Comparing two-wire microphone circuits for automotive applications

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Introduction

To balance driver interactivity with safety, many of today's vehicles have microphones for functions like phone integration, noise cancellation and emergency (or eCall) systems. The addition of microphones in modern vehicles necessitates small size, affordability and performance. This article describes the basics of common automotive two- and three-wire microphone systems and compares the performance and size of discrete microphone circuits to operational amplifier (op amp)-based circuits.

Two- versus three-wire microphone topologies

Figure 1 compares typical two- and three-wire microphone topologies. In a two-wire microphone circuit, the output signal is current-modulated on the microphone's power-supply voltage node, or V+. There is usually a 680-Ω resistor that converts the modulated current to a voltage, which is then filtered and amplified with a signal-conditioning circuit before being digitized by an analog-to-digital converter (ADC). In a three-wire microphone circuit, the audio signal is separate from the V_{DD} and GND nodes. Note that in a three-wire circuit, V_{DD} can be a separate supply from the one shown in Figure 1 because the audio and power are on separate nodes.

While three-wire microphone circuits generally have better performance in total harmonic distortion plus noise (THD+N) and consume less power, two-wire microphone circuits are far more common because they're smaller, cost less and have fewer components. In addition, two-wire microphone circuits are lighter because they don't require as much wiring. In this article, the focus is on the two-wire implementation.

Two-wire implementation without op amps (discrete)

Figure 2 depicts a simplified schematic of a two-wire implementation that does not use op amps, known as a discrete implementation. This circuit has a gain of approximately 41 dB in the pass band, which is from 10 Hz to 3 kHz. The microphone element could be either a microelectromechanical system, an electromagnet dynamic microphone or an electret microphone. It converts sound

Figure 1. Two- versus three-wire microphone topologies

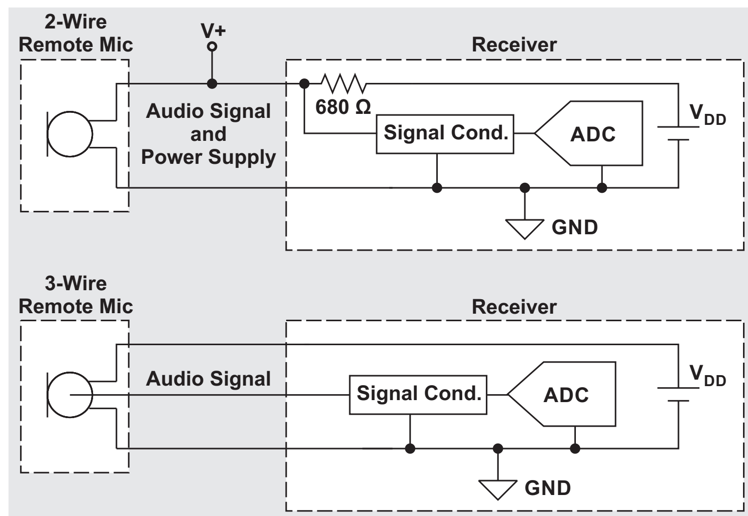
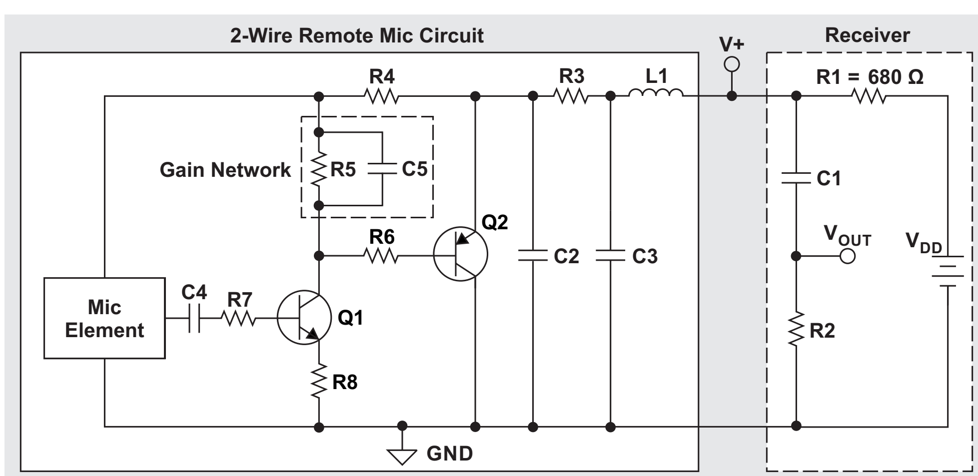


Figure 2. Discrete implementation of a two-wire microphone circuit



to a voltage, which is fed through a high-pass filter to the base terminal of an NPN transistor (Q1). Q1 and the passive-gain network amplify the audio signal. The passive-gain network shown in Figure 2 is simplified down to just two components (R5 and C5), but is more complicated in typical designs; therefore multiple components must be changed to modify the gain of the circuit. Driving the load, R1, requires a second transistor stage, Q2. The audio signal, which ultimately appears as a change in current in the microphone's power-supply node, or V+, is usually transmitted through a long cable and converted to a voltage via resistor R1 at the receiver.

