Low-Noise Directional Studio Microphone Reference Design

CIRCUIT FUNCTION AND BENEFITS

The circuit shown in Figure 2 implements a professional-grade studio or live performance microphone using up to 32 analog MEMS microphones connected to op amps and a difference amplifier. The circuit is designed to be very low-noise and its output is linear for acoustic inputs up to 131 dB SPL (sound pressure level). The ±9 V and +1.8 V power rails are generated from two voltage regulators powered from a single +9 V battery.

The INMP411 consists of a MEMS microphone element and an impedance-matching amplifier. This microphone supports acoustic inputs up to 131 dB SPL and has a low-frequency response that is flat to 28 Hz. These features make this microphone ideal for full-bandwidth, wide dynamic range audio capture applications, such as in a recording studio or on stage.

The ADA4075-2 op amps are used to perform several different functions in this circuit, including a summing amplifier and all-pass filter. This op amp is low-noise, low-power, and low-distortion, making it a good choice for a battery-powered high-performance audio application.

The AD8273 converts the single-ended microphone signal into a differential signal that can be output on a standard microphone XLR connector. The gain setting resistors are internal to the difference amplifier, so it can create a high-performance differential signal with no external components. The difference amplifier has very low distortion, low noise and good output drive capability, making it a good choice for driving a differential microphone output.

The power supplies for this circuit are generated from an ADP1613 dc-to-dc switching converter and an ADP1720 linear regulator (see Figure 9 for schematic). The ADP1613 in a SEPIC-Ćuk configuration generates the ±9 V rails for the amplifiers and the ADP1720 generates the MEMS microphones' 1.8 V supply. These regulators efficiently generate the necessary voltage supplies with very low ripple.
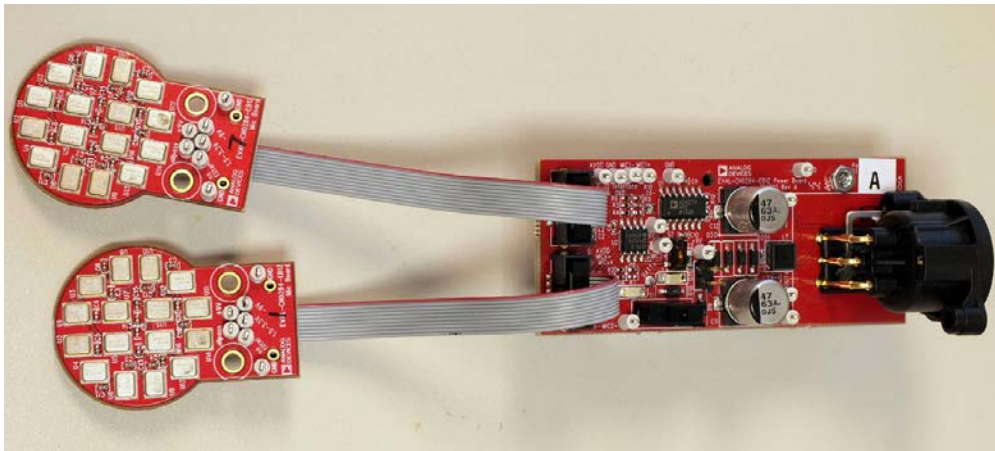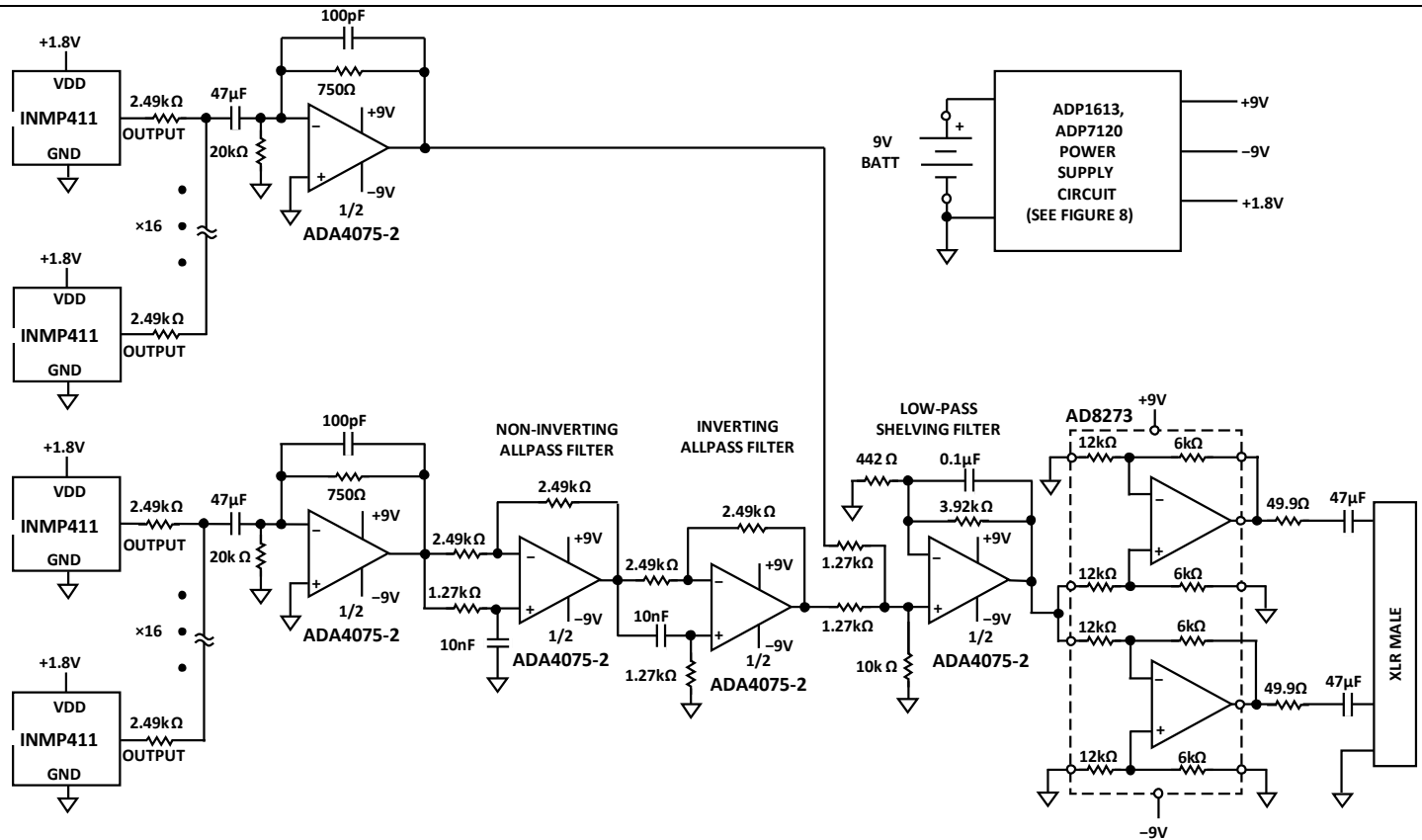

Figure 1. EVAL-CN0284EB1Z Evaluation Kit

Figure 2. Microphone Circuit Diagram
(Simplified Schematic: All Connections and Decoupling Not Shown)

CIRCUIT DESCRIPTION

An array of many INMP411 MEMS microphones are closely spaced in this circuit to improve the overall SNR of the system to a point that it can be used for very low noise recording studio applications. The circuit can be used with either one or two clusters of microphones, depending on the desired directionality. Using two microphone arrays and some simple filtering enables some basic beamforming to achieve a supercardioid directional response; while the directional response of a single microphone array is basically omnidirectional, like the response of a single MEMS microphone.

Following the summing, filtering, and beamforming, the signal is still single-ended. The AD8273 difference amplifier converts this single-ended signal into a differential signal that is output on the XLR jack.

This circuit can be powered from a single 9 V battery, and two regulators generate the ±9 V and +1.8 V supplies. The amplifiers use the bipolar supply, while the MEMS microphones operate from the single low-voltage 1.8 V supply.

