Low Cost FM Radio LNA using BFP460

Matched to 50 Ohm at Input and Output

Application Note 204

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RF and Protection Devices

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Matched to 50 Ohm at Input and Output

Revision History: 2010-03-31, Revision 1.0	
Previous Revision:	
Page	Subjects (major changes since last revision)

1 Introduction

FM Radio has a long history to its credit starting from its development in 1933. Today, FM radio is an integral part of almost all mobile phones, including the ultra low cost phones. FM Radio broadcast today is not just used to listen to songs and news, but also used for RDS (Radio Data System) to receive various services including TMC (Traffic Message Channel) which gives traffic information for navigation purposes. In addition, some handsets are being equipped with FM Radio transimission capability to send voice signals to car audio systems or Hi-Fi systems.

Therefore, FM system design in a phone is getting more and more complex. Till recently, the headset served as the antenna for FM Radio reception, wherein the antenna size is a bit relaxed and the antenna performance is satisfactory. A new trend has emerged to be able to use FM radio also without the headset, wherein the antenna embedded into the phone. But in this case, the space constraint poses a challenge on the antenna design. Shrinking the size of the antenna reduces antenna gain and bandwidth, which introduces a high loss into the system which deteriorates the receiver performance, namely the receiver sensitivity. This application note presents Infineon solution to the aforementioned challenges leading to the design of a high performance RF front end with the lowest power consumption.

A general topology for the RF front-end of FM Radio is as shown in **Figure 1**. Variations of the given application schematic are possible based on the complete system design and concept. These may include systems with only external headset antenna, only internal embedded antenna or both antennas co-existing. Infineon offers the complete chain of RF front-end parts between the antenna and the receiver IC for FM Radio, which include ESD protection devices, RF switches and LNAs. The focus of this application note is Low Noise Amplifier for FMR.

A ESD protection circuit is needed at the antenna to protect the front-end system from ESD strikes, as the antenna is susceptible to ESD events. More details and Infineon solutions for ESD protection can be found in app.

A Single Pole Double Throw or SPDT RF switch is used to toggle between the headset and embedded antenna. The switch being in front of the LNA and in the vicinity of strong cellular signals should introduce minimal loss to the system and offer high linearity. To know more about Infineon solutions for RF Switches, please refer to Reference [2].

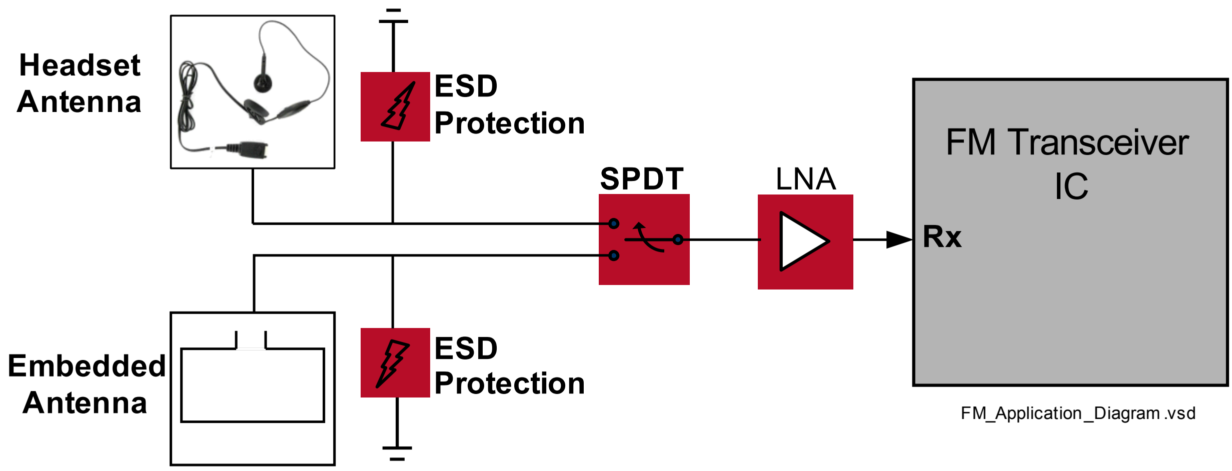

Figure 1 FM Radio RF Front-End schematic

A Low Noise Amplifier or LNA follows the switch, which significantly reduces the noise figure of the whole receiver chain, thereby improving the receiver sensitivity. However, there are a few challenges in the design of the LNA for this purpose. Using it in a hand held device demands low current consumption and high linearity due to the co-existence of cellular bands. In a system with internal antenna, due to the very small size, the antenna impedance is very high and thus the LNA has to be matched to this high impedance and in addition offer a low noise figure.

