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Recommendations for Mounting and Connecting the ADMP421 Bottom Port Digital MEMS Microphone

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INTRODUCTION

The ADMP421 is a high-performance, bottom ported, digital MEMS microphone featuring a flat wideband frequency response up to 15 kHz. While the microphone's own response exhibits very little variation over its operating range, changes to this response may be introduced when the microphone is placed inside a device case. This application note provides mounting recommendations for minimizing the influence of packaging on the microphone performance in the final product. Electrical connections, codec interface, and performance aspects are discussed as well.

This application note discusses the following:

- Mechanical design considerations: PCB mounting, use of gaskets and spacers, avoiding resonances.
- Electrical connections: digital data format, codec interfaces, evaluation board.
- Application-enabling performance aspects.

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MECHANICAL DESIGN CONSIDERATIONS

The ADMP421 bottom ported microphone is designed to be reflow-soldered directly onto a PCB. A hole in the PCB is required to let the sound into the microphone package. In addition, the PCB with the microphone is placed in a housing, which also must have an opening connecting the microphone to the outside environment.

The PCB, together with the housing, forms elements of an acoustic circuit that may affect the frequency response of the microphone. This application note provides recommendations to help ensure the best audio performance from the microphone.

SOUND PATH DESIGN

The microphone requires a path for the sound into the package through the bottom port. Due to the flat frequency response of the ADMP421, as well as the small size of the microphone package and its related features, the exact geometry of the sound path does not significantly influence the response of the microphone. Since all dimensional references in acoustics are related to the wavelength of sound, the following formula for converting frequency to wavelength is useful:

$$\lambda = c / f$$

where:
λ is the wavelength, m.
c is the speed of sound, approximately 340 m/sec.
f is the frequency, Hz.

For example, at 10 kHz, the wavelength is 34 mm (see Figure 1).

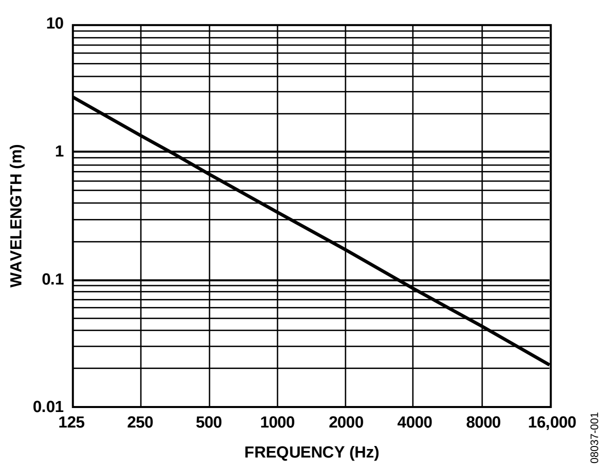

Figure 1. Wavelength of Sound vs. Frequency

PCB THICKNESS AND USING FLEX PCB

The performance of ADMP421 is not affected by PCB thickness. The microphone can be mounted on a flexible PCB using the guidelines listed in the microphone data sheet available at www.analog.com.

PCB SOUND HOLE SIZE

The response of the ADMP421 is not affected by the PCB hole size as long as the hole is not smaller than 0.25 mm (0.010 inch) in diameter. A 0.5 mm to 1 mm (0.020 inch to 0.040 inch) diameter for the hole is typical. Take care to align the hole in the microphone package with the hole in the PCB.

AVOIDING RESONANCES

One acoustical structure that can influence sound, even when its dimensions are much smaller than the wavelength, is a Helmholtz resonator. This consists of a wide section forming an inner cavity, and a narrow hole, or vent, to the outside. A Helmholtz resonator may be formed when, for example, a wide gasket is used between the microphone PCB and the device case (see Figure 2).

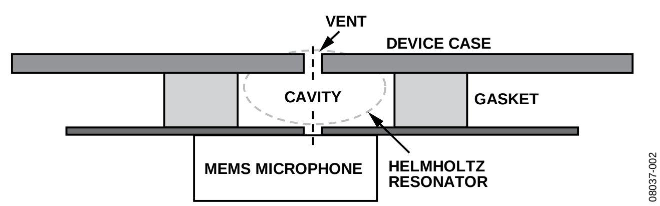

Figure 2. Helmholtz Resonator Example

This structure may result in a high frequency response peak and should be avoided, unless the peak is sought by the product designer. To avoid this resonance, the gasket should be as small as possible, or the board should be placed directly against the device case. When a longer acoustic path is required by industrial design constraints, the effective path diameter should be close in size or smaller than the device case opening (vent) (see Figure 3).