Summing Amplifiers

The ADA4075-2 is used as a summing amplifier in two places in this circuit. First, the outputs of each of the 16 INMP411 mics in the array are summed together in an inverting summing amplifier with a gain of 0.31. The input summing resistors are all 2.49 kΩ, therefore the contribution of each microphone to the output is equal. Every time the number of microphones in the array is doubled, the overall SNR increases by about 3 dB. This is because the microphone signals sum coherently, increasing the amplitude of the output by 6 dB for each doubling of the number of microphones, while the noise adds incoherently, adding 3 dB to the noise

floor. The result is a net increase of 3 dB in the SNR. This circuit uses 16 INMP411 microphones, each with an individual SNR of 62 dBA, therefore after four doublings of the number of microphones, the SNR of the array improves by 12 dB to 74 dBA.

The INMP411 has an output impedance of 200 Ω, so the 2.49 kΩ summing resistor reduces the amplitude of each mic's output signal by 7.5%, or 0.7 dB.

The feedback resistor in the summing amplifier is 750 Ω, which gives the amplifier an overall gain of 0.31 (−10 dB) following the summing node. The ADA4075-2 is unity gain stable, so this amplifier can be used for a gain <1. If another op amp were to be used in this circuit, its closed-loop gain should be checked to ensure that it is stable at this low gain.

This reduction in level ensures the output at the XLR plug is similar to a typical recording microphone. A microphone with a sensitivity above about −30 dBV may be considered too "hot" and therefore difficult to use in a typical recording setup. If a microphone with higher sensitivity is desired, then the size of this feedback resistor can be increased thereby increasing the gain. Other than maintaining typical microphone output levels, the output level is limited only by the supply voltages.

The input of the ADA4075-2 is also ac-coupled because the INMP411 output is biased at 0.8 V. The output of this stage and the rest of the amplifier stages are biased at 0 V.

The second ADA4075-2 summing amplifier is used either to sum two in-phase arrays or to sum one microphone array with another delayed and inverted array for beamforming processing.

Polarity

The amplifier summing the signals from the 16 INMP411 microphones is inverting. This is done to preserve the polarity of the input acoustic signal. The INMP411 has an acoustically-inverted output, meaning that a positive pressure input results in a negative output voltage. This signal is inverted in the first amplifier stage so that it is not inverted with respect to the acoustic input at the XLR output jack. All other stages in the signal path are non-inverting, except for the inversion necessary in one of the two microphone paths for the beamforming processing.

Beamforming

Beamforming involves processing the output of multiple microphones (or in this case, multiple mic arrays) to create a directional pickup pattern. For recording and live sound applications it is important that the microphone only picks up sound from one direction, such as from the singer or instrument, and attenuates the sound that is off the main axis. Beamforming is implemented in this design using analog delays, an equalization filter, and a summing amplifier.
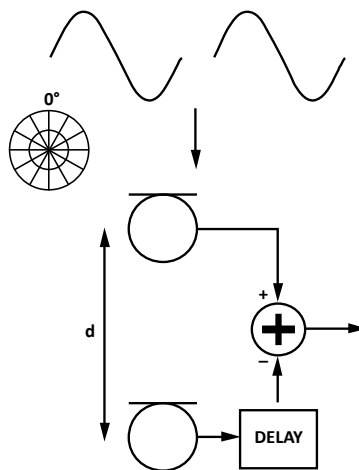

Figure 3. Endfire Beamforming Array

As shown in Figure 3, a two-element array is set up by placing two microphone boards distance, d, apart. A cardioid pattern (Figure 4) is achieved by delaying the signal from one array board by amount of time it takes sound to travel between the two boards, and subtracting this delayed signal from the signal from the first microphone array board. With this type of spatial response, the microphone rejects sounds from the sides and rear, while picking up sounds incident to the front of the microphone.
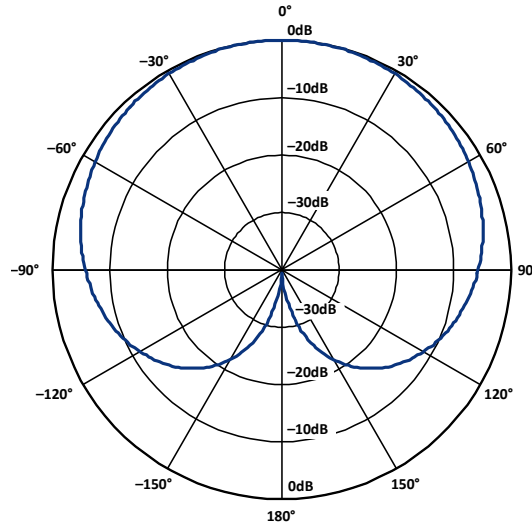

Figure 4. Cardioid Response

Allpass Filters

In this design, the two microphone array boards are separated by about 18 mm. To create a perfect cardioid pattern, the rear microphone array's output needs to be delayed by 52.4 μs. A series of two allpass filters are used to delay the signal as shown in Figure 5.
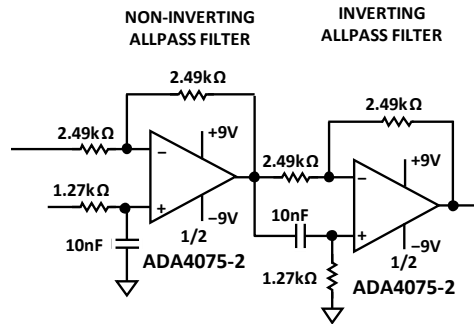

Figure 5. Non-Inverting and Inverting Allpass Filters

In the allpass filter design, there is a trade-off between the length of the delay and the frequency range over which the delay is constant. As the group delay at lower frequencies is increased, the group delay is constant over a smaller frequency range. In this circuit, each allpass filter contributes about 25 μs of delay up to about 4 kHz (with 10% tolerance). Above this frequency, the group delay at the filter output starts to decrease rapidly (Figure 6), which quickly degrades the performance of the beamforming algorithm. At these higher frequencies, the primary contribution to the design's directionality is the physical size of each microphone board (1.1" diameter).
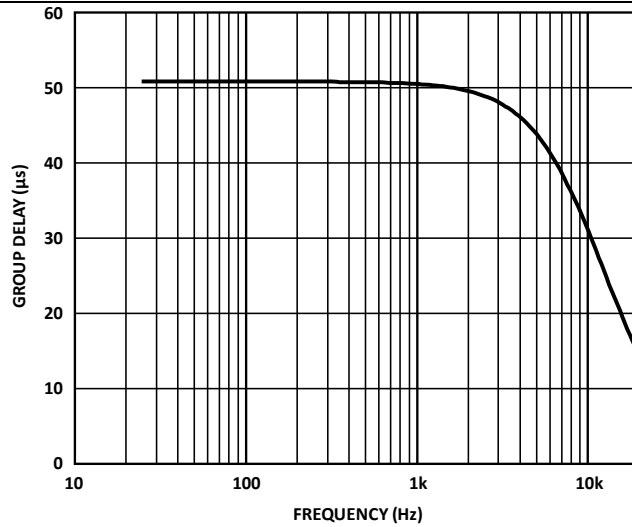
Figure 6. Two-Stage Allpass Filter Group Delay

The delayed signal from the rear array also needs to be inverted so that it can be subtracted from the front array's signal in the summing amplifier circuit. This is done by implementing the first allpass filter with a non-inverting output and the second allpass filter with an inverting output.

The group delay (t_G) of the filter is calculated by the equation:

$$t_G = \frac{2RC}{1 + (\frac{f}{f_0})^2}$$

Where $f_0 = 1/(2\pi RC)$. In this design, R = 1.27 kΩ and C = 10 nF, so f_0 is 12.5 kHz. The design and equations for these allpass filters were taken from Analog Devices Tutorial MT-202 and the Linkwitz Lab website.

Shelving Filter

The frequency response of the signal following the beamforming processing has a first-order roll off at low frequencies. If this is uncorrected, the microphone's output has poor low-frequency response, therefore a shelving filter is used to boost the response at these frequencies. The first-order non-inverting shelving low-pass filter shown in Figure 7 is designed to have a gain of 20 dB at low frequencies with a shelf rising from 4 kHz down to 400 Hz. The frequency response is shown in Figure 8. This shelving filter flattens out at 20 dB of gain at about 100 Hz, so the microphone's response still rolls off with a −6 dB/octave slope below this.

