

## Use of NUF4220MN for ESD Protection and EMI Filtering of Audio Lines

### Background

Demand for better audio performance with higher efficiency in cell phones has forced significant changes in the design of the audio networks. To improve audio quality at the speaker for instance, cell phone manufacturers need to use low impedance speakers. One of the consequences of going to low impedance speakers is that the impedance of the network needs to also be low. This translates to the amplifier operating at lower impedances and acting like an ideal voltage source. Any significant resistance in this network path can significantly attenuate the audio signal. Similarly, for the audio network to operate at the highest levels of efficiency there needs to be minimal loss in the network. At the same time cell phone designers need to concern themselves with providing ESD (Electro Static Discharge) protection along the audio path, especially at hands free jacks, and filtering out EMI (Electro Magnetic Interference). This increases the difficulty for the cell phone designers because both the ESD protection and EMI filter need to be located between the audio amplifier and the speaker.

The NUF4220MN provides 15 kV (Contact) ESD protection in compliance with EIC61000-4-2 with two 7.0 V Zener diodes per audio line. The NUF4220MN also provides greater than 30 dB of attenuation between 800 MHz and 3.0 GHz while offering a low DC resistance of about 1.2  $\Omega$ . With four lines, the NUF4220MN offers a number of possible solutions to ESD and EMI filtering problems on audio lines.

### Circuit Description

The NUF4220MN is comprised of four identical LC (Inductor-Capacitor) based EMI filters. Each of these filters is made up of two Zener diodes that provide ESD protection and also act as the capacitors for the filter and a series inductor as seen in Figure 1. Each Zener diode provides 200 pF of capacitance at zero Volts bias and acts as a Transient Voltage Suppressor (TVS) with a reverse breakdown of approximately 7.0 V. The integrated inductor offers 5.2 nH of inductance while adding only 1.2  $\Omega$  of series resistance. The NUF4220MN offers excellent space savings by integrating four EMI filters with ESD protection into a single 2.0  $\times$  2.0 mm DFN (Figure 2) package that would replace up to 20 equivalent components.



