ESD128-B1-W0201
ESD129-B1-W01005

ESD Protection in Chip Size Package (CSP) tailored for the NFC

Near Field Communication
- Technical overview
- Frontend ESD protection

Application Note AN244

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RF and Protection Devices

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Application Note AN244	
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Page	**Subjects (major changes since last revision)**
	Tailored version for the ESD128-B1 / ESD129-B1 in CSP size 0201 / 01005
	Removing the ESD110 from the AN. For ESD110 ref. to V1.2

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1 Near Field communication - Overview

Near Field Communication or NFC, is a short-range high frequency wireless communication technology which enables the exchange of data between devices over about a 10…20 centimeter distance. The technology is a simple extension of the ISO/IEC 14443 proximity-card standard (proximity card, RFID) that combines the interface of a smartcard and a reader into a single device. An NFC device can communicate with both existing ISO/IEC 14443 smartcards and readers, as well as with other NFC devices, and is thereby compatible with existing contactless infrastructure already in use for public transportation and payment. NFC is primarily aimed for usage in mobile phones.

NFC communicates via magnetic field induction, where two loop antennas are located within each other's near field, forming an air-core transformer (Figure 1, Figure 2, Figure 4). It operates within the globally available and unlicensed radio frequency ISM band (Industrial, Scientific and Medical) of 13.56 MHz.

- Working distance with compact standard antennas: up to 20 cm.
- Supported data rates: 106, 212, 424 kbit/s.
- Manchester coding with 10% ASK (Amplitude Shift Keying) modulation rate.
- Modified Miller coding with 100% ASK modulation rate.
- NFC device can work in passive mode (battery off) and in active mode:
    - card emulation: the NFC device behaves like an existing contactless card or RFID tag. The NFC device is passive and is triggered by an active initiator
      NO continuous application, only active for a short time frame.
    - reader mode: the NFC device (initiator) is active and read a passive RFID tag, for example for interactive advertising.
    - P2P mode: two NFC devices are communicating together and exchanging information. Both NFC devices has to be in the active mode.

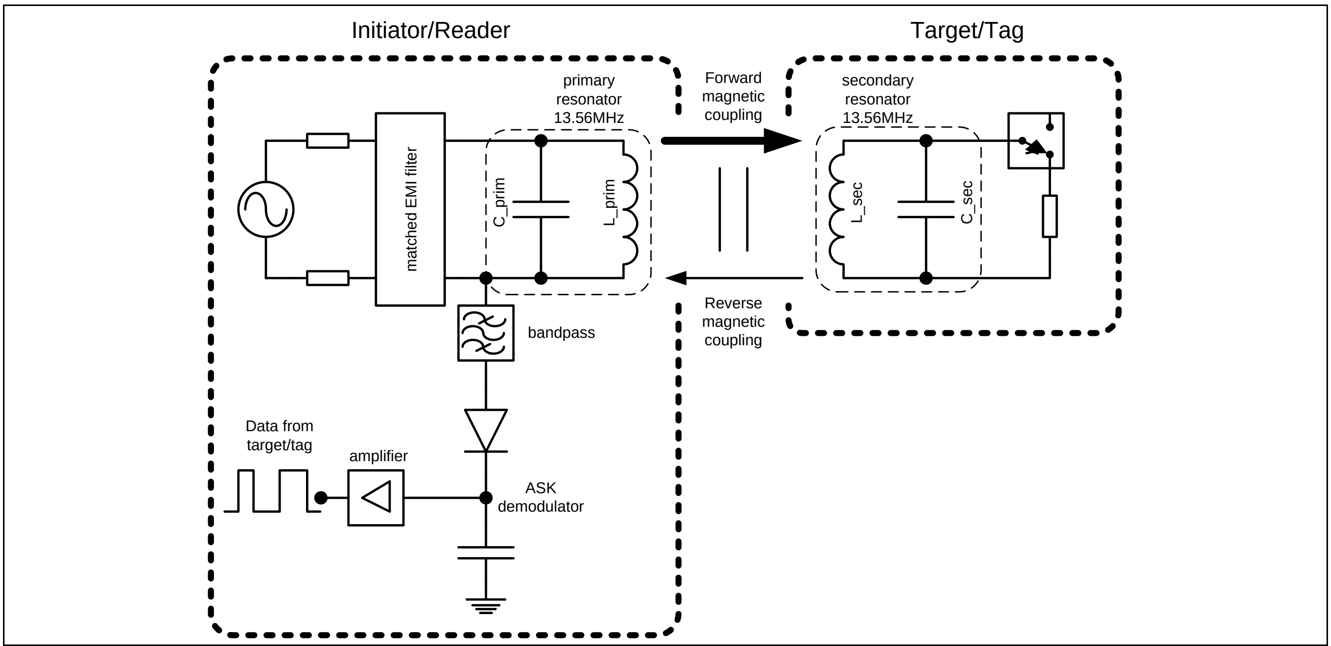

Figure 1 NFC Modules acting as tag/target (passive mode) or acting as initiator/reader (active mode).

