BGF113

Tailored ESD and EMI protection for audio interfaces

Effective protection against Electrostatic Discharge (ESD) damage and Electromagnetic Interference (EMI) on mobile phone external interfaces

Application Note AN209

Revision: Rev. 1.1
2011-07-06

www.infineon.com/ESD-EMI-protection-for-Audio-Interfaces

RF and Protection Devices

Edition 2011-07-06
Published by
Infineon Technologies AG
81726 Munich, Germany

Application Note AN209	
Revision History: 2011-07-06	
Previous Revision: prev. Rev. x.x	
Page	**Subjects (major changes since last revision)**

Table of Content

List of Figures

1 ESD and EMI protection for audio interfaces in mobile phones

1.1 Be protected against Electrostatic Discharge (ESD) damage and Electromagnetic Interference (EMI) while enjoying clear audio on your mobile phone

All electronic systems, especially those serving in external connectivity applications, are vulnerable to electrostatic discharge (ESD) and electro-magnetic interference (EMI).

ESD hazards are generated everywhere – by the electronic equipment user – as well by other electronic equipment itself. The ESD hazard depends on numerous environmental conditions that are beyond the control of the typical equipment user – such as the type of floor material or floor covering being used, the relative humidity, etc. EMI attacks can be generated by adjacent systems, or by the system itself.

Self generated EMI attacks are a serious problem especially for TDMA phones (e.g. GSM). In this case, digital interfaces and the audio section of electronic devices are affected by the relatively high RF power bursts generated by the RF Power Amplifier, with a repetition rate of 217 Hertz.

ESD strikes can cause permanent, irreparable damage the equipment, whereas an EMI attack affects the data integrity on digital interfaces or the audio performance / speech-quality of the mobile phone.

The suppression of EMI and protection against ESD events at the audio interfaces has become increasingly important with the widespread proliferation of mobile electronics devices and the increasingly crowded nature of our electromagnetic spectrum. To be most cost-effective, measures against EMI and ESD have to be addressed and implemented in the early stages of system development.

A major driving factor forcing increased attention to ESD-robustness is the advancement and miniaturization of semiconductor technology itself. With regard to ESD-robustness, the semiconductor industry can be said to be "a victim of its own success". The shrinking of semiconductor structures in all dimensions which has been a key factor in semiconductor technology advancement also forces reductions in insulating layer thicknesses such as gate oxides used in CMOS processes. The increasingly thinner gate oxide layers used in modern, higher-speed and higher performance semiconductor processes result in a lower tolerance for destructive ESD strikes. The oxide layers become more susceptible to punch-through due to ESD events as their dimensions shrink.

To fulfil the ESD requirements according to the different specifications e.g. IEC61000-4-2, human body model, ESD protection is typically implemented by using a varistor, a polymer device or especially by a TVS diode (Transient Voltage Suppression diode).

1.2 Requirements for a modern ESD protection, best fulfilled by a TVS diode Applications

- fast transient time
- low breakdown / trigger voltage
- low peak voltage of <100V, low clamping voltage
- very low junction capacitance starting from 0.2pF
- Very good linearity, very low signal distortion
- high ESD robustness e.g. according IEC61000-4-2 / >15kV contact discharge

For high speed circuits, ESD protection is implemented with ESD protection devices which have extremely low capacitance to avoid a low-pass filter effect. Low-pass filtering of the high speed data signal would distort the signal, "smooth" the signal shape, and increase the Bit Error Rate (BER). In severe cases, the original signal could suffer enough degradation to the point where the user ends up with an undetectable data stream.

2 Combining ESD-Protection and EMI suppression in one integrated device

ESD protection has to be placed close to the point where ESD spikes are most likely to be injected into the system. The best location is directly at the interface connector, regardless of analogue or digital interface.

For improving ESD protection and EMI suppression at the same time, two TVS ESD diodes with a series resistor in between can be combined to reduce the remaining ESD peak-voltage significantly and in addition, creates an EMI RC-lowpass filter function.

