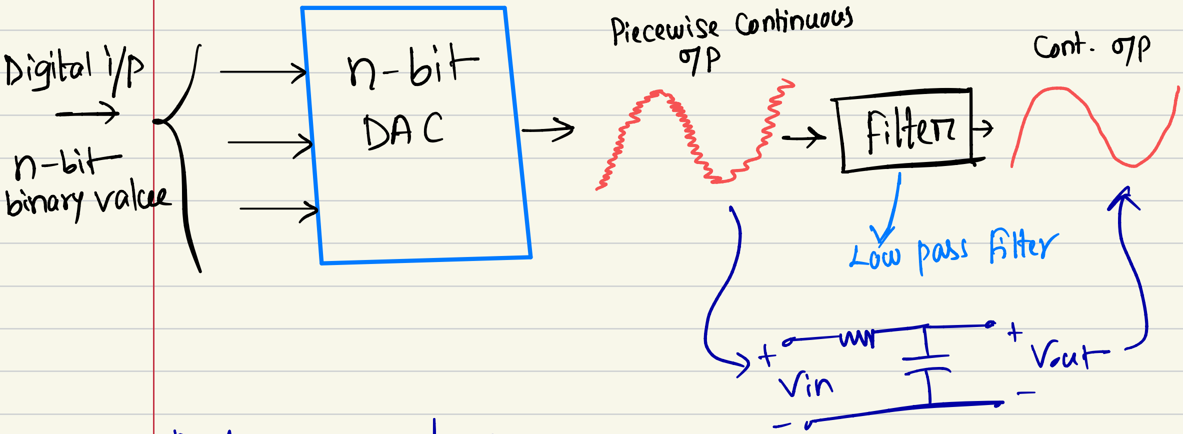
Digital to Analog Conversion



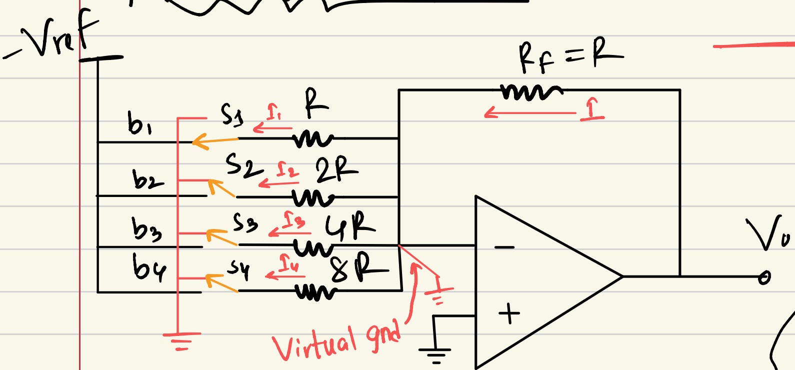
D/A Converters

- Binary Weighted Resistor D/A converter.
- R-2R Ladder

Binary weighted D/A converter:

→ 4 bit D/A conv.

Inputs → $b_1 b_2 b_3 b_4$



Inverting Summing Amplifier

$b_2 b_1 b_0$

100

$1\times2^2+0\times2^1+0\times2^0$

$=4+0+0=4$

→ Digital

011

$0\times2^2+1\times2^1+1\times2^0$

$=0+2+1=3$ → Analog

$b_{n-1}\times2^{n-1}+\dots+b_1 2^1+b_0 2^0$

$\rightarrow$ If b_1 is 1 $\rightarrow$ S_1 is connected to the resistor.

$\rightarrow$ If b_1 is 0 $\rightarrow$ S_1 is connected to ground.

here, $I = \frac{V_o - 0}{R} = \frac{V_o}{R}$

if $b_1 = 1 \rightarrow I_1 = \frac{0-(-V_{ref})}{R} = \frac{V_{ref}}{R}$

if $b_1 = 0 \rightarrow I_1 = \frac{0-0}{R} = 0$

$\therefore I_1 = b_1 \frac{V_{ref}}{R}$

Similarly $\rightarrow I_2 = b_2 \frac{V_{ref}}{2R}$

$I_3 = b_3 \frac{V_{ref}}{4R}$

$I_4 = b_4 \frac{V_{ref}}{8R}$

We can write, $I = I_1 + I_2 + I_3 + I_4$

$$\Rightarrow \frac{V_o}{R} = b_1 \frac{V_{ref}}{R} + b_2 \frac{V_{ref}}{2R} + b_3 \frac{V_{ref}}{4R} + b_4 \frac{V_{ref}}{8R}$$

$$\Rightarrow \boxed{V_o = V_{ref}\left(b_1 + \frac{b_2}{2} + \frac{b_3}{4} + \frac{b_4}{8}\right)}$$