1.1 Passive Communication Mode

The initiator device provides a magnetic carrier field and the NFC device (target) answers by modulating the existing magnetic field. In this mode, the target device creates its operating power from the initiator provided electromagnetic field, thus making the Target device a transponder.

This mode is similar to the RFID (Radio Frequency Identification Device) working mode.

The basic principle of this passive mode is the magnetic air coupling between Initiator´s (reader) primary coil L_prim and the the target coil L_sec on secondary side. Energy is transmitted from L_prim to L_sec and picked up on the secondary side (target) (forward response). On one hand the received magnetic energy is used to power the tag, on the other the received magnetic field is modulated. The tag is responding by modulating the Q-factor of the secondary resonance circuit L_sec/C_sec by switching on and off a shunt resistor according to the data sequence. This periodic attenuation of the secondary resonance circuit is visible on primary side (reverse response) and can be detected. The reverse response is reduced by reducing the coupling factor k, as a result of increasing the distance between the initiator (primary) and the target (secondary).

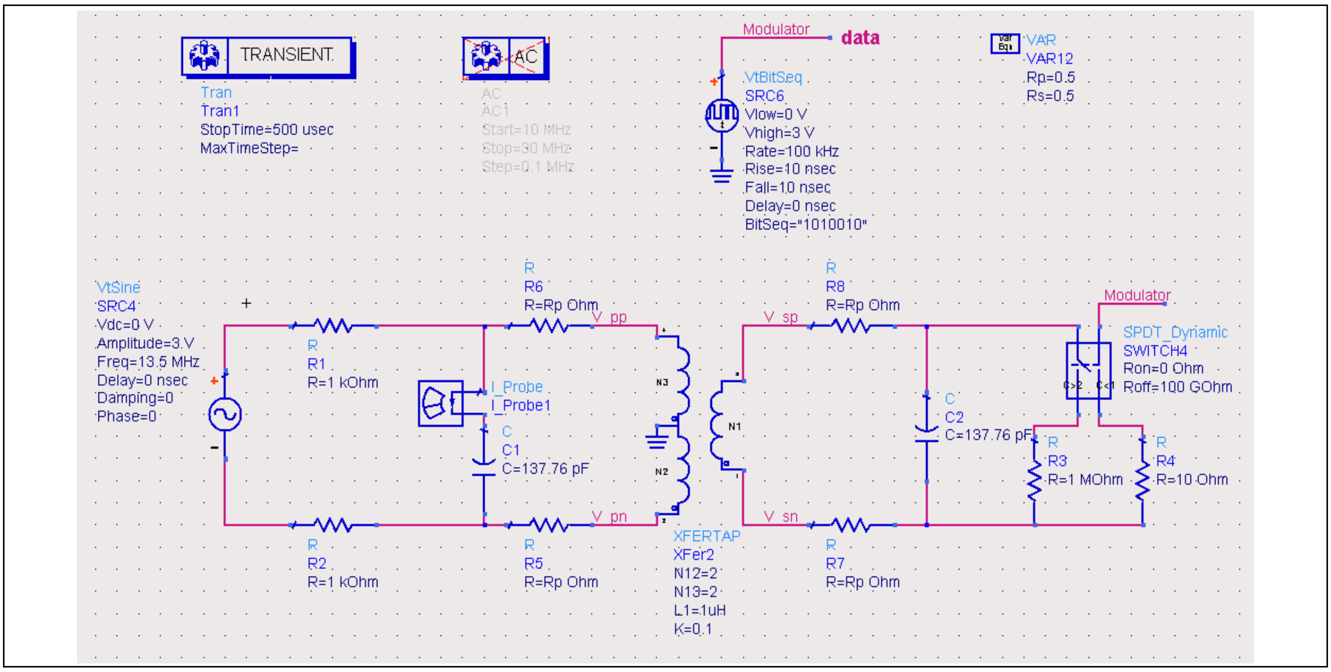

Figure 2 Time domain RF simulation of the NFC principle.