The combination of two TVS diodes – each having capacitance - and a resistor in between - can be integrated on one Silicon die, which makes the devices very compact and robust. The shunt C – series R – shunt C structure can easily be visualized as a simple lowpass filter (Figure 1).

Furthermore several of these ESD/EMI protection structures can be arranged on one chip to get a protection array for a data bus or different analogue lines.

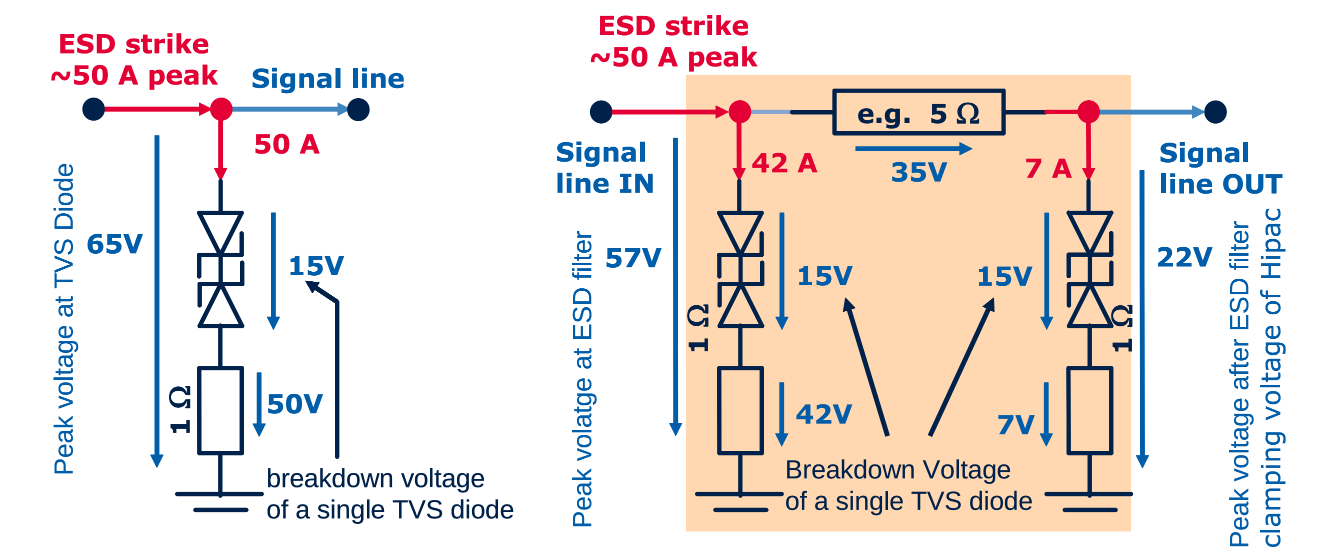

Figure 1 ESD improvement and EMI filter functionality provided by integration

ESD performance improvement can be realized even with a low resistor value.

Increasing the EMI resistor value, the remaining peak voltage @ the ESD / EMI filter comes very close to the ESD diodes' breakdown voltage. To control the cut off frequency, the EMI RC-lowpass filter, the overall filter capacitance can be increased on the die and the EMI resistor can be adjusted in a wide range.

The Infineon product-line of Silicon integrated passive devices like resistors, capacitors, inductors combined with active components e.g. TVS diodes is called “Hipac”.

2.1 Root cause of EMI, affecting the audio section

In the mobile phone there is conductive EMI, affecting the V_bias line for internal and external sections like audio- and microphone. On the other hand there is the radiated RF-EMI generated by the RF power amplifier (PA) and by the mobile phone antenna.

This RF-EMI is absorbed by the internal signal tracks and the external headset cable. In the audio microphone section, the analogue (Electret) microphone provides a kind of differential signal fed by internal differential tracks or by external line-pair to the differential baseband (BB) audio amplifier. If measures are not taken to suppress RF-EMI, common-mode signals getting into the audio lines or traces can adversely impact Mobile Phone audio quality, resulting in hisses, crackles, buzzes and generally poor sound quality.