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## APPLICATION NOTE

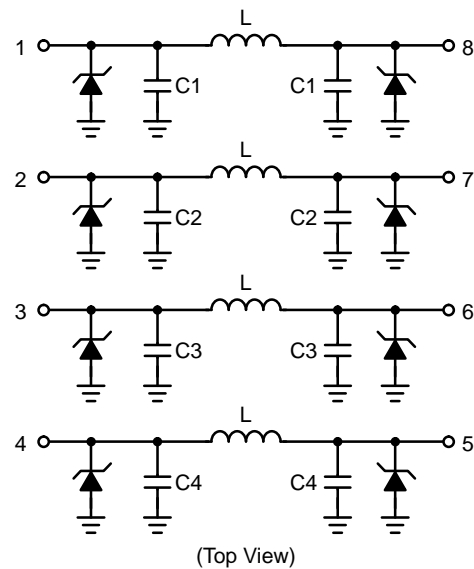


Figure 1. Equivalent Discrete Pi Filter and Pin Out of the NUF4220MN

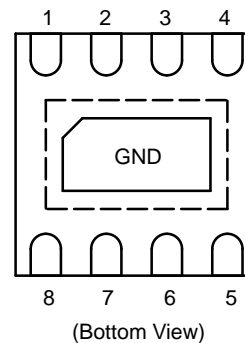


Figure 2. Package View of the NUF4220MN

## AND8275/D

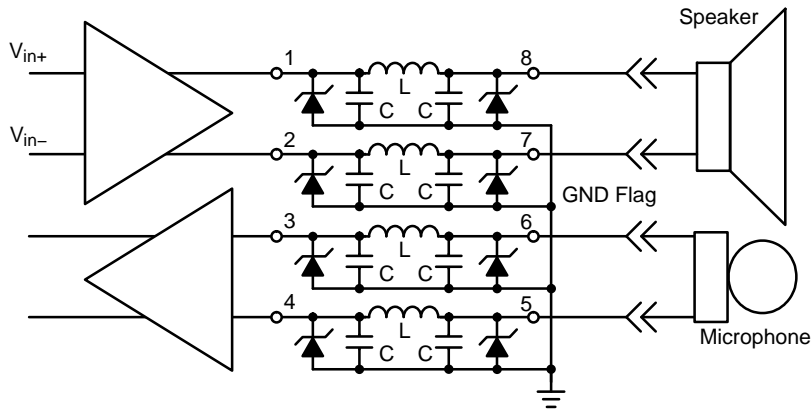
### Functionality

The typical implementation of the NUF4220MN is to have the part as near as possible to known sources of ESD, such as at the jack for a hands free speaker/microphone headset. Having ESD protection immediately after the jack makes good design sense; it is one of the few locations on the phone that ESD has a direct path from the external world to the inner workings of the cell phone. The NUF4220MN, with 15kV of ESD protection and 7.0 V Zener diodes can protect the more sensitive components from all but the most catastrophic ESD events. It is important that the ESD protection withstands large amounts of energy but also “clamps” the ESD to an acceptable level. *AND8245/D* discusses many aspects of choosing an audio ESD/EMI filter. The NUF4220MN’s 7.0 V breakdown voltage makes

it suitable for applications where the peak operating voltages do not exceed 5.0 V.

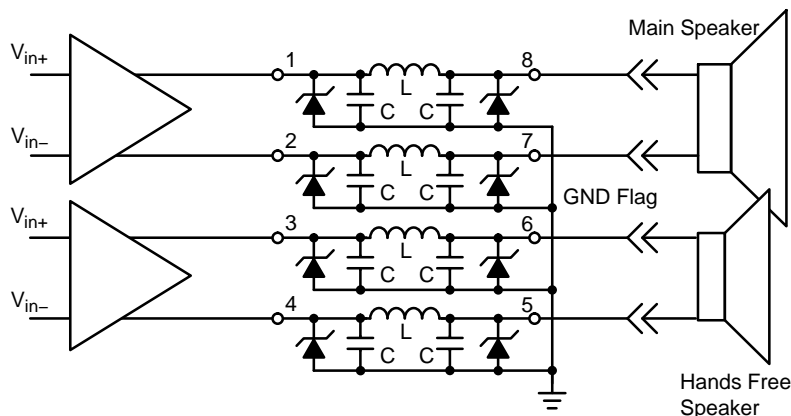
It also makes sense to have an EMI filter in the same place, after the headset jack. This is because the wires from the ear piece to the cell phone itself acts as an antenna. By having an EMI filter in place reduces the conducted EMI received through the headset jack and keeps the conducted EMI from interfering with other internal functions.

The NUF4220MN can be used in a number of configurations. The first and the most typical is to use two channels to provide EMI filtering and ESD protection between the speaker and the amplifier and the remaining two channels to protect the microphone line as shown in Figure 3. This configuration is what would typically be used next to a headset jack.



**Figure 3. NUF4220MN in Differential Mode Configuration with Speaker Output and Microphone Input in a Typical Configuration**

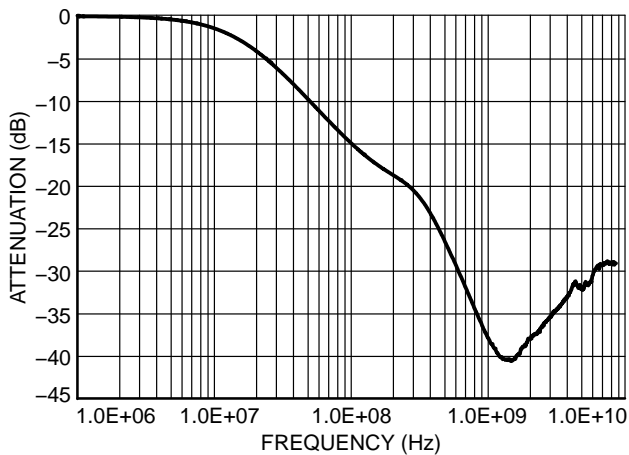
Most cell phones no longer have a single speaker. Cell phones now-a-days typically have a hands free speaker along with the normal earpiece speaker.



