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 × V_{ref}; however, it can easily be signal-conditioned to produce a bipolar range.

Solution

The DAC's output voltage is:

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

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:

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

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:

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

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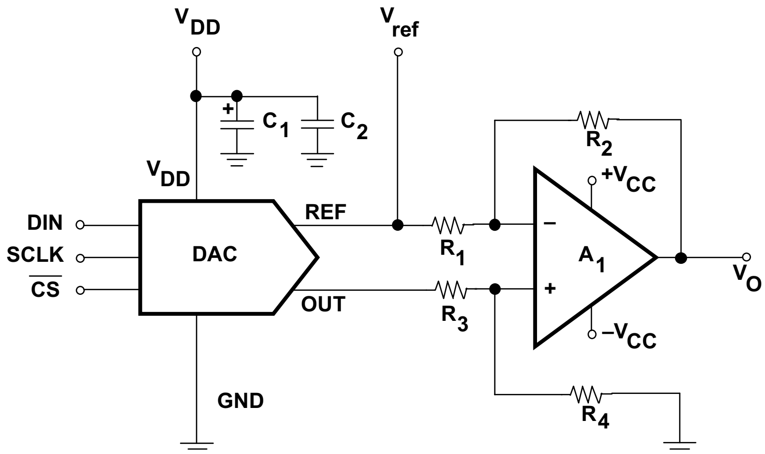

DAC = TLV5638
A_1 = TLE2142
R_1, R_3 = 15 kΩ
R_2, R_4 = 100 kΩ
C_1 = 4.7 µF
C_2 = 10 nF
V_{DD} = 5 V
V_{CC} = ± 15 V
V_{ref} = 2.048 V (DAC integrated)
V_O = –13.8 V to +13.8 V

Figure 1. TLV56xx With Bipolar Output

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

In this case, Equation 1 becomes:

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

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:

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

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.

Revision History

Changes from Original (December 2000) to A Revision	Page
• Changed format to current TI application report template.	1

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

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