2.2 Conductive EMI

A significant voltage drop of the mobile phone's battery voltage can be detected in Power Amplifier On mode. This voltage drop is caused by the large inrush of current to the RF Power Amplifier (PA), with average current of more than 2 amperes, combined with the battery's internal resistance. Careful PCB design can avoid an additional voltage drop via the PA Supply & Ground current tracks (Figure 2).

To avoid the "harmonic rich" conductive PA-EMI on the supply voltage for the audio section (and for other noise sensitive sections as well) an active voltage stabilization and an additional Vcc filter section is mandatory to get rid of the EMI at 217Hz found in GSM phones, as well as EMI at the related harmonics located in audio spectrum. The RF-PA-based EMI effect is often called "Audio Buzz".

2.3 Radiated EMI

Radiated RF-EMI is picked up by the internal PCB tracks and the external headset cable (common mode interferer). The RF interferer is fed to the differential audio amplifier, located in the baseband (BB) chip.

Although the Baseband (BB) Audio amplifier is not able to handle RF signals, the power envelope (pulse shaped) of the GSM signal creates distortion, noise and intermodulation products which fall into the audio frequency band. Before the EMI signal enters the differential BB-Audio amplifier, a wideband RF filter is required to get rid of all signals above the audio band (~30kHz…~6Ghz). The filter should be symmetrical for both differential audio branches and requires a good GND connection to act as a common mode filter (Figure 2).

