

## EMI and ESD Filtering of Audio Interconnects

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### APPLICATION NOTE

#### Background

The continued ever-increasing integration of more functions into personal electronic devices such as cell phones has made electronics manufacturers demand more integrated functions to reduce part count and save board space. Cell phone manufacturers have also driven component manufacturers to produce more efficient parts to increase the battery life on cell phones. Quite often though this is done at the cost of added sensitivity to ESD. Concurrently, as data rates and clock speeds increase the need to filter Electromagnetic Interference (EMI) also needs to be resolved. The ON Semiconductor NUF2441FC was designed to provide both ESD protection and EMI filtering for headset and speaker phone lines in cell phones with low line losses. This dual function component reduces part count and significant board space in a Flip-Chip package offer excellent performance at a low cost.

#### Circuit Description

The NUF2441FC is a dual line bidirectional low pass EMI filter with integrated ESD protection for two single ended lines or a differential pair. Each filter is comprised of a 2.9 nH inductor and two Zener diodes. Each diode functions as a capacitor with an equivalent capacitance of 120 pF. The series inductor has a typical equivalent series resistance of 0.25  $\Omega$ . This low resistance is ideal in an audio circuit where line losses need to be kept to a minimum. The capacitors in this filter are made up of back to back Zener Transient Voltage Suppressor (TVS) diodes that offer ESD protection to both positive and negative ESD spikes. Figure 1 shows the equivalent circuit of the NUF2441FC.

The NUF2441FC is rated to 30 kV in compliance to the IEC61000-4-2 requirements for both contact and air discharge. The Zener diodes provide ESD protection by clamping to a nondestructive 16 V dissipating destructive energy to ground. The resulting Pi-Filter has very low Audio band insertion loss while having greater than 30 dB of rejection from 800 MHz to 5.0 GHz with 50  $\Omega$  loads. The NUF2441FC also offers great space savings by integrating an equivalent 10 discrete components into a 1.7 x 1.2 mm Flip-Chip package (Figure 2).

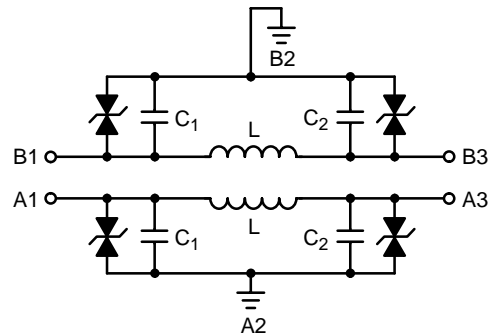
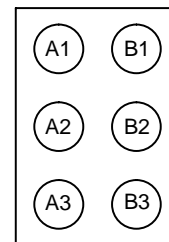


Figure 1. Equivalent Discrete Pi-Filter and Pinout

#### PIN CONFIGURATION



(Bump View)

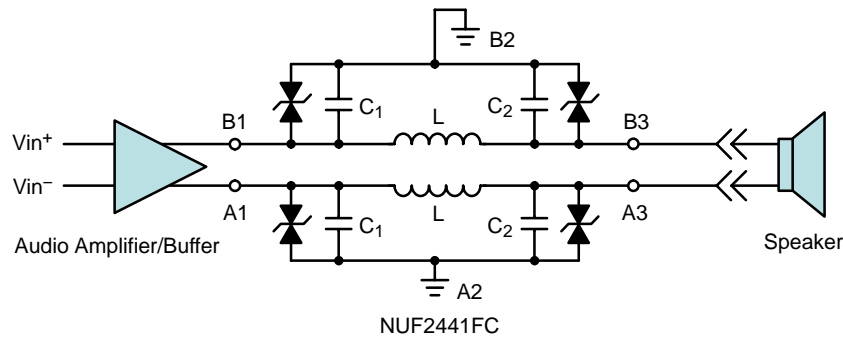
Figure 2. Package View of the NUF2441FC

#### Functionality

The NUF2441FC can be used in a number of configurations in cell phones needing ESD and EMI filtering for headset and speaker phones. The most common configurations include using the two filters in a differential pair mode for a single input or output without a ground reference or in a single-ended mode with two lines with a common ground reference.

For speaker line protection the NUF2441FC would be placed after the Audio Amplifier/Buffer and before the connector going to the speaker. In differential mode applications where a common ground is not present for the speaker as shown in Figure 3, the NUF2441FC may be connected to the two outputs of a differential amplifier with the output pins going to the speaker connector. Each line would then be individually filtered for EMI and protected against ESD.