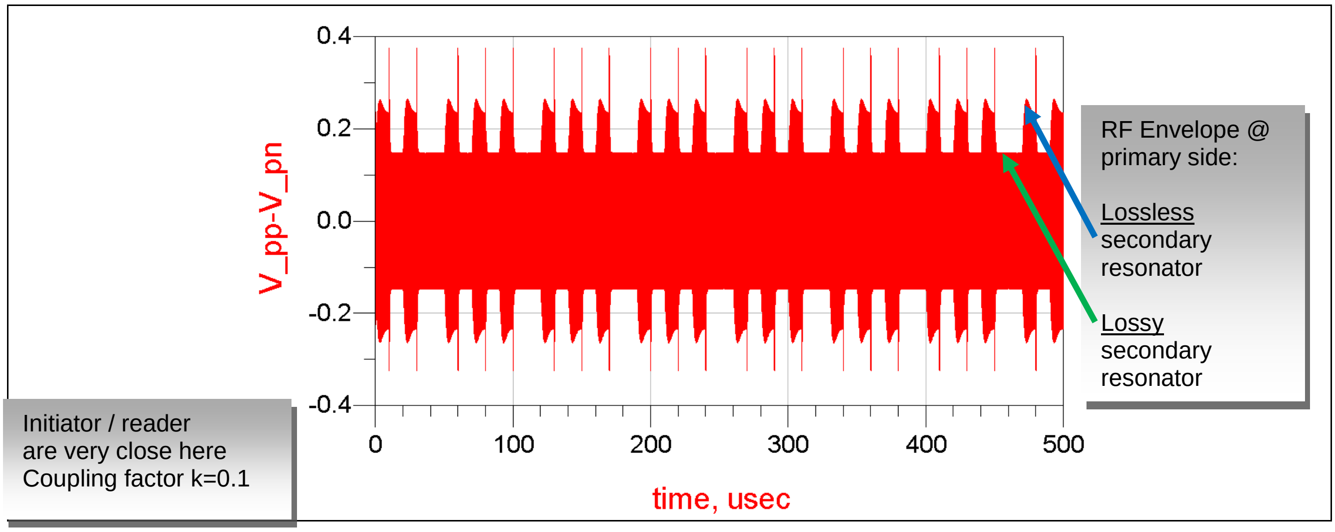

Figure 3 RF envelope (13.56MHz) @ the primary res., toggling the secondary res. lossless / lossy.

1.2 Active Communication Mode

Running this mode the NFC device can act as an initiator (active reader) to get contact with a passive target.

Two NFC devices can act as initiator and target device and communicate by alternately generating their own modulated field. A device deactivates its RF field while it is waiting for data. In this mode, both devices typically need to have a power supply.

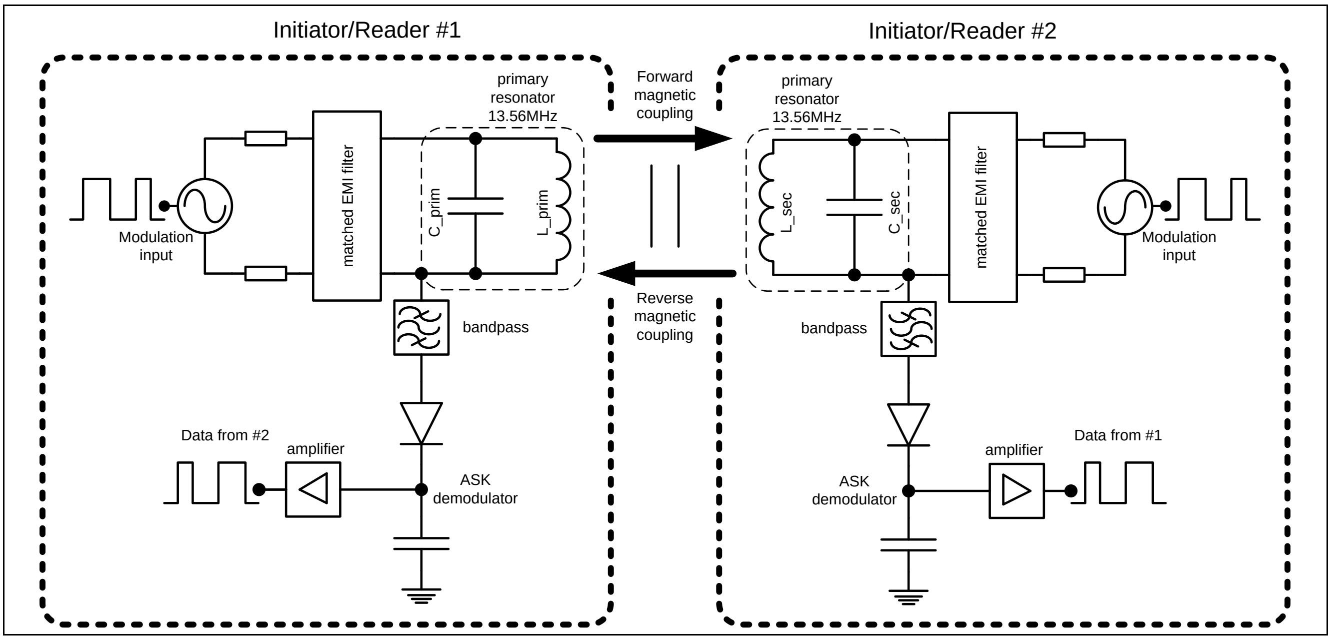

Figure 4 NFC Modules both in active mode (e.g. in a P2P network)

2 Current and future applications for NFC devices

Plenty of applications are present in the market yet, or will enter the market soon.

- Mobile Commerce:
  - Mobile ticketing – for airplanes, for public transport, for concerts/events.
  - Mobile payment — the device acts as a debit/ credit payment card.
  - Electronic money – like a stored value card.
- Proof of Identity
  - Access control for buildings, or IT equipment.
  - Electronic keys - car keys, house/office keys, hotel room keys, etc.

NFC can be used to configure and initiate other wireless network connections such as Bluetooth, Wi-Fi. The time consuming configuration procedure for identification to a Bluetooth or WiFi system is reduced by a “one touch” of two mobiles equipped with NFC devices

To provide the required security level for all these applications, the NFC modem is combined with a secure controller (NFC module). In a mobile phone the NFC module is also linked to the SIM card.

