AN-1498
APPLICATION NOTE

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Programmable Gain Element Using the AD5426/AD5432/AD5443 Current Output DACs

CIRCUIT FUNCTION AND BENEFITS

This circuit provides a programmable gain function using a multiplying digital-to-analog converter (DAC) and an operational amplifier (op amp). The maximum gain value and the temperature coefficient (TC) are set by the external resistors and the resolution of the programmable gain is set by the resolution of the DAC.

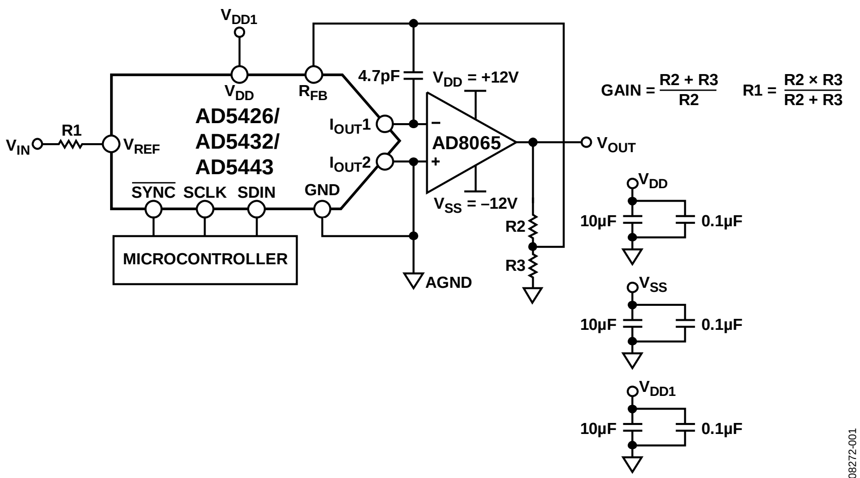

Figure 1. Programmable Gain Circuit Using a Current Output DAC (Simplified Schematic)

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CIRCUIT DESCRIPTION

The circuit shown in Figure 1 is the recommended method for increasing the gain of the circuit. The R1, R2, and R3 resistors must have similar temperature coefficients (TCs), but they do not need to match the temperature coefficients of the DAC. This approach is recommended in circuits where gains of greater than 1 are required.

The gain is calculated with the following equation:

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

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_{OUT} is the output voltage.
V_{IN} is the input voltage.

The benefit of this circuit is its ability to overcome gain TC errors using resistor matching. The TCs of the external resistors must match each other, but do not need to match the DAC internal ladder resistance.

Resistor R1 is required because R1 plus the input impedance of the DAC must equal the total feedback resistance, which is RFB + R2||R3. The input impedance of the DAC is RFB, therefore

$$R1 + RFB = RFB + R2||R3$$

$$R1 = R2||R3$$

The values of the R1 and R2 resistors must be chosen so the output voltage does not exceed the output range of the op amp for the given supply voltage. The bias current of the op amp is multiplied by the total feedback resistance (RFB + R2||R3) to give an associated offset. Therefore, the values of R1 and R2 cannot be too large or they have a significant effect on the overall output offset voltage.

The input offset voltage of an op amp is multiplied by the variable gain (due to the code dependent output resistance of the DAC) of the circuit. A change in this noise gain between two adjacent digital fractions 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. The AD8065 benefits from a low input offset voltage and low input bias currents to overcome this issue.

COMMON VARIATIONS

The OP1177 is another op amp for the current to voltage (I to V) conversion circuit. It also provides a low input offset voltage and ultralow input bias current. For the selection of the reference, the input voltage is restricted by the rail-to-rail voltage of the op amp selected and the gain set up by Resistors R2 and R3.

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