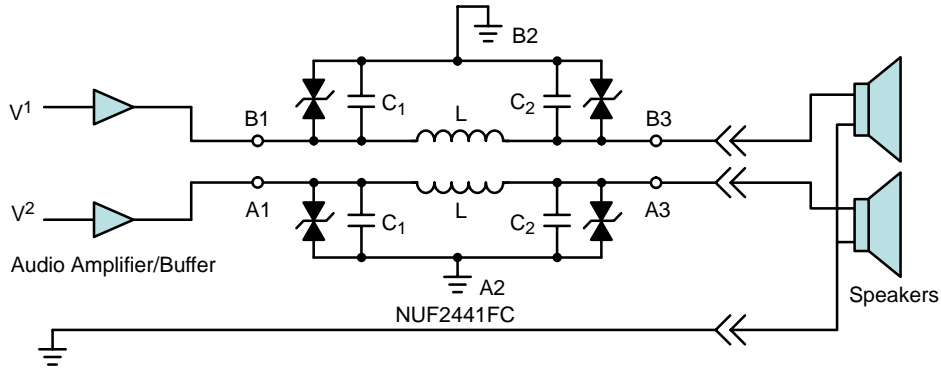
## AND8165/D



**Figure 3. NUF2441FC in Differential Mode Configuration with Speaker Output**

When a common ground is used for two separate audio outputs each channel would be connected to one of the two filters with the speaker return lines connected to ground (Figure 4). Each channel would have full ESD protection even though the return path is unfiltered. This is because the

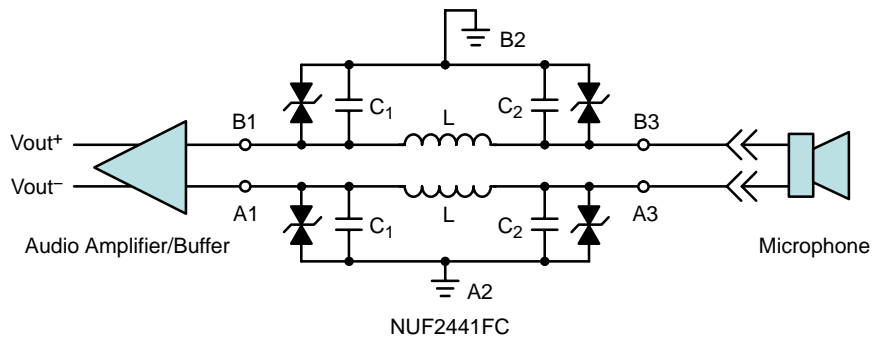
NUF2441FC uses bidirectional Transient Voltage Suppressors. Again, this means regardless whether the ESD is positive or negative, the energy is dissipated to ground thus protecting the more sensitive components.



**Figure 4. NUF2441FC with Two Single-Ended Mode Speakers**

Similarly, the input from a microphone can be protected from ESD by placing the NUF2441FC after the connector and before any receiving component (Figure 5). This has the

added advantage of also filtering out any EMI that may otherwise enter the system.

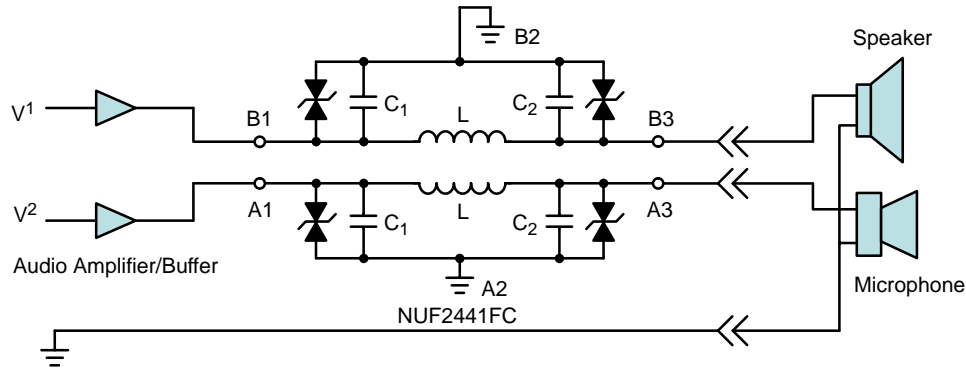


**Figure 5. NUF2441FC in Differential Mode Configuration with Microphone Input**

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With greater than 40 dB of isolation between the two individual filters the NUF2441FC can also be used to protect both incoming and outgoing audio as seen in Figure 6. So

long as the microphone and the speaker can share a common ground each line can be protected by its own filter.



**Figure 6. NUF2441FC with Single-Ended Mode Microphone Input and Single-Ended Speaker Output**

### Circuit Performance

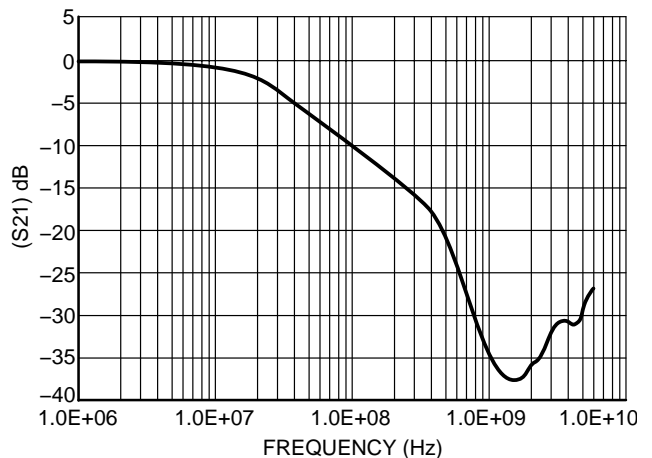
The NUF2441FC provides ESD protection compliant to IEC61000-4-2 for both lines. Each line has two TVS devices that result in protection to 30 kV for contact and air discharge. *For more information on ESD and IEC61000-4-2 refer to “EMI Filtering, USB Upstream Line Termination and ESD Protection Using the STF202 Device”.*