Summing the outputs from the front and rear microphone arrays boards also is implemented in this amplifier.
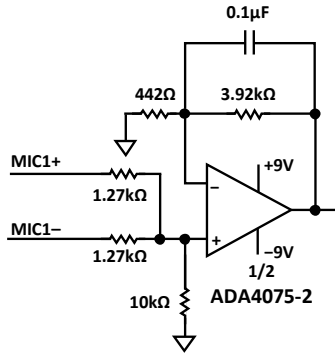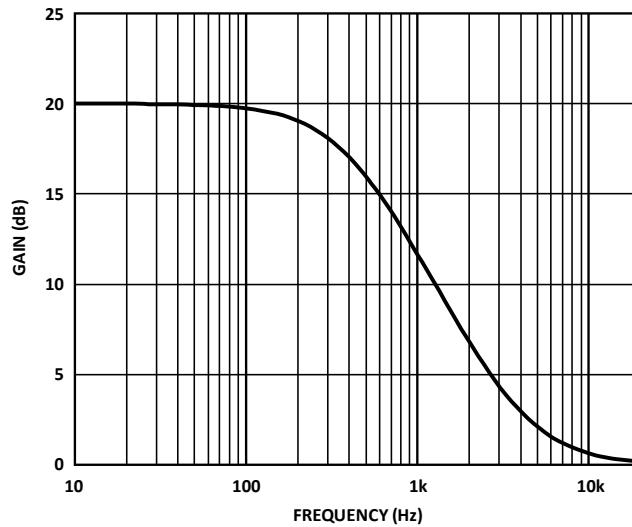
Figure 7. Shelving Filter

Figure 8. Shelving Filter Response

The gain (V_{OUT}/V_{IN}) of the filter is calculated by the equation:

$$\frac{V_{OUT}}{V_{IN}} = G_1 \sqrt{\frac{1+\left(\frac{f}{f_2}\right)^2}{1+\left(\frac{f}{f_1}\right)^2}}$$

Where G_1 = f_2/f_1 = 1+R_2/R_1. The filter's corner frequencies f_1 and f_2 are calculated by:

$$f_1 = \frac{1}{2\pi CR_2}$$

$$f_2 = \frac{1}{2\pi C \left(\dfrac{R1R2}{R1+R2} \right)}$$

In this design, R1 = 442 Ω, R2 = 3.92 kΩ and C = 0.1 µF, so f_1 is 406 Hz and f_2 = 4.1 kHz. The design and equations for this shelving lowpass filter were also taken from the Linkwitz Lab website.

If a single microphone array board is used in the design, then the allpass and shelving filter circuits are not needed, and the output of the summing amplifier can be connected directly to the AD8273 for the single-ended-to-differential conversion.

Single-Ended-to-Differential Conversion

The AD8273 difference amplifier performs the single-ended-to-differential conversion for the output signal. This amplifier is configured for a gain of 1 (0 dB) to keep the microphone's output level from being too high. One of the internal amplifiers of the AD8273 is set up in a non-inverting configuration, and the other is inverting. Individually, each of these amplifiers has a gain of 0.5 (−6 dB), but the single-ended-to-differential conversion results in a +6 dB gain, resulting in the overall 0 dB gain in this sub-circuit. The AD8273 does not require any external components except for the power supply decoupling capacitors; all gain-setting resistors are internal to the IC, so they are very well-matched, and the amplifier's output has very low distortion.

The AD8273 has good output drive capability and can easily drive a highly capacitive load. This is necessary because the output might be connected to a long (multiple meters) XLR cable.

The outputs of the AD8273 drive 49.9 Ω series resistors and a 47 µF ac-coupling capacitor. The series capacitor is necessary because the microphone could be connected to an input that provides +48 V phantom power, which is often used as a bias and supply for an electret microphone. Phantom power can typically only supply less than 10 mA, which is more than this circuit uses, so it is not used as the supply. The capacitor's rating is 63 V so the circuit is protected from the 48 V bias that could be present on both the + and − outputs.

±9 V Power Supply

All of the amplifiers in this design are powered from ±9 V supplies. These voltages are generated from an ADP1613 in a SEPIC-Ćuk configuration. This circuit generates the positive and negative supply rails from a single input voltage as shown in Figure 8.

The design for the bipolar supply design was created using Analog Devices' ADIsimPower™ tools. The ADP161x SEPIC-Ćuk Design Tool takes some basic design parameters as an input and generates a schematic, BOM, and performance specifications for the given circuit. This design was created using the following specifications:

- V_{IN} minimum = 7.5 V

- V_{IN} maximum = 9.0 V

- V_{OUT} = 9.0 V

- I_{OUT} = 40 mA

- Ambient temperature = 55°C

- Design optimized for lowest cost

The total current drawn from the battery when the complete system is operational is 82 mA. Of this total current, about 17.5 mA is used by each microphone board, and 47 mA is used by the power board. With this load, a typical 9V battery lasts about five hours.
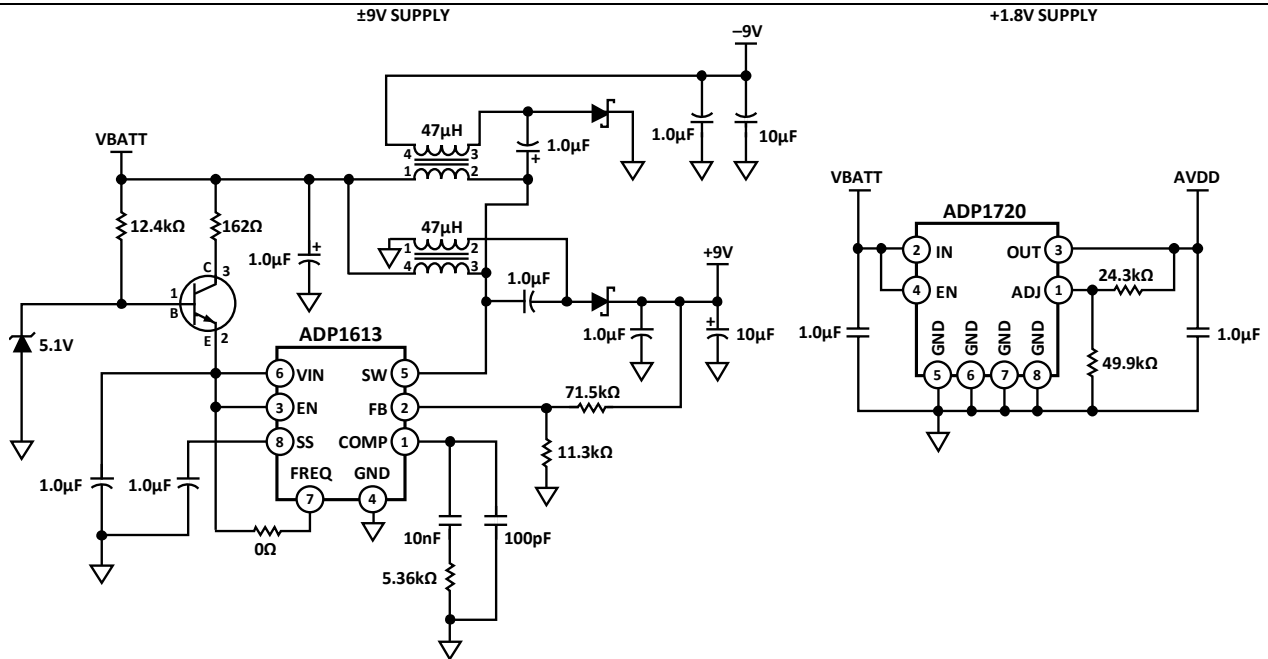
Figure 9. Details of Power Supply Circuit

+1.8 V Power Supply

The +1.8 V supply is used to power the INMP411 MEMS microphones and is generated from the ADP1720 linear regulator. This regulator drops the regulated +9 V supply to the necessary 1.8 V in a very small PCB footprint, requiring only one small (1 µF) bypass capacitor on both the input and the output and two resistors to set the output voltage. The INMP411 draws a maximum of 220 µA with a 1.8 V supply, so the highest current needed from this regulator output (with 32 INMP411s connected) is 7.04 mA. At this maximum load, the regulator dissipates 50.7 mW:

$$P = (9\ V - 1.8\ V) \times 7.04\ mA = 50.7\ mW$$

Additional Circuitry

This section describes the function of additional components that are used on the EV_CN0284-EB1Z but are not part of the core circuit design. This primarily includes RF filtering and overvoltage protection circuitry

RF Filtering

Between the AD8273's differential output and the XLR plug, there are a few components intended to filter high-frequency noise that may be picked up by the board or the microphone XLR cable. Each half of the differential signal has an LC filter, to remove EMI or RF noise. There is also a common mode choke between the two differential legs to remove common mode currents, while allowing differential currents to pass.

