Multiplying DAC makes programmable resistor

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Figure 1 shows a configuration that implements a digitally programmable resistor using a quad op amp and a multiplying DAC. The circuit is equivalent to a voltage-controlled resistor. The simulated resistor has a value that reflects the ratio of a fixed resistor ($R_X$) and a control voltage. Applications include generating precise resistance values for remotely controlling monostable multivibrators and configuring voltage-controlled loads in simulation circuits. The circuit provides linear control of resistance using the AD7538 14-bit multiplying DAC. You can obtain logarithmic control of the resistance by using an AD7111A logarithmic DAC as the voltage-control element.

Figure 1 A multiplying DAC implements a linear, digitally programmable resistor.

Analysis of the circuit in Figure 1 reveals the following:

$$v_1 = v_{IN} \left( \frac{R_2}{R_1 + R_2} \right) \left( v_{IN} + Dv_{IN} \right)$$
where $D$ is input code to the multiplying DAC.

$$V_2 = V_i + V_i \left( \frac{R_3}{R_3 + R_4} \right).$$

If $R_1 = R_2 = R_3$, then

$$V_2 = V_{IN} - D V_{IN},$$

$$I_{IN} = \frac{V_{IN} - V_2}{R_X} = \frac{D V_{IN}}{R_X}, \text{ and}$$

$$R_{IN} = \frac{V_{IN}}{D V_{IN} / R_X} = \frac{R_X}{D}.$$  

The circuit in Figure 1 operates as a voltage-controlled current source. You can adapt it for use as a basic functional block in the design of a biquad filter. In the adaptation, you modify the circuit to provide a voltage-controlled capacitor rather than a resistor. (DI #2384).

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