2 Performance Overview

The following table gives a quick overview on the performance of the FM Antenna LNA described in this application note.

Table 1 Electrical characteristics at
T_A = 25°C, V_{CC} = 2.6V, ICC_q =4.2 mA
Measured in a 50 Ohm system

Parameter	Symbol	Values			Unit
		Min.	Typ.	Max.	
Frequency	*freq*		100		dB
Insertion power gain	$\|S_{21}\|^2$		17.1		dB
Input return loss	RL_{IN}		13.9		dB
Output return loss	RL_{OUT}		12.2		dB
Isolation	*ISO*		28.6		dB
Noise figure[1)]	*NF*		1.2		dB
Input 1dB gain compression point	P_{-1dB}		-24.5		dBm
Input 3rd Order Intercept Point	*IIP3*	-	-	-	dBm

1) Noise Figure value is excluding PCB and SMA connector losses

3 Application Circuit

The FM Radio application schematic for the BFP460 is shown in **Figure 2** and the function of each component is explained in **Table 2**.

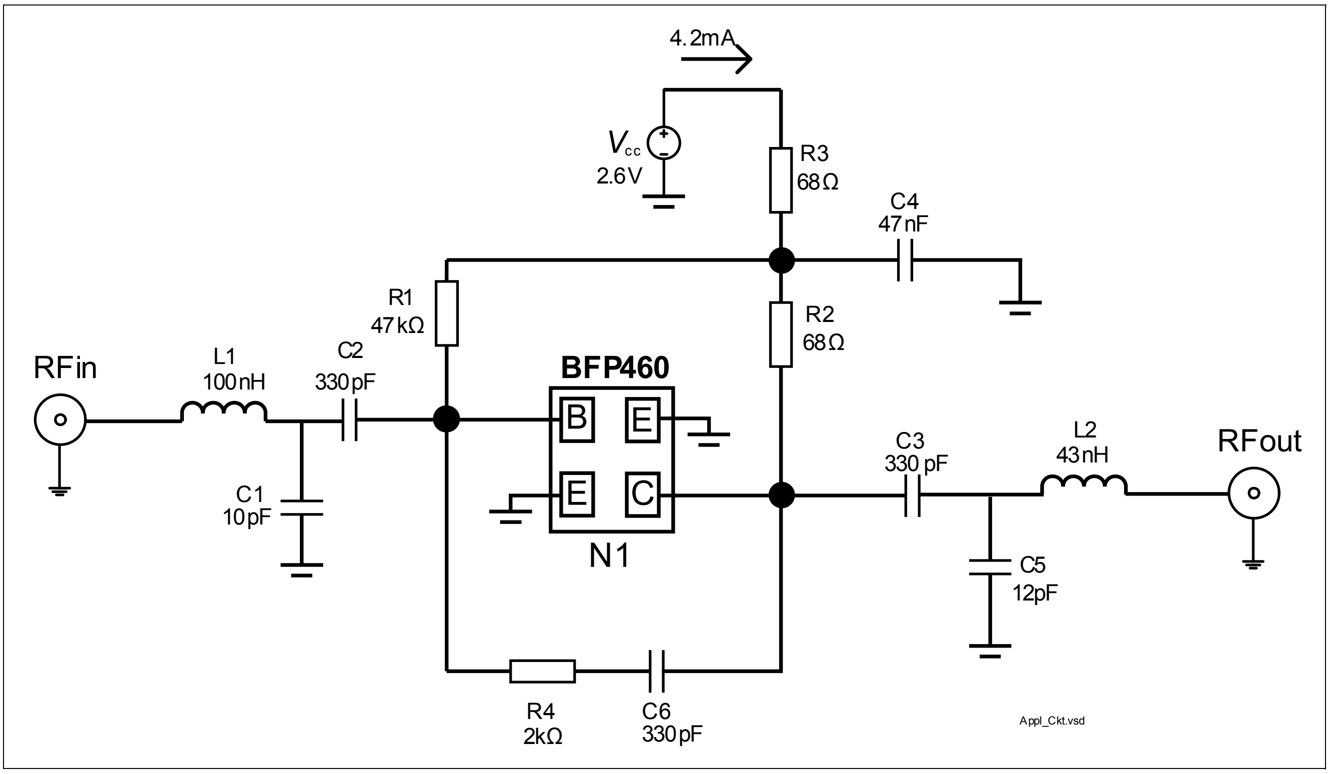

Figure 2 Application schematic for FM Radio

Table 2 Bill of material