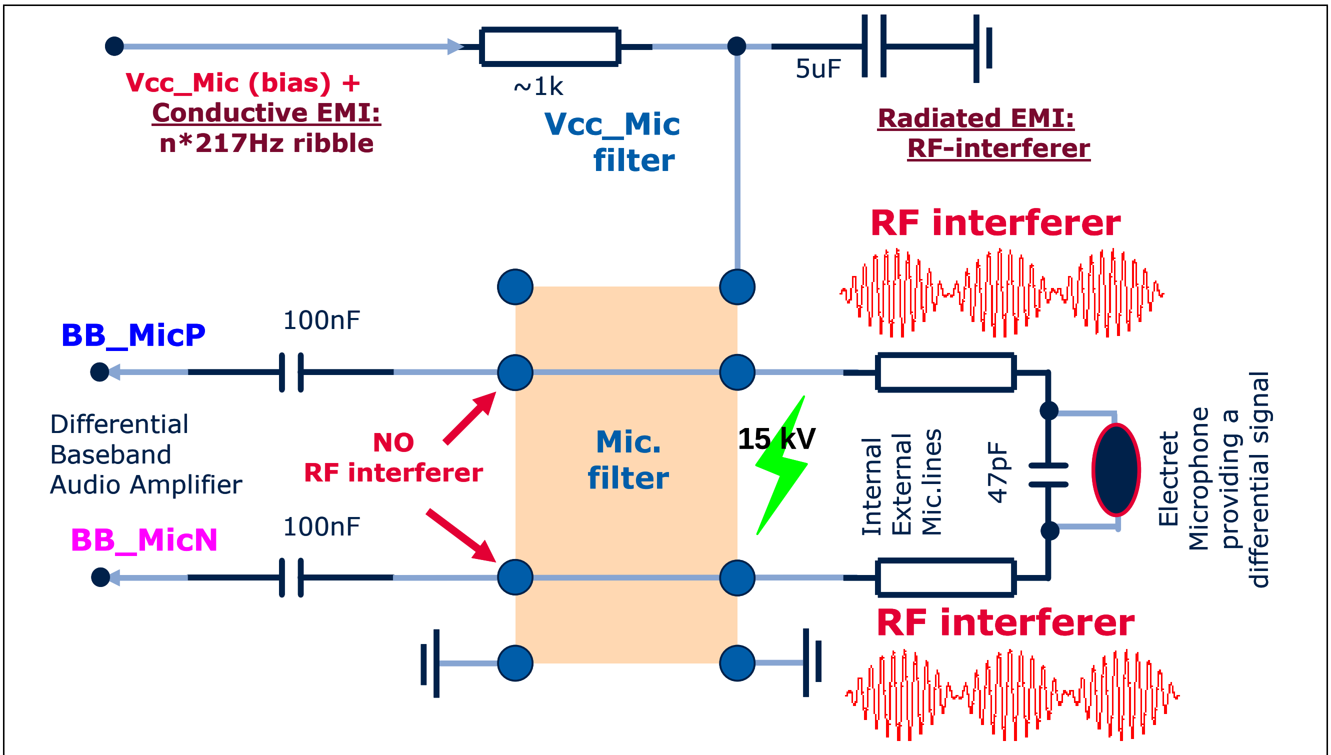

Figure 2 Conductive and radiated EMI affecting the audio microphone section

3 Tailored Audio filter for EMI / ESD suppression

Combining ESD protection and EMI suppression by implementing TVS diodes, additional capacitances and EMI resistors, a "PI"-filter low-pass structure fulfills the different requirements in a convenient way. The EMI filter section for the audio signal and for the microphone bias voltage can be implemented in the same device.

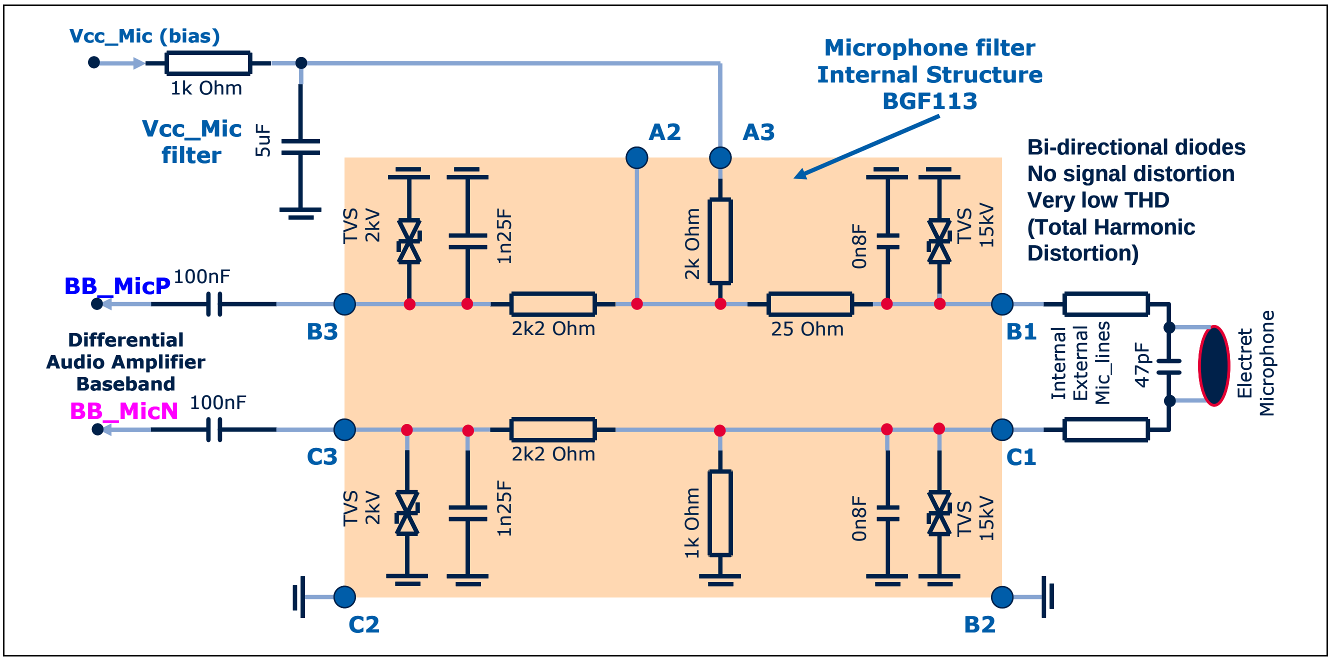

Figure 3 Audio microphone ESD/EMI suppression structure (based on IFX BGF113)

In a real world application the microphone filter is driven by the Electret microphone with a J-FET output. The J-FET acts like a voltage-controlled-current-source. The load for the microphone filter is the differential BB audio amplifier, providing an input impedance of about >10k Ohm in parallel with <10pF referenced to GND at both differential input branches (Figure 3).