The connection of the microphone signals between the microphone boards and the power board also have an LC filter to reduce high-frequency noise that may be picked up by the ribbon cable connection. A similar LC filter (Figure 10) is also used on the output of all of the regulated voltage supplies.
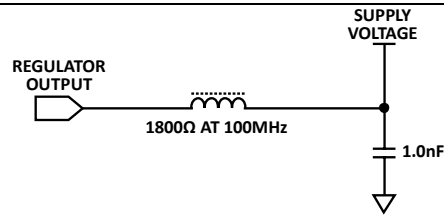
Figure 10. RF Noise Filter

Spike Suppression

Back-to-back 5.1 V Zener diodes are connected between each side of the differential output signal and ground. These diodes are used to clamp voltage spikes greater than ±5.1 V that may be conducted on the output cable.

Low Battery Indicator

LED D11 is used to indicate when the battery voltage is low and should be replaced. The LED is placed in series between the battery positive terminal and the regulated +9 V supply. When the battery voltage droops below 9 V by more than the LED forward voltage (2 V), then the LED indicator turns on. The output voltage of many 9 V batteries starts to drop rapidly once it falls below 7 V.

PERFORMANCE AND MEASUREMENTS

Sensitivity Performance

The sensitivity of the microphone array is higher than that of each individual microphone because their outputs are summed. The INMP411 has a sensitivity of −46 dBV. With the outputs of sixteen microphones summed together, and the other gains applied to the signal path, the sensitivity of the circuit with a single array is −33 dBV. If the beamforming part of the circuit is enabled when two array boards are used, the sensitivity is −27 dBV.
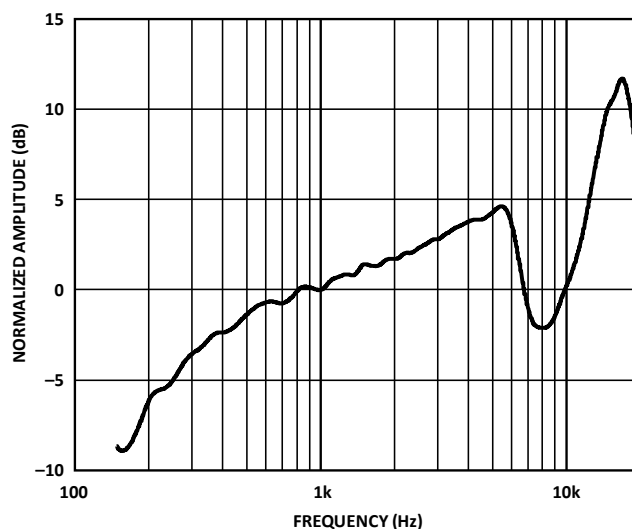
Frequency Response Performance

Figure 11. On-Axis (0°) Frequency Response

The frequency response of the microphone design is dependent on the orientation of the microphone. Figure 11 shows the frequency response for the sound incident on-axis. Off-axis, there is less of a low-frequency roll-off caused by the beamforming processing, so the fixed shelving filter results in a higher low frequency boost.

The dip in the response at 8 kHz is a result of the beamforming processing; this is the point at which the inverted signal from the rear array board is most nearly in-phase with the non-inverted front microphone signal, resulting in significant attenuation of the overall subtracted output signal.

The summing amplifers and single-ended-to-differential circuit all have very flat frequency response across the audio bandwidth, so they do not contribute significantly to the overall frequency response of the system design. The AD8273 has very good output drive capability, so it doesn't contribute a roll-off at high frequencies, even with long, highly-capacitive XLR cables connected.

Noise Performance

Summing the outputs of 16 INMP411 microphones theoretically improves the SNR by 12 dB from that of a single microphone. For each doubling of the number of microphones in the array, the SNR should increase by about 3 dB. This is because the signals add coherently and increase the amplitude by 6 dB, while the noise adds incoherently for a 3 dB increase in noise level.

The INMP411 has an A-weighted 62 dB SNR, so the array of 16 microphones has a theoretical SNR of about 74 dBA. For a −33 dBV sensitivity, this means that the noise floor across a 20 kHz bandwidth is at −107 dBV (4.47 µV rms). This is equal to an acoustic noise floor of 20 dB SPL. In practice, the measured noise floor is typically 1-2 dB higher than this, possibly because the spacing of the 16 microphones in the summing array is large enough that the individual microphone signals are not perfectly coherent.

The op amp and difference amplifier circuits following the microphones are significantly lower-noise than the microphones themselves, so the microphones are the limiting factor in the noise of the overall design.

When two of the 16× microphone array boards are used for beamforming, the overall system SNR is degraded by about 3 dB. The EV_CN0284-EB1Z board's SNR when configured in a beamforming array is about 71 dB, which is an equivalent acoustic noise floor (or equivalent input noise) of 21 dB SPL.

THD & Linearity Performance

The primary contribution to the distortion in the circuit comes from the INMP411 microphones. The other analog amplifier components operate in a linear region, with the signals not close to the supply rails. The INMP411 has an acoustic overload point of 131 dB; this is the point at which THD is 10% for an individual microphone and is commonly referred to as the clipping point in audio applications. All microphones in the array are simultaneously exposed to similar SPLs, so the circuit's total distortion curve looks very similar to that of an individual microphone. The distortion curve for the INMP411 is shown in Figure 12.
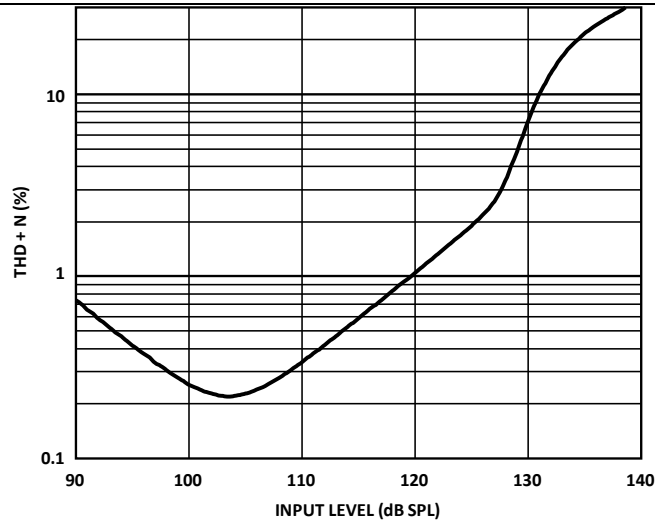
Figure 12. INMP411 dB SPL vs %THD+N