Component	Value	Manufacturer / Type	Function
N1	BFP460 Transistor	Infineon Technologies / SOT343	LNA Active device
C_1	10 pF	Various / 0402	Input matching
C_2	330 pF	Various / 0402	DC blocking
C_3	330 pF	Various / 0402	DC blocking
C_4	47 nF	Various / 0402	DC stabilization
C_5	12 pF	Various / 0402	Output matching
C_6	330 pF	Various / 0402	RF Feedback
R_1	47 kOhm	Various / 0402	Biasing
R_2	68 Ohm	Various / 0402	Biasing, Matching, Stability
R_3	68 Ohm	Various / 0402	Biasing
R_4	2 kOhm	Various / 0402	RF Feedback
L_1	100 nH	Murata/ Wire-wound/ 0402	Input Matching
L_2	43 nH	Murata/ Wire-wound/ 0402	Output Matching

4 Evaluation Board

To enable a fast and stand alone evaluation of the application circuit described in this document, Infineon offers an application board, which is as shown in the **Figure 3**.

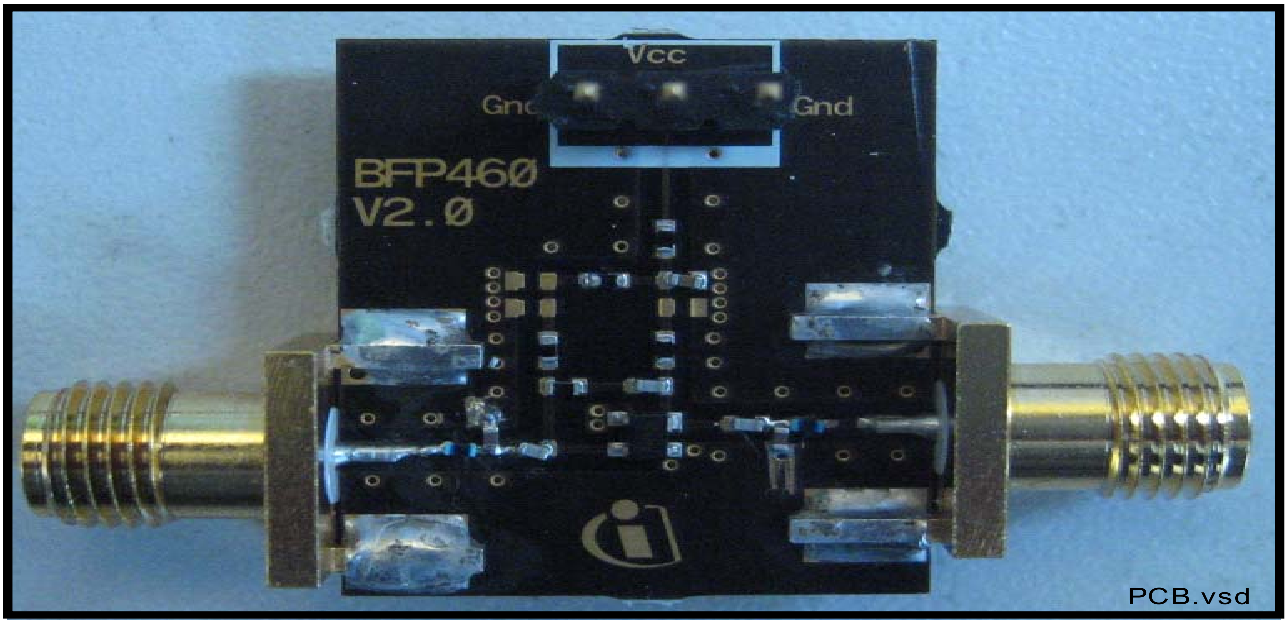

Figure 3 Evaluation Board

The PCB cross-section of the evaluation board is as shown in **Figure 4**.