3 NFC implementation in the mobile phone

To provide a highly secure environment especially for mobile commerce, the entire NFC communication has to be controlled by several security authorities. Therefore the NFC modem is linked to the SIM card and to the secure controller. The link between the SIM card and NFC modem is done via the standardized Single Wire Protocol (SWP). In case the SIM card contacts can be accessed by the user, a proper ESD protection for all SIM Card pins including the SWP pin is required. Because SWP´s signaling nature, ESD protection must show a low capacitance. A recommendation is the Infineon ESD108-B1 / ESD109-B1 (< 0.5pF)

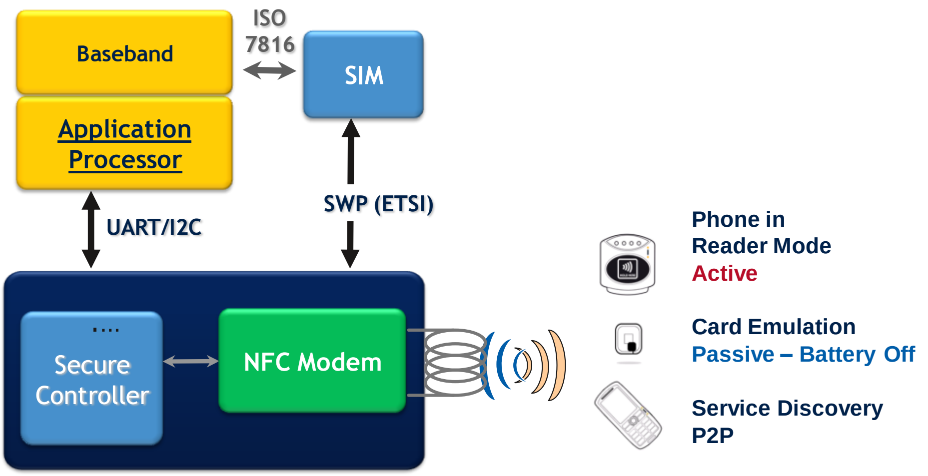

Figure 5 Implementation of a NFC module in the mobile phone.

The signal generation and signal extraction is done completely in the NFC modem for the active mode as well as for the passive mode.

The front-end of the NFC modem includes the mandatory transforming EMI filter and the magnetic loop antenna. This loop antenna inductor in combination with a capacitance provides the resonance circuit, tuned to 13.56 MHz.

The resonance circuit on primary side (initiator/reader) is coupled to the resonance circuit of secondary side (NFC modem in passive mode, target/tag). Coupling factor “k” is quite small and depends on the distance between reader and target.

The inductors L_prim and L_sec on primary and secondary sides work as an air-coupled transformer with k<<1.

The distance between primary and secondary side is within the nearfield of the magnetic field. There is no conversion from magnetic energy to electrical and back (far-field behavior). Because of the very small antenna in relation to the wavelength at 13.56 MHZ, the conversion from magnetic near field distribution in an electromagnetic far field distribution is very weak. This limits the range of an NFC system significant to < 20cm, even for special equipment to < 10m.

For passive mode (battery off mode) of the NFC module the NFC module is powered by the magnetic field of the initiator/reader and modulates this information data by switching his 13.56 MHZ resonance circuit between lossless and lossy mode. The loss of energy in the secondary resonance circuit causes a feedback return to the primary resonance circuit and drops down the voltage slightly across the primary resonance circuit (Figure 2, Figure 3).

This can be detected by an ASK demodulator and a logarithmic amplifier.

For the active mode the NFC modem can work as a (initiator/reader) and collects data from a passive target/tag.

To transmit data from one NFC module to another NFC module in a kind of peer to peer configuration, both NFC modules has to be in active mode and act as data transmitter and data receiver. In this case the TX signal is directly ASK modulated.

In a mobile phone the NFC frontend is often separated into the TX driver with the EMC filter and RX signal decoupling and the high impedance 13.56 MHz resonator. The 13.56 MHz resonator includes the loop antenna (resonator´s inductance) and a parallel capacitor (resonator´s capacitance).

Because of the loop antenna size, the 13.56 MHZ resonance circuit is located often in the bottom shell of the mobile, which can be removed by the user. An interface is generated inside the NFC frontend which then becomes ESD critical. A proper ESD protection becomes mandatory to protect the EMI filter and the driver of the NFC frontend, located on main mobile phone PCB.