Similarly

$\rightarrow$ for 3 bits $\rightarrow$ $V_o = V_{ref}\left(b_1 + \frac{b_2}{2} + \frac{b_3}{4}\right)$

$\rightarrow$ for 5 bits $\rightarrow$ $V_o = V_{ref}\left(b_1 + \frac{b_2}{2} + \frac{b_3}{4} + \frac{b_4}{8} + \frac{b_5}{16}\right)$

Practice Problem

Let 4 bit Binary weighted Resistor have
$V_{ref} = 16V$

i) if i/p is 1010, $V_o = ?$
ii) what is the maximum value of o/p.?

Soln:

i) $b_1 b_2 b_3 b_4$ $V_{ref} = 16V$
1010

$$\therefore V_0 = V_{ref}\left(b_1 + \frac{b_2}{2} + \frac{b_3}{4} + \frac{b_4}{8}\right)$$
$$= 16\left(1 + 0 + \frac{1}{4} + 0\right)$$
$$= 20V \quad \text{(Ans.)}$$

ii) max if $b_1 b_2 b_3 b_4 = 1111$

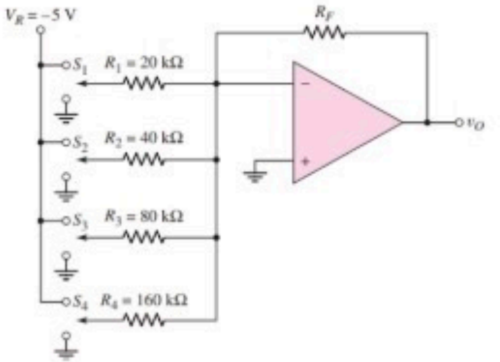
$$\therefore V_o = 16\left(1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8}\right)$$
$$V_{max} = 30V \quad \text{(Ans.)}$$

PP-2

Design 6 bit BWR D/A where $V_{max} = 10V$
Draw the ckt also.

PP-3

(a)	**Determine** the output voltage, ***vo*** in V of the 4-bit weighted-resistor D/A in the following figure for input =1010 and input=1100? Assume R_f= 5kΩ.
(b)	**Identify** the maximum allowed tolerance (± percent) in the value of R_1 so that the maximum error in the output is limited to $\pm\frac{1}{2}$ **LSB** quantized voltage value? (hint: Do two separate calculations for output error being $+\frac{1}{2}$**LSB** and $-\frac{1}{2}$**LSB** Then, calculate the percentage change in R1 in these two cases.)



a) Input = 1010 ; $R_F = 5k\Omega$

$$V_O = 5 \times \frac{5}{20} + 5 \times \frac{5}{80} = \boxed{1.5625V}$$

Input = 1100 ; $R_F = 5k\Omega$

$$v_o = 5 \times \frac{5}{20} + 5 \times \frac{5}{40} = \boxed{1.875V}$$

b) $1 \text{ LSB} = 5 \times \frac{5}{160} = 0.15625\text{ V}$

$\Rightarrow \frac{1}{2}\text{LSB} = 0.078125V$

$1 \text{ MSB} = 1.25V \rightarrow$

$V_O = 1.25 \pm 0.078125V$

$= 1.328125V$ or $1.171875V$

$V_o = 1 \text{ MSB} + \frac{1}{2}\text{LSB}$ or $V_o = 1 \text{ MSB} - \frac{1}{2}\text{LSB}$ Output error

$-5 \times \frac{5}{R_1} = 1.328125V$

or

$-5 \times \frac{5}{R_1} = 1.171875V$

$\Rightarrow$

$R_1 = 18.823k\Omega \rightarrow$ % change in $R_1 = \frac{20 - 18.823}{20} \times 100 = \boxed{5.88\%}$

or $21.33 k\Omega \rightarrow$ % change in $R_1 = \frac{21.33 - 20}{20} \times 100 = 6.67\%$

$\boxed{\text{Max tolerance} \rightarrow 5.88\%}$