DAC :-

Digital-To-Analog Conversion (DAC) :-

DAC is the process of taking a value represented in digital code (such as straight binary or BCD) and converting it into a voltage or current which is proportional to the digital value, in fact or some other proportionality factor of the binary number.

Example :-

A 5-bit DAC has a current output. For a digital input of 10100, an output current of 10 mA is produced. What will I_{out} be for a digital input of 11101.

Solution :-

The digital input 10100 is the binary equivalent 0f $(20)_{10}$. Since I_{out}=10mA for this case the proportionality factor is 0.5

$\therefore\ I_{out} = 0.5 \times binary\ value$

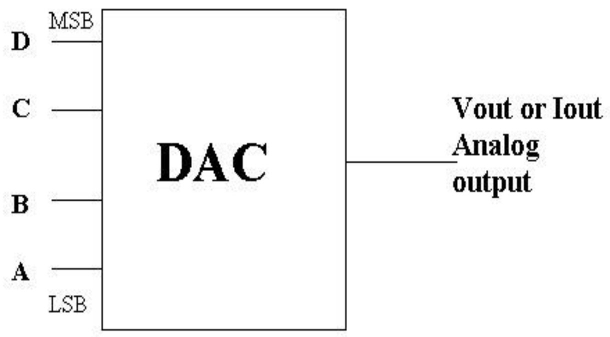
For the binary value 11101 :-

$(11101)_2 = (29)_{10}$

I_{ou}t=0.5 x 14.5 mA

Input weights :-

For the DAC shown below it should be noted that each digital input contributes a different amount to the analog output. This easily seen if we examine the cases where only one input is HIGH.



D	C	B	A	V_{out} (V)
0	0	0	1	1
0	0	1	0	2
0	1	0	0	4
1	0	0	0	8

The contributions of each digital input are weighted according to their position in the binary number. Thus, in the above table. A, which is the LSB, has a weight of 1V, B has weight of 2V, C has a weight of 4V, and D, the MSB, has the largest weight, 8V.

Example :-

A 5-bit DAC produces V_{out}=0.2V for a digital input of 00001. Find the value of V_{out} for a 11111 input.

Solution :-

$$0.2_{(LSB)}+0.4+0.8+1.6+3.2_{(MSB)} = 6.2V$$

Resolution (step size) :-

Resolution is define as the smallest change that can occur in the analog output as a result of a change in the digital input. The resolution is always equal to the weight of the LSB and is also referred to as the step size.

The percentage Resolution can be defined as:

$$\% Resolution = \frac{step\ size}{Full\ scale} \times 100\%$$

Example :-

A 10-bit D/A has a step size of 10 mV. Determine the full scale output voltage and percentage resolution.

Solution:-

With 10 bits. There will be 2^{10}-1=1023 steps of 10 mV each. The full scale output voltage will therefore be :-

10mV x 1023 = 10.23V and

$$\% Resolution = \frac{step\ size}{Full\ scale} \times 100\% \cong 0.1\%$$

Example :-

A computer controlling the speed of a motor. The 0-2 mA analog current from the DAC is amplified to produce motor speeds from 0 t0 1000 rpm. How many bits should be used if the computer is to be able to produce a motor speed that is within 2 rpm of the desired speed.

Solution:-

The motor speed will range from 0 to 1000 rpm as DAC goes from zero to full-scale. Each step in the DAC output will produce a step in the motor speed.

The step size to be no greater than 2 rpm. Therefore, a 500 steps is needed

$\therefore\ 2^N - 1 \geq 500$

$2^N \geq 501$

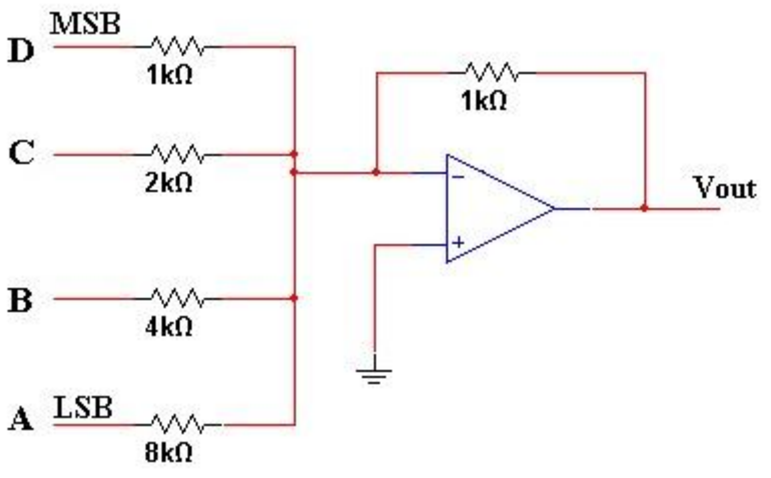
Since $2^9 = 512$, therefore we needs 9-bit DAC.

Disadvantages of weighted resistance D/A :-

1) No, of Resistance is very high when N No. of i/p bits is high so produce so many errors to cct.
2) When No. of i/p bits increased the MSB resistance is very small so will draw very much high currents so not good .

