AN-1426
APPLICATION NOTE

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

Precision, Unipolar, Inverting Conversion Using the AD5546/AD5556 DAC

CIRCUIT FUNCTION AND BENEFITS

This circuit provides precision, unipolar, inverting data conversion using the AD5546/AD5556 current output digital-to-analog converter (DAC) with the ADR03 precision reference and AD8628 operational amplifier (op amp). This circuit provides accurate, low noise, high speed output voltage capability and is well suited for process control, automatic test equipment, and digital calibration applications.

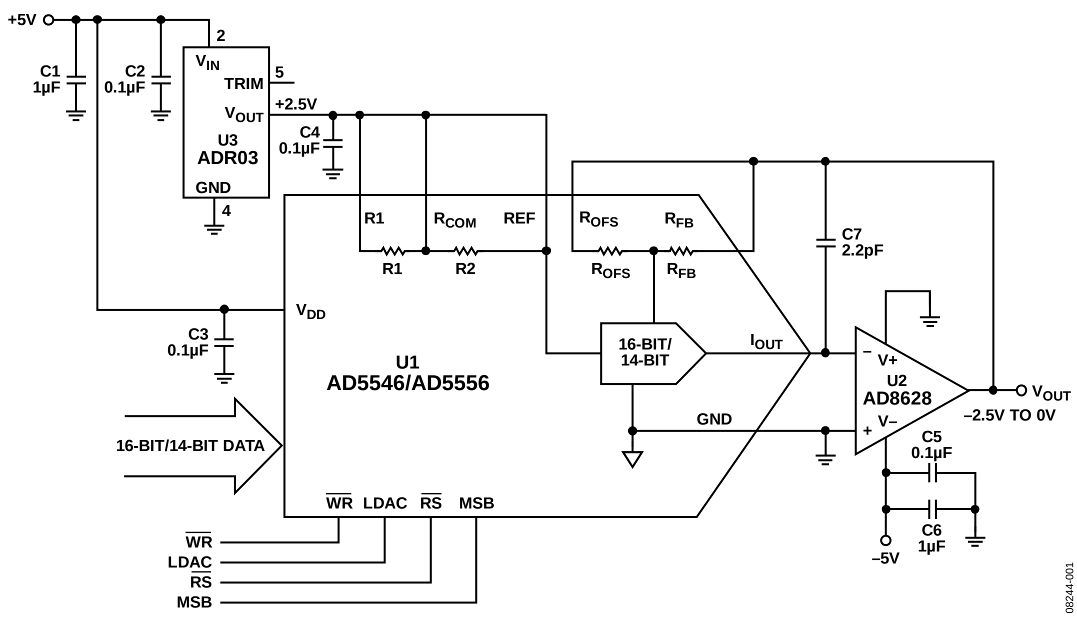

Figure 1. Unipolar Multiplying Mode, V_{OUT} = 0 V to $-V_{REF}$ (Simplified Schematic)

TABLE OF CONTENTS

REVISION HISTORY

11/2016—Rev. A to Rev. B
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CIRCUIT DESCRIPTION

The AD5546/AD5556 are 16-bit and 14-bit, precision, multiplying, low power, current output, parallel input DACs. They operate from a single 2.7 V to 5.5 V supply with ±15 V multiplying references for four quadrant outputs. Built-in four quadrant resistors facilitate the resistance matching and temperature tracking that minimize the number of components needed for multiquadrant applications.

This circuit uses the ADR03, which is a high accuracy, high stability, 2.5 V precision voltage reference. Because voltage reference temperature coefficient and long-term drift are primary considerations for applications requiring high precision conversion, this device is an ideal candidate.

An op amp is used in the current-to-voltage (I-V) stage of this circuit. Bias current and offset voltage of an op amp are both important selection criteria for use with precision current output DACs. Therefore, this circuit employs the AD8628 auto-zero op amp, which has ultralow offset voltage (1 μV typical) and bias current (30 pA typical). The value of C7 for this circuit is 2.2 pF, which is optimized to compensate for the external output capacitance of the DAC.

Note that the AD8628 has rail-to-rail input and output stages, but the output can only come within a few millivolts of either rail depending on load current. For the circuit shown, the output can swing from −2.5 V to approximately −1 mV.

The input offset voltage of the op amp is multiplied by the variable noise gain (due to the code dependent output resistance of the DAC) of the circuit. A change in this noise gain between two adjacent digital codes produces a step change in the output voltage due to the input offset voltage of the amplifier. This output voltage change is superimposed on the desired change in output between the two codes and gives rise to a differential linearity error, which, if large enough, can cause the DAC to be nonmonotonic. In general, the input offset voltage must be a fraction of a least significant bit (LSB) to ensure monotonic behavior when stepping through codes. For the ADR03 and the AD5546, the LSB size is

$$\frac{2.5\ \text{V}}{2^{16}} = 38\ \mu\text{V} \quad (1)$$

The input offset voltage of the AD8628 auto-zero op amp is typically 1 μV, which is negligible compared to the LSB size.

The input bias current of an op amp also generates an offset at the voltage output as a result of the bias current flowing through the feedback resistor, RFB. In the case of the AD8628, the input bias current is only 30 pA typical, which flowing through the RFB resistor (10 kΩ typical), produces an error of only 0.3 μV.

The AD5546/AD5556 DAC architecture uses a current steering R-2R ladder design that requires an external reference and op amp to generate the output voltage. V_{OUT} can be calculated for the AD5546 using the equation

$$V_{OUT} = \frac{-V_{REF} \times D}{2^{16}} \quad (2)$$

where D is the decimal equivalent of the input code.

V_{OUT} can be calculated for the AD5556 using the equation

$$V_{OUT} = \frac{-V_{REF} \times D}{2^{14}} \quad (3)$$

where D is the decimal equivalent of the input code.

COMMON VARIATIONS

For multichannel applications, the AD8629 is a dual version of the AD8628. The ADR01 and ADR02 are other low noise references available from the same reference family as the ADR03. Other suitable low noise references are the ADR441 and ADR445 products. The size of the reference input voltage is restricted by the rail-to-rail voltage of the op amp selected.

These circuits can also be used as a variable gain element by utilizing the multiplying bandwidth nature of the R-2R structure of the AD5546/AD5556 DAC. In this configuration, remove the external precision reference and apply the signal to be multiplied to the reference input pins of the DAC.

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