



ROHINI

COLLEGE OF ENGINEERING & TECHNOLOGY

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(AUTONOMOUS)

DATA CONVERTERS

- Most of the real world physical quantities such as voltage, current, temperature, pressure and time etc are available in analog form.
- Even though an analog signal represents a real physical parameter with accuracy, it is difficult to process, store, or transmit the analog signal without introducing considerable error because of superimposition of noise as in the case of amplitude modulation.
- Therefore, for processing, transmission and storage purposes, it is often convenient to express these variables in digital form. It gives better accuracy and reduces noise.
- The operation of any digital communication system is based upon Analog to Digital (A/D) and Digital to Analog (D/A) conversion.
- Figure 10.1, highlights a typical application with in which A/D and D/A conversion is used.

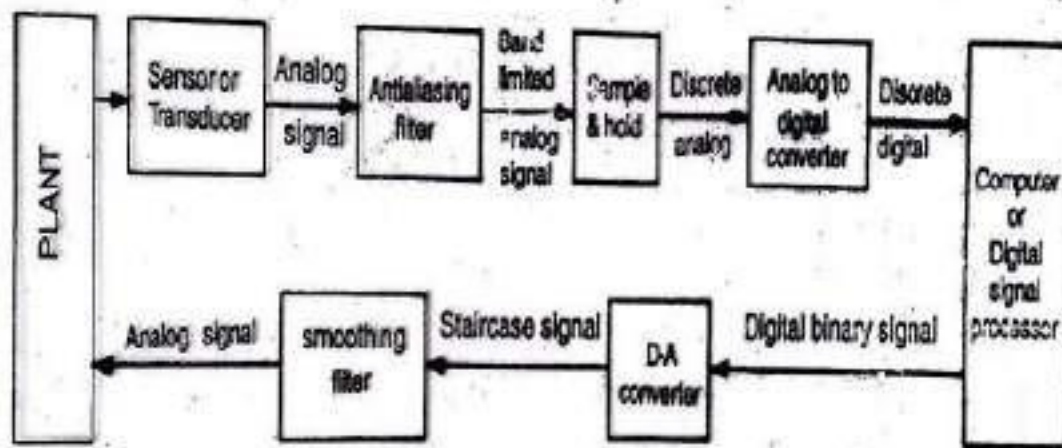


Fig. 10.1 Circuit showing application of A/D and D/A converter



- The analog signal obtained from the transducer is band limited by antialiasing filter. The signal is then sampled at a frequency rate more than twice the maximum frequency of the band limited signal.
- The sampled signal has to be held constant while conversion is taking place in A/D converter. This requires that ADC should be preceded by a sample and hold (S/H) circuit.
- The ADC output is a sequence in binary digit. The micro-computer or Digital signal processor performs the numerical calculations of the desired control algorithm.
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- The ADC output is a sequence in binary digit. The micro-computer or Digital signal processor performs the numerical calculations of the desired control algorithm.
- The D/A converter is to convert digital signal into analog and hence the function of DAC is exactly opposite to that of ADC. The D/A converter is usually operated at the same frequency as the ADC.
- The output of a D/A converter is commonly a staircase. This staircase like output is passed through a smoothing filter to reduce the effect of quantization noise.

Applications of A/D and D/A conversion

- The scheme given in Figure 10.1 is used either in full or in part in applications such as digital audio recording and playback, computer, music and video synthesis, pulse code modulation transmission, data acquisition, digital multi meter, direct digital control, digital signal processing, microprocessor based instrumentation.

Basic DAC techniques

The schematic of a DAC is shown in Figure 10.2.

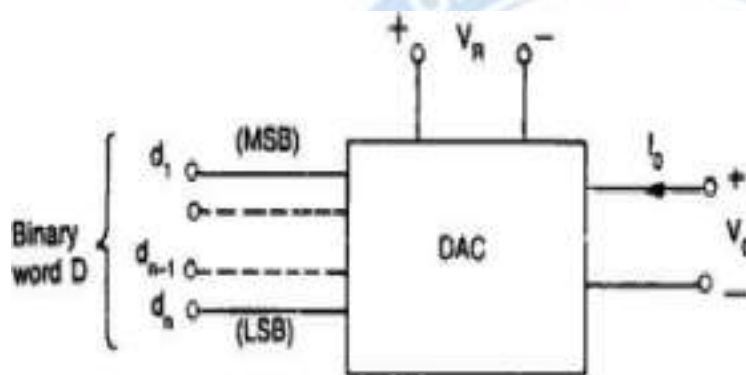


Fig. 10.2 Schematic of a DAC

- The input is an n-bit binary word D and is combined with a reference voltage V_R to give an analog output signal.
- The output of a DAC can be either a voltage or current.
- For a voltage output DAC, the D/A converter is mathematically described as $V_o = K V_{fs}(d_1 2^{-1} + d_2 2^{-2} + d_3 2^{-3} + \dots + d_n 2^{-n})$ --- (1)