DAC circuits :-

1\ Basic Circuit



$$V_{out} = -(\frac{1}{8}A + \frac{1}{4}B + \frac{1}{2}C + D)$$

Note :- the binary input (A,B,C and D) represents 5V for logic 1 and 0V for logic 0.

Example:-

For the above DAC circuit. Determine the analog voltage V_{out} equivalent to the following binary input :-

a) A=0, B=1, C=1, D=0

b) A=0, B=0, C=1, D=1

Solution :-

a)

$$V_{out} = -(\frac{1}{8}A + \frac{1}{4}B + \frac{1}{2}C + D)$$

$$V_{out} = -5\left(\frac{1}{4} + \frac{1}{2}\right) = -\frac{15}{4} = -3.75V$$

b)

$$V_{out} = -5\left(\frac{1}{2} + 1\right) = -\frac{15}{2} = -7.5V$$

Note:- DAC resolution is 0.625V

Example :-

Repeat previous example with R_f=250Ω

Solution :-

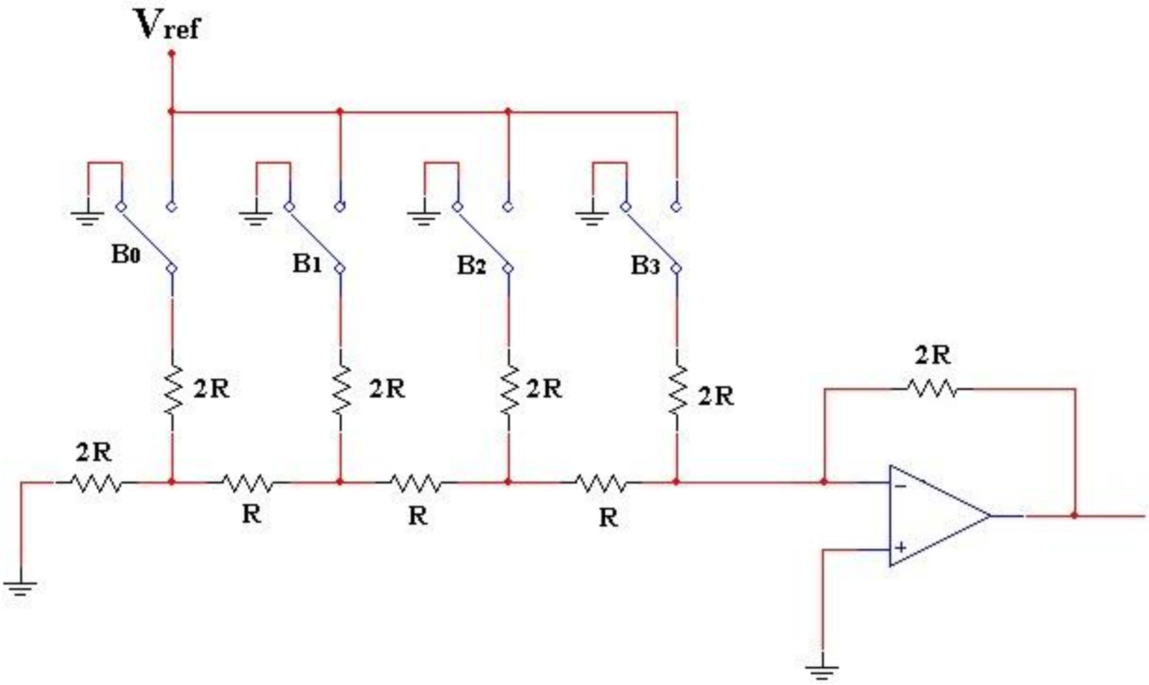
a) $V_{out} = -5\left(\frac{0.25}{4} + \frac{0.25}{2}\right) = -1.565V$

b) $V_{out} = -5\left(\frac{0.25}{4} + 0.25\right) = -1.875V$

Note:- DAC resolution is 0.15625V

2\ R/2R Ladder :-

The DAC circuit we have looked at thus far use binary weighted resistors. This method has a problem of large difference in resistor values between the LSB and MSB and this very difficult in the Ic fabrication technology. For this reason it is preferable to have a circuit that uses resistances that are fairly close in value. One of the most widely used DAC circuits that stratifies this requirement is the R/2R ladder network. As shown below.



$$V_{out} = -\frac{V_{ref}}{8} \times (B)_{10} \qquad For\ 4-bit\ DAC$$

$$In\ general \quad V_{out} = -\frac{2V_{ref}}{2^{N-T}} \times (B)_{10}$$

Example :-

For the following binary input to the R/2R ladder DAC, find the equivalent analog output when V_{ref} =5V

a) 1011 b) 0111 c) 10111

Solution :-

a) $(1011)_2 = (11)_{10}$

$$V_{out} = -5 \times \frac{11}{8} = -6.875\, Volt$$

b) $(0111)_2 = (7)_{10}$

$$V_{out} = -5 \times \frac{7}{8} = -4.375\, Volt$$

c) $(10111)_2 = (23)_{10}$

$$V_{out} = -5 \times \frac{23}{16} = -7.1875\, Volt$$