**Figure 4. NUF4220MN in Differential Mode Configuration with Speaker Output and Hands Free Speaker**

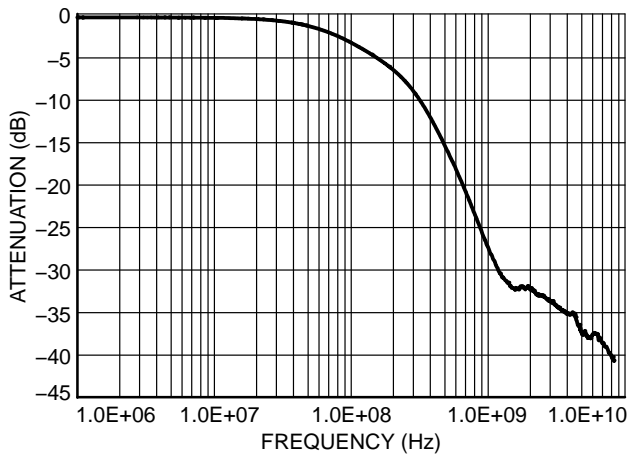
The NUF4220MN when used in a configuration similar to those shown in Figures 3 and 4 the back side ground flag must be connected directly to analog ground as explained in *AND8200/D* (Design Considerations for ESD/EMI Filters:

1) Having the shortest path to analog ground ensures the best EMI Filtering. When in this configuration the NUF4220MN provide over 30 dB of attenuation between 800 MHz and 5.0 GHz in a 50  $\Omega$  network as shown in Figure 5.



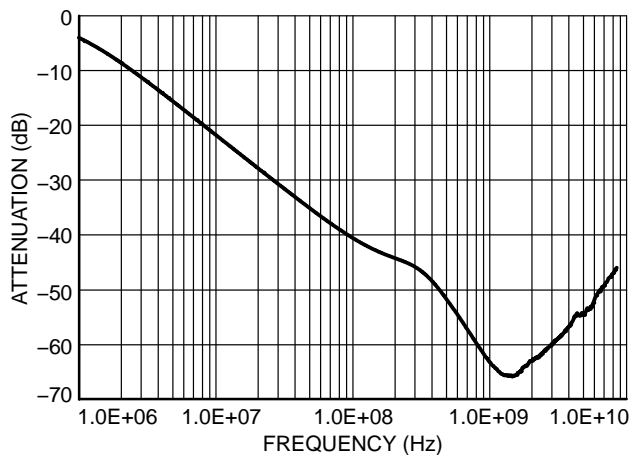
**Figure 5. Insertion Loss of the NUF4220MN with a Network Impedance of 50 Ω with the Back Side GND Connected to Board Ground.**

A more realistic application for the NUF4220MN would be to use the filter in an 8.0 Ω environment such as shown in Figure 4 in an audio output configuration. The lower network impedance changes the filtering behavior of the NUF4220MN such that the attenuation is limited to 20 dB at 800 MHz as shown in Figure 6. The low resistance of the inductor minimizes signal loss in the pass band maintaining the integrity of the audio signal.



