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# Low Noise Analog MEMS Microphone and Preamp with Compression and Noise Gating

## CIRCUIT FUNCTION AND BENEFITS

This circuit, shown in Figure 1, interfaces an analog microelectromechanical systems (MEMS) microphone to a microphone preamplifier (preamp). The ADMP504 consists of a MEMS microphone element and an output amplifier. MEMS microphones have a high signal-to-noise ratio (SNR) and a flat wideband frequency response, making them an excellent choice for high performance, low power applications.

The SSM2167 is a low voltage, low noise mono microphone preamp that is a good choice for use in low power audio signal chains. This preamp includes built in compression and noise gating, which gives it an advantage for this function over using just an op amp in the preamp circuit. Compressing the dynamic range of the microphone signal can reduce the peak signal levels and add additional gain to low level signals. Noise gating attenuates the level of signals below a certain threshold, so that only desired signals, such as speech, are amplified, and noise in the output signal is reduced. These features help to improve the intelligibility of the voice signal picked up by the microphone.

## CIRCUIT DESCRIPTION

**Table 1. Devices Connected/Referenced**

| Product | Description |
|---|---|
| ADMP504 | Ultralow noise analog MEMS microphone |
| SSM2167 | Microphone preamp with 18 dB fixed gain |

The ADMP504 analog MEMS microphone is connected to the INPUT pin of the SSM2167 through a 0.1 µF capacitor. This coupling capacitor is necessary because the output of the microphone is biased at 0.8 V, and the input of the preamp is biased at 0.4 V. The input of the preamp and the ac coupling capacitor between the microphone and the preamp input form a high-pass filter.

The −3 dB corner frequency of this filter is 1/(2πRC), where C is the capacitor size, and R is the input impedance of the preamp (100 kΩ). For a 0.1 µF coupling capacitor, the corner frequency of the high-pass filter is 16 Hz. Increasing the capacitor size lowers the corner frequency of the filter.

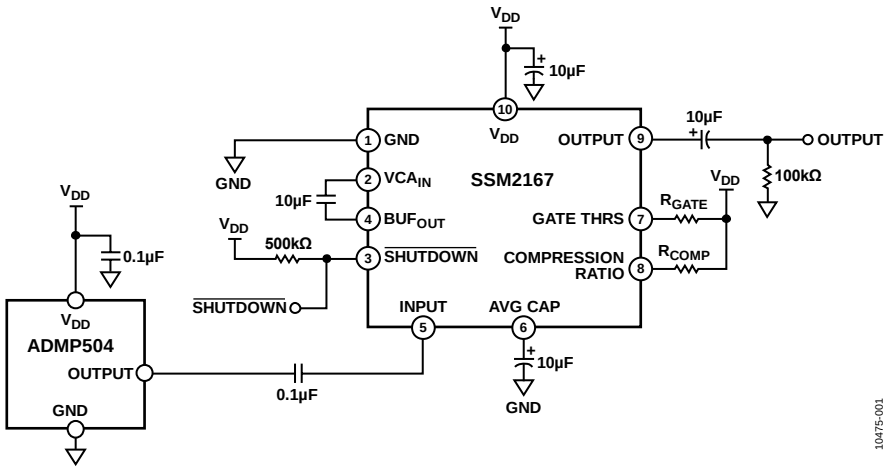


*Figure 1. Analog MEMS Microphone Connection to Preamp*

The time constant of the true rms level detector of the SSM2167 is controlled by the size of the capacitor connected to the AVG CAP pin (Pin 6). A 10 µF capacitor results in a time constant of about 100 ms, which is a reasonable setting for speech signals. This time constant controls the averaging of the rms detector, as well as the release time of the compressor. A smaller capacitor used here gives a shorter time constant, and a larger capacitor results in a longer time constant. The time constant, in milliseconds, is calculated by 10 × $C_{AVG}$, where $C_{AVG}$ is in µF.

Both the microphone and the preamp can be powered from a single 2.5 V to 3.3 V supply.