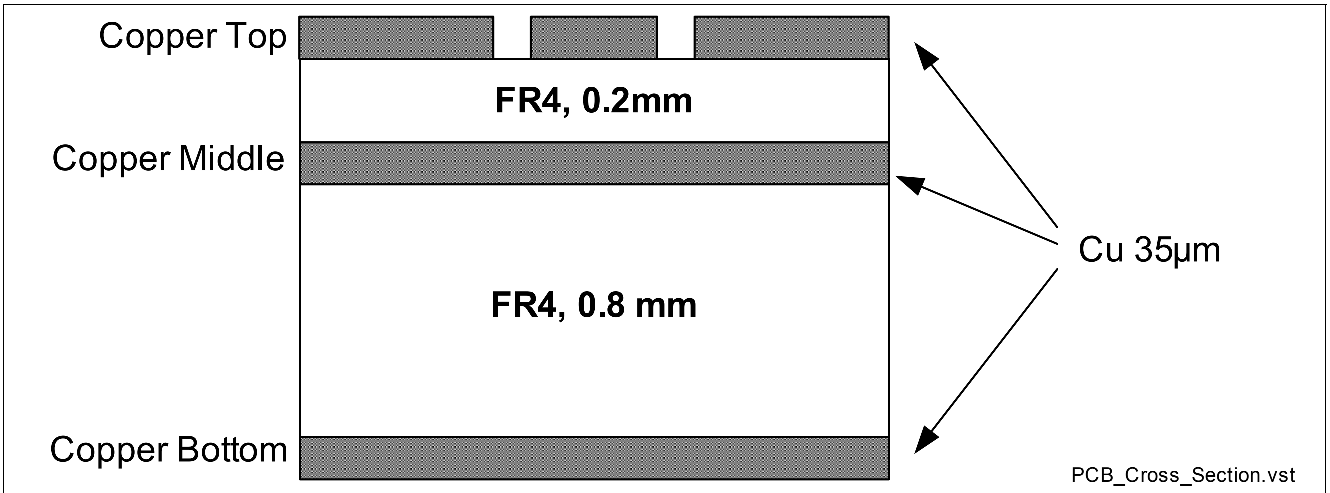

Figure 4 PCB Cross-section

5 Measurement Results

This section presents the measurement results of the aforementioned application circuit on the evaluation board. The measurements were performed at 25°C and include the losses of both SMA connectors and the PCB microstrip lines.

5.1 Narrowband Results

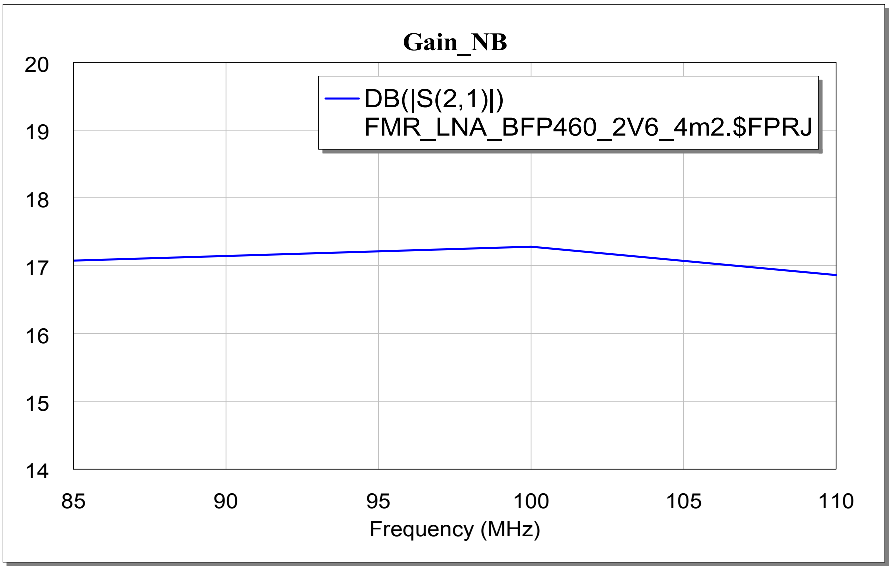

Figure 5 Power Gain (dB)