A good seal between the device case and the gasket and between the PCB and the gasket is important. The influence of the stiffness of the gasket material on the overall microphone performance is negligible. Examples of gasket material include rubber, silicone, neoprene, or closed-cell foam.

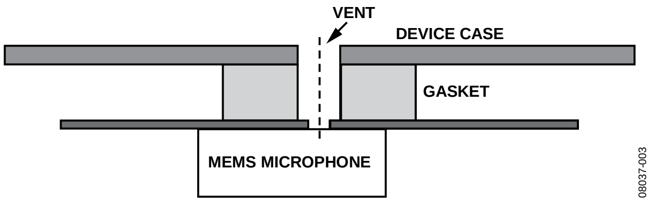

Figure 3. Recommended Gasket Design Example

To calculate the Helmholtz resonance frequency the following formula can be used:

$$f_b = \frac{c \times D}{4\sqrt{\pi \times V \times (L + \sqrt{\pi} \times D/2)}}$$

where:
f_b is the resonance frequency, Hz.
c is the speed of sound, approximately 340 m/sec.
D is the vent diameter, mm.
V is the cavity volume, mm^3.
L is the vent length, mm.

The calculated resonance frequency may differ from the actual measurement results due to nonrigid gasket walls, leakages, and other imperfections. Use this formula for an estimate of where in the frequency domain the resonance is likely to be located rather than to establish an exact value.

ELECTRICAL CONNECTIONS

ANALOG DEVICES CODECS SUPPORTING PDM DATA FORMAT

The ADMP421 output data is in pulse density modulated (PDM) digital format. The Analog Devices, Inc., ADAU1361 and ADAU1761 codecs feature digital microphone inputs that support the PDM format. See Figure 4 and refer to the respective data sheets for more details on digital microphone interface.

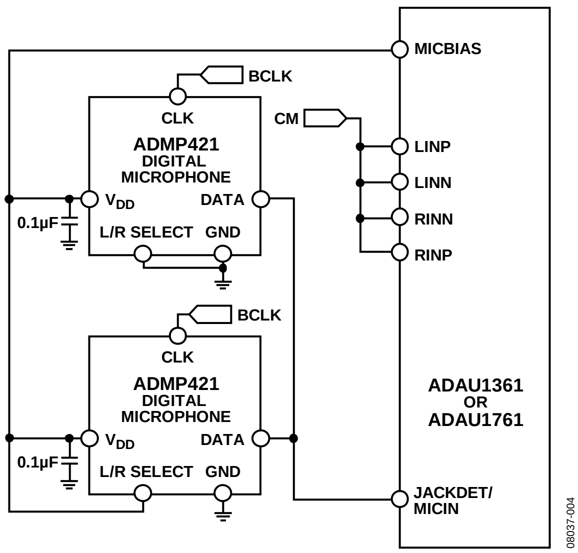

Figure 4. ADAU1361 and ADAU1761 Interface Block Diagram with Two ADMP421 Microphones

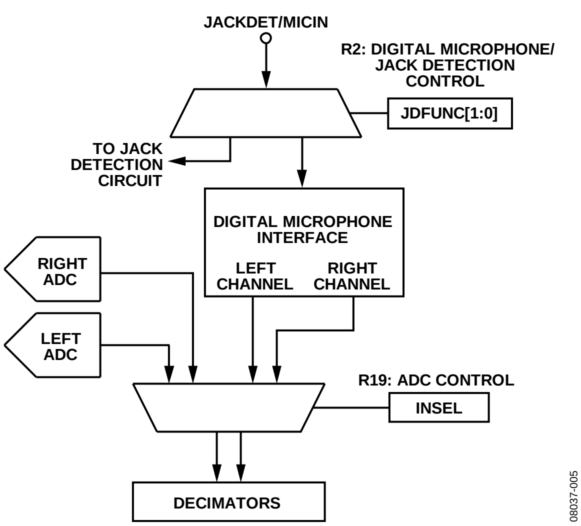

Figure 5. Digital Microphone Signal Routing Block Diagram

When using ADMP421 connected to the JACKDET/MICIN pin, the JDFUNC Bits[1:0] in Register R2 (Address 0x4008) must be set to enable the microphone input and disable the jack detection function. The ADAU1361 must operate in master mode and source BCLK to the input clock of the digital microphones.

The digital microphone signal bypasses record path mixers and ADCs and is routed directly into the decimation filters. The digital microphone and ADCs share decimation filters and, therefore, both cannot be used simultaneously. The digital microphone input select bit, INSEL, can be set in Register R19 (ADC control register, Address 0x4019).