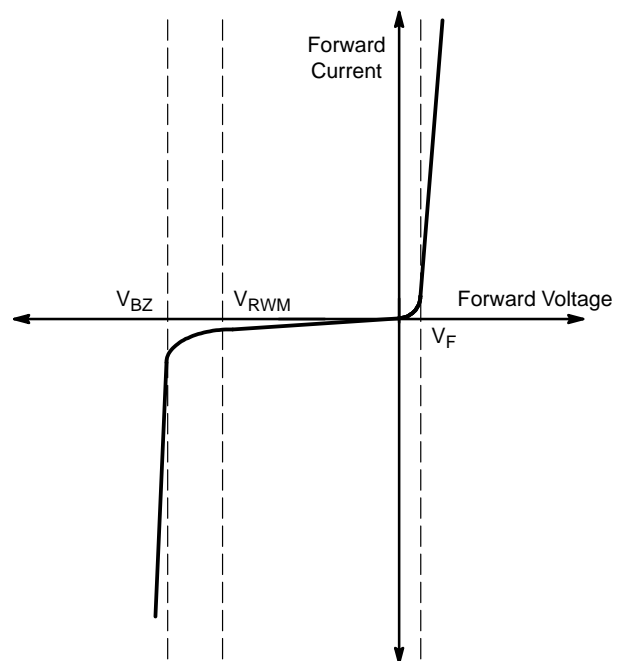
**Figure 6. Insertion Loss of the NUF4220MN with a Network Impedance of 8.0 Ω with the Back Side GND Connected to Board Ground**

When used in conjunction with microphones, the network impedance is significantly higher; the filtering response would be similar to that shown in Figure 7. The high impedance from the microphone and the amplifier input causes the cut off frequency to be significantly lower than when the filter is used in lower impedance networks.



**Figure 7. Insertion Loss of the NUF4220MN with a Network Impedance of 1000 Ω with the Back Side GND Connected to Board Ground**

In this typical configuration the NUF4220MN provides asymmetrical ESD protection. As seen in Figure 8 the IV characteristics of the filter are that of a 7 V Zener diode. The reverse break down occurs near 7 V while the forward break down is on the order of -0.8 V. This configuration is fine so long as the peak audio signal remains less than 5 V and greater than 0 V. Examples of this are explained in AND8245/D (Design Considerations for ESD/EMI Filters: 2) Low Pass Audio Filter Applications).

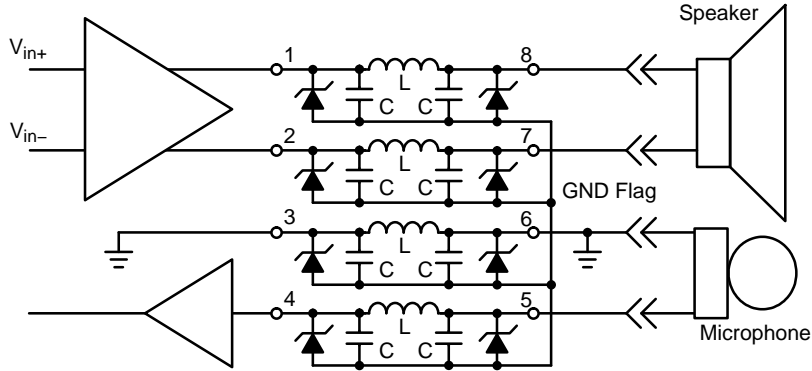


**Figure 8. IV Characteristics of Zener Diodes when Filter's Back Side Ground Contact is Connected to the Board Analog Ground**

**Alternative Configuration**

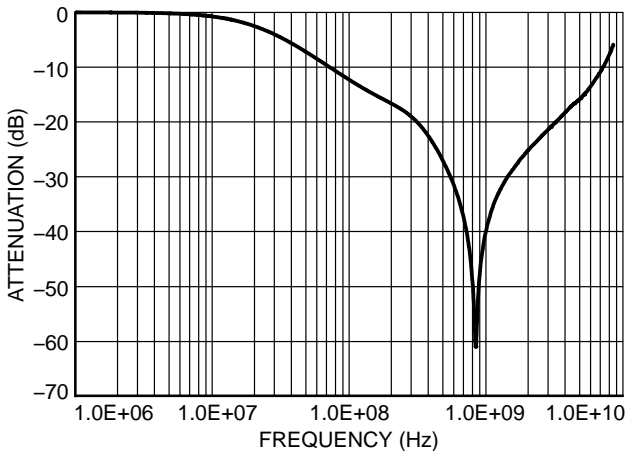
In cases where the audio signal has no DC Voltage offset and has both positive and negative voltage swing a unidirectional diode configuration may not be suitable. An upper and a lower voltage rail are required. What can be done though in the case of the NYF4220MN is to NOT

connect the GND flag to any system GND, allowing it to electrically float. Then sacrifice one of the signal lines by connecting the IO pins of the channel to board GND. Figure 9 shows an example of this where pins 3 and 6 are tied to GND while the remaining three signal lines are used for EMI filtering and ESD protection.

