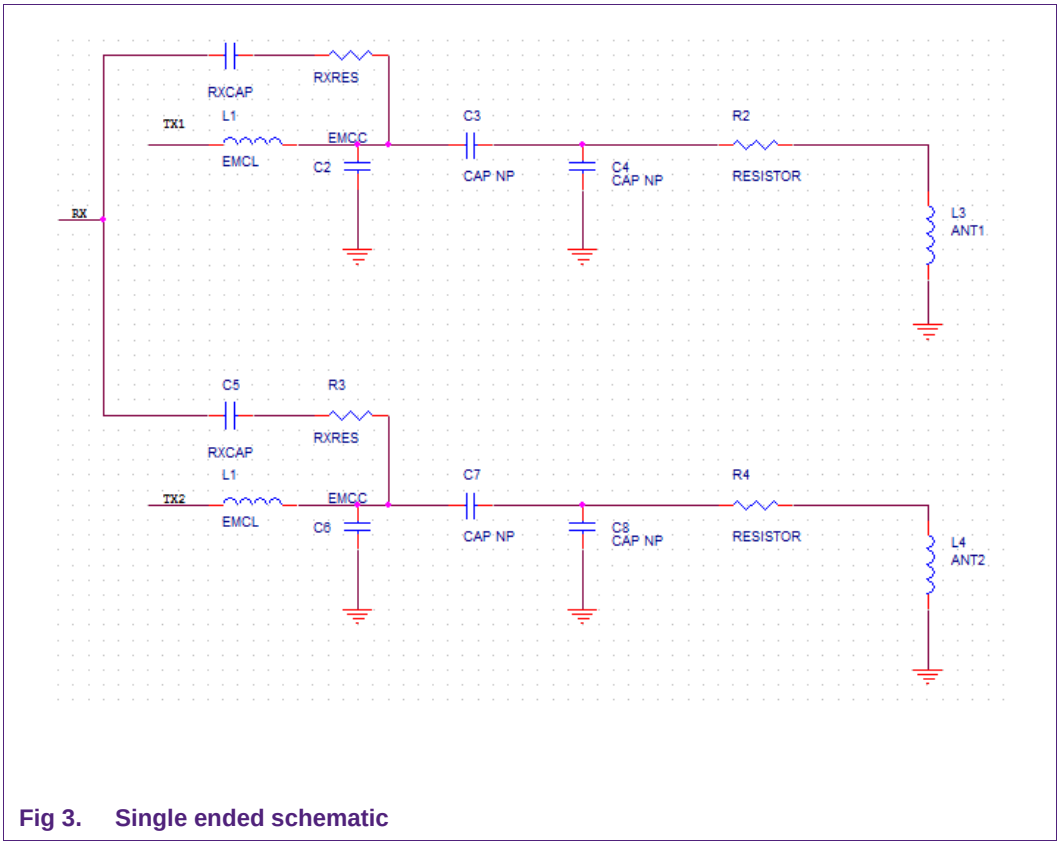

Fig 3. Single ended schematic

3.2 Register control

RC632 family ICs have a register called TxControl (addr 0x11). The two least significant bits are called TX1RFEn and TX2RFEn. Using these bits the 13.56 MHz output can be individually enabled/disabled on TX1 and TX2. To enable the antenna connected to TX1 only TxControl has to be set to 0x51. The reader can then poll for cards with only this antenna enabled. To enable the antenna connected to TX2 only, TxControl has to be set to 0x52. The reader can then poll for cards with only this antenna enabled. To enable both antennas at the same time TxControl has to be set to 0x53.

PN512 family ICs have a similar register called TxControlReg (addr 0x14). Similar to RC632 family ICs, the two least significant bits are called Tx1RFEn and Tx2RFEn (the other bits in the register are slightly different than RC632 family). To enable the antenna connected to TX1 only TxControlReg has to be set to 0x01. The reader can then poll for cards with only this antenna enabled. To enable the antenna connected to TX2 only, TxControlReg has to be set to 0x02. The IC will poll for cards with only this antenna enabled. To enable both antennas at the same time TxControlReg has to be set to 0x03.

