Application Report

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Bipolar Voltage Outputs for the TLV56xx Family of DACs

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ABSTRACT

A method for generating a symmetrical, bipolar, output swing voltage from a TI TLV56xx-family digital-to-analog converter (DAC) by using a bipolar operational amplifier (op amp), TLE2142, is presented. The resulting output voltage has a wide range that is limited only by the choice of op amp used for conditioning the DAC output signal. The example in this report realizes an output voltage range of ±13.8 V for a 10-kΩ load.

Design Problem

Some applications require digital-to-analog signal conversion with a bipolar output-voltage range. The output-voltage range of a standard unipolar DAC is generally between zero and $2 \times V_{ref}$; however, it can easily be signal-conditioned to produce a bipolar range.

Solution

The DAC's output voltage is

$$OUT = 2\,V_{ref}\,\frac{CODE}{(0x1000)}$$

where *CODE* is the DAC's digital input, *OUT* is its analog output, and V_{ref} is the reference voltage, which may be already integrated into the DAC. Within the 12-bit TLV56xx family of DACs, *CODE* can have any value between 0x000 and 0xFFF.

The conversion of a strictly non-negative voltage range into a symmetrical bipolar range is achieved using a standard op amp connected as a difference amplifier as shown in Figure 1.

Referring to Figure 1, the output voltage of the op amp A_1 is

$$V_O = \frac{R_4}{R_3 + R_4}\left(1 + \frac{R_2}{R_1}\right)OUT - \frac{R_2}{R_1}\;V_{ref} \tag{1}$$

When $R_2/R_1 = R_4/R_3$ the op amp works as a real differential amplifier and, in this case, equation (1) simplifies to:

$$V_O = \frac{R_2}{R_1}\left(OUT - V_{ref}\right) = A_{DM}\left(OUT - V_{ref}\right)$$

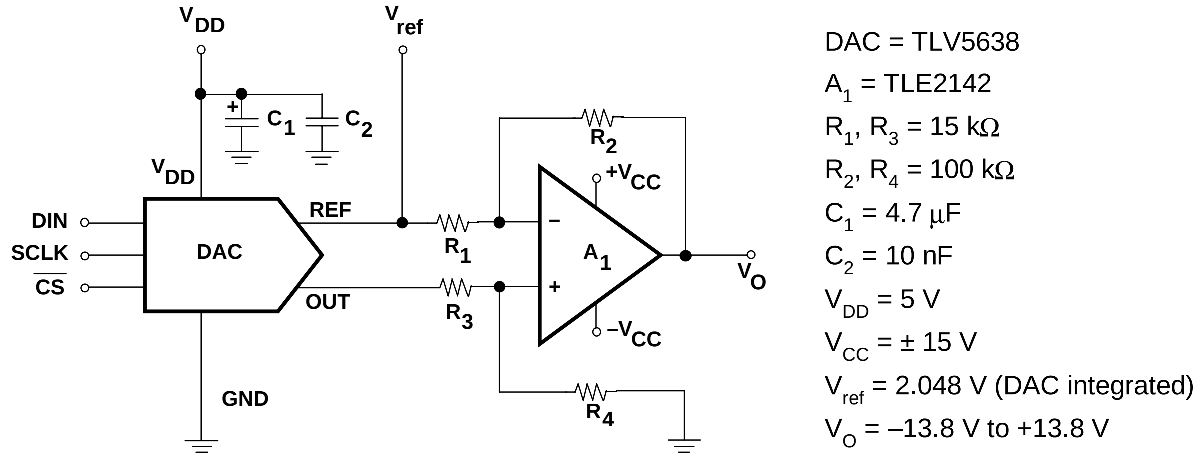

Figure 1. TLV56xx With Bipolar Output

$$\frac{R_4}{R_3} = (1+x)\frac{R_2}{R_1}; \quad |x| << 1$$

In this case, equation (1) becomes

$$V_O = \frac{R_2}{R_1}\left[\frac{\left(1+\frac{R_2}{R_1}\right)(1+x)}{1+\frac{R_2}{R_1}(1+x)}OUT - V_{ref}\right] \approx A_{DM}\left[\left(OUT - V_{ref}\right) + \frac{OUT}{1+\frac{R_2}{R_1}}\; x + O(x^2)\right]$$

When OUT and V_{ref} share the common-mode voltage, V_{CM}, the output voltage and the common-mode gain are nonzero and

$$A_{CM} = \frac{V_O}{V_{CM}} \approx \left(\frac{R_2}{R_1 + R_2}\right)x$$

The common-mode rejection ratio, *CMRR*, is then

$$CMRR = \left|\frac{A_{DM}}{A_{CM}}\right| = \left(\frac{R_1 + R_2}{R_1}\right)\frac{1}{|x|} \approx \frac{R_2}{R_1}\cdot\frac{1}{|x|}; \qquad R_2 >> R_1$$

This result shows that it is crucial to choose very precise pairs of resistors to obtain an acceptably-high value of the common-mode rejection ratio.

Conclusion

An easy, cost-effective method to generate bipolar outputs from a DAC is by using a bipolar difference amplifier to condition the DAC's output signal. The output voltage range depends mainly on the choice of op amp and its resistors. However, an acceptable common-mode rejection ratio can be obtained only by using resistor pairs of very high accuracy. Therefore, for those applications that are CMRR critical, an instrumental amplifier should be used instead.

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