

Circuits from the Lab®
Reference Designs

Circuits from the Lab® reference designs are engineered and tested for quick and easy system integration to help solve today's analog, mixed-signal, and RF design challenges. For more information and/or support, visit www.analog.com/CN0226.

Devices Connected/Referenced

AD5116	Single-Channel, 64-Position, Push-Button, $\pm 8\%$ Resistor Tolerance, Nonvolatile Digital Potentiometer
SSM2375	Filterless, High Efficiency, Mono 3 W Class-D Audio Amplifier
AD8515	1.8 V Low Power CMOS Rail-to-Rail Input/Output Operational Amplifier
ADA4051-2	1.8 V, Micropower, Zero-Drift, Dual Rail-to-Rail Input/Output Op Amp

Portable Audio Amplifier with Volume Control

EVALUATION AND DESIGN SUPPORT

Circuit Evaluation Boards

[CN-0226 Circuit Evaluation Board \(EVAL-CN0226-EB1Z\)](#)

Design and Integration Files

[Schematics](#), [Layout Files](#), [Bill of Materials](#)

CIRCUIT FUNCTION AND BENEFITS

The circuit shown in Figure 1 is a complete low cost, low power, mono audio amplifier with volume control, glitch reduction, and a 3 W Class-D output driver.

The volume is controlled manually with a simple push-button interface to a 64-position digital potentiometer. An automatic store function retains the last volume setting, and an LED provides visual information of the maximum/minimum volume.

The *SSM2375* Class-D driver amplifier provides up to 3 W output power into 3 Ω load, with 93% power efficiency at 5 V, built in pop and click suppression, and shutdown mode.

The circuit provides a preconditioning input stage, allowing compatibility with a wide range of audio input signals and can be powered with a cell battery.

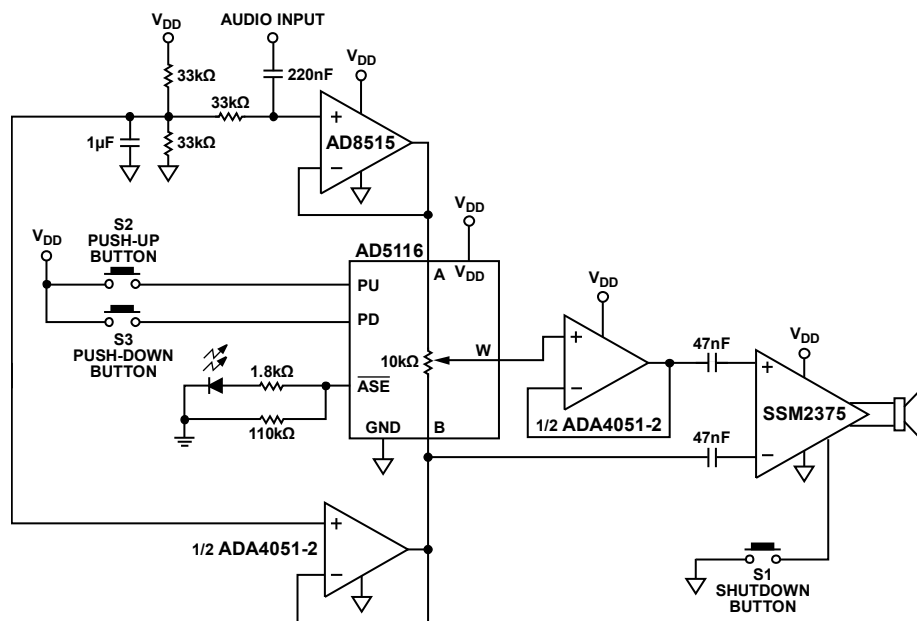


Figure 1. Audio Volume Control (Simplified Schematic: Decoupling and All Connections Not Shown)

Rev. 0

Circuits from the Lab reference designs from Analog Devices have been designed and built by Analog Devices engineers. Standard engineering practices have been employed in the design and construction of each circuit, and their function and performance have been tested and verified in a lab environment at room temperature. However, you are solely responsible for testing the circuit and determining its suitability and applicability for your use and application. Accordingly, in no event shall Analog Devices be liable for direct, indirect, special, incidental, consequential or punitive damages due to any cause whatsoever connected to the use of any Circuits from the Lab circuits. (Continued on last page)

CIRCUIT DESCRIPTION

This circuit employs the 64-position **AD5116** digital potentiometer in conjunction with the **SSM2375** Class-D amplifier, dual **ADA4051-2**, and single **AD8515** op amps, providing an ease of use circuit for low power and/or portable applications.