With a −27 dBV sensitivity, the microphone's output with 131 dB SPL input is 2.27 V$_{RMS}$ (6.40 V$_{P-P}$). This is well within the linear region for the amplifiers operating with a ±9 V supply, so the linearity and distortion is controlled by the INMP411 performance. Figure 13 shows the linearity (input in dB SPL vs. output in dBV) for this circuit design.
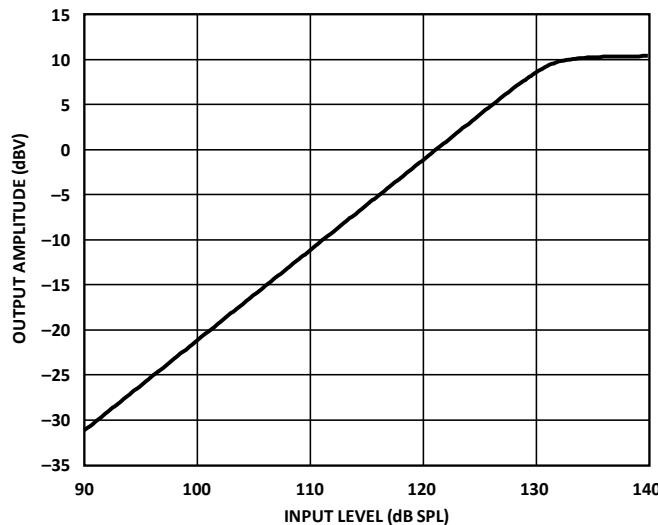

Figure 13. Measured Linearity of Circuit

Directionality Performance

The INMP411 microphones are omnidirectional, when used individually. When put in a large array like this, the design has some directionality. That is, the level of the output depends on the orientation of the array with regard to the position of the sound source.

A single array board exhibits little directionality at low frequencies (<4 kHz). In the mid frequency range, the array boards attenuate the sounds from the rear and sides by as much as 5 dB to 6 dB because of the acoustic shadowing from the PCB itself. At some higher frequencies where the wavelength of sound is on the order of the size of the array PCB, such as around 8 kHz, the array has significant directionality. Directionality measurements with a single microphone board are shown in Figure 14.
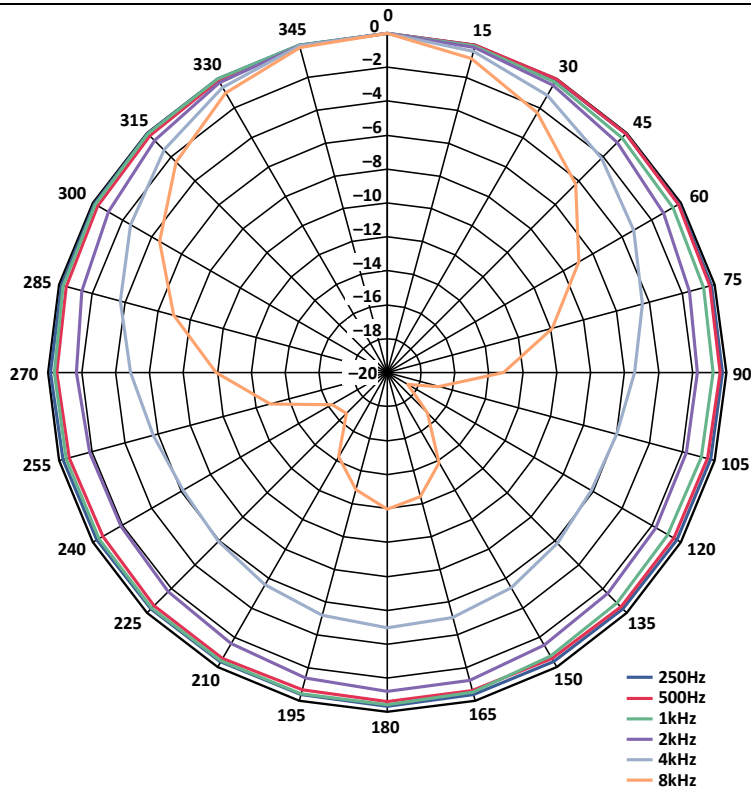
Figure 14. Directionality of a Single Array Board at Different Frequencies

The primary purpose of having two array boards spaced a fixed distance apart from each other is to create a directional response. The combination of the distance between the two boards and the beamforming circuit results in an array that has considerable rejection of sounds from the sides and rear of the assembly. Figure 15 shows the response of two boards whose faces are spaced 18 mm apart from each other. The measurements of this setup show a supercardioid directional response, with significant attenuation of sounds from the rear and sides, but with a small rear lobe. The nulls in the directional response of this design are at about 135° and 225°. At most frequencies in the voice range (250 Hz to 4 kHz), there is at least 15 dB of off-axis attenuation.
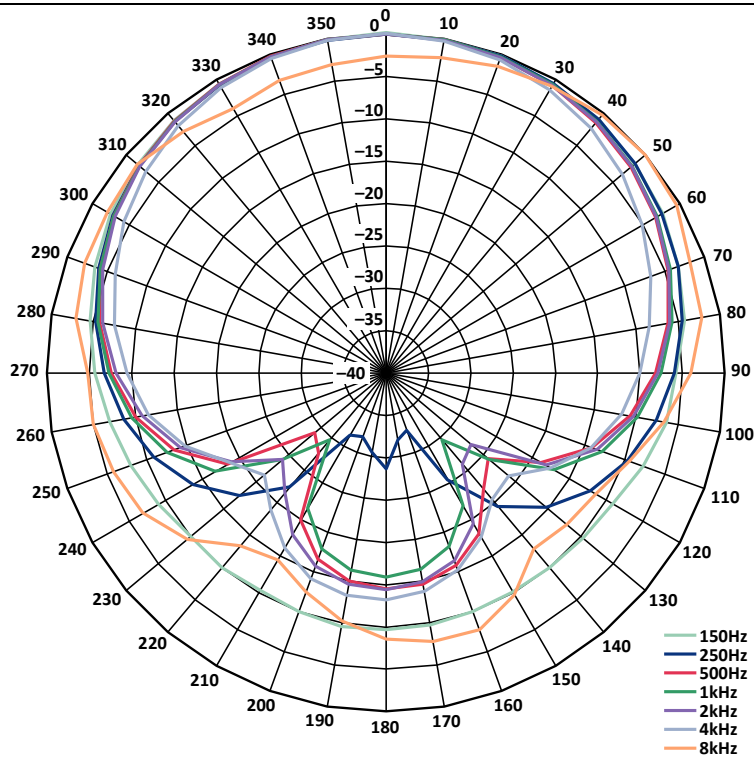
Figure 15. Directionality of a 2-Board Endfire Array at Different Frequencies

COMMON VARIATIONS

Other op amps or difference amps can be used, depending on the need of the specific design. Many op amps with lower noise, lower power, or lower operating voltage rails than the ADA4075-2, some of which may be a better choice if the design parameters are different than what's presented here. Application Note AN-1165 lists many op amps that would be suitable alternatives.

The ADMP510 is another analog microphone in an even smaller package and has a lower noise floor than the INMP411. The ADMP510 has an SNR of 65 dBA, while the mic in this design has a 62 dBA SNR. A summed array of 16 ADMP510 microphones could have an SNR as high as 77 dBA. However, the ADMP510's acoustic overload point is 124 dB SPL, compared with 131 dB SPL for the INMP411. This makes the ADMP510 a better choice for a microphone designs that may not be used in loud environments and require a lower noise floor.

A fixed-output version of the ADP1720 could also be used if the microphones operate from a 3.3 V supply. This version would eliminate the need for the two external output voltage setting resistors.

CIRCUIT EVALUATION AND TEST

A hardware evaluation kit for this reference circuit is available as part number EV_CN0284-EB1Z.

Equipment Needed

The EV_CN0284-EB1Z kit includes:

- Two microphone array boards with sixteen INMP411 microphones.
- One output and power board that includes the voltage regulators and output amplifiers.
- Two ribbon cables to connect the two boards.
- One +9 V battery.

The evaluation kit's output is on a standard XLR plug that can be connected to an audio preamp, mixer, sound card, or any other microphone interface.

Getting Started

The evaluation kit can be configured with either one or two microphone array boards. Below are the steps to follow for evaluating the circuit.