In the application, the audio response has to be very flat in the entire audio band and should provide a large rejection at the mobile TX bands from 800MHz to 2500MHz. A wideband EMI attenuation starting from 100 kHz is advantageous to suppress all spurs, glitches and clock-signals which originate inside or outside of the phone. Audio performance such as the 3dB cut of frequency and audio flatness is determined by the integrated audio filter as well as the values of the serial blocking capacitors, the Vcc_Mic filter as well as the input impedance of the differential BB audio amplifier (Figure 4).

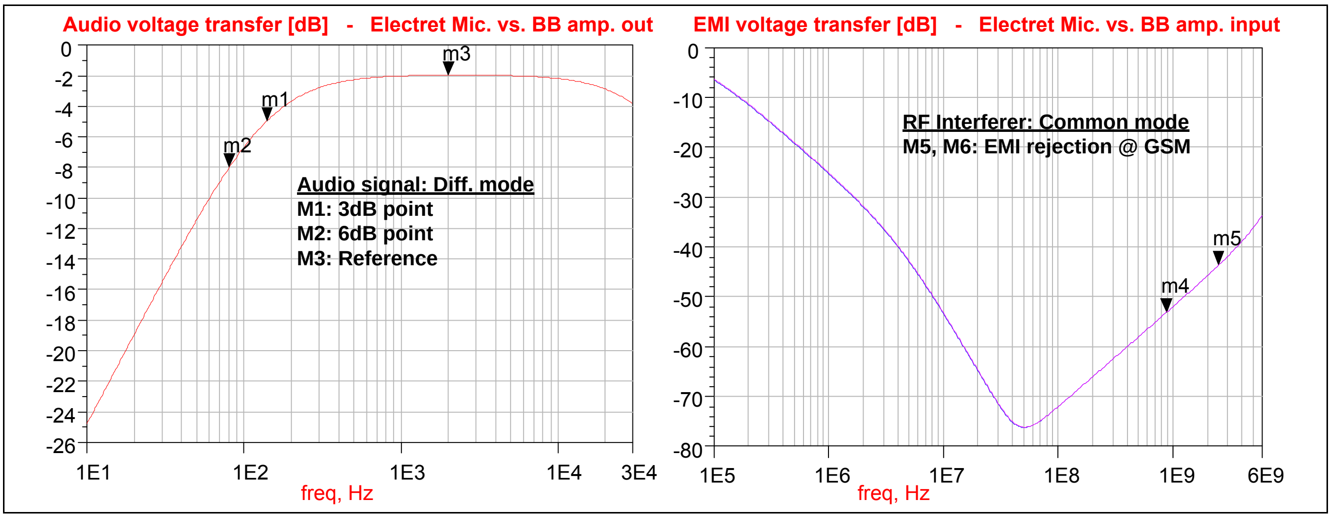

Figure 4 Audio and EMI frequency response of the audio filter in real world application

To avoid any audio distortion potentially created by the audio signal and the RF-EMI signals 'mixing' in the TVS diodes, the TVS device breakdown voltage has to be significantly higher than the maximum audio and RF-EMI peak voltages present. Furthermore, leakage current and changes of the TVS junction capacitance has to be very low over a wide voltage range.

The integrated IFX audio filter (e.g. BGF113) provides the full ESD protection capability according IEC61000-4-2 / "15kV contact" and a very good EMI filter functionality in a WLP (Wafer Level Package) in size 1.16mm * 1.16mm. The eight electrical contacts are realized with solder balls in 400um pitch.

Comparing to discrete ESD/EMI solutions for audio interfaces, there are less parasitic effects with this integrated solution. This results in very broadband filter functionality. Furthermore a significant reduction in required PC Board area is achieved, reducing cost.

Overall cost of discrete designs including logistics, pick and place, board space and component cost ad up to 0.5-1c$ per passive discrete device. Hipac solutions provide higher through-put rates in phone production lines providing an additional cost benefit.

Authors

Alexander Glas, Infineon “RF and Protection Devices”

w w w . i n f i n e o n . c o m

Published by Infineon Technologies AG