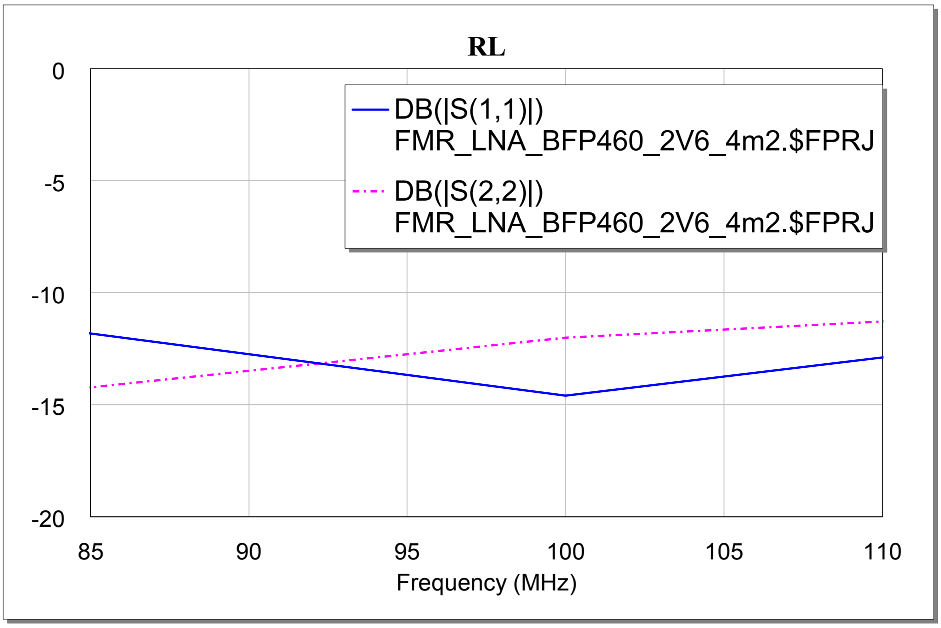

Figure 6 Input and Output Reflection Coefficient (dB)

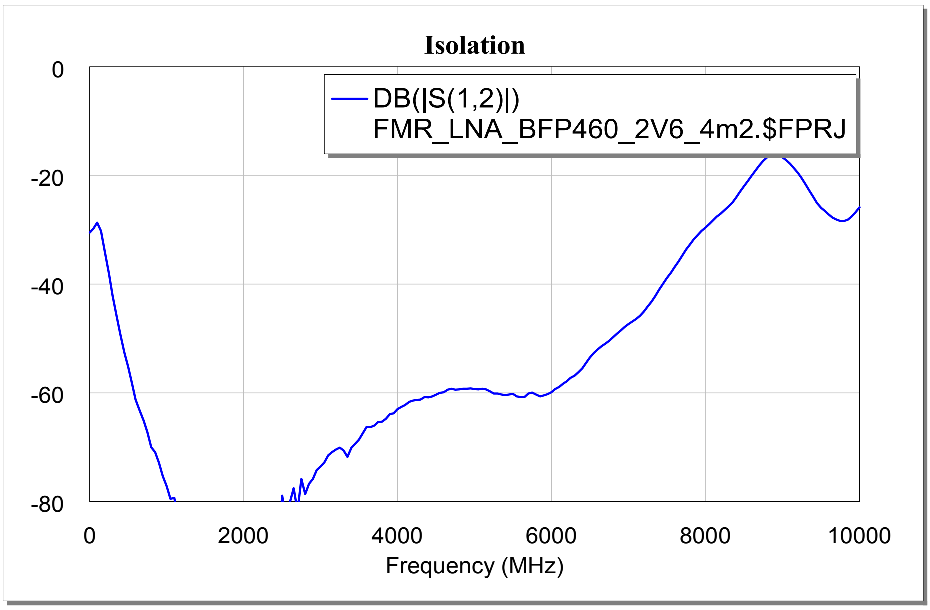

Figure 7 Input to Output Isolation (dB)