Figure 5 depicts the digital microphone signal routing. In addition, for the ADAU1761 the DSPRUN bit must also be asserted in Register R62 (DSP run register, Address 0x40F6) for digital microphone operation.

EVALUATION BOARD

The EVAL-ADMP421Z evaluation board schematic and layout are shown in Figure 6 and Figure 7, respectively.

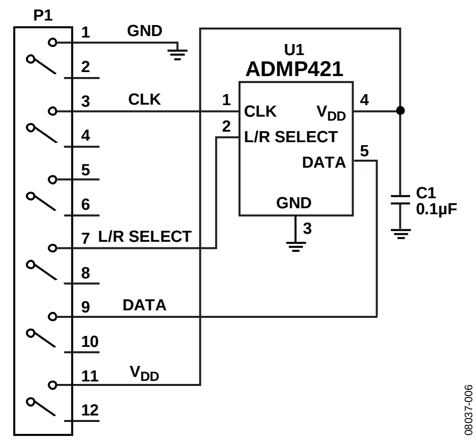

Figure 6. ADMP421 Evaluation Board Schematic

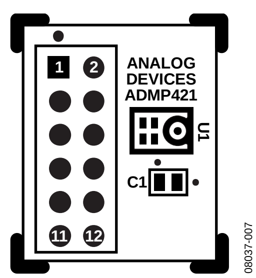

Figure 7. ADMP421 Evaluation Board Layout

Table 1. Evaluation Board Connector Pin Functions

Pin No.	Description
1	GND
2, 4, 5, 6, 8, 10, 12	Not connected
3	CLK
7	L/R SELECT
9	DATA
11	V_{DD}

The ADMP421 evaluation board is designed to plug directly into Connector J6 on the Analog Devices EVAL-ADAU1761Z evaluation board.

CONNECTING TWO MICROPHONES TO A SINGLE DATA LINE

As illustrated in Figure 4, two microphones can be connected to a single DATA wire for stereo operation. This is possible because the DATA output is in high impedance mode in half of every clock cycle. The L/R SELECT pin controls assignment of the microphone to left or right output channel as described in Table 2.

Table 2. L/R SELECT Pin Assignment

L/R SELECT Connected To	Selected Mode
Logical Low (GND)	Right microphone (DATA1)
Logical High (V_{DD})	Left microphone (DATA2)

The DATA1 output bit is valid when the clock is low. The DATA2 output bit is valid when the clock is high. This means that the right channel (DATA1) bit must be read on the low-to-high clock transition, and the left channel (DATA2) bit must be read on the high-to-low clock transition. See Figure 8 for a suggested two-microphone connection schematic. Depending on the distance between the two microphones, a separate 0.1 µF V_{DD} bypass capacitor may be required per microphone.

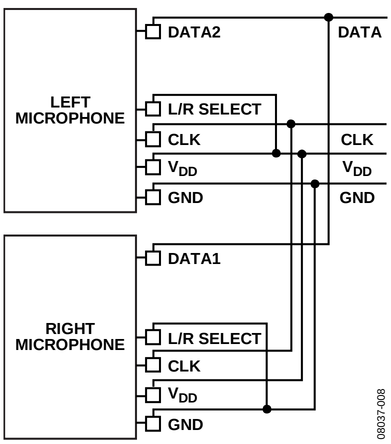

Figure 8. Two ADMP421 Microphones Connected to a Single DATA Wire

WIRE LENGTH RECOMMENDATIONS

For out-of-product evaluations, the ADMP421 can be connected to a codec directly with the wire lengths up to 6 inches (15 cm). When longer wires are required, a 100 Ω resistor is recommended on the clock output of the codec to minimize overshoot or ringing of the clock signal. In some cases, a clock buffer may be necessary to avoid performance degradation with excessively long wires. A schematic for a simple clock buffer is suggested in Figure 9.

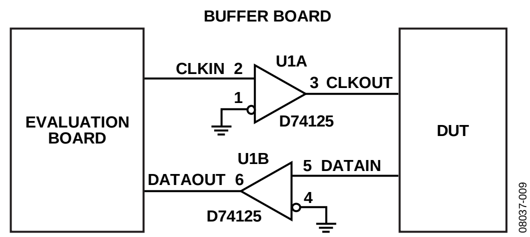

Figure 9. ADMP421 Buffer Schematic Suggestion

PCB LAND PATTERN LAYOUT

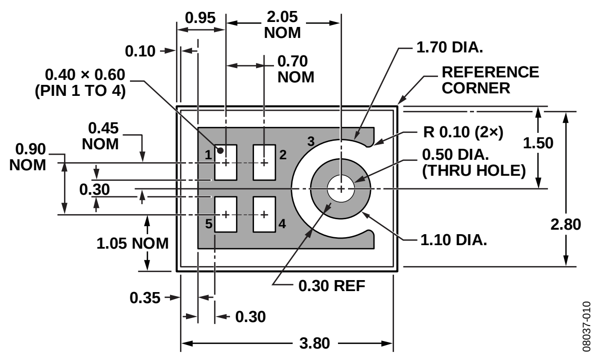

Figure 10. ADMP421 Solder Pads (Dimensions Shown in Millimeters)