The SSM2167 preamp requires the following additional external passive components for its operation:

- 10 µF capacitor between the $V_{DD}$ pin and ground
- 10 µF capacitor between the $VCA_{IN}$ and $BUF_{OUT}$ pins
- AC coupling capacitor on the $\overline{\text{OUTPUT}}$ pin
- 500 kΩ pull-up resistor on the $\overline{\text{SHUTDOWN}}$ pin
- $R_{GATE}$: sets the threshold of the noise gate
- $R_{COMP}$: sets the compression ratio

The ADMP504 has a −38 dBV sensitivity, which means that an input signal of 94 dB sound pressure level (SPL) (1 Pa) is output from the microphone at −38 dBV. The maximum input level of this microphone is 120 dB SPL. At the maximum input level, the output of the microphone is −12 dBV. Its dynamic range is 91 dB, so the noise floor of the microphone is at −103 dBV.

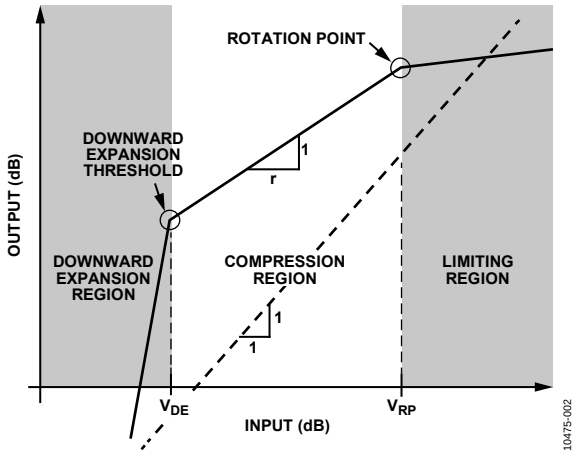


*Figure 2. Gain Regions*

Gain is applied to the SSM2167 input signal in three different regions—downward expansion, compression, and limiting, as shown in Figure 2. The SSM2167 applies a fixed 18 dB of gain to input signals and can also apply an additional variable gain to signals between the downward expansion point and rotation point.

The downward expansion threshold is the boundary between the downward expansion and compression regions. This point is set by the selection of Resistor $R_{GATE}$ (see Table 2). The threshold can be set at a point for input signals between 77 dB and 92 dB SPL, or −55 dBV to −40 dBV input to the preamp.

**Table 2. Noise Gate Threshold Settings**

| Preamp Noise Gate Threshold (dBV) | Microphone (dB SPL) | $R_{GATE}$ (kΩ) |
|---|---|---|
| −40 | 92 | 0 (short to $V_{DD}$) |
| −48 | 84 | 1 |
| −54 | 78 | 2 |
| −55 | 77 | 5 |

The compression region lies between the downward expansion and limiting regions. In this region, the dynamic range of the input signal can be reduced, or compressed, so that the output signal level is more smooth and constant. The SSM2167 can achieve compression ratios of up to 10:1. This downward compressor increases the level of the signal below the rotation point threshold. The level of compression is controlled by Resistor $R_{COMP}$, as detailed in Table 3.

**Table 3. Compression Ratio Settings**

| Compression Ratio | $R_{COMP}$ Value (kΩ) |
|---|---|
| 1:1 | 0 (short to $V_{DD}$) |
| 2:1 | 15 |
| 3:1 | 35 |
| 5:1 | 75 |
| 10:1 | 175 |

The boundary between the compression and limiting regions is fixed at a −24 dBV preamp input signal level, which corresponds to a 108 dB SPL acoustic input to the microphone. Above this point, after the 18 dB of fixed gain, the preamp output is limited to a −6 dBV level.

Figure 3 shows the voltage output levels vs. acoustic input levels of the circuit for a selection of different compression ratios.