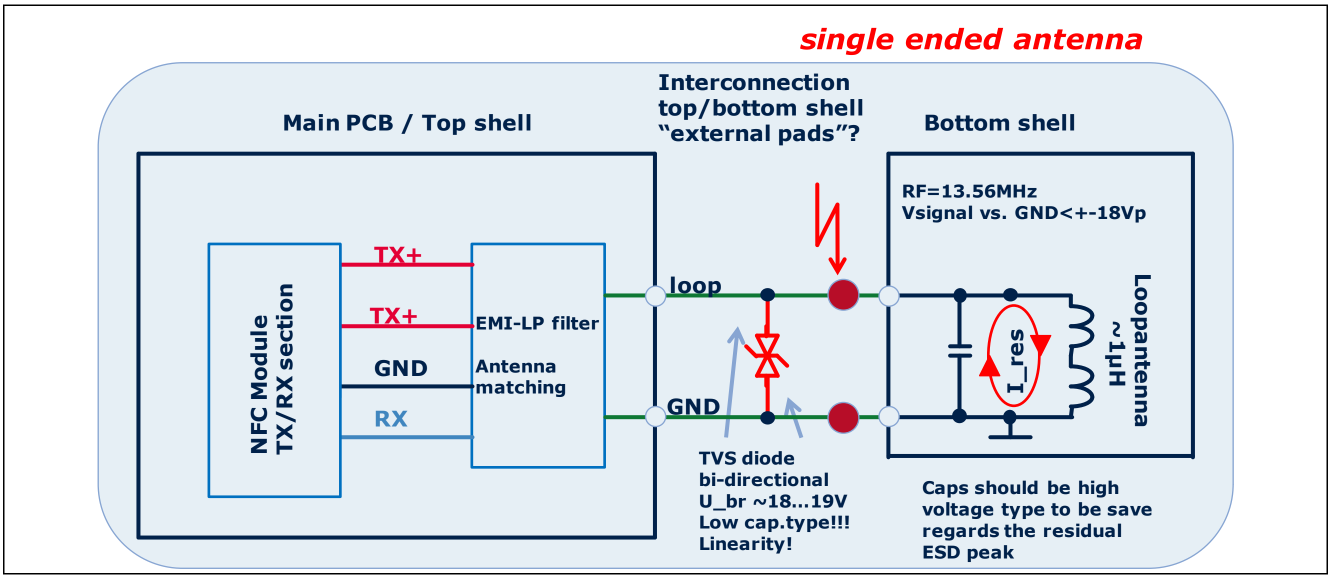

Figure 6 <u>Single ended</u> **NFC antenna frontend used in a mobile phone.**

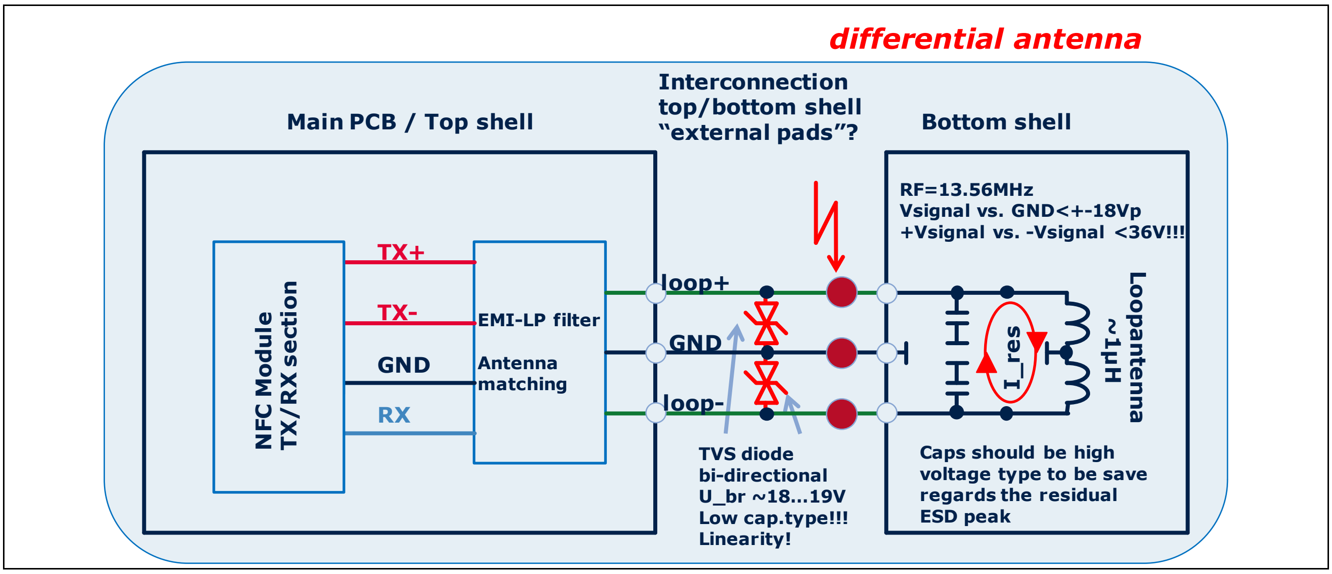

Figure 7 <u>Differential</u> **NFC antenna frontend used in a mobile phone (lower EMI radiation).**

