Two-DAC circuit adds and subtracts

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A typical way to add two binary words and provide an analog output is to use several digital ICs that drive a DAC. The circuit in **Figure 1** eliminates the use of several digital-IC packages and, hence, the need for the digital power supply. The circuit simultaneously carries out addition and subtraction on two 8-bit binary words and presents the output in bipolar analog form.

The hardware consists of four ICs, and the operation takes only 85 nsec, which is the settling time of the DACs plus the settling time of the op amp. IC_1, a precision 10V reference, provides the reference current for both multiplying DACs: IC_2 and IC_3. For these DACs, $I_{REFA}=10V/R_1$, and $I_{REFB}=10V/R_2$. In this case, $I_{REFA}=I_{REFB}=I_{REF}=2$ mA.

The output currents, I_{OA} and I_{OB}, depend on the respective A and B binary inputs and the input reference currents as follows:

$$I_{OA} = I_{REF} \bullet \left(\frac{N_A}{2^n}\right), \quad (1)$$

and

$$I_{OB} = I_{REF} \bullet \left(\frac{N_B}{2^n}\right), \quad (2)$$

where n is the number of input bits and N_A and N_B range in value from 0 to $2^n–1$, in accordance with the input binary words.

The DAC-08 has complementary current outputs. Therefore, you can express the complements of I_{OA} and I_{OB} as

$$\overline{I_{OA}} = I_{FS} - I_{OA}, \qquad (3)$$

and

$$\overline{I_{OB}} = I_{FS} - I_{OB}, \qquad (4)$$

where I_{FS}, the full-scale current of the DAC, is

$$I_{FS} = \frac{2^n - 1}{2^n} \cdot I_{REF}. \qquad (5)$$

The circuit configures IC_{4B} as a current-to-voltage converter. Thus,

$$V_{OUT(A+B)} = I_{OA} \cdot R_5 + I_{OB} \cdot R_5. \qquad (6)$$

Substituting I_{OA} and I_{OB} from **Equations 1** and **2** into **Equation 6** yields

$$V_{OUT(A+B)} = I_{REF} \cdot \left(\frac{N_A}{2^n}\right) \cdot R_5 + I_{REF} \cdot \left(\frac{N_B}{2^n}\right) \cdot R_5 = \frac{I_{REF} \cdot R_5}{2^n} \cdot (N_A + N_B). \qquad (7)$$

IC_{4A} serves as both a current-to-voltage converter for $\overline{I_{OB}}$ and a buffer to the potential drop across R_3 because of the flow of $\overline{I_{OA}}$. Thus, assuming $R_3=R_4$,

$$V_{OUT(A-B)} = \overline{I_{OB}} \cdot R_4 - \overline{I_{OA}} \cdot R_3 = (\overline{I_{OB}} - \overline{I_{OA}}) \cdot R_4. \qquad (8)$$

Substituting I_{OA} and I_{OB} from **Equations 3** and **4** into **Equation 8** and assuming that $R_4=R_5$ result in

$$\begin{aligned} V_{OUT(A-B)} &= \left[(I_{FS} - I_{OB}) - (I_{FS} - I_{OA})\right] \cdot R_4 \\ &= (I_{OA} - I_{OB}) \cdot R_5 \\ &= \left[I_{REF} \cdot \left(\frac{N_A}{2^n}\right) - I_{REF} \cdot \left(\frac{N_B}{2^n}\right)\right] \cdot R_5 \\ &= \frac{I_{REF} \cdot R_5}{2^n} \cdot (N_A - N_B). \end{aligned} \qquad (9)$$

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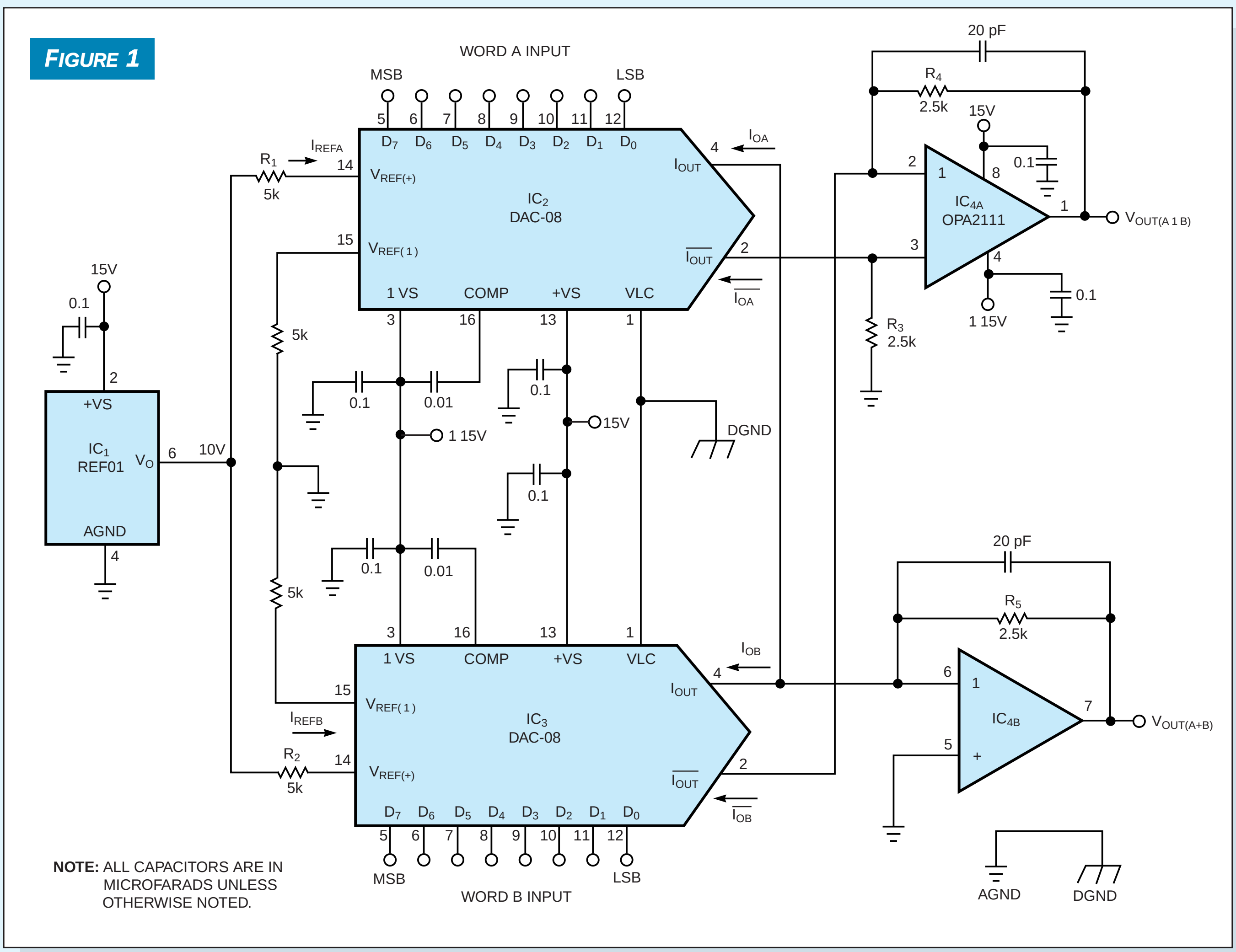

Two DACs and two op amps simultaneously carry out both addition and subtraction on two 8-bit binary words.