Introduction
The purpose of this application note is to guide the user in the application and selection of microphones that can be connected with two wires only.

The majority of Sonion microphones require three terminal connections, one for supply voltage, ground and a third for the output signal, see figure 1. The conventional way of connecting microphones is shown in figure 2.

Sonion also offers microphones that can be connected with 2 wires only – having a shared terminal for supply and output signal. A microphone that is suited for a 2-wire connection is called a Two-Wire microphone.

Reducing the number of terminal connections from three to two has the following application benefits:
• It requires 4 fewer solder operations in dual microphone applications
• It requires 1 less wire to route through thin-tube applications when the microphone is placed in the user’s ear.

Figure 3
(Left) Dual microphone application requiring 6 wires and 12 solder connections (Right) Thin-tube application requiring multiple wires routed to the ear.
Connecting Two-Wire Microphones

Two-Wire microphones require a current source. In a two-wire application the current source is directly connected to the output signal terminal, while leaving the supply terminal disconnected. The output signal is then separated from the current source through a coupling capacitor at the input of the front-end. Figure 4 shows the connection of a Two-Wire microphone.

Figure 4
Connection of a Two-Wire microphone with an ideal current source.

The current source can be either passive or active. The simplest form is a passive implementation wherein the current source consists of a voltage source in series with a bias resistor. A bias resistor must be added to the hearing aid hybrid and placed between the supply voltage and the output signal terminal of the microphone (figure 5).
In this configuration, the current drain supplied to the microphone can be set by selecting the proper resistor value for the available supply voltage. The current drain can be set by the design engineer, because Sonion Two-Wire Microphones can operate over a wide range of supply currents from a minimum of 3μA - 100μA at maximum.

For any given supply voltage $V_{sup}$ and desired current drain $I_{sup}$, the value of the bias resistor $R_{bias}$ can be determined by means of the following formula:

$$R_{bias} = \frac{V_{sup} - V_\text{O}}{I_{sup}} \approx \frac{V_{sup} - 0.60V}{I_{sup}}, \quad V_{sup} \geq 0.9V$$

Here $V_\text{O}$ is the DC output voltage of the microphone, which is typically between 0.50V-0.60V for all Sonion Two-Wire microphone series. It must be noted that the supply voltage should be at minimum 0.9V to allow sufficient output voltage swing. This is required to prevent clipping for high sound pressure levels.
Performance Characteristics of Two-Wire Microphones
Unlike microphones that require 3 terminal connections, Two-Wire microphones allow the user to define the current drain used in the microphone. As a result, some of the performance parameters of Two-Wire microphones are user-defined. The main performance consequences are discussed in the following paragraphs.

Output Impedance
From the previous paragraph it might look attractive to choose a (very) high bias resistor, driving the supply current to only a few micro amps. However, there are some drawbacks to this strategy.

The output impedance of Two-Wire Microphones increases rapidly as you lower the current drain to the microphone. These are the characteristics of CMOS output stage transistors used in our microphone pre-amplifiers. Figure 6 shows measurements on the output impedance characteristics of Two-Wire microphones. It can be clearly seen from figure 6 below, that the output impedance is inversely proportional to current drain.

Figure 6
The dependence of the output impedance of a Two-Wire Microphone vs. current drain supply

![Figure 6](image)

Lowering the supply current to only a few micro amps, results in raising the impedance of the entire output source and all other wires connected to it. This can become a problem as the length of the wire(s) increases. A high impedance wire acts more like an “antenna” than a low impedance wire, especially in situations where it is interacting with outside electrical interferences.

In addition, the sensitivity will be reduced or “loaded down” if the output impedance of the microphone is not significantly lower than the input impedance of the HI front-end or measurement amplifier connected to it. This is explained in the next paragraph.
Sensitivity
The sensitivity of the microphone can be affected by both the implementation of the current source and the input impedance of the hearing aid front-end. That is because the bias resistor of the current source acts together with the input impedance of the front-end as a load to the microphone. This can be explained by looking at the equivalent electrical circuit of the microphone.

A microphone can be represented by its equivalent circuit model, i.e. a voltage source \( v_{\text{mic}} \) with a series resistance \( R_{\text{out}}(I_{\text{sup}}) \). The series resistance \( R_{\text{out}} \) is the current-dependent output impedance as shown in figure 6. Figure 7 shows the same schematic representation of a two-wire connection as in figure 5 but this time with the equivalent electrical circuit of a microphone.

**Figure 7**
**Equivalent electrical circuit of a Two-Wire microphone with an external passive current source.**

For AC signal analysis, both the supply voltage and the coupling capacitor can be considered as a short circuit and can be omitted. Figure 8 shows the equivalent circuit.
The current source and the HI front-end form a voltage divider with the microphone signal output. The following is the equivalent formula:

\[
\frac{v_{in}}{v_{mic}} = \frac{R_{bias} \parallel R_{in}}{R_{out}(I_{sup}) + R_{bias} \parallel R_{in}} \times v_{mic}
\]

The voltage signal gain \(G\) from microphone to front-end is then given by

\[
G = 20 \cdot \log_{10} \left( \frac{v_{in}}{v_{mic}} \right) = 20 \cdot \log_{10} \left( \frac{R_{bias} \parallel R_{in}}{R_{out}(I_{sup}) + R_{bias} \parallel R_{in}} \right), \quad G \leq 0
\]

The highest voltage gain is achieved, i.e. \(G = 0\) dB, if both the bias resistor \(R_{bias}\) and the input impedance \(R_{in}\) of the front-end are much higher than the output impedance \(R_{out}(I_{sup})\) of the microphone.

For example, driving the microphone with a low current \(I_{sup}\) of 3 μA, the output impedance of the microphone is 19k Ω according to figure 5. This requires both the input impedance of the front-end and the bias resistor of the current source to be significantly higher. In case each of those two impedances is lower than 100k Ω, the voltage signal at the input of the front-end is 1.5 dB lower than at the microphone output.

**Power Supply Rejection Ratio**

The power supply rejection ratio of Two-Wire microphones is determined by the current source configuration that you choose. The noise from the battery (or voltage regulator) is reduced by the voltage divider network of the bias resistance of the current source and the output impedance of the microphone. Figure 9 shows the electrical circuit equivalent for a twowire connection with voltage noise \(v_{noise}\) on the supply voltage.
The power supply rejection ratio (PSRR) can be derived as follows:

\[ PSRR = 20 \cdot \log_{10} \left( \frac{v_{\text{noise}}}{v_{\text{out}}} \right) = 20 \cdot \log_{10} \left( \frac{R_{\text{bias}} + R_{\text{out}}(I_{\text{sup}})}{R_{\text{out}}(I_{\text{sup}}) \parallel R_{\text{in}}} \right) \]

For \( R_{\text{in}} \gg R_{\text{out}} \) i.e the input impedance of the front-end is much higher than the output impedance of the microphone, it can be approximated that

\[ PSRR \approx 20 \cdot \log_{10} \left( \frac{R_{\text{bias}} + R_{\text{out}}(I_{\text{sup}})}{R_{\text{out}}(I_{\text{sup}})} \right) \]

This shows that high power supply rejection is achieved by a current source with a high bias resistor. For example, a Two-Wire application that supplies the microphone with 10 μA from a current source with 30k Ω bias resistance and 0.9 V supply voltage, will have an output impedance of the microphone of 8k Ω (see figure 5) and PSRR of 13.5 dB.
Two-Wire Microphones Offered
Sonion offers several Two-Wire microphones in the different microphone series. Please contact Sonion for design assistance and component selection for your particular application.