The THD+N performance for this circuit on a printed circuit board (PCB) was measured over temperature, for both frequency and amplitude. Using a two-layer board with primarily 0201- and 0603-sized passive components, the final board area measured approximately 2 by 1.25 cm, or 2.5 cm^2.

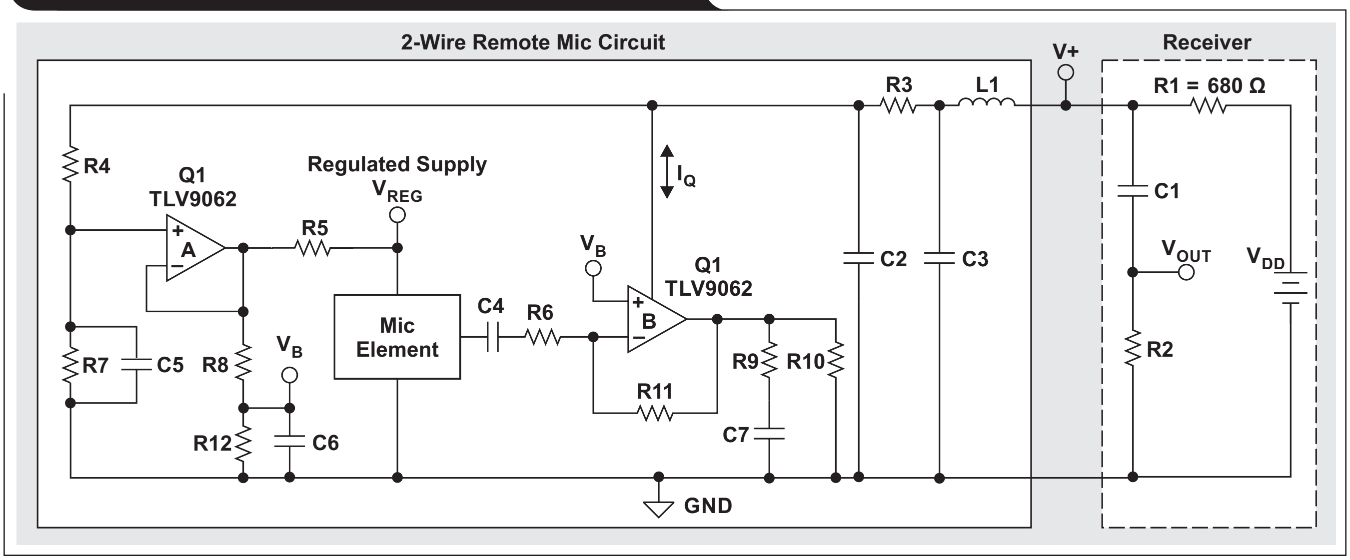
Two-wire implementation with op amps

Figure 3 depicts a simplified schematic of a two-wire implementation of the microphone circuit that uses the TLV9062-Q1 dual op amp. This circuit has a gain of slightly less than 40 dB in the pass band, which is from 30 Hz to 7 kHz. The receiver and filtering components, L1, R3, C2 and C3, are the same as the discrete circuit. The microphone output is AC-coupled and connected to an inverting amplifier with an inverting gain set by R11/R6.

One advantage of this implementation is that the gain can easily be changed by modifying either R11 or R6, whereas changing the gain in the discrete approach is not as straightforward. The output of channel B is connected to a DC load (R10) and an AC load (R9 and C7). As the output of channel B varies, these loads affect the quiescent current, I_Q, of the op amp. It is this modulating current that flows through R1 that creates the output voltage, V_{OUT}. The supply voltage for the microphone element is derived from V+, which is divided down by R4/R7/C5 and then buffered by channel A of the op amp. This provides the microphone element with a regulated supply voltage because it effectively decouples the ripple on the V+ node, which is caused by the modulated current, I_Q. The resistor divider created by R8 and R12 provides a bias voltage, V_B, for channel B of the op amp to ensure that the input signal is within the linear operating region of the amplifier's common-mode voltage.

A PCB was created for this circuit and used to measure the THD+N performance over temperature for both frequency and amplitude. Using a two-layer board with primarily 0402- and 0603-sized passive components and a VSSOP package for the op amps, the final board area measured approximately 2 by 1.4 cm, or 2.8 cm^2. This is not much larger than the discrete implementation, despite using a relatively large package for the dual-channel op amp. As more automotive-qualified amplifiers are released in smaller packages—for example, thin small-outline transistor package, SOT-23-8 (or DDF)—the op amp implementation can be smaller than the discrete implementation.