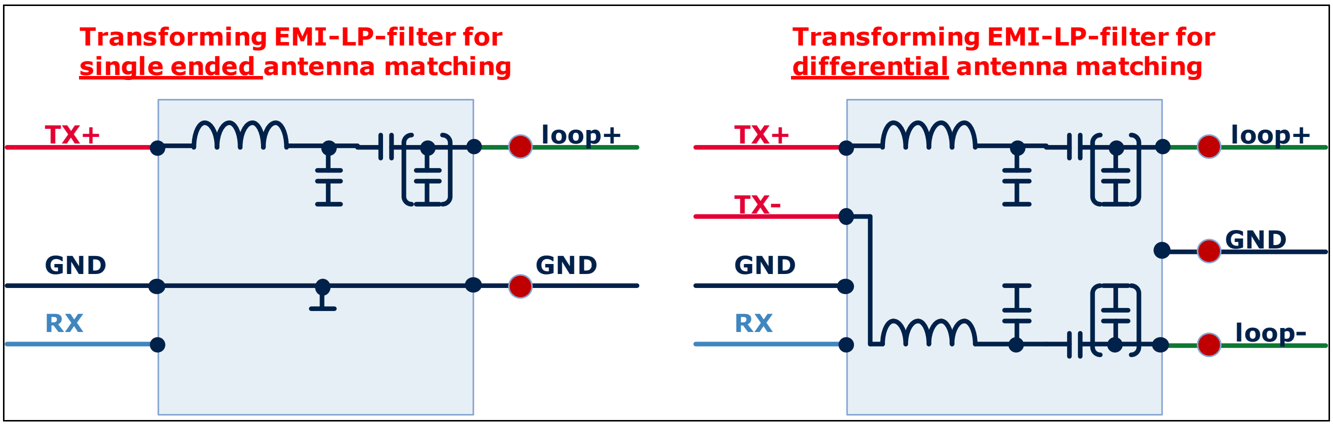

Figure 8 **Single ended and differential driven transforming EMI filter to reduce the harmonics and to increase the voltage swing across the resonant antenna circuit.**

Besides the high impedance resonant loop antenna other antenna structures are possible. They might have different requirements for ESD protection. Please contact the local Infineon sales office for assistance.

4 Requirements for proper NFC frontend ESD protection

In single ended and in differential driven antenna frontends, the RF signal (13.56 MHz) @ the resonator can be up to about +-18Vp vs. GND. Therefore the TVS diode has to be a so called **bi**-directional type, to be suitable for a wanted voltage swing of about +18Vp and for -18Vp. A **uni**-directional TVS diode would clip on negative voltage swings.

In a single ended antenna frontend, the usable antenna voltage is defined at “loop+” vs. “GND” (e.g. +-18Vp). In a differential driven frontend, wanted antenna voltage at “loop+” vs. “loop-“ can be e.g. +-36V**pp**. Therefore the wanted antenna voltage in differential driven antenna frontends can be 2 times the antenna voltage of a single ended system. Furthermore the unwanted EMI radiation in a diff. driven frontend, affecting other circuit structures, is significant lower.

4.1 Uni-directional TVS diode vs. bi-directional TVS diode

Uni-directional TVS diode:

A **uni-**directional TVS diode is designed for a wanted signal between ~0V and “maximum working voltage”. The ESD protection capability is granted for a **uni**-directional diode for positive **AND** negative ESD strikes in the same way.

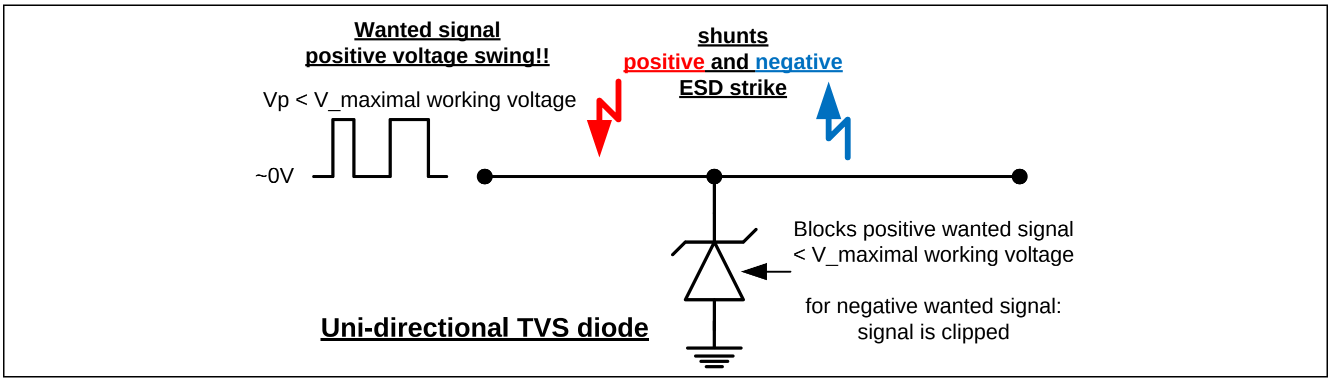

Figure 9 **Correct application for a uni-directional TVS diode.**

Bi-directional TVS diode:

A **bi**-directional TVS diode is designed for a wanted signal between "**negative** maximum working voltage" and "**positive** maximum working voltage". The ESD protection capability is granted for a **bi**-directional diode for positive **AND** negative ESD strikes in the same way.