The filtering requirements for EMI filters have two main components. The first is the range of frequencies that are to be filtered out. This band of frequencies typically start at 800 MHz and ends at 2.4 GHz. The reason this band of frequencies is so important is that cell phone frequencies (GSM) begins at 800 MHz and Bluetooth operates at 2.4 GHz with many cell phone and other communication bands in between. The next requirement is how much to attenuate this band. Because of the sensitivity of many of the RF components in cell phones 25 dB could work but more than 30 dB of attenuation would be preferred. A signal that is attenuated by 30 dB is reduced in power by a factor of 1000.

The flip side to the EMI filter is the Pass band. The EMI filter is no good if it does not pass the desired signal, in this case, audio. If the insertion loss is high more power is needed to drive the speaker and a receiver with greater sensitivity is needed to acquire the audio from the microphone. A low audio band insertion loss equates to better efficiency. By limiting the losses from the filter, driver amplifiers do not need to have an output power much greater than necessary to overcome the filter losses and deliver only desired power to the speaker. Low insertion loss is also important for

receiving signals from the microphone. For this case, a receiving amplifier does not need to be as sensitive. Audio levels that may otherwise be attenuated to a level difficult to receive would not need a receiver as sensitive. Figure 7 shows the NUF2441FC has very low insertion loss in the audio band and excellent rejection of over 30 dB in rejection band.

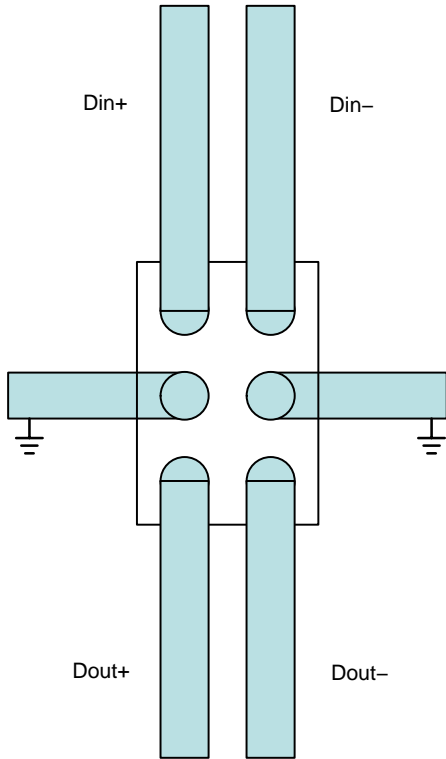
The NUF2441FC could also be used for data transmission. Under 50  $\Omega$  loads the filters have a cut off frequency ( $F_C$ ) of 30 MHz. This means the NUF2441FC can adequately filter EMI and protect from ESD on data and clock line with rates up to 3.0 MHz.



**Figure 7. Insertion Loss of the NUF2441FC at 50  $\Omega$**

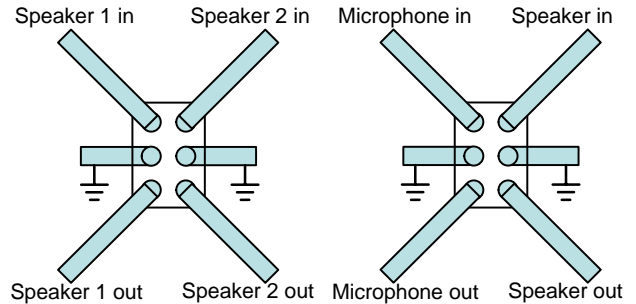
**Design Considerations**

When used in a differential mode configuration (Figure 8), both the input and output lines should remain parallel to maintain proper impedances and line lengths. If the line lengths become significantly different errors in the differential signal can be generated and uncontrolled EMI can be generated. The ground bumps need the shortest possible path analog ground to ensure the EMI filter attenuates in a predictable manner.



**Figure 8. Proposed Layout for Differential Lines.**


If the NUF2441FC is used in a single-ended mode (Figure 9) the input line when approaching the filter and the output lines when leaving the filter should be at 90° to each other. This helps minimize the crosstalk between the lines. The audio lines need to share a return path connecting with the filters ground bumps to analog ground.



**Figure 9. Proposed Layout for Single-Ended Lines**

**Bibliography**

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2. Brooks, Douglas, "Rules For Handling Differential Signals," EETimes, January 07, 2002.
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4. ON Semiconductor Application Note AND8026/D.

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