The input signal is filtered by a high-pass filter that removes any dc offset voltage and centers the signal between the supply rails. The high pass filter also improves the power supply rejection (PSR). A separate filter is provided for the $V_{DD}/2$ bias voltage, as shown in Figure 2.

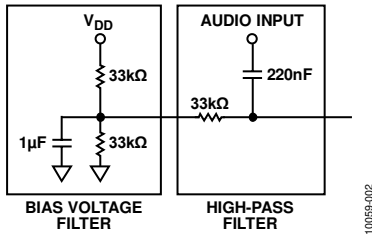


Figure 2. Input Filter Configuration

The filter formed by the 1 µF capacitor and the 33 kΩ divider resistors has a cutoff frequency of approximately 10 Hz. The high pass filter formed by the 33 kΩ resistor and the 220 nF capacitor has a cutoff frequency of approximately 22 Hz.

The bias voltage filter rejects supply noise at 10 Hz and above.

The **AD5116** is configured in the potentiometer mode, thereby attenuating the audio input signal and is available in 80 kΩ, 10 kΩ, and 5 kΩ resistance values. Selecting the resistance represents a trade-off between linearity, noise, bandwidth, and total harmonic distortion (THD) performance. The 10 kΩ option was chosen for the circuit in Figure 1, although the 5 kΩ option yields a slight reduction in noise.

The dual **AD8515** is a low cost, low power, rail-to-rail, input/output operational amplifier and is used to buffer the audio signal and drives the A terminal of the **AD5116**.

One-half of the **ADA4051-2** op amp provides the low impedance $V_{DD}/2$ bias voltage to the B terminal of the **AD5116**. Setting the bias voltage at $V_{DD}/2$ provides optimum signal headroom and best THD performance.

The other half of the **ADA4051-2** op amp is used to buffer the W terminal output of the **AD5116**.

The **AD5116** provides an automatic store feature that ensures it retains the last volume position. The \overline{ASE} pin has a double function when the automatic store is enabled. The pin indicates when the end of the resistance has been reached, which indicates the maximum/minimum volume. An LED is provided for visual information of the event.

The **SSM2375** is a high efficiency Class-D amplifier that provides up to 3 W output power. The device provides a 12 dB gain with a built in pop and click suppression circuit that minimizes the transition glitches from the digital potentiometer.

A third push-button is provided on the board to shut down the audio output.

Figure 3 shows the THD + N performance of the circuit operating on a 5 V power supply with a 4 Ω + 15 µH load. Note that the THD + N increases at the 2 W output power level.

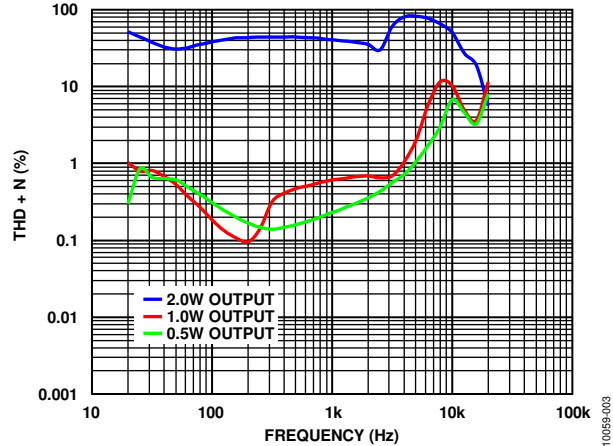


Figure 3. THD + N Performance of Circuit Using 5 V Power Supply, 4 Ω + 15 µH Load, Gain = 3 dB

Audio Input Signal Level Calculation

The **SSM2375** output power is given by

$$Output\ Power\ (W) = \frac{(IN \times GAIN)^2}{R_{LOAD}}$$

where:

IN is the rms input voltage or $V_{PEAK} / \sqrt{2}$.