1. Using the provided 10-pin ribbon cables, connect the microphone array boards to the power board. If just one microphone board is used, connect it to header J1 on the power board. If using two microphone boards, the front microphone board should be connected to J1 and the rear microphone board to J2.
2. Set switch S2 on the power board either to add (+ position, switch down) or take the difference of (– position, switch up) the signals from the two microphone boards. If you are configuring a beamforming array with two microphone boards, set the switch for the difference of the two signals; this signal path also enables the low-pass shelving filter. If using just one microphone board, set the switch to +.
3. Insert a 9 V battery in the battery pack BT1 on the back side of the power board. If a battery is not available, power from an external source can be connected to header J4, with the positive voltage on the bottom pin and ground on the top.
4. Connect an XLR cable between the output plug (J3) on the power board and the input of a microphone preamp or mixer.
5. Turn on the circuit by moving switch S1 to the right. This connects the battery to the power circuit and the evaluation kit is now active.

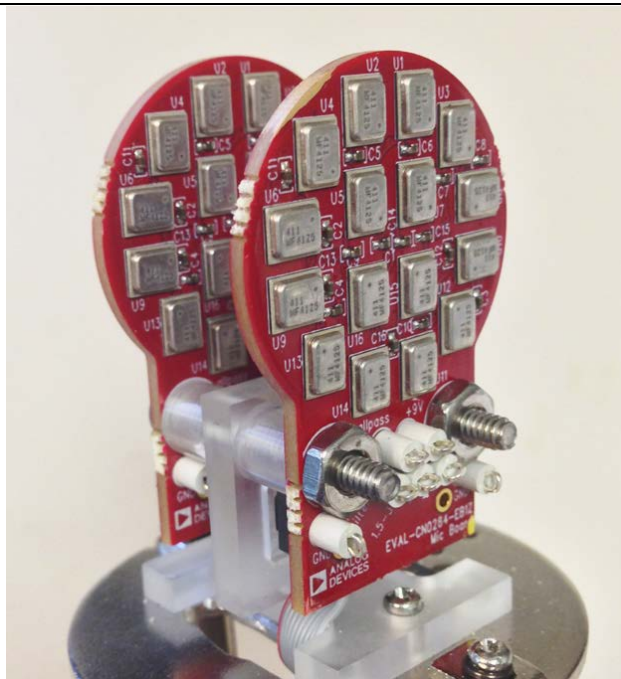**Figure 16. Two Microphone Boards with 18 mm Spacer**

SCHEMATICS, LAYOUTS, AND BILLS OF MATERIALS
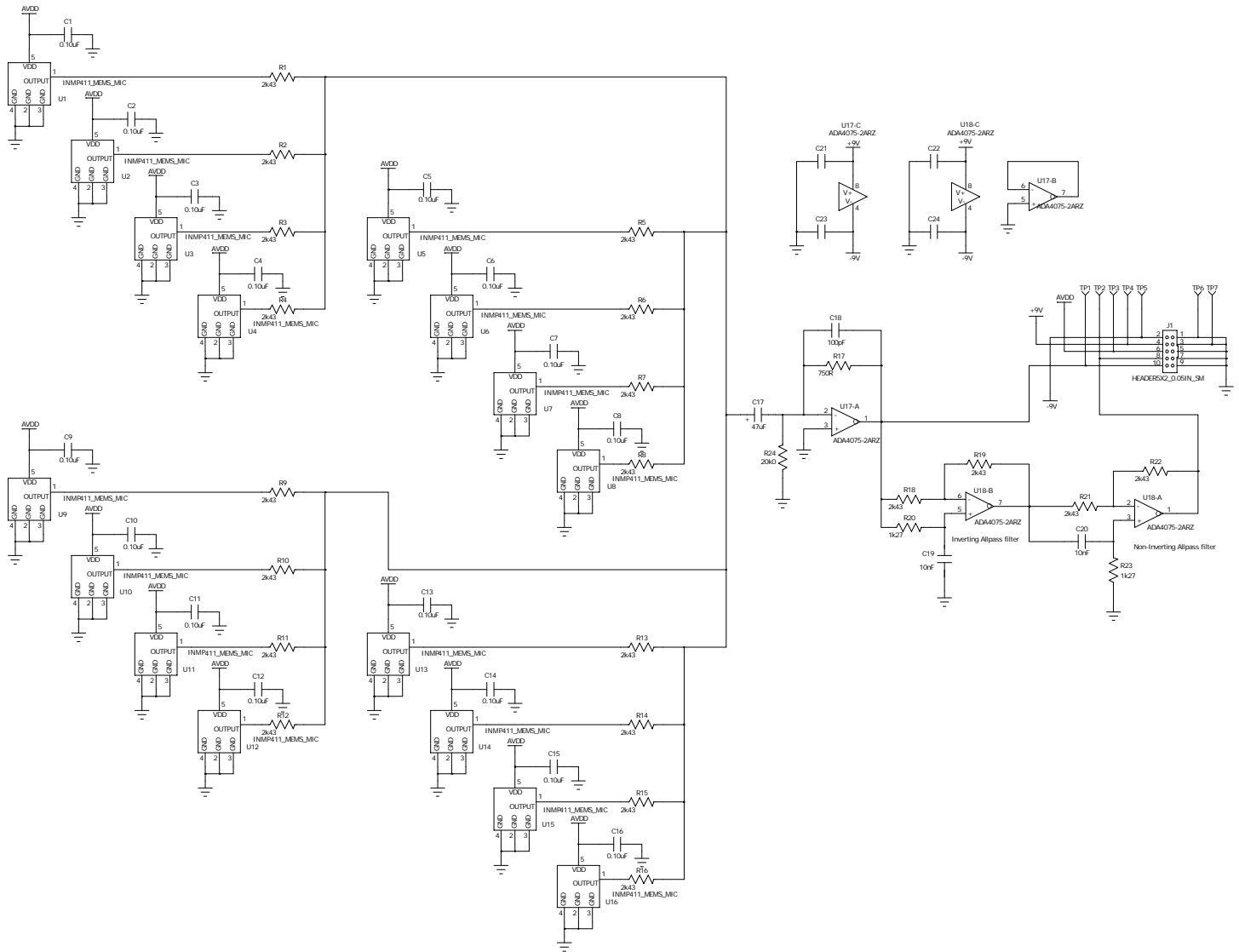
Figure 17. Microphone Board Schematic