Note that this concept can also be applied to the PN532, PN533, and PR533. In these ICs the register used to control TX1 and TX2 is called CIU_TxControl and has address 0x6304. The bits in this register have the same functionality as TxControlReg in PN512.

3.3 Advantages and disadvantages

Advantages of this concept:

- No external switches needed
- Less passive components
- Easier tuning procedure than using external switch concept below

Disadvantages of this concept:

- With a single ended design only about 50% of the power of a differential design is available on a single antenna.
- This concept can only handle two antennas and not three or more.
- With a single ended design the power draw on TVDD is not constant, therefore more filtering on TVDD pin may be needed.

4. Differential design with external circuitry (RC663, RC632, and PN512 families)

4.1 Introduction to concept

To achieve multiple antennas with the RC663 family the switch has to be implemented externally. Also, this is the only applicable concept if more than two antennas are required in the design.

In order to switch each antenna in and out of the circuit high voltage NFET transistors are used. The NFETs are placed on both sides of all the antennas and are used to switch ground in and out of both sides of the antennas.

Below shows the schematic with the switching concept using two antennas. Here we just show the components external to the reader IC (host is also not shown). TX1, TX2, RX1, RX2 will connect to the reader IC (for RC632 family and PN512 family devices there is only one RX pin instead of two). GPIO1 and GPIO2 will connect to the host microcontroller's GPIOs. The schematic shows two antennas, but this same concept can also apply to three or more antennas.

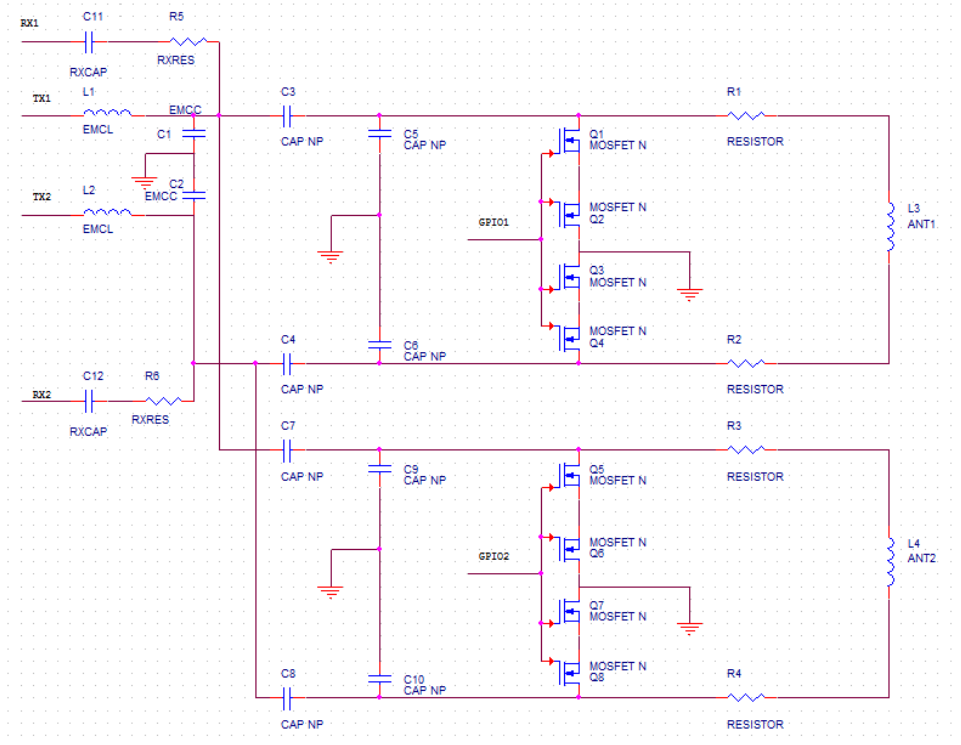

Fig 4. Multiple antennas with external switches

The schematic is the same as a traditional reader design with an NXP reader IC, with the exception of the multiple antennas and the high voltage transistors added in order to switch each antenna in and out.