R_{LOAD} is the speaker impedance.

GAIN is the linear gain, by default 1.4125 (3 dB).

The **SSM2375** gain can be set from 0 dB to 12 dB in 3 dB steps, as shown in Table 1.

Table 1. SSM2375 Gain Configurations

Gain Setting (dB)	GAIN Pin Configuration
12	Tie to VDD through 47 kΩ resistor
9	Tie to GND through 47 kΩ resistor
6	Tie to VDD
3	Open
0	Tie to GND

Optimum layout, grounding, and decoupling techniques must be utilized to achieve the desired performance (see the **MT-031** and **MT-101** tutorials). As a minimum, a 4-layer printed circuit board (PCB) must be used with one ground plane layer, one power plane layer, and two signal layers.

A complete design support package including schematic, layout, assembly, and bill of materials (BOM) is available at www.analog.com/CN0226-DesignSupport.

COMMON VARIATIONS

The circuit can be configured for ultralow power operation. If the circuit is used in a low power system, all three op amps can be replaced with the quad [AD8508](#), which provides a very low supply current of 20 μ A per amplifier and allows full functionality at a supply of 2.5 V.

It is also possible to externally implement an automatic shutdown to improve the attenuation at minimum volume using a D-type flip-flop, as shown in Figure 4.

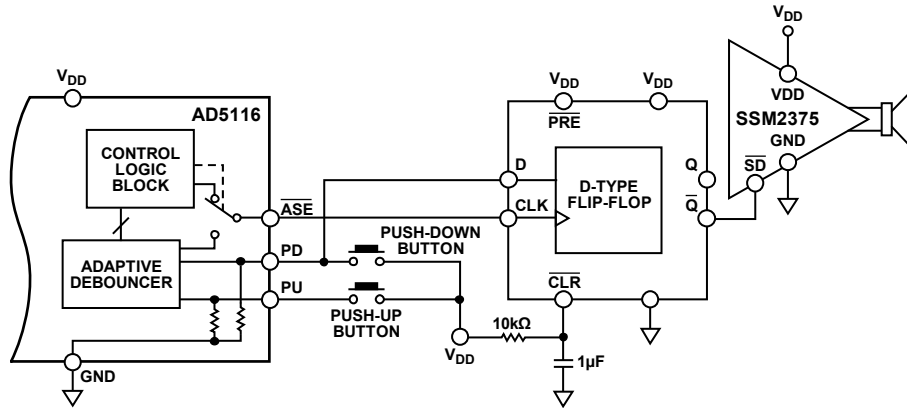


Figure 4. Automatic Shutdown Mode

10059-004

CIRCUIT EVALUATION AND TEST

The circuit is tested using standard audio test equipment and methods.

Equipment Needed

The following equipment is required:

- EVAL-CN0226-EB1Z evaluation board
- DC power supply (2.7 V to 5.5 V)
- Audio Precision 2700 series audio analyzer or equivalent
- Audio Precision AUX-0025 filter or equivalent

