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# Precision, Bipolar Configuration for the AD5547/AD5557 DAC

## CIRCUIT FUNCTION AND BENEFITS

This circuit provides precision, bipolar data conversion using the AD5547/AD5557 current output digital-to-analog converter (DAC) with the ADR01 precision reference and AD8512 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.

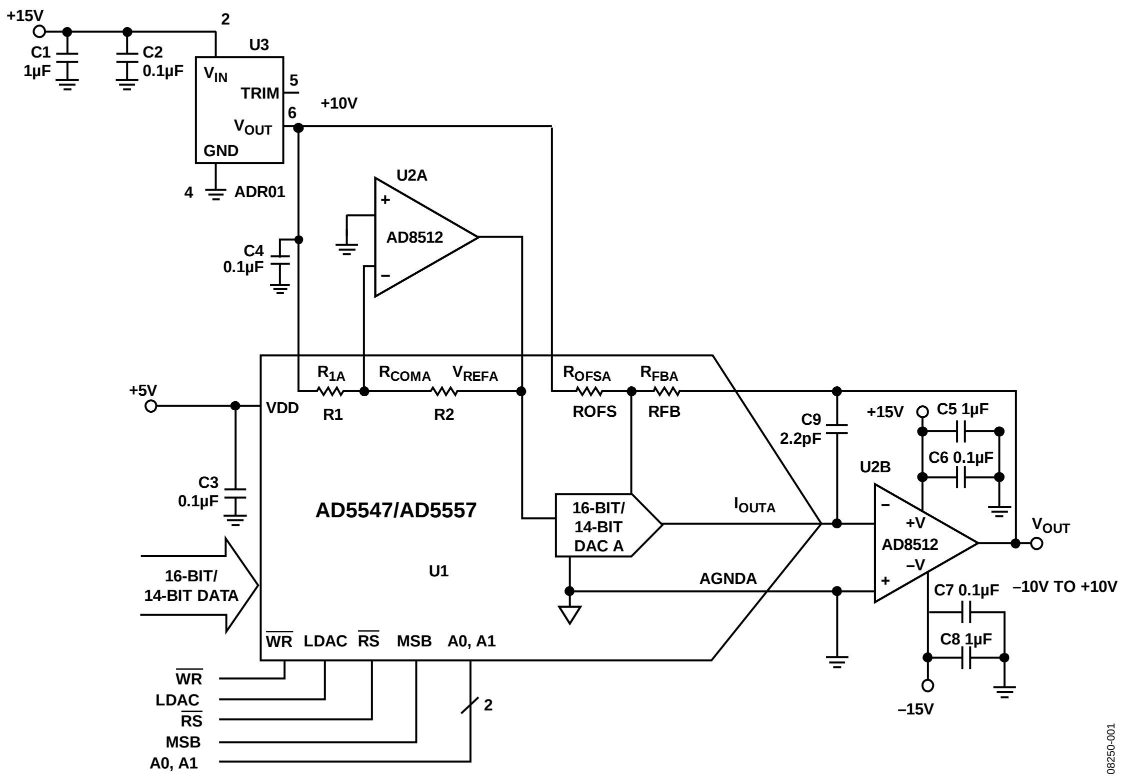


*Figure 1. 4-Quadrant Multiplying Mode, $V_{OUT}$ = –VREF to +VREF (Simplified Schematic)*

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## REVISION HISTORY

**11/2017—Rev. A to Rev. B**
Document Title Changed from CN0028 to AN-1491 ........ Universal
Changes to Figure 1 ........ 1

**5/2009—Rev. 0 to Rev. A**
Updated Format ........ Universal

**10/2008—Revision 0: Initial Version**

## CIRCUIT DESCRIPTION

The AD5547/AD5557 are dual-channel, precision 16-bit/14-bit, multiplying, low power, current output, parallel input DACs. The devices operate from a 2.7 V to 5.5 V single supply with ±15 V multiplying references for 4-quadrant outputs. Built in 4-quadrant resistors facilitate the resistance matching and temperature tracking that minimize the number of components needed for multiquadrant applications.

This circuit uses the ADR01, which is a high accuracy, high stability, 10 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. The 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 AD8512 op amp, which has ultralow offset voltage (80 µV typical for the Grade B device) and input bias current (25 pA typical). C9 is a compensation capacitor. The value of C9 for this application is 2.2 pF, which is optimized to compensate for the external output capacitance of the DAC.

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 should a fraction of an LSB to ensure monotonic behavior when stepping through codes. For the ADR01 and the AD5547, the LSB size is

$$\frac{10\text{ V}}{2^{16}} = 153\ \mu\text{V} \tag{1}$$

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 AD8512, the input bias current is only 25 pA typical, which when flowing through the RFB resistor (10 kΩ typical) produces an error of only 0.25 µV.

The AD5547/AD5557 DAC architecture uses a current, steering rail-to-rail ladder design that requires an external reference and op amp to convert to an output voltage ($V_{OUT}$).

Calculate $V_{OUT}$ for the AD5547 by using the following equation:

$$V_{OUT} = \left[\frac{V_{REF} \times D}{2^{16-1}}\right] - V_{REF} \tag{2}$$

where $D$ = 0 to 65,535 for the 16-bit DAC ($D$ is the decimal equivalent of the input code).

Calculate $V_{OUT}$ for the AD5557 by using the following equation:

$$V_{OUT} = \left[\frac{V_{REF} \times D}{2^{14-1}}\right] - V_{REF} \tag{3}$$

where $D$ = 0 to 16,383 for the 14-bit DAC ($D$ is the decimal equivalent of the input code).

## COMMON VARIATIONS

The AD8605 is another excellent op amp candidate for the I-V conversion circuit. It also has a low offset voltage and low bias current. The ADR02 and ADR03 are other low noise references available from the same reference family as the ADR01. Other suitable low noise references are the ADR441 and ADR445 devices. The size of the reference input voltage is restricted by the rail-to-rail voltage of the op amp selected.

To use these circuits as a variable gain element, utilize the multiplying bandwidth nature of the rail-to-rail structure of the AD5547/AD5557 DAC. In this configuration, remove the external precision reference and apply the signal to be multiplied to the reference input pins of the DAC.

## REFERENCES

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AN08250-0-11/17(B)