AN-520

2-Wire Configuration to use MEMS with ECM Circuits

Introduction

For decades the Electret Condenser Microphone (ECM), was the most common type of microphone found in consumer electronics. Since the advent of the MEMS microphone, ECMs are regularly being replaced across the consumer electronics industry. In many cases, it is critical to maintain backwards compatibility with standards designed for ECM microphones, such as for headset connectors which carry stereo audio alongside a microphone signal to a computer or phone.

How ECMs and MEMS microphones are powered

Typical ECMs contain the ECM module containing capacitive condenser microphone sensor coupled with a pre-charged electret and a single JFET used as a buffer/amplifier. To learn more about how ECM microphones work, please refer to our article, How are electret microphones and MEMS microphones different?. To interface with the microphone, a method known as “phantom biasing” is used where the DC bias for the JFET is superimposed on the signal such that there are only two connections to the microphone, Signal/Bias and Ground. Most ECMs are commonly specified using a 5 V supply and a 2.2 kΩ load resistor but can operate using a much lower supply voltage, so other voltages, such as 2.2 V are common. Three-wire ECMs are also available, but these are typically reserved for pro-audio applications. While three-wire ECM circuits have better linearity and require less power, two-wire ECM circuits are far more common as they are smaller, cost less and use fewer components. One drawback to the two-wire configuration is that PSRR is limited by the direct connection from Vdd to the output. A three-wire configuration can be designed to have high PSRR without impacting the gain or output swing.

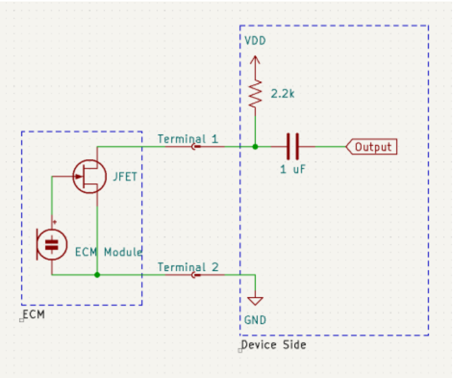


Figure 1: ECM Two Wire Circuit

Analog MEMS microphones on the other hand require three to four connections. They have either a single ended or differential output, ground, and a dedicated supply voltage. MEMS microphones rely on a dedicated ASIC with several functions. The ASIC is responsible not only for buffering the output of the transducer but also must provide the bias for the transducer via a charge pump. Digital MEMS microphones which include an ADC are also common. As such, the supply voltage must be provided separately from the output. If the ASIC were designed to use the two-wire configuration, the ASIC would need to also separate the supply voltage unnecessarily. MEMS microphones address the tradeoffs between two- and three-wire configurations for ECMs. MEMS microphones have less complex supporting circuitry, high PSRR, and are very small and low cost. It is possible to use a very simple circuit to use a MEMS microphone with existing two-wire circuitry designed for ECMs.

Implementation

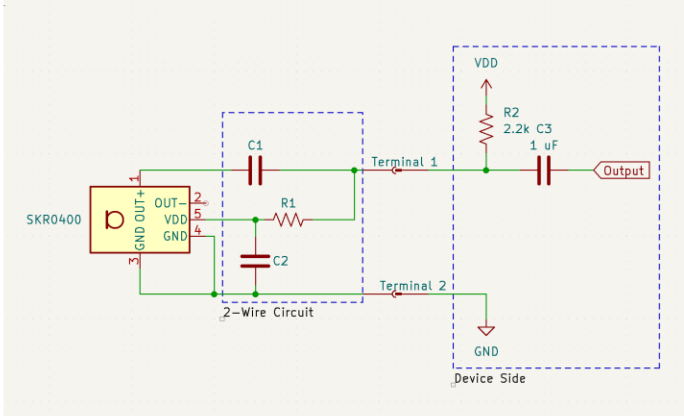


Figure 2: Two Wire Circuit for MEMS Microphones

To use a MEMS microphone with existing two-wire circuitry, a few changes must be made. First the bias voltage intended for the JFET must be isolated from the output signal to be used as a supply voltage for the MEMS microphone. To power the ECM, the source device, such as the headset jack on a PC, contains R2 and C3. For this implementation, we will use the SKR0400 microphone and assume that R2, C3, and V_{DD} are fixed with R2 = 2.2 kΩ and V_{DD} = 2.2 V.

The two-wire circuit consists of two simple filters to separate the supply voltage from the output signal line. C1, R1, R2, and the microphone form a high-pass filter which AC couples the output but blocks DC voltage from entering Out+ on the microphone. C2 and R1 form a low-pass filter which blocks the AC output signal from V_{DD} on the microphone. R1 and R2 act as a voltage divider with the microphone to bring V_{DD} down to within the operating range of the MEMS microphone. For this, R1 must be large enough to provide adequate load for the output and set V_{DD} within the operating range of the microphone.

To determine these values, first determine R1 to get the appropriate supply voltage and then use C1 and C2 to appropriately set the filters such that they do not impact the audio band.