Functional Block Diagram

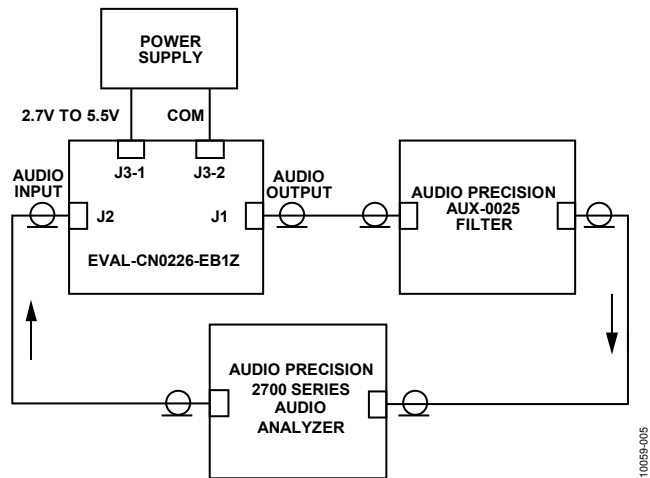


Figure 5. Test Setup Functional Diagram

Setup and Test

Connect the equipment as shown in Figure 5. Connect the power supply to the EVAL-CN0226-EB1Z board.

Use standard audio test methods to make the required measurements.

Figure 6 shows a photograph of the EVAL-CN0226-EB1Z board.

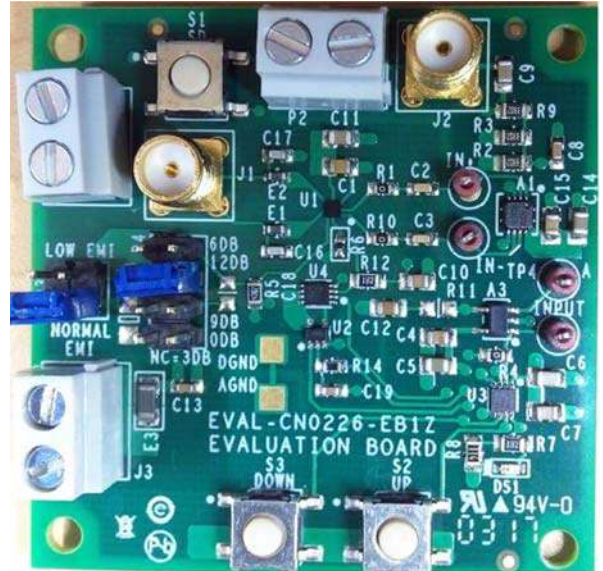


Figure 6. Photo of EVAL-CN0226-EB1Z

LEARN MORE

CN-0226 Design Support Package:

www.analog.com/CN0226-DesignSupport

MT-031 Tutorial. *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND"*. Analog Devices.

MT-091 Tutorial. *Digital Potentiometers*. Analog Devices.

MT-101 Tutorial. *Decoupling Techniques*. Analog Devices.

Kitchin, Charles. AN-581 Application Note. *Biasing and Decoupling Op Amps in Single Supply Applications*. Analog Devices.

Usach Merino, Miguel. *Insight into digiPOT Specifications and Architecture Enhances AC Performance*. Analog Dialogue, (Volume 45, August 2011), Analog Devices.

Data Sheets and Evaluation Boards

[CN-0226 Evaluation Board \(EVAL-CN0226-EB1Z\)](#)

[AD5116 Data Sheet](#)

[SSM2375 Data Sheet](#)

[AD8515 Data Sheet](#)

[ADA4051-2 Data Sheet](#)

REVISION HISTORY

4/2017—Revision 0: Initial Version

(Continued from first page) Circuits from the Lab reference designs are intended only for use with Analog Devices products and are the intellectual property of Analog Devices or its licensors. While you may use the Circuits from the Lab reference designs in the design of your product, no other license is granted by implication or otherwise under any patents or other intellectual property by application or use of the Circuits from the Lab reference designs. Information furnished by Analog Devices is believed to be accurate and reliable. However, Circuits from the Lab reference designs are supplied "as is" and without warranties of any kind, express, implied, or statutory including, but not limited to, any implied warranty of merchantability, noninfringement or fitness for a particular purpose and no responsibility is assumed by Analog Devices for their use, nor for any infringements of patents or other rights of third parties that may result from their use. Analog Devices reserves the right to change any Circuits from the Lab reference designs at any time without notice but is under no obligation to do so.

©2017 Analog Devices, Inc. All rights reserved. Trademarks and registered trademarks are the property of their respective owners.
CN10059-0-4/17(0)