Microphone 1 Input

Microphone 2 Input

+/-9V Supply

+1.8V Supply
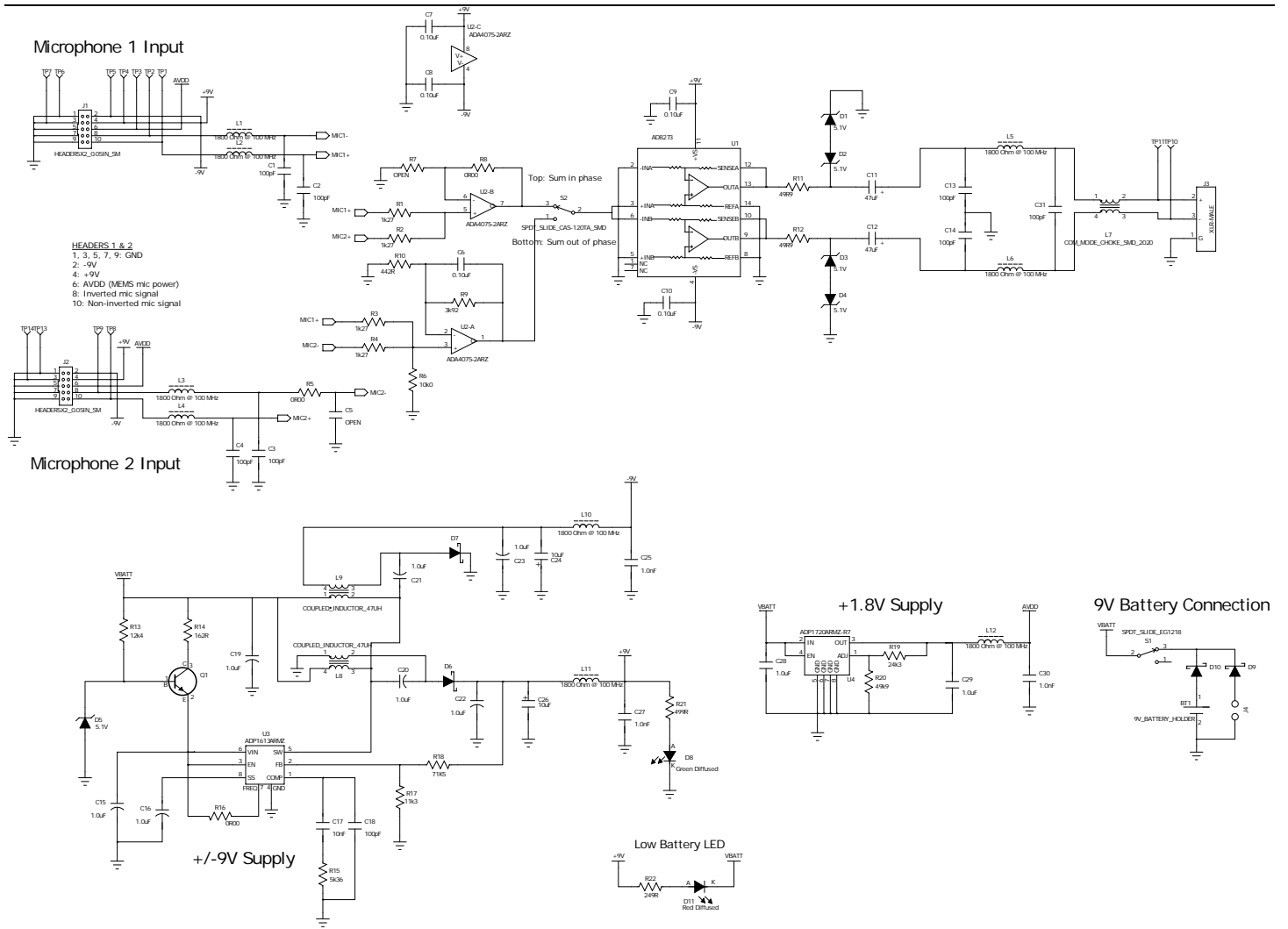
9V Battery Connection

Low Battery LED

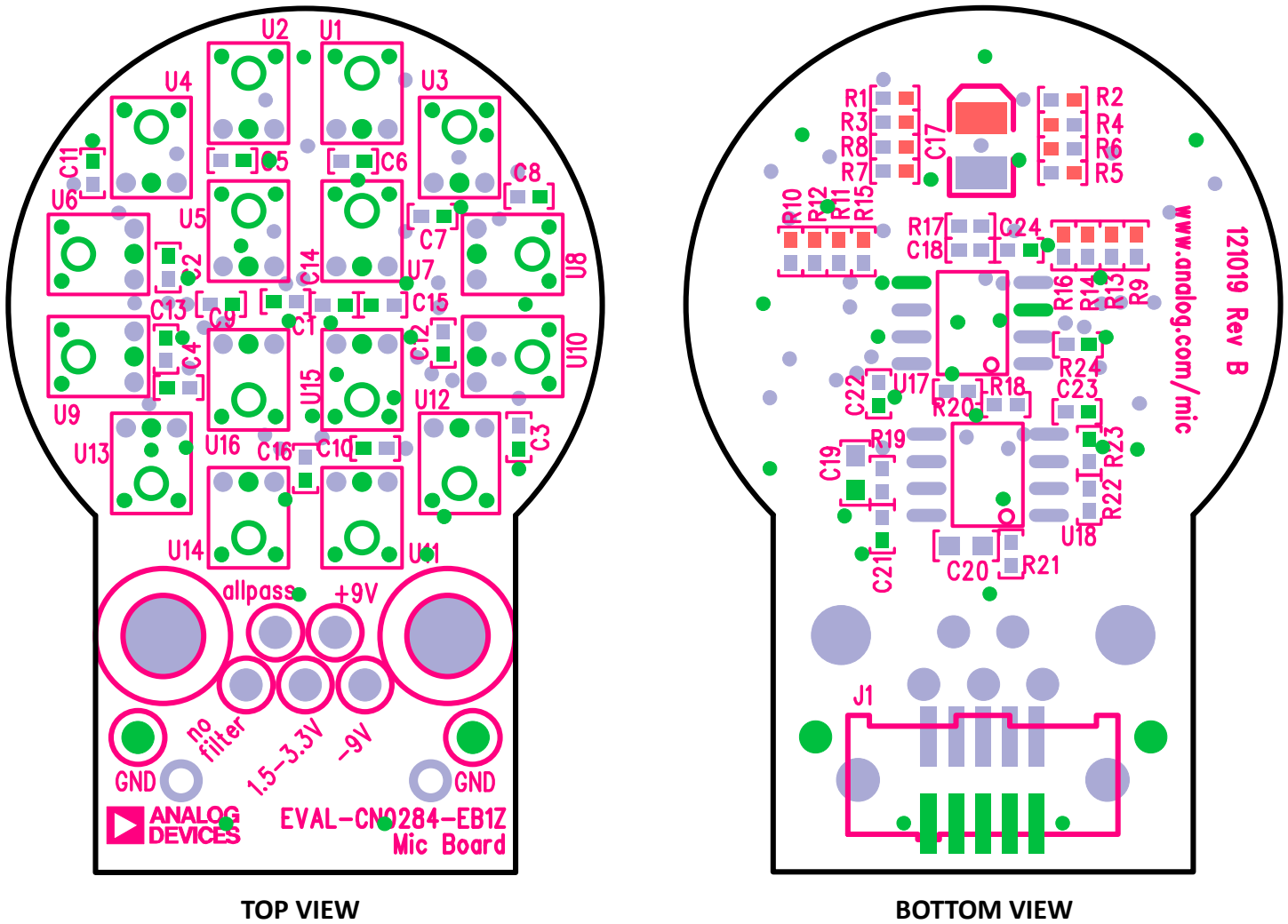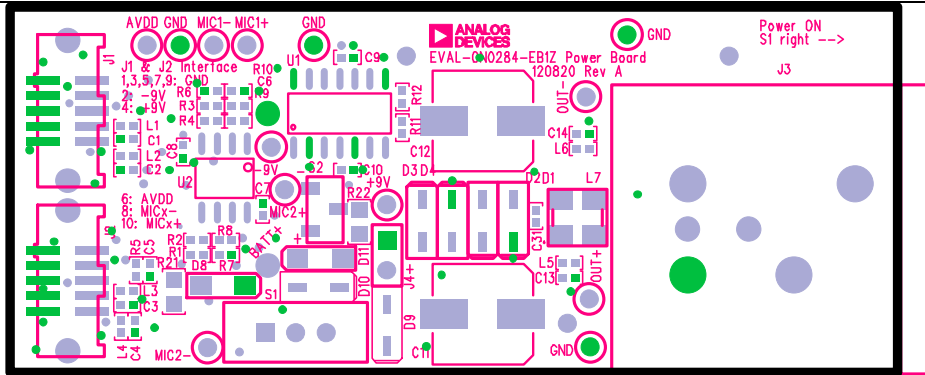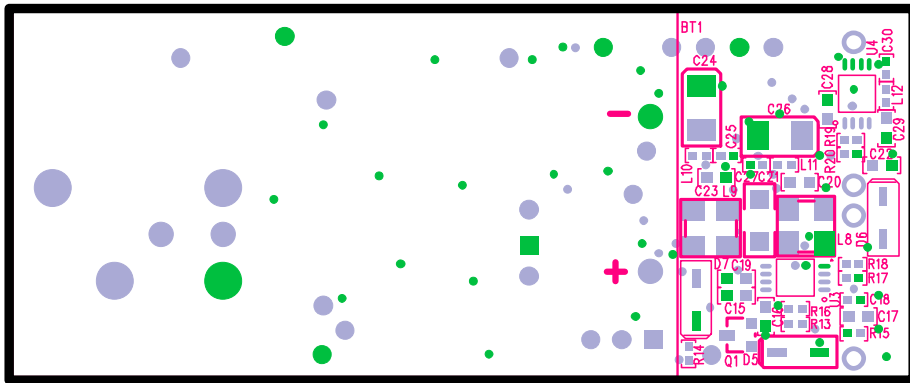**Figure 18. Power Board Schematic**