Where V_o = output voltage, V_{fs} = full scale output

voltage K = scaling factor usually adjusted to unity

$d_1 d_2 d_3 \dots d_n$ = n-bit binary fractional word

d_1 = MSB with weight of $V_{fs}/2$,
 $V_{fs}/2^n$

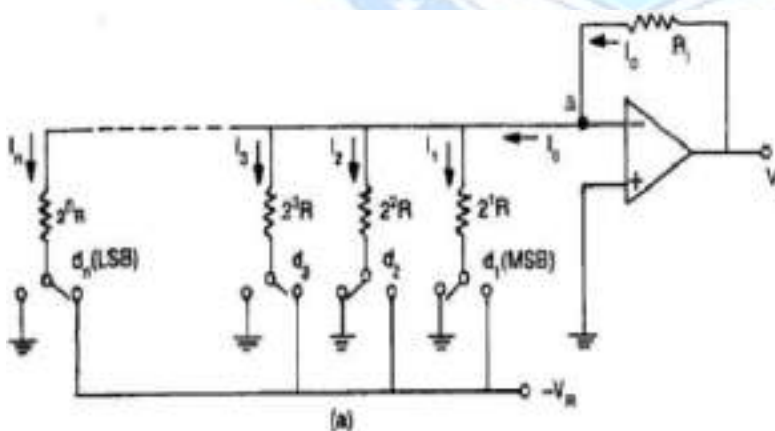
d_n = LSB with a weight of

There are various ways to implement eq(1). Here we shall discuss the following resistive techniques only

- ❖ Weighted resistor DAC
- ❖ R-2R Ladder DAC
- ❖ Inverted R-2R Ladder DAC

WEIGHTED RESISTOR DAC:

One of the simplest circuits shown in Figure 10.3a uses a summing amplifier with a binary weighted resistor network. It has n -electronic switches $d_1, d_2, d_3, \dots, d_n$, controlled by Binary input word.



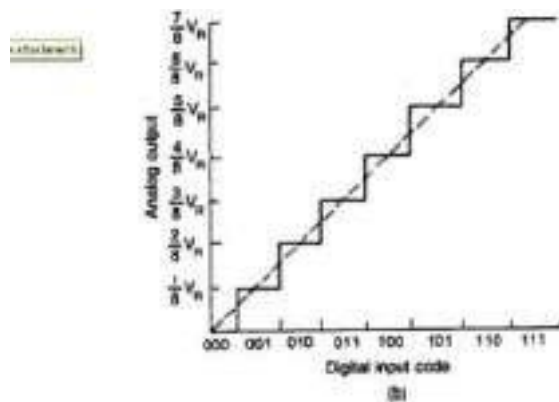


Fig. 10.3 (a) A simple weighted resistor DAC (b) Transfer characteristics of a 3-bit DAC

- These switches are single pole double throw (SPDT) type.
- If the Binary input to a particular switch is 1, it connects the resistance to thereference voltage ($-V_r$). And if the input bit is zero, the switch connects the resistor toground.
- From Figure 10.3a, the output current I_o for an ideal op-amp can be written as $I_o = I_1 + I_2 + \dots + I_n$

$$= (V_r/(2R)) d_1 + (V_r/(2^2 R)) d_2 + \dots + (V_r/(2^n R)) d_n$$

$$= V_r/R (d_1 2^{-1} + d_2 2^{-2} + \dots + d_n 2^{-n})$$

The output voltage

$$V_o = I_o R_f = V_r R_f/R (d_1 2^{-1} + d_2 2^{-2} + \dots + d_n 2^{-n}) \quad (2)$$

Comparing eq(1) with eq(2), we get

if $R_f = R$, then $K=1$, and $V_{fs} = V_r$

- The circuit shown in Figure 10.3a uses a $-ve$ reference voltage. The analog output voltage is therefore $+ve$ staircase as shown in Figure 10.3b for a 3-bit weighted resistor DAC.
- It may be noted that

- Although the op-amp in Figure 10.3a is connected in inverting mode, it can also be connected in non-inverting mode.
- The op-amp is simply working as a current-to-voltage converter.
- The polarity of the reference voltage is chosen in accordance with the type of the switch used. For example, for TTL compatible switches, the reference voltage should be +5V and the output will be –ve.

