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 × Vref; however, it can easily be signal-conditioned to produce a bipolar range.

Solution

The DAC’s output voltage is:

\[ \text{OUT} = 2V_{\text{ref}} \times \frac{\text{CODE}}{(0x1000)} \]

where CODE is the DAC’s digital input, OUT is its analog output, and Vref 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 A1 is:

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

(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:

\[ V_O = \frac{R_2}{R_1} (\text{OUT} - V_{\text{ref}}) = A_{\text{DM}}(\text{OUT} - V_{\text{ref}}) \]
In this case, Equation 1 becomes:

\[
\frac{V_O}{V_{CM}} = \frac{A_{CM} (1 + x)}{1 + \frac{R_2}{R_1}} \approx A_{CM} \left(1 + \frac{R_2}{R_1} \right) x + O(x^2)
\]

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

\[
A_{CM} = \frac{V_O}{V_{CM}} \approx \left(1 + \frac{R_2}{R_1} \right) x
\]

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

\[
CMRR = \left| A_{CM} \right| = \left(1 + \frac{R_2}{R_1} \right) \frac{1}{x} \approx \frac{R_2}{R_1} \times \frac{1}{x} ; \quad R_2 \gg R_1
\]

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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