# Inverted R-2R DAC

There are two ways in which the R-2R ladder network may be used as a DAC—known respectively as the voltage mode and the current mode. They are sometimes called "normal"

The circuit shown in Figure is a simple 4-bit digital-to-analog converter. It is actually just a variant of a simple op amp summer circuit, i.e., an operational amplifier configured to output a voltage that is proportional to the sum of the input voltages. In this circuit, the inputs are binary weighted with respect to each other, with the binary weighting of the inputs achieved by the R-2R ladder resistor network at the non-inverting input of the op-amp.

As its name implies, the R-2R network consists of resistors with only two values, R and 2R (10K and 20K, respectively, in the circuit shown). The input $S_N$ to bit N is '1' if it is connected to a voltage $V_R$ and '0' if it is grounded. The output $V_o$ of an R-2R ladder DAC with N bits is:

$$V_o = V_R/2^N (S_{N-1}2^{N-1} + S_{N-2}2^{N-2}+...+S_02^0).$$

Thus, the output Vo of the 4-bit R-2R ladder DAC in Figure 1 is:

$$V_o = V_{Ref} (S_3/2 + S_2/4 + S_1/8 + S_0/16)$$

where $S_3$, $S_2$, $S_1$, and $S_0$ are the logic inputs ('1' or '0') for bits 3, 2, 1, and 0, respectively.

The number of bits of this DAC may be increased by connecting more switches with corresponding R/2R resistors.

While some types of multiplying DACs will work only with references of one polarity (two quadrants) others handle bipolar (positive or negative) references, and can work with an ac signal as a reference as well. A bipolar DAC that will work with bipolar reference voltages is known as a four-quadrant multiplying DAC. Some types of MDACs are so configured that they can work with reference voltages substantially greater than their supply voltage. Current-mode ladder networks and CMOS switches permit positive, negative, and ac Voltage as previously shown in

Figure. While this is a simple implementation of an MDAC, several others are possible. Another popular form of R-2R DAC switches equal currents into the R-2R network as shown in Figure . This architecture was first implemented by Bernard M. Gordon at EPSCO (now Analogic, Inc.) in a vacuum tube 11-bit, 50-kSPS successive approximation ADC. Gordon's 1955 patent application (Reference 5) describes the ADC, which was the first commercial offering of a complete converter. In this architecture the output impedance of the DAC is equal to R, and this structure is often used in high-speed video DACs. A distinct advantage is that only a 2:1 resistor ratio is required regardless of the resolution.

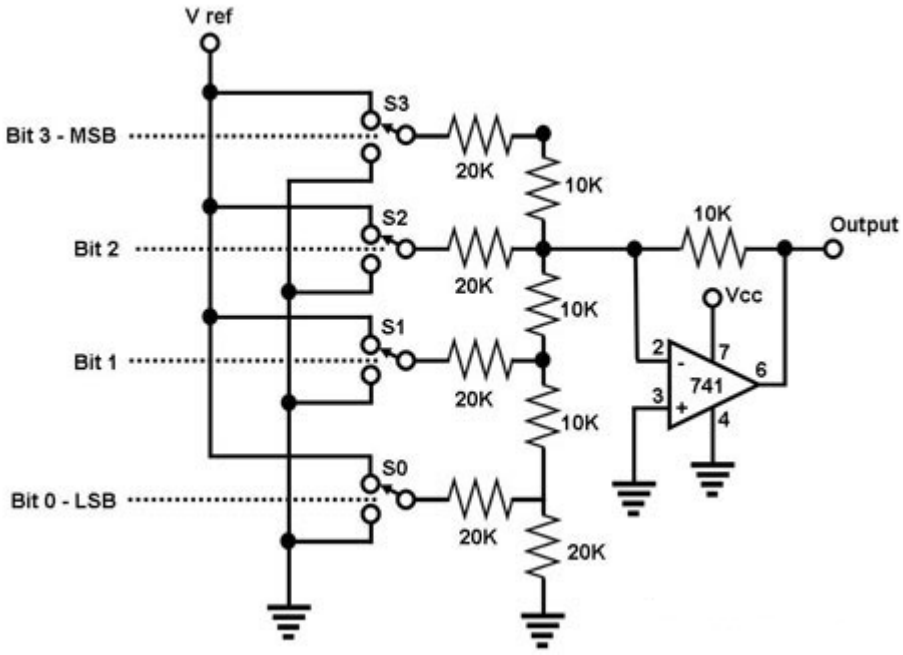


**Figure 5.4**