The recommended PCB land pattern layout for ADMP421 is the same as the solder pads on the microphone package (see Figure 10). The land pattern should be laid out to a 1:1 ratio. Care should be taken to avoid applying solder paste to the sound hole in the PCB. Connections to Pin 1, Pin 2, Pin 4, and Pin 5 should be routed using vias due to a ground trace (Pin 3) running around the perimeter.

PERFORMANCE

LOW VIBRATION SENSITIVITY

The ADMP421 exhibits low vibration sensitivity due to very low surface density (mass per unit area) of the membrane. The surface density of a membrane is a product of the membrane's material density and thickness. The equivalent sound pressure generated by axial vibration is then

$$p_a = \rho \times t \times a$$

where:
p_a is the equivalent sound pressure, Pa.
ρ is the membrane material density, kg/m^3.
t is the membrane thickness, m.
a is the vibration acceleration, m/s^2.

Due to a much lower surface density of the MEMS microphone membrane, the vibration signal generated by ADMP421 is significantly lower than that of a typical electret condenser microphone (ECM). Table 3 provides examples of axial vibration sensitivity of several types of microphones for your reference. These calculated equivalent sound pressure levels are in excellent agreement with experimental data where available.

Table 3. Vibration Sensitivity of Various Condenser Microphones and Axial Acceleration

Microphone, Membrane Material, Thickness	SPL at 1 m/sec^2, dB	SPL at 1 G, dB
Bruel & Kjaer ½" mic, metal, 4 µm	65	85
A Typical ECM, Mylar 10 µm	57	77
Analog Devices MEMS, p-Si, 0.9 µm	40	60

This low mechanical vibration sensitivity of MEMS microphones enables better performance in many applications. One particular application where low vibration sensitivity becomes critical is that of a microphone in a speakerphone with echo cancelling. Vibration signal picked up by a microphone may significantly impair the performance of an acoustic echo cancellation algorithm. Note that this reduction in parasitic pickup applies to mechanical vibration only. When the vibration produces sound at the microphone location, the microphone pickup of that sound is determined by its acoustic sensitivity.

EXTENDED FREQUENCY RESPONSE

The ADMP421 features uniform extended frequency response, making it an excellent choice for applications such as wideband speech and music capture. Unlike when using microphones with high-frequency resonance peaks, adding acoustically resistive material to the microphone port does not improve the response and is not required. In general, additional signal processing, such as low-pass or notch filters, is also unnecessary.

FREQUENCY RESPONSE REPEATABILITY

The ADMP421 frequency response displays low variability from part to part due to high repeatability of the semiconductor manufacturing process. This response consistency makes multimicrophone applications, such as beamforming, possible without additional testing and matching of microphones. Due to the minimum-phase nature of these tiny MEMS microphones, their phase responses are directly related to the magnitude responses and, therefore, are tightly matched as well. Figure 11 illustrates an example of overlaid magnitude responses of 40 randomly selected ADMP421 microphones. Note that the responses are normalized at 1 kHz.

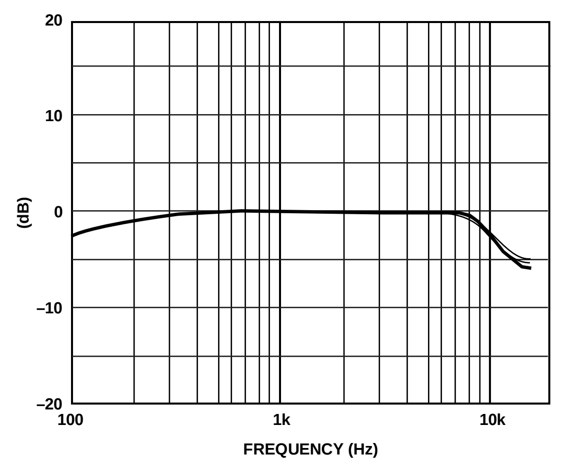

Figure 11. Frequency Responses of Multiple ADMP421 Microphones

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