5.2 Wide-Band Characteristics

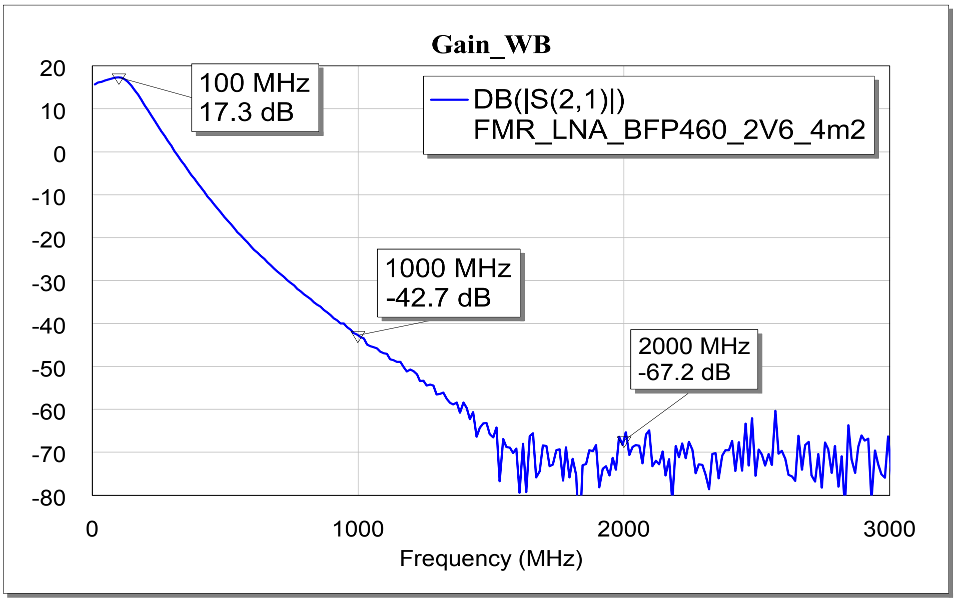

Figure 8 Wide-Band Gain

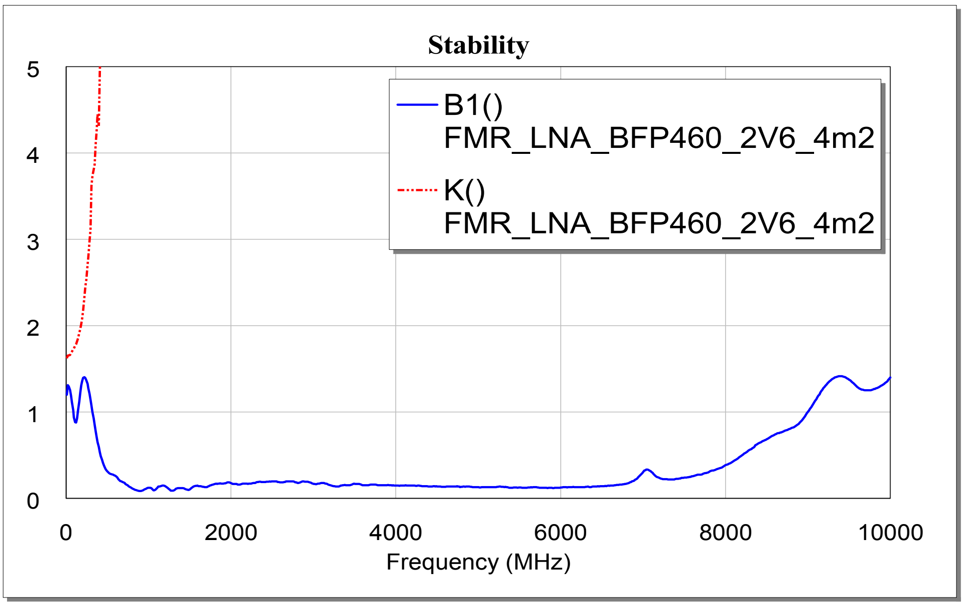

Figure 9 Stability Factor (necessary and sufficient condition for "Unconditional Stability": k>1 & B1>0)

Appendix 1: ESD protection circuit for system level ESD robustness

Introduction

With the advancement in miniaturization of semiconductor structures, ESD handling capability of the devices is becoming a concern. Increasing ESD handling capability of the I/O ports costs additional chip size and affects the I/O capacitance significantly. This is very important for high frequency devices, especially when high linearity is required. Therefore, tailored and cost effective ESD protection devices can be used to build up an ESD protection circuit. To handle ESD events during assembly, devices normally have on-chip ESD protection according to the device level standards e.g. “Human Body Model” JEDEC 22-A-115. To fulfill the much more stringent system level ESD requirements according to IEC61000-4-2 as shown in **Figure 10**, the external ESD protection circuit has to handle the majority of the ESD strike. The best external ESD protection is achieved using a TVS diode assisted by additional passive components.