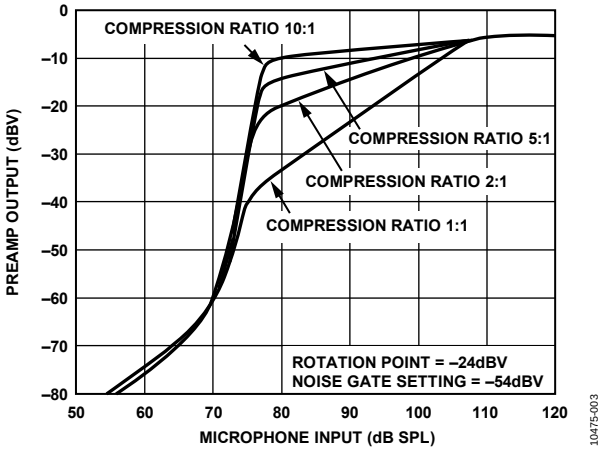


*Figure 3. Preamp Output vs. Microphone Input Characteristics*

The SSM2167 output is biased at 1.4 V. The 10 µF ac coupling capacitor, in series with the output signal, allows the output to be connected to grounded loads. The 100 kΩ resistor references the back side of the coupling capacitor to ground to avoid pops when loads are hot plugged. This resistor is not necessary in a design where the load is hardwired to the output of the preamp.

## NOISE PERFORMANCE

Both the ADMP504 and SSM2167 are low noise audio devices. The SNR of the ADMP504 is 65 dB, which gives a −103 dBV noise floor. The noise floor of the SSM2167 with 10:1 compression (worst case setting for noise) is −70 dBV. Therefore, the noise level of the microphone signal can be increased by more than 20 dB before combining the noise floors of the two devices results in a degradation of the overall noise floor of the system. For example, a loud 100 dB SPL signal output picked up by the microphone with the preamp set to a 10:1 compression ratio has about 24 dB of gain added to the system. The added gain puts the noise floor of the microphone signal at −79 dBV (−103 dBV + 24 dB). Combining a −79 dBV noise source with the −70 dBV noise floor of the preamp results in degradation in the system of only about 0.5 dB; therefore, the noise floor of the output signal in these conditions is about −69.5 dBV.

When the output signal of the microphone is at a level below the downward expansion threshold, a fixed 18 dB gain is applied to the signal, which keeps the noise floor of the signal well below the noise floor of the SSM2167.

## COMMON VARIATIONS

This circuit can also be set up with the SSM2166 instead of the SSM2167. The SSM2166 is a more flexible, but more expensive, preamp. The rotation point and voltage-controlled amplifier (VCA) gain on the SSM2166 can be adjusted with external components, while these settings are fixed on the SSM2167. The SSM2166 also has a lower noise floor than the SSM2167 and is provided in a larger package (14-lead SOIC_N).

The ADMP504 can also be replaced with the ADMP401, ADMP404, or ADMP405. These three MEMS microphones have a 62 dB SNR, while the SNR of the ADMP504 is 65 dB. The ADMP401 has a −42 dBV sensitivity, while the ADMP504, ADMP404, and ADMP405 have a −38 dBV sensitivity. The ADMP405 is identical to the ADMP404 except that it has a low frequency cutoff at 200 Hz vs. the 100 Hz cutoff of the ADMP404. This higher frequency cutoff makes the ADMP405 attractive for reducing low frequency wind noise. The ADMP404 and ADMP405 are also pin-compatible with the ADMP504.

## LEARN MORE

The ADMP MEMS microphone products mentioned in this application note are manufactured by InvenSense, 1745 Technology Dr., San Jose, California 95110.

Elko, Gary W. and Kieran P. Harney. "A History of Consumer Microphones: The Electret Condenser Microphone Meets Micro-Electro-Mechanical-Systems," *Acoustics Today*, 2009.

Khenkin, Alex. AN-1003 Application Note, *Recommendations for Mounting and Connecting Analog Devices, Inc., Bottom-Ported MEMS Microphones*, Analog Devices Inc., 2013.

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Scarlett, Shawn. AN-583 Application Note, *Using the SSM2167 Evaluation Board*. Analog Devices, Inc., 2013.

### *Data Sheets and Evaluation Boards*

SSM2167 Data Sheet

SSM2167 Evaluation Board

## REVISION HISTORY

**11/14—Rev. 0 to Rev. A**

Changed Title of Document from CN-0262 to AN-1326 ..... Universal
Deleted Evaluation and Design Support Section ..... 1
Added Table 1; Renumbered Sequentially ..... 1
Changes to Circuit Description Section and Figure 3 Caption ..... 2
Changes to Learn More Section and Data Sheets and Evaluation Boards Section ..... 3
Deleted Circuit Evaluation and Test Section ..... 4

**1/12—Rev. 0: Initial Version**


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