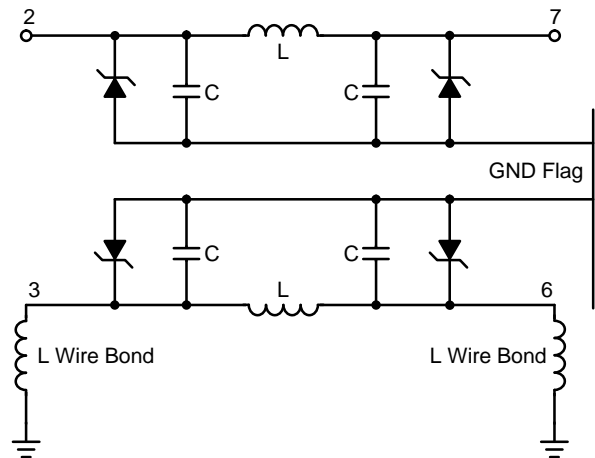


**Figure 9. NUF4220MN in Differential Mode Configuration with Speaker Output and Microphone Input with a Floating Back Side GND and Pins 3 and 6 Tied to Board Ground**

As it would be expected the filtering properties in this alternative configuration change. Figure 10 shows the changed response at 50 Ω. This is a result of the capacitance from the GND path channel in series with the filtering channels. Where normally the line capacitance of the filter is around 400 pF, because there is 200 pF per Diode, the addition of the capacitance from the GND path channel in series with the capacitors in the filter channel halves the effective capacitance. Additionally as seen in Figure 11 there is contribution of the wire bonds in the GND path channel in series with the capacitor chain.



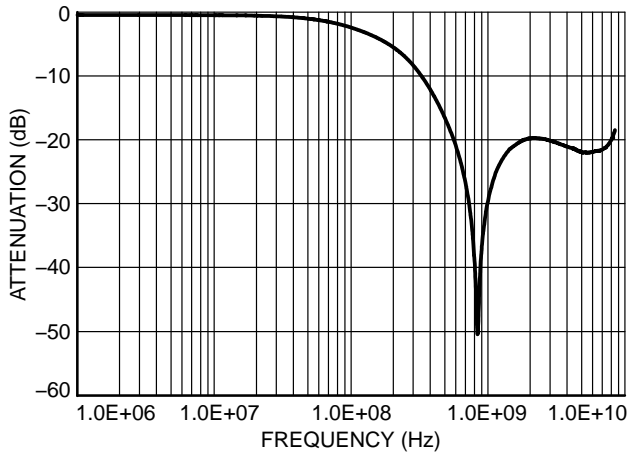
**Figure 10. Insertion Loss of the NUF4220MN at 50 Ω with the Back Side GND Floating and Pins 3 and 6 Tied to Board Ground**



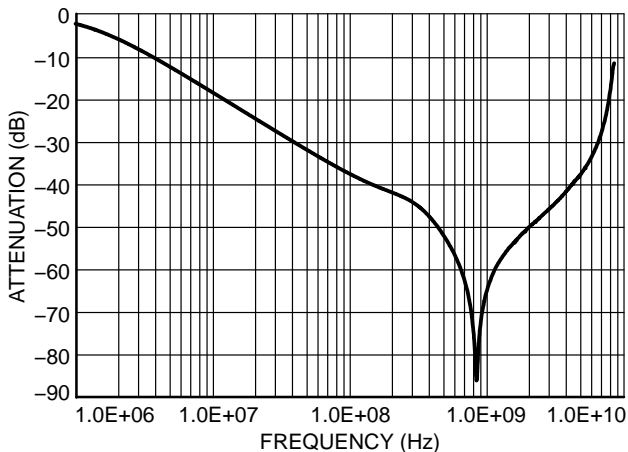
**Figure 11. Electrical Representation of a Single Channel used for Audio Filtering with One Channel in the Ground Path to Create an Effective Back to Back Diode Structure**