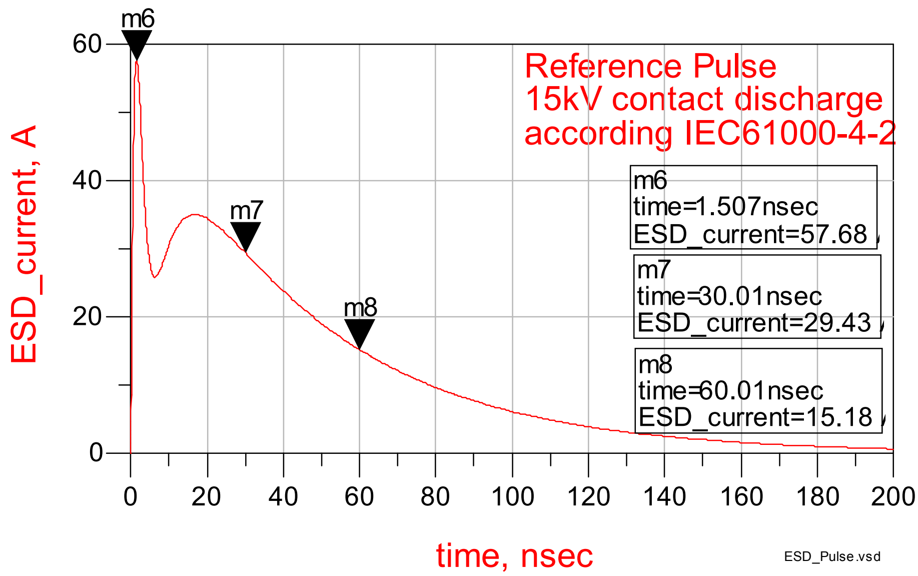

Figure 10 ESD test pulse according to system level specification IEC61000-4-2 – Contact Discharge 15kV

Some examples of RF applications addressed by the Infineon ESD protection proposal are given below:

- FM Radio (76 MHz -110 MHz)
- WLAN 802.11b/g/n (2.4 GHz, Tx ~ +20 dBm)
- Bluetooth (2.4 GHz, Tx ~ +20 dBm)
- Automatic Meter Reading, AMR (900 MHz, TX ~ +20 dBm)
- Remote Keyless Entry, RKE (315 MHz - 434 MHz - 868 MHz - 915 MHz, Tx~13 dBm)
- GPS (1575 MHz, Rx only but can be affected by RF interferer)

For an ESD protection device tailored for medium power RF signals (=< +20 dBm), following requirements are essential:

1. RF requirements
   a) Bidirectional characteristic to handle DC free signals without clipping / signal distortion
   b) A highly symmetrical behavior of the ESD device for positive and negative voltage swings is mandatory to keep the power level of even Harmonics low
   c) Breakdown voltage of 5 V-10V, to avoid signal distortion at high RF voltage swing applied at the TVS diode, located close to the antenna
   d) High linearity
   e) Low leakage current and stable diode capacitance vs. RF voltage swing
   f) Ultra low diode capacitance is mandatory

2. ESD requirements:
   a) Lowest dynamic resistance R_{dyn} to offer best protection for the RFIC; R_{dyn} is characterized by Transmission Line Pulse (TLP) measurement
   b) Very fast switch-on time (<<1nsec) to ground the initial peak of an ESD strike according to IEC61000-4-2
   c) No performance degradation over a large number of ESD zaps (>1000

Two-step ESD Protection approach

General structure for a 2-step ESD approach according to **Figure 11** enables to split the entire ESD current between the internal and external ESD protection device. The external device is much more robust and handles the majority of the ESD current. To avoid any impact on the RF behavior of the system and to minimize non linearity effects, the TVS diode should possess an ultra low device capacitance.

Therefore the bi-directional (symmetrical) Infineon TVS Diode ESD0P2RF is well suited, which provides a diode capacitance as low as 0.2 pF and a R_{dyn} of only 1 Ohm. ESD robustness can be improved one step more by adding a small serial resistor between the external TVS diode and the RF amplifier input. A resistor of ~2.2 Ohm is a good compromise between additional ESD performance and insertion loss. The TVS diode ESD0P2RF in combination with the 2.2 Ohm ESD resistor would incur less than 0.23dB insertion loss up to 3 GHz.