Figure 3. Two-wire microphone circuit with op amps



Performance comparison

In order to compare performance over temperature, measurements were taken at room (25°C), hot (65°C) and cold (–20°C) temperatures.

Figure 4 compares the THD+N performance versus the output amplitude for the discrete and operational amplifier implementations using a typical 1-kHz input signal. For optimal THD+N performance, an output amplitude from 0.7 to 1.5 V_{PP} is recommended. There is almost no deviation over temperature for the operational amplifier implementation.

Figure 5 compares the THD+N performance versus frequency for the discrete and op amp implementations. An output voltage of 1 V_{PP} was selected because it is within the optimal performance range shown in Figure 4. Some automotive manufacturers use signals larger than 1.5 V_{PP}, but this comes at the expense of THD+N performance, as shown in Figure 4. Using the typical telephone frequency range, 300 Hz to 3.4 kHz, the measurements show that the op amp implementation has both better THD+N performance and less deviation over temperature.

Figure 4. Output THD + N performance of discrete and op amp circuits

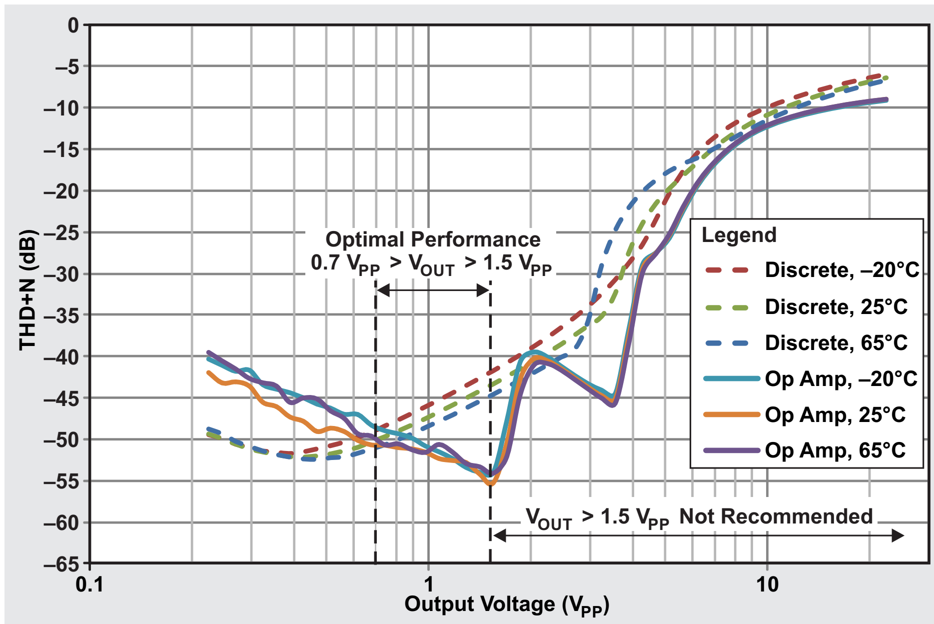
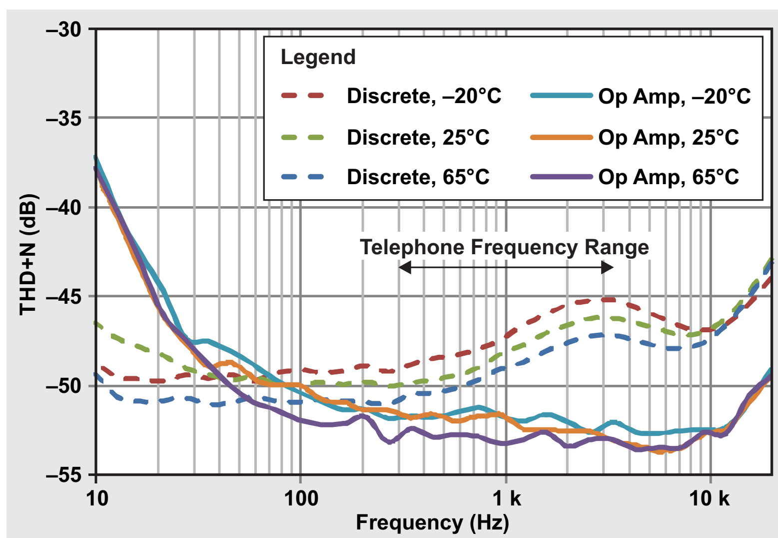


Figure 5. Output THD + N vs. frequency for discrete and op amp circuits



Conclusion

An op amp implementation of a two-wire automotive microphone circuit is not only feasible, but can also have better THD+N performance over frequency, amplitude and temperature. While the PCB space required for a VSSOP (DGK) op amp package is negligibly larger, smaller op amp packages, such as the SOT-23-8 (DDF), will yield smaller solutions than the discrete approach.

Related Web sites

Product information:

TLV9062-Q1

Automotive amplifiers

Operational amplifiers

Package information:

VSSOP (DGK)

SOT-23-8 (DDF)

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