We need the supply voltage to drop from 2.2 V to 1.8 V at the microphone. At 1.8 V, we know that the microphone draws 115 µA. Using R1, we can set the voltage drop using Ohm's law:

$$V = I \cdot R$$

We are looking for the voltage across R1 and R2 to equal V_{dd} - V_{mic}:

$$V_{dd} - V_{mic} = I_{mic} \cdot (R1 + R2)$$

Rearranging this gives us:

$$R1 = \frac{V_{dd} - V_{mic}}{I_{mic}} - R2$$

Plugging in values gives:

$$R1 = \frac{0.4\ V}{115\ \mu\text{A}} - 2.2\ \text{k}\Omega$$

$$R1 = 1.3\ \text{k}\Omega$$

To calculate the capacitors for the filters, we will start with the low pass filter between C2 and R1. We want the cut-off frequency to be well below the frequency range of the microphone so that the AC signal is removed from the supply voltage. For this filter we will target a cut-off frequency of approximately 10 Hz. We can calculate cut-off frequency using the following equation:

$$f_c = \frac{1}{2\pi \cdot R1 \cdot C2}$$

Rearranging this to find C2 gives:

$$C2 = \frac{1}{2\pi \cdot R1 \cdot f_c}$$

$$C2 = \frac{1}{2\pi \cdot 1.3\ \mathrm{k\Omega}\ \cdot 10\ \mathrm{Hz}}$$

$$C2 = \frac{1}{2\pi \cdot 1.3\ \mathrm{k\Omega}\ \cdot 10\ \mathrm{Hz}}$$

$$C2 = 12\ \mathrm{\mu F}$$

The nearest common capacitor is 10 µF which will provide a cutoff frequency of 12 Hz.

For the high pass filter, first we must calculate the resistance provided by R1, R2, and the microphone. For this, R1 and R2 are in series, and that pair is in parallel with the microphone. The total resistance can be found with the following:

$$R_f = \frac{R_{mic} \cdot (R1 + R2)}{R1 + R2 + R_{mic}}$$

Knowing the voltage and current of the microphone, we can find the equivalent resistance of the microphone using Ohm’s law:

$$R_{mic} = \frac{V_{mic}}{I_{mic}}$$

$$R_{mic} = \frac{1.8\ \mathrm{V}}{115\ \mathrm{\mu A}}$$

$$R_{mic} = 1.5\ \mathrm{k\Omega}$$

So the resistance of the filter is:

$$R_f = \frac{1.5\ \mathrm{k\Omega}\ \cdot (1.3\ \ \mathrm{k\Omega} + 2.2\ \ \mathrm{k\Omega})}{1.3\ \mathrm{k\Omega} + 2.2\ \ \mathrm{k\Omega} + 1.5\ \ \mathrm{k\Omega}}$$

$$R_f = 1\ \mathrm{k\Omega}$$

So to find C1 for a high pass filter with a cut-off frequency of 10 Hz:

$$C1 = \frac{1}{2\pi \cdot 1\ \mathrm{k\Omega}\ \cdot 10\ \mathrm{Hz}}$$

$$C1 = {\sim}15\ \mathrm{\mu F}$$

Our final two-wire circuit is shown below:

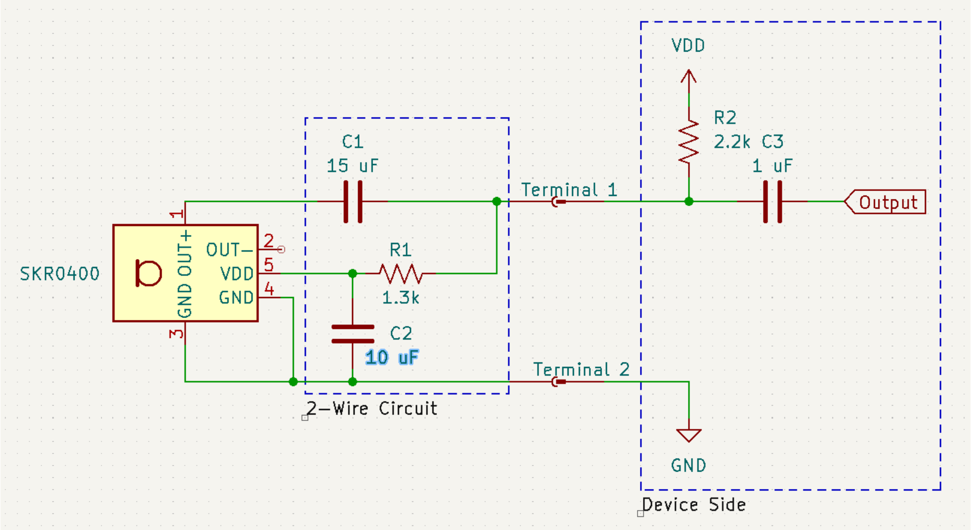


Figure 3: 2-wire Circuit

The external components, two capacitors and a resistor are very low cost. Depending on the supply voltage of the interface, the resistor value can be tweaked to optimize performance. These values give a starting point and can be tweaked for specific requirements.

