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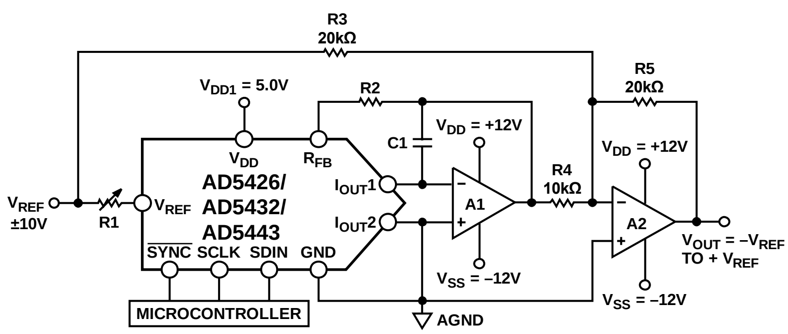
Precision, Bipolar Configuration for the AD5426/AD5432/AD5443 8-Bit to 12-Bit DACs

CIRCUIT FUNCTION AND BENEFITS

This circuit is a bipolar, precision dc digital-to-analog converter (DAC) configuration that employs a precision multiplying DAC and a low noise operational amplifier (op amp). The DAC is the core-programmable element and the amplifier selection dictates the performance in terms of precision or speed. For an accurate, high precision, low noise application, the AD8066 dual op amp can provide the current to voltage (I to V) conversion and the bipolar output.



NOTES
1. R1 AND R2 ARE USED ONLY IF GAIN ADJUSTMENT IS REQUIRED. ADJUST R1 FOR V_{OUT} = 0V WITH CODE 10000000 LOADED TO DAC.
2. MATCHING AND TRACKING IS ESSENTIAL FOR RESISTOR PAIRS R3 AND R4.
3. C1 PHASE COMPENSATION (1pF TO 2pF) CAN BE REQUIRED IF A1/A2 IS A HIGH SPEED AMPLIFIER.

Figure 1. Bipolar, Precision DC Conversion (Simplified Schematic)

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CIRCUIT DESCRIPTION

Using a single op amp, this circuit can be configured to provide two-quadrant multiplying operation. When a single op amp (A1) is connected, the output voltage (V_{OUT}) of A1 is calculated by the following equation:

$$V_{OUT(A1)} = -V_{REF} \times (D/2^N)$$

where:
D is the digital word loaded to the DAC and *N* is the number of bits: D = 0 to 255 (8-bit AD5426), D = 0 to 1023 (10-bit AD5432), and D = 0 to 4095 (12-bit AD5443).
V_{REF} is the reference input voltage.

In some applications, it can be necessary to generate a full, four-quadrant multiplying operation or a bipolar output swing. To accomplish this, use another external amplifier (A2) and the R3, R4, and R5 external resistors, as shown in Figure 1. In this circuit, the second amplifier, A2, provides a gain of 2. Biasing the external amplifier with an offset from the reference voltage results in a full four-quadrant multiplying operation. The transfer function of this circuit shows that both negative and positive output voltages are created as the input data, D, is incremented from code zero ($V_{OUT} = -V_{REF}$), to midscale (V_{OUT} = 0 V), to full-scale ($V_{OUT} = +V_{REF}$).

Calculate V_{OUT} using the following equation:

$$V_{OUT} = V_{REF} \times (D/2^{N-1}) - V_{REF}$$

This circuit uses the ADR01, a high accuracy, high stability, 10 V precision voltage reference. The reference is connected to the V_{REF} input of the circuit in Figure 1. Because the temperature coefficient and long-term drift are primary considerations for applications requiring high precision conversion, this device is ideal.

The supply voltage of the op amp limits the reference voltage that can be used with the DAC. The input bias current and input offset voltage of an op amp are important selection criteria for precision current output DACs. This circuit employs the AD8066 op amp, which has ultralow input offset voltage (0.4 mV typical) and input bias current (2 pA typical).

The input offset voltage of the op amp, A1, 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 that, if large enough, can cause the DAC to be nonmonotonic. In general, the input offset voltage is a fraction of an LSB to ensure monotonic behavior when stepping through codes. For the 12-bit AD5443, the LSB size is $10\ V/2^{12}$ = 2.44 mV, while the input offset voltage of the AD8066 is only 0.4 mV.

Use proper grounding, layout, and decoupling techniques for proper operation of the circuit. Decouple all power supply pins directly at the pin with a low inductance, 0.1 µF ceramic capacitor. Ensure that the connection to ground is made directly to a large area ground plane. Additional decoupling using a 1 µF to 10 µF electrolytic capacitor is recommended on each power supply where it enters the printed circuit board (PCB). The decoupling capacitors are not shown in Figure 1 for simplicity.

COMMON VARIATIONS

The OP2177 is another dual op amp for the I to V conversion circuit. It also provides a low input offset voltage (15 µV typical) and ultralow input bias current (0.5 nA typical). The ADR02 and ADR03, with 5.0 V and 2.5 V outputs, respectively, are other low noise references available from the same reference family as the ADR01. Another suitable family of low noise references that are the ADR441 and ADR445 products. The value of the reference input voltage, V_{REF}, is restricted by the rail-to-rail output voltage swing of the operational amplifier selected.

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