The transistors must have a Vds rating higher than the maximum voltage on the antennas (typically a 60V rating should be sufficient, but the maximum voltage on the antenna has to measured to confirm this rating). To minimize the power loss when the transistors are turned on, the Rdson value of the transistors should be as low as possible. The gates of the four transistors per antenna can all be connected together and then connected to the host MCU's GPIO. The host can enable/disable each antenna by pulling the gates of the four transistors high or low. If the gates are pulled high, the Vgs is greater than Vth and the transistors are turned "on." This shorts GND onto both sides of the antenna and therefore removes the antenna from the circuit. To enable the antenna the gates of the transistors are pulled low which makes Vgs less than Vth. This turns the transistors "off" so that the antenna is no longer grounded on both sides and the antenna can function normally.

Examples of transistors that can work are NXP's 2N7002P series transistors (use as low Rdson as practical).

4.2 Cold switching

It is recommended for EMI reasons to only switch antennas when both TX1 and TX2 drivers are disabled. On RC663 family devices TX1 and TX2 drivers are disabled by clearing bit TxEn in register DrvMode (addr 0x28). Before switching antennas in and out of the circuit this bit should be cleared. After the switching is complete the drivers can be re-enabled by setting this bit.

4.3 Advantages and disadvantages

Advantages of this concept:

- This concept works on RC663 family where TX1/TX2 are not individually controllable.
- Nearly full power on all antennas is available (one antenna on at a time).
- Ability to have more than two antennas.
- Less filtering on TVDD required compared to single ended design since with differential driver there is a constant current requirement on TVDD.

Disadvantages of this concept:

- External NFETs required for switching.
- More passive components required.
- Tuning procedure is more difficult than doing single ended design

4.4 Tuning

Tuning using this concept is a bit more complicated than tuning a single directly matched antenna. This is because one antenna has to be switched into the circuit and the tuning procedure performed, but the series capacitors on the disabled antennas are still in the circuit and must be taken into account in the tuning. As an example the tuning for the above schematic is performed below.

