Using a MEMS Microphone in a 2-Wire Microphone Circuit

INTRODUCTION

MEMS microphones are being used to replace electret condenser microphones (ECMs) in audio circuits. These two types of microphones perform the same function, but the connection between the microphone and the rest of the system is different for ECMs and MEMS microphones. This application note explains those differences and provides design details for a simple MEMS microphone based replacement circuit.

ECM CONNECTIONS TO AUDIO CIRCUITS

An ECM has two signal leads: output and ground. The microphone is biased through a DC bias on the output pin. This bias is typically sourced through a bias resistor and the signal between the microphone output and the preamp input is AC-coupled.

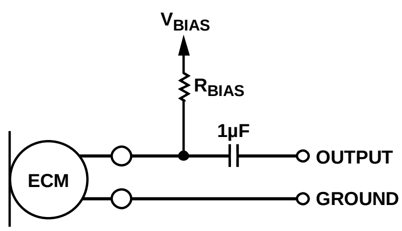

Figure 1.ECM Circuit Connection

An example of a common use of an ECM is as an in-line voice microphone in a headset connected to a phone. In this application, the connector between the headset and the phone has four pins: left audio output, right audio output, the microphone signal, and ground. The output signal and DC bias voltage of the ECM are carried on the same signal line in this design. The bias voltage source is typically about 2.2 V.

MEMS MICROPHONE DIFFERENCES

An analog MEMS microphone does not use an input bias voltage on its signal pin. Rather, it is a three-terminal device with separate pins for power, ground, and output. The V_{DD} pin is usually supplied with 1.8 to 3.3 V. The MEMS microphone's signal output is biased at a DC voltage, usually at or close to 0.8 V. In a design, this output signal is typically AC-coupled.

A key advantage of using a MEMS microphone instead of an ECM is its improved power supply rejection (PSR). A MEMS microphone typically has a PSR of at least −70 dBV, while an ECM has no power supply rejection because the bias voltage is connected to the microphone directly through a resistor.

CIRCUIT CHANGES TO REPLACE AN ECM WITH A MEMS MICROPHONE

The basic challenge to using a MEMS microphone in a system originally designed around an ECM is that there are not separate signals for power and the microphone output, such as with the headset microphone. A MEMS microphone can be used in a design like this if some small changes are made to the circuit. First, the DC bias provided downstream in the signal chain must be isolated from the output signal of the microphone. Second, this DC bias must be used to power the MEMS microphone without allowing the output signal of the microphone to interfere with the power supply. The DC bias isolation can be provided with an AC-coupling capacitor and the MEMS microphone power can be provided from a carefully-designed circuit that serves as a voltage divider and a low-pass filter. The ADMP504 MEMS microphone is used as an example in the following design. A 2.2 kΩ bias resistor is used here.

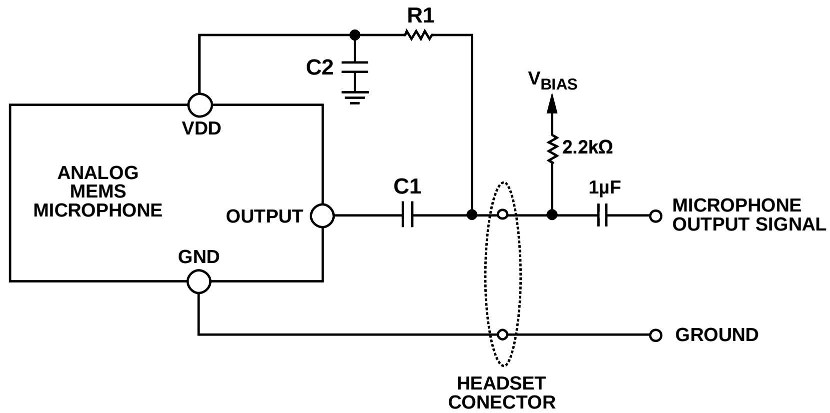

Figure 2. MEMS Microphone with a Single Wire for Power and Output Signal

Figure 2 shows an example of a design that achieves this. In a headset design, the portion of the circuit to the left of the headset connector would be in the actual headset, and the 2.2 kΩ bias resistor and 1 µF coupling capacitor would be in the source device, such as a smartphone.