There are a couple of reasons why this alternative configuration has such a different insertion loss response. The first is the effective line capacitance is about half of the standard configuration. With the signal pins of the one sacrificed channel tied to ground that filter's capacitors are in series with the remaining filters' capacitors to ground. Secondly, the wire bonds from the sacrificed channel are also in series with the capacitors. This sets up a RC resonance that occurs roughly at 800 MHz. Fortunately this may be desirable for applications where there is an RF signal between 800 MHz and 900 MHz.

When in this configuration again it should be observed the frequency response of the filter under more realistic loads. Figure 12 with a network impedance of  $8\ \Omega$  shows the insertion loss response in the modified configuration. The characteristic resonance is seen at  $\sim 800\text{ MHz}$  with excellent attenuation but the higher frequency response is limited to 20 dB of attenuation. When the network impedance is  $1000\ \Omega$  as in Figure 13 the attenuation is significant across all frequency bands above the audio frequency band.



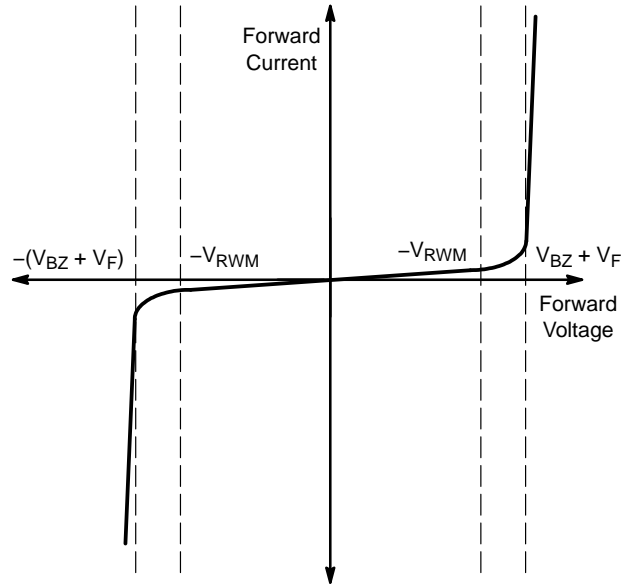
**Figure 12. Insertion Loss of the NUF4220MN at  $8\ \Omega$  with the Back Side GND Floating and Pins 3 and 6 Tied to Board Ground**



**Figure 13. Insertion Loss of the NUF4220MN at  $1\text{ k}\Omega$  with the Back Side GND Floating and Pins 3 and 6 Tied to Board Ground**

One of the chief advantages of this configuration is the effective creation of a back to back Zener diode structure. This structure provides ESD protection between  $\pm (V_{BZ} +$

$V_F)$  as shown in Figure 14. This gives the audio signal an operating range of  $\pm V_{RWM}$  where the  $V_{RWM}$  is about 5 V. This configuration is ideal for applications where the audio signal is centered on Analog Ground.



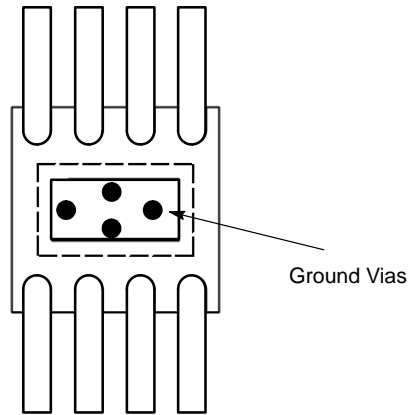
**Figure 14. IV Characteristics of the Effective Back to Back Zener Diodes when the Filter's Back Side Ground Contact is Floating and One Channel Acts as the Ground Path**