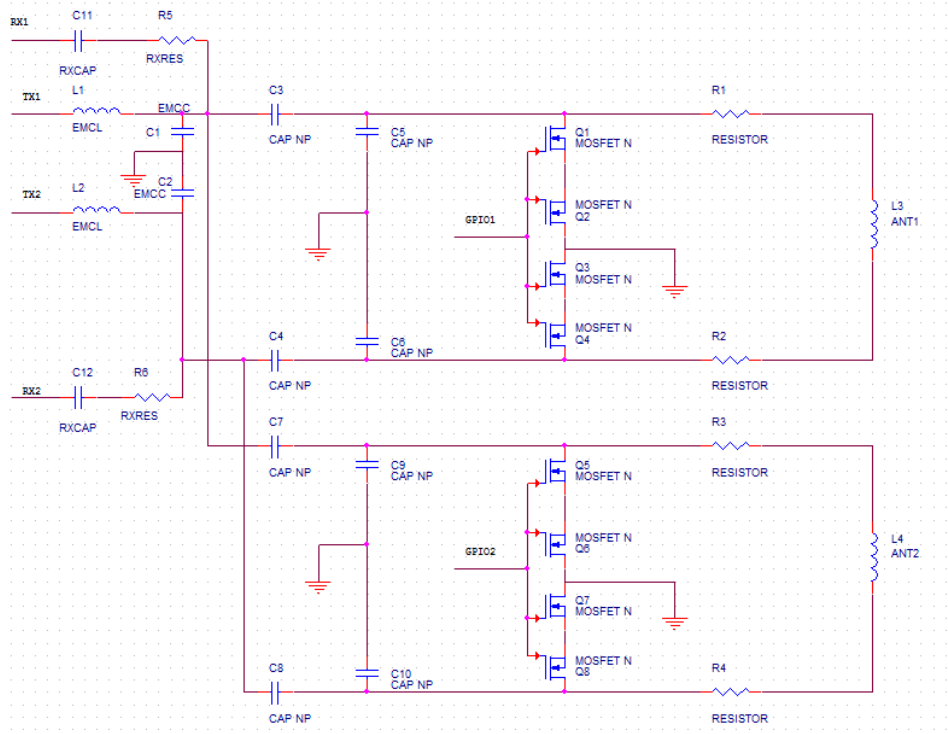

Fig 5. Starting schematic

First, the L3 antenna is tuned, therefore L3 must be in the circuit and L4 must be disabled. In order to switch ground onto both sides of the L4 antenna, the lower transistors Q5, Q6, Q7, and Q8 have to be switched to the “on” state. When both sides of the antenna are grounded, L4, R3, R4, C9, and C10 are removed from the circuit and the following equivalent schematic applies:

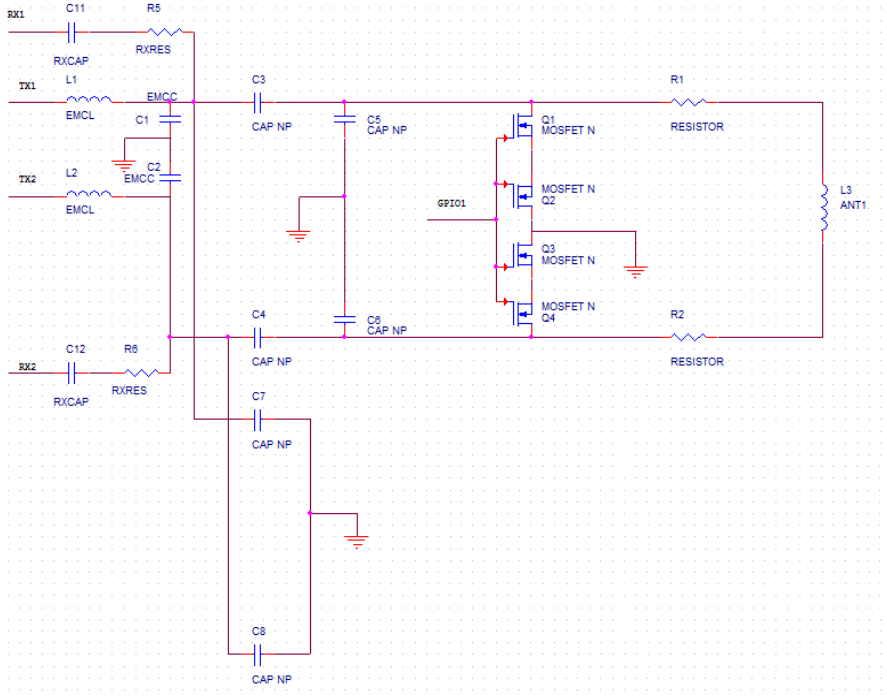

Fig 6. Equivalent schematic when tuning L3

In figure 6 capacitors C7 and C8 go in parallel to the EMC capacitors C1 and C2 when the bottom antenna is switched out of the circuit. This increases the EMC capacitance and will therefore lower the resonance frequency of the EMC filter. This must be taken into account when tuning each antenna with this topology. With the bottom antenna in the disabled state the series and parallel capacitors of the top antenna can be adjusted to achieve the desired impedance at 13.56 MHz. After that the top antenna is switched into the disabled state and tuning procedure repeated for the bottom antenna (if both antennas have the same layout then the tuning values should be very similar).

Some things to keep in mind:

- Keep the capacitance values of the EMC capacitors (C1 and C2 in Figure 6) relatively low, since the series capacitors (C7 and C8 in Figure 6) go in parallel during the switching and increase the overall capacitance.
- Keep the capacitance values of the series capacitors (C3, C4, C7, and C8 in Figure 6) low if possible so they do not influence the EMC resonance a great deal.

Put an extra turn or two onto each antenna to increase the inductance value (do not exceed a maximum of 3 µH). This is because with this concept (especially if there are more than two antennas) all of the series capacitors of the disabled antennas add in parallel to the capacitance values of the EMC filter. This makes the tuning procedure more difficult if antennas with low inductance values are tuned.

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