Problems with Weighted Resistor DAC

- The accuracy and stability of a DAC depends up on the accuracy of the resistors and tracking of each other with temperature.
- There are, however, a number of problems associated with this type of DAC.
- One of the disadvantages of Binary weighted resistor type DAC is the wide range of resistor values required.
- It may be observed that for better resolution, the input binary word length has to be increased. Thus, as the number of bits increases, the range of resistance value increases.
- For 8-bit DAC, the resistors required are $2^1 R$, $2^2 R$, -----, $2^8 R$. The largest resistor is
- 128 times the smallest one for only 8-bit DAC.
- For a 12-bit DAC, the largest resistance required is 5.12 M Ω if the smallest is 2.5K Ω .
- The fabrication of such a large resistance in IC is not practical. Also the voltage drop across such a large resistor due to the bias current would also affect the accuracy.
- The choice of smallest resistor value as 2.5 K Ω is reasonable, otherwise

loading effect will be there.

- The difficulty of achieving and maintaining accurate ratios over such a wide range especially in monolithic form restricts the use of weighted resistor DACs to below 8 bits.

R-2R LADDER DAC:

- Wide range of resistors are required in Binary Weighted Resistor type DAC. This can be avoided by using R-2R Ladder type DAC where only two values of resistors are required.
- It is well suited for integrated circuit realization. The typical value of R ranges from 2.5 K Ω to 10K Ω .
- For simplicity, consider a 3-bit DAC as shown in Figure 10.5a, where the switch position d1 d2 d3 corresponds to the Binary word 100.
- The circuit can be simplified to the equation form of Figure 10.5b and finally to Figure 10.5c.
- Then, voltage at node C can be easily calculated by the set procedure of network analysis as
- $-V_r ((2/3) R) / (2R + (2/3)R) = -V_r/4$
- The output voltage
- $V_o = -2R/R(-V_r/4) = V_r/2 = V_{fs}/2$

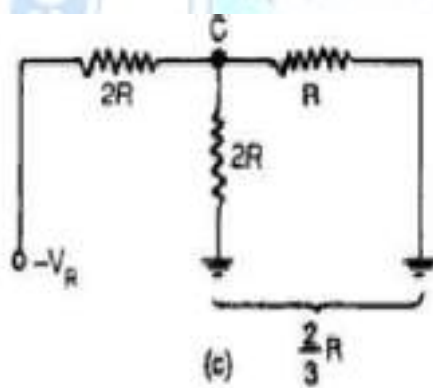
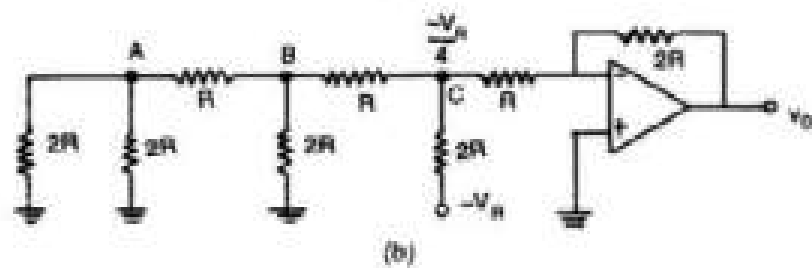
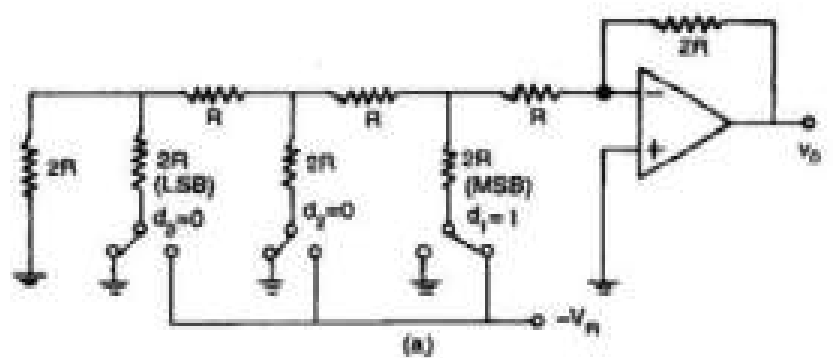


Fig. 10.5 (a) R-2R ladder DAC (b) Equivalent circuit of (a), (c) Equivalent circuit of (b)