**Circuit ESD Performance**

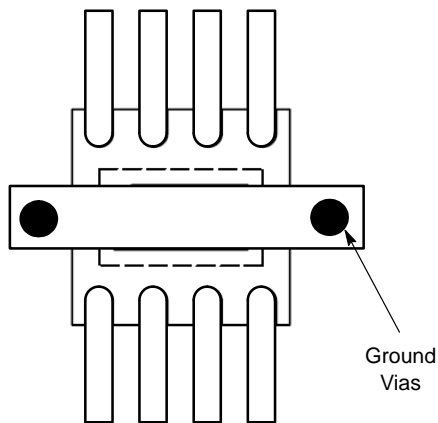
The NUF4220MN provides ESD protection compliant to IEC61000-4-2 for all four lines. Each line has two TVS devices that result in protection to 15 kV for contact discharge. For more information on ESD and IEC61000-4-2 refer to Application Note AND8074/D “EMI Filtering, USB Upstream Line Termination and ESD Protection Using the STF202 Device”.

**Design Considerations**

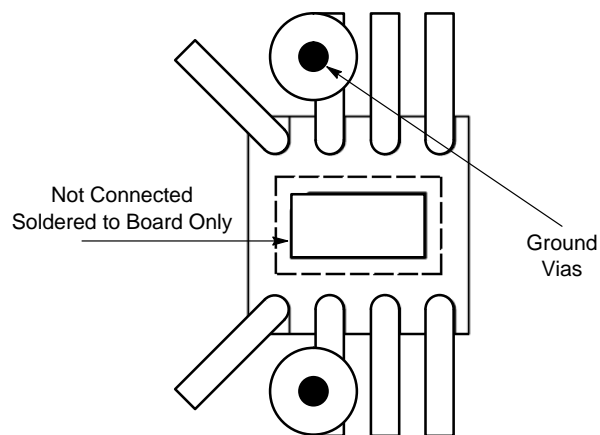
When designing in the NUF4220MN or any EMI filter one of the most critical design aspects is Grounding. Ideally the Ground of the NUF4220MN is tied directly to Analog Ground. The reason is that as the electrical path grows between the Ground flag of the NUF4220MN and Analog Ground the filtering properties of the NUF4220MN diminishes. As explained in Application Note AND8200/D “Design consideration for ESD/EMI Filters: I” the filtering bandwidth of the NUF4220MN shrinks as the inductance in the Ground Path increases. Figures 15, 16 and 17 show simple layout suggestions for that can be used to maximize filtering and ESD performance.



**Figure 15. Preferred Placement of Ground Vias for the Standard Configuration. The Placement of the Vias Directly Under to the NUF4220MN Greatly Reduces the Parasitic Ground Path Inductance**



**Figure 16. Alternative Placement of Ground Vias for the Standard Configuration. If there are Routing are via Placement Constraints the Vias can be Placed Outside the are used by the NUF4220MN but at the Cost of Introducing Parasitic Ground Path Inductance**




**Figure 17. Placement of Ground Vias for the Alternative Configuration. Placement of the Ground Vias should be as Close as Possible to the Pins of the Channel that is being used for the Ground Path**

# AND8275/D

## REFERENCES

- [1] Brooks, Douglas, "Rules for Handling Differential Signals," EETimes, January 07, 2002.
- [2] ON Semiconductor Application Note [AND8026/D](#): Solving EMI and ESD Problems with Integrated Passive Device Low Pass Pi Filters
- [3] ON Semiconductor Application Note [AND8074/D](#): EMI Filtering, USB Upstream Line Termination and Protection Using the STF202 Device
- [4] ON Semiconductor Application Note [AND8104/D](#): Microintegration™ Technology Solutions for Protection in High Speed I/O Data Lines
- [5] ON Semiconductor Application Note [AND8165/D](#): EMI and ESD Filtering of Audio Interconnects
- [6] ON Semiconductor Application Note [AND8200/D](#): Design Considerations for ESD/EMI Filters: I
- [7] ON Semiconductor Application Note [AND8245/D](#): Design Considerations for ESD/EMI Filters: II

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