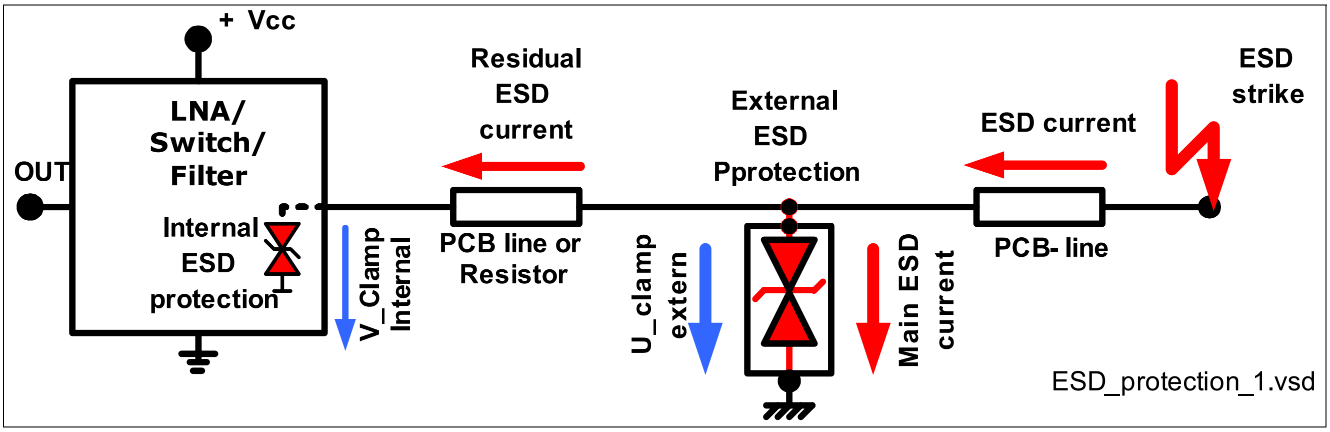

Figure 11 Smart 2-step ESD protection approach based on external and internal ESD protection structure

For further ESD improvement it is highly recommend to add a serial capacitor (C1). The capacitor cuts off most of the high energy created by the ESD strike. For better ESD robustness, C1 should be as small as possible, but has to match to the intended application frequency as well. For a broadband ESD protection (80MHz…3GHz) C1 should be about 100pF…150pF. Optional matching can be implemented with a serial inductor L1 for a dedicated frequency. In combination with L1, C1 can be reduced significantly which improves the ESD performance.

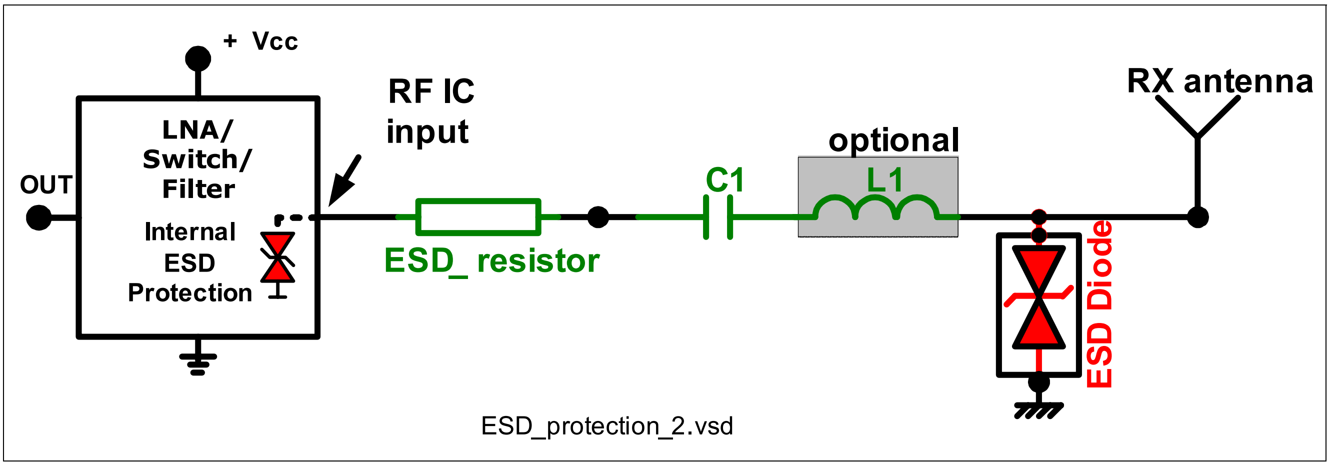

Figure 12 Standard ESD protection topology with optional ESD resistor, blocking capacitor and a serial inductor

References

[1] BFP460 Datasheet, Infineon Technologies AG

[2] Application Note **AN175**, RF CMOS SPDT Switches, Infineon Technologies AG

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