Resistors R1 and R_{BIAS} form a voltage divider with the MEMS microphone to bring the V_{BIAS} voltage down to the supply voltage at the V_{DD} pin. Depending on the values of V_{BIAS}, R_{BIAS} and the desired V_{DD} voltage, Resistor R1 may need to be very small, as is seen in the example below. The necessary series resistance (R_{BIAS} + R1) can be calculated by modeling the microphone as a resistor through which a fixed current is flowing. The typical supply current of the ADMP504 when V_{DD} = 1.8 V is 180 µA. Using Ohm's law with 1.8 V on V_{DD}, this microphone can be modeled as a 10 kΩ resistor. The voltage divider equation used to solve for the appropriate value for resistor R1 is:

$$[\text{Microphone } V_{DD}] = [\text{Bias voltage}] \times (10\ \text{k}\Omega/(10\ \text{k}\Omega + R1 + R_{BIAS})).$$

From this equation, it can be calculated that a 2.2 kΩ R_{BIAS} resistor and a 499 Ω R1 resistor divide the voltage from the 2.2 V bias voltage to the 1.73 V microphone V_{DD}. There is a trade-off in choosing the value of R1; a higher value results in a lower V_{DD}, but this larger value may also be necessary to prevent C2 from being too large, as described below.

Two different models of this voltage divider are shown in Figure 3. On the left, the ADMP504 microphone is modeled as a 180 µA current source, and on the right the microphone is modeled as a 10 kΩ resistor with a 1.8 V V_{DD}.

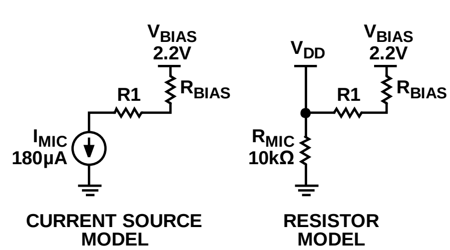

Figure 3.Voltage Divider Models

Capacitor C2, and Resistor R1 form a low-pass filter to filter the audio output of the microphone from its voltage supply signal. This filter corner frequency should be far below the lower filter corner of the microphone itself. Designing the low-pass filter to be at least two octaves below the microphone's lower corner frequency is a good starting point. For the ADMP504, this corner is at 100 Hz. A 10 µF capacitor and a 499 Ω R1 resistor give a filter with a 31 Hz corner frequency. A larger capacitor or resistor lowers this corner frequency even further, but the resistor size for this filter must be balanced with its contribution to the voltage divider that is supplying V_{DD} to the microphone.

The equation for the low-pass filter's −3 dB point is

$$f_{-3\,dB} = 1/(2\pi \times R1 \times C2)$$

where
R1 is the resistor in the voltage divider.
C2 is the low-pass filter capacitor.

Capacitor C1 AC-couples the microphone output so that its biased output is isolated from the microphone bias voltage supplied from the phone. This capacitor also forms a high pass filter with R_{BIAS}, R1, and the microphone's equivalent resistance for a given V_{DD}. The total resistance to be considered in calculating the high-pass filter corner frequency is the series resistance of R_{MIC} and R1 in parallel with R_{BIAS}. This resistance can be calculated by the equation $R_{TOTAL} = ((R_{MIC} + R1) \times R_{BIAS})/(R_{MIC} + R1 + R_{BIAS})$.

For the example given here, R_{TOTAL} = 1810 Ω. The high-pass filter corner frequency is given by

$$f_{-3\,dB} = 1/(2\pi(R_{TOTAL} \times C1)$$

For a filter corner at least an octave below the low-frequency roll-off of the ADMP504 at 100 Hz, C1 should be at least 1.8 µF.

Figure 4 shows a complete headset circuit using the ADMP504 MEMS microphone and appropriate resistor and capacitor values, based on the given V_{BIAS} and R_{BIAS} values with which we've been working.

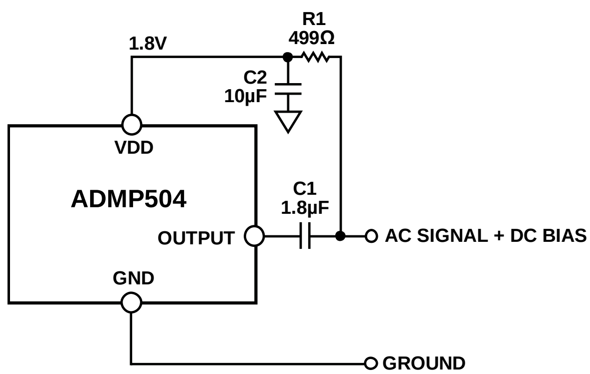

Figure 4. Circuit with ADMP504 MEMS Microphone

CONCLUSION

The circuit described here allows a MEMS microphone to be used in a design where there are not separate signals available for power and the microphone output. The circuit uses only two capacitors and one resistor to enable a MEMS microphone to be used in a 2-wire microphone circuit.

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