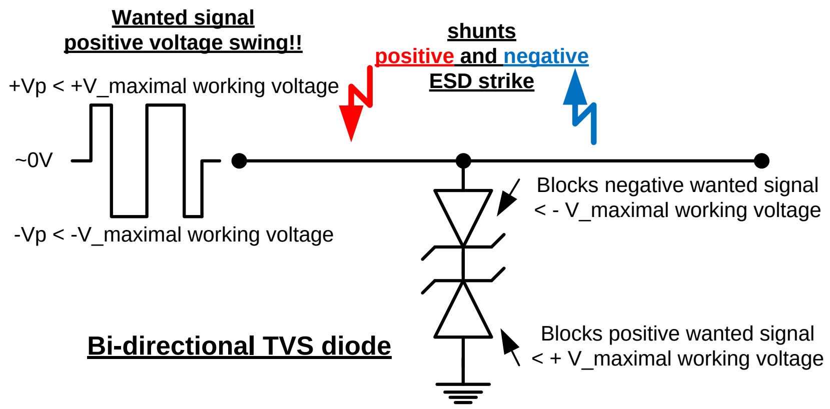

Figure 10 Correct application for a Bi-directional TVS diode.

4.2 Principles of the transforming EMI filter

In the NFC system, the TX driver (low output impedance of some 10 Ohm) generates a differential 13.56 MHZ signal between 0V and may be 3V (~3V for a mobile phone application). The shape of this signal locks like a square wave. This 0V/3V signal is fed to a transforming EMC filter (figure 7). One job of the transforming EMC filter is to eliminate all harmonics to avoid interference with the GSM master-clock close to 27.12 MHZ. The other function is to shift up the NFC driver signal to a higher amplitude and impedance level. Impedance level is moving to about 1k Ohm or more and signal amplitude could become more than 10Vp or even higher at the resonant 13.56 MHZ antenna based on:

1) the transformation relation and
2) loss in the transforming EMI filter and in the 13.56 MHZ resonance circuit. But a strong impedance transformation ratio (to a high voltage swing at the antenna) makes the resonance circuit very narrowband and very sensitive to parasitic effects or capacitive hand-effect caused by the user.

4.3 ESD requirements

Therefore "maximum working voltage" of the TVS diode has to fit with the maximum peak voltage @ the 13.56 MHZ resonator. Below the "maximum working voltage" / "trigger voltage" the TVS diode is nearly a perfect "open circuit" and is NOT clipping the signal. Exceeding this value the TVS diode turns into a short.

Increasing the "maximum working voltage" of the TVS diode and inherently the "minimal trigger voltage" will cause a higher clamping voltage in case of an ESD event. This higher clamping voltage means a higher ESD stress for the EMC filter/NFC modem. So it is always a tradeoff between actual required "maximum working voltage" and the desired ESD performance.

ESD128-B1 and ESD129-B1 are so called "snapback devices". At the time they are triggered the clamping voltage snaps back to the lower hold voltage (17V typ.). ESD clamping voltage starts at snapback voltage and grows up by $R_{dynamic}$ * I_{ESD}. To keep the residual V_{camp} low, R_{dyn} has be be small as possible (Figure 11).

The snap back approach helps to keep the clamping voltage low.

4.4 ESD protection in point of RF performance

The ESD protection circuit should not create harmonic distortion to the 13.56 MHZ RF signal. Therefore the TVS diode has to be linear as much as possible.

The TVS diode´s "Maximum working voltage" has to be high enough to withstand the maximum peak voltage @ the 13.56 MHZ resonator without signal clipping.

The bi-directional TVS diodes ESD128-B1 and ESD129-B1 with a trigger voltage of 20V (min. value) and typical 22V fit excellent into this application. In point of TVS diode capacitance, both ESD128-B1 and ESD129-B1 show outstanding 0.3pF (typical capacitance at 1MHz).

4.5 ESD performance in point of residual ESD stress

The residual ESD voltage in case of an ESD strike depends on the TVS diode´s breakdown voltage and on the diodes´ "switch on" resistance (R_{dyn}). The dynamic resistance (R_{dyn}) can be characterised by the TLP (Transmission Line Pulse), where we feed a short, well defined current pulse through the diode and measure the clamping voltage across the TVS diode. This clamping voltage is visible to the subsequent circuit and can still cause a residual ESD stress for the device. The R_{dyn} for both ESD128-B1 and ESD129-B1 is about 850 mOhm, which is state of the art in this application.