Figure 19. Microphone Board Layout

TOP VIEW

BOTTOM VIEW

Figure 20. Power Board Layout

TABLE 1. MICROPHONE BOARD BILL OF MATERIALS

Qty	Reference	Value	Manufacturer	Part Number	Description
20	C1-16 C21-24	0.10uF	Murata ENA	GRM155R71C104KA88D	Multilayer Ceramic 16V X7R (0402)
1	R24	20k0	Yageo	RC0402FR-0720KL	Chip Resistor 1% 63mW Thick Film 0402
1	C18	100pF	Murata ENA	GRM1555C1H101JZ01D	Multilayer Ceramic 50V NP0 (0402)
20	R1-R16 R18-19 R21-22	2k49	Yageo		Chip Resistor 1% 63mW Thick Film 0402
2	C19-20	10nF	TDK Corp	C1608C0G1E103J	Multilayer Ceramic 25V NP0 (0603)
1	C17	47uF	Kemet	T520B476M010ATE035	Tantalum Capacitor 105deg SMD
2	R20 R23	1k27	Vishay/Dale	CRCW04021K27FKED	Chip Resistor 1% 63mW Thick Film 0402
2	U17-18	ADA4075-2ARZ	Analog Devices Inc.	ADA4075-2ARZ	Ultralow Noise Amplifier at Lower Power
16	U1-16	INMP411	InvenSense, Inc	INMP411	Analog Microphone
1	J1	2x5 0.05" SM	SAMTEC	SHF-105-01-L-D-SM	5 x 2 Shroud Polarized Header 0.05inch Surface Mount
7	TP1-7	5002	Keystone Electronics	5002	Mini Test Point White .1" OD
1	R17	750r			Chip Resistor 1% 63mW Thick Film 0402
1			SAMTEC	FFSD-05-D-03.00-01-N-R	2x5 0.05" spacing, 3" cable

TABLE 2. POWER BOARD BILL OF MATERIALS

Qty	Reference	Value	Manufacturer	Part Number	Description
1	BT1		MPD	BH9VPC	9V Battery Holder, PC Mount
2	C11-12	47uF	Panasonic	EEE-1JA470UP	Electrolytic Capacitor 85deg SMD
8	C1-4 C13-14 C18 C31	100pF	Murata ENA	GRM1555C1H101JZ01D	Multilayer Ceramic 50V NP0 (0402)
8	C15-16 C19-20 C22-23 C28-29	1.0uF	Murata ENA	GRM188R71C105KA12D	Multilayer Ceramic 16V X7R (0603)
1	C17	10nF	TDK Corp	C1608C0G1E103J	Multilayer Ceramic 25V NP0 (0603)
1	C21	1.0uF	Panasonic EC	ECJ-3YB1E105K	Multilayer Ceramic 25V X7R 1206
2	C24 C26	10uF	Rohm	TCA1C106M8R	SMD Tantalum Capacitor 1206 16V
3	C25 C27 C30	1.0nF	Murata ENA	GRM1555C1H102JA01D	Multilayer Ceramic 50V NP0 (0402)
1	C5	OPEN	Do Not Stuff	Do Not Stuff	Do Not Stuff

5	C6-10	0.10uF	Murata ENA	GRM155R71C104KA88D	Multilayer Ceramic 16V X7R (0402)
1	D11	Red Diffused	Lumex Opto	SML-LX1206IW-TR	Red Diffused 6.0millicandela 635nm 1206
5	D1-5	5.1V	Diodes, Inc	DDZ9689-7	Zener 5.1V 500mW SOD-123
4	D6-7 D9-10	BAT54T1G	On Semiconductor	BAT54T1G	Schottky 30V 0.2A SOD123 Diode
1	D8	Green Diffused	Lumex Opto	SML-LX1206GW-TR	Green Diffused 10millicandela 565nm 1206
2	J1-2	2x5 0.05" SM	SAMTEC	SHF-105-01-L-D-SM	5 x 2 Shroud Polarized Header 0.05inch Surface Mount
1	J3	NC3MAH	Neutrik	NC3MAH	PC-Mount Male XLR-3 Receptacle
1	J4	2-Jumper	Sullins Electronics Corp	PBC02SAAN; or cut PBC36SAAN	2-pin Header Unshrouded Jumper 0.10"
9	L1-6 L10-12	1800 Ohm @ 100 MHz	muRata	BLM15HD182SN1	Chip Ferrite Bead 1800 Ohm @ 100 MHz
1	L7	DLW5BTN101SQ2L	Murata Electronics	DLW5BTN101SQ2L	Common Mode Choke 100 Ohm 100MHz
2	L8-9	47uH	Coilcraft	LPD4012-473	Miniature Coupled Inductor
1	Q1	MMBT3904LT1G	ON Semiconductor	MMBT3904LT1G	NPN Gen Purp Transistor
1	R10	442R	Stackpole	RMCF0402FT442R	Chip Resistor 1% 63mW Thick Film 0402
2	R11-12	49R9	Yageo	RC0402FR-0749R9L	Chip Resistor 1% 63mW Thick Film 0402
1	R13	12k4	Panasonic EC	ERJ-2RKF1242X	Chip Resistor 1% 100mW Thick Film 0402
1	R14	162R	Panasonic ECG	ERJ-2RKF1620X	Chip Resistor 1% 63mW Thick Film 0402
4	R1-4	1k27	Vishay/Dale	CRCW04021K27FKED	Chip Resistor 1% 63mW Thick Film 0402
1	R15	5k36	Yageo	RC0402FR-075K36L	Chip Resistor 1% 63mW Thick Film 0402
1	R17	11k3	Yageo	RC0402FR-0711K3L	Chip Resistor 1% 63mW Thick Film 0402
1	R18	71K5	Yageo	RT0402FRE0771K5L	Chip Resistor 1% 63mW Thick Film 0402
1	R19	24k3	Stackpole	RMCF0402FT24K3	Chip Resistor 1% 63mW

					Thick Film 0402
1	R20	49k9	Yageo	RC0402FR-0749K9L	Chip Resistor 1% 63mW Thick Film 0402
1	R21	604R	Panasonic EC	ERJ-6ENF6040V	Chip Resistor 1% 125mW Thick Film 0805
1	R22	280R	Panasonic EC	ERJ-6ENF2800V	Chip Resistor 1% 125mW Thick Film 0805
3	R5 R8 R16	0R00	Panasonic ECG	ERJ-2GE0R00X	Chip Resistor 5% 100mW Thick Film 0402
1	R6	10k0	Yageo	RC0402FR-0710KL	Chip Resistor 1% 63mW Thick Film 0402
1	R7	OPEN	Do Not Stuff	OPEN	Do Not Stuff
1	R9	3k92	Stackpole	RMCF0402FT3K92	Chip Resistor 1% 63mW Thick Film 0402
1	S1	SPDT	E-Switch	EG1218	SPDT Slide Switch PC Mount
1	S2	SPDT	Copal Electronics	CAS-120TA	SPDT Slide Switch SMD J Hook
13	TP1-11 TP13-14	5002	Keystone Electronics	5002	Mini Test Point White .1" OD
1	U1		Analog Devices Inc.	AD8273ARZ	Very Low Distortion, Dual-Channel, High Precision Difference Amplifier
1	U2	ADA4075-2ARZ	Analog Devices Inc.	ADA4075-2ARZ	Ultralow Noise Amplifier at Lower Power
1	U3		Analog Devices Inc.	ADP1613ARMZ-R7	650 KHZ /1.3 MHZ STEP-UP PWM DC-TO-DC SWITCHING CONVERTER WITH 2.0 A CURRENT LIMIT
1	U4	ADP1720ARMZ-R7	Analog Devices Inc.	ADP1720ARMZ-R7	Adjustable, High Voltage, Micropower Linear Regulator

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Data Sheets and Evaluation Boards

INMP411 Data Sheet

INMP411 Flex Evaluation Board (EV_INMP411-FX)

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