The two-wire configuration of the SKR0400 gives several performance advantages over traditional electret mics, while saving the time and costs needed for product redesign.

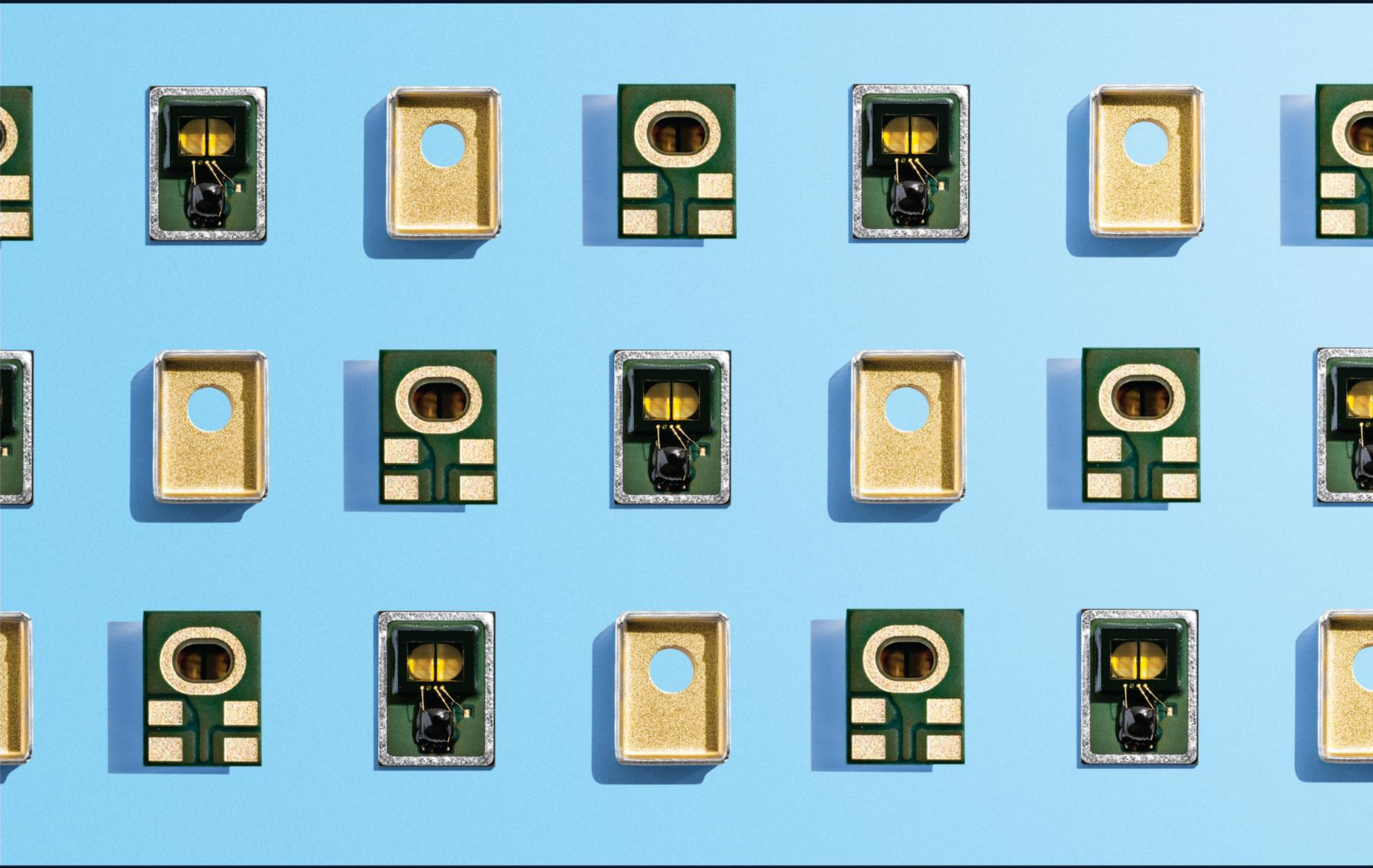
Additional Support

For further information on Soundskrit's products, visit our website at http://www.soundskrit.ca where you can find more application notes, datasheets, and purchasing information. If you have any questions or need technical support, please reach out to applications@soundskrit.ca.

Revision Label	Revision Date	Sections Revised
-	June 2023	Initial release
A	September 2023	Added calculation details

Soundskrit developed the first high-performance directional MEMS microphone on the market, leveraging years of research in bio-inspired MEMS based on how spiders and other insects in nature hear. In combination with Soundskrit’s in-house audio processing algorithms, directional microphones can be used to capture and isolate any sound in an environment with a fraction of the size, power, and computation of traditional omnidirectional-based microphone arrays.

Soundskrit was founded in 2019 and is headquartered in Montreal, Quebec with an R&D facility in Ann Arbor, Michigan.



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