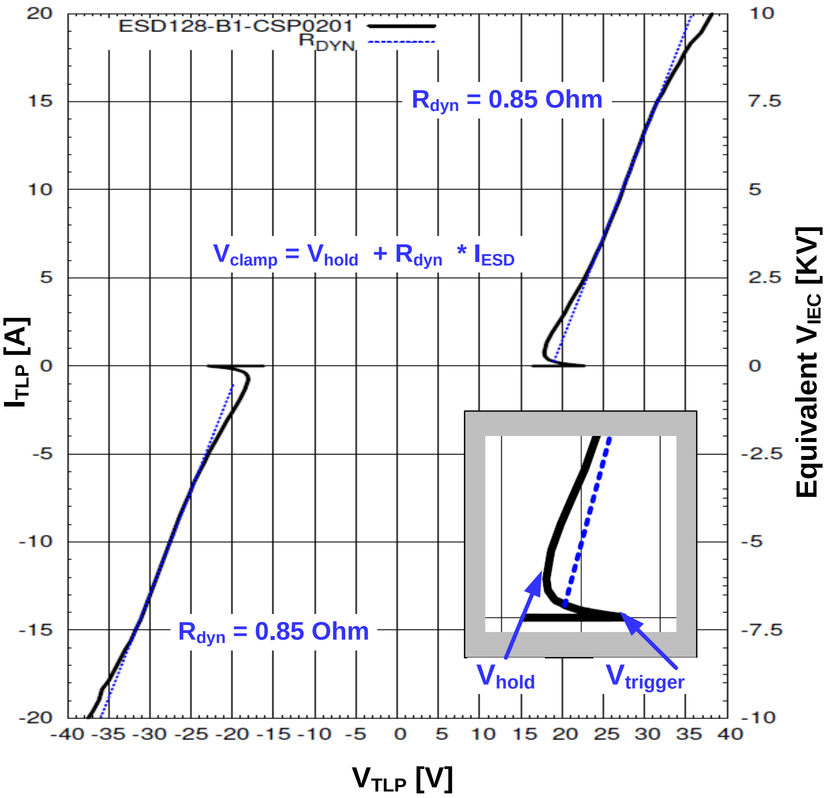

Figure 11 TLP characteristic of the NFC TVS diodes ESD128-B1 / ESD129-B1

Regarding TLP measurement we refer to Infineon AG - Application Note AN210:

« Effective ESD Protection Design at System Level using VF-TLP Characterization Methodology »

5 Summary

ESD protection in the NFC frontend is easy to realize with application tailored TVS diodes. Numerous of basic conditions have to be addressed.

The Infineon ESD128-B1 and ESD129-B1 are specifically developed for this application. ESD128-B1 and ESD129-B1 provide the right breakdown voltage in combination with a very low diode capacitance, which keeps the non-linear distortions very low. Package wise the ESD128-B1-CSP0201 and ESD129-B-01005 are available in leadless Chip Size Package (CSP), correlating to SMD (EIA) size 0201 and to SMD (EIA) size 01005.The electrical parameters of these two diodes in data sheet are about the same.

For PCB design and for the assembly process it is mandatory to follow the:

Recommendations for Printed Circuit Board Assembly of Infineon WLL Packages.

6 Appendix: TVS diode measurement results in real application

6.1 Breakdown voltage and leakage current characterisation of NFC TVS Diodes

Table 3-1 **DC Characteristics** at T_A = 25 °C, unless otherwise specified[1)]

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Reverse current	I_R	–	<1	30	nA	V_R = 18 V
Trigger voltage	V_{t1}	20	22	–	V	
Holding voltage	V_h	13	17	21	V	I_T = 40 mA

1) Device is electrically symmetrical

Figure 12 DC characterisation of ESD128-B1 / ESD129-B1 according to data sheets.

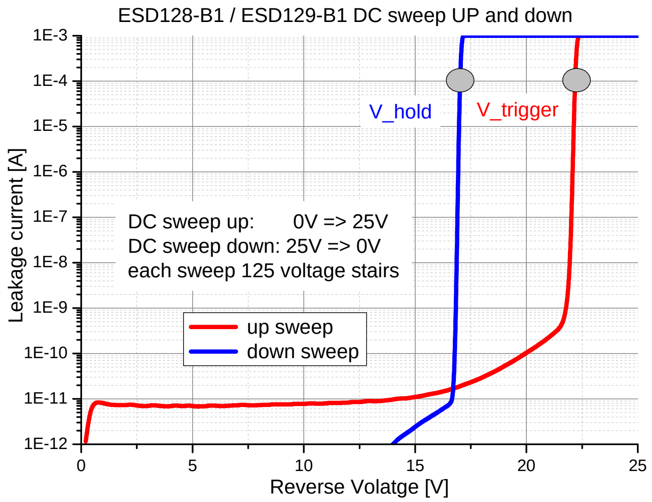

Figure 13 UP and DOWN DC sweep to show leakage current characterisation of ESD128-B1 / ESD129-B1. Trigger voltage for the UP-sweep and hold voltage for the DOWN sweep is marked.

According to the measurement shown above, the ESD128-B1 / ESD129-B1 diode remains in isolating mode till the trigger voltage of ~22V is reached. Exceeding the trigger voltage the TVS diode becomes conductive till the applied voltage falls below the hold voltage (snap-back characteristic). A Hysteresis is visible in (Figure 13).

In case an AC signal exceeds the trigger voltage, the diode starts periodically to clip the signal smoothly which cause harmonics. In the highly resonant NFC antenna system the mentioned harmonics are filtered effective. The diode is acting as a smooth limiter without any damage.

This limiter function protects the NFC modem to become damaged regarding to high input signals.

7 Authors

Alexander Glas

Infineon Principal Engineer “RF and Protection Devices”.

8 Reference

Infineon AG - Application Note AN210:

« Effective ESD Protection Design at System Level using VF-TLP Characterization Methodology »

Recommendations for Printed Circuit Board Assembly of Infineon WLL Packages.

For data sheets and further documents please visit www.infineon.com/ESDprotection

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