Module-3

Analog Signal Processing

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TRY Yourself

1. $V_{REF} = 5V$

   LSB change $= 1mV$

   $\therefore N = \log_2\left(\frac{V_{REF}}{LSB}\right) = \log_2 5000 = 12.288$

   $\Rightarrow \boxed{N = 13}$

   $\therefore$ Resolution $= 13$

2. Let V_{cn} be actual change on a bit-to-bit basis.

   V_s is ideal change : $V_s = 1 LSB$ [$V_s = 0$ for $0 \to 1$]

   DNL at each step $= (V_{cn} - V_s)$ LSB's.

STEP	V_{cn}	DNL
0-1	0 LSB	0 LSB
1-2	1 LSB	0 LSB
2→3	1.5 LSB	0.5 LSB
3-4	0 LSB	-1 LSB
4-5	1.5 LSB	0.5 LSB
5-6	2 LSB	1 LSB
6-7	1 LSB	0 LSB
7-8	0.5 LSB	-0.5 LSB
8-9	-0.5 LSB	-1.5 LSB
9-10	1 LSB	0 LSB
10-11	2.5 LSB	1.5 LSB
11-12	$\boxed{-1 LSB}$	$\boxed{-2 LSB}$
12-13	2 LSB	1 LSB
13-14	2.5 LSB	1.5 LSB
14-15	0 LSB	-1 LSB

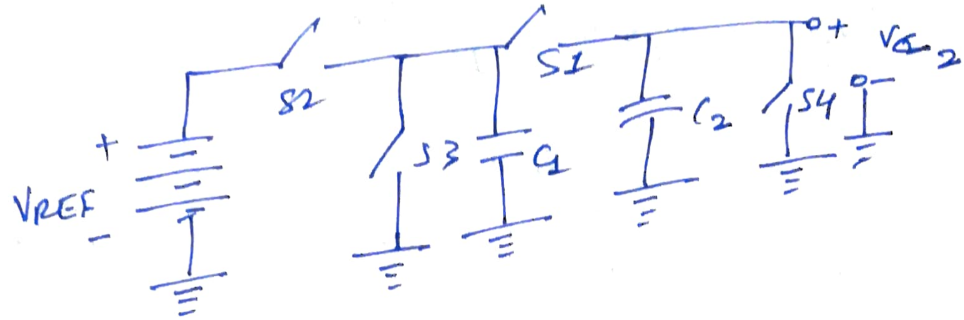
Worst case DNL = $\underset{+ve}{\underline{1.5 LSB}}$ and $\underset{-ve}{\underline{-2 LSB}}$

Maximum +ve INL = 1 LSB (5-6, 6-7, 13-14)

Maximum -ve INL = -1.5 LSB (11-12)

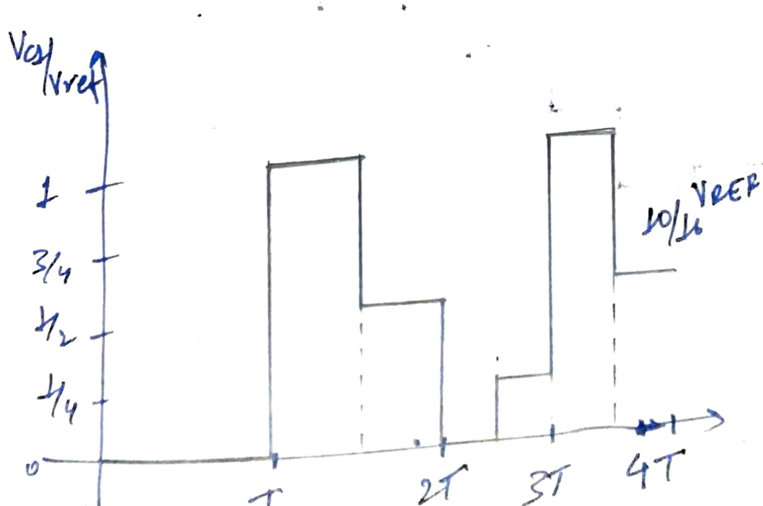
3) SERIAL DAC

$C_1 = C_2$



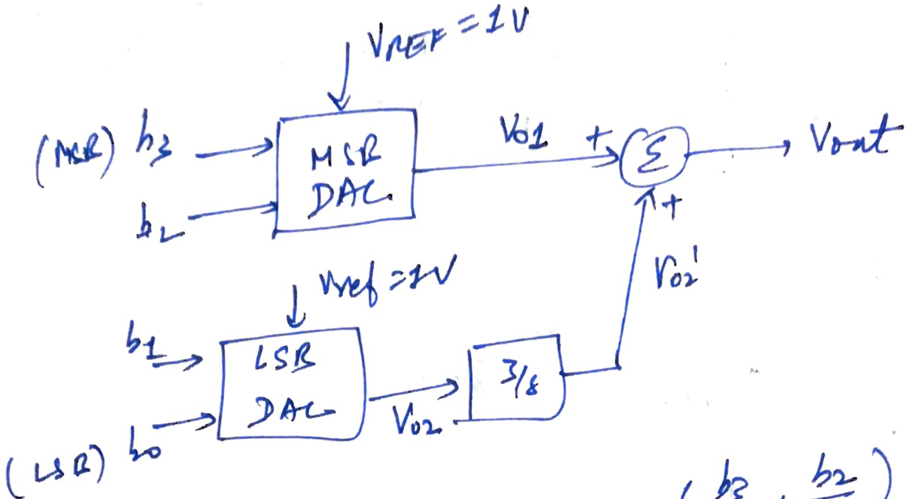
$b_1 b_2 b_3 b_4 = 1010$

Time (in T)	Bit & value	V_{C1}/V_{REF}	V_{C2}/V_{REF}
0-0.5	b_4 | 0	0	0
0.5-1	b_4 | 0	0	0
1-1.5	b_3 | 1	1	0
1.5-2	b_3 | 1	0.5	0.5
2-2.5	b_2 | 0	~~0.25~~ 0	0.5
2.5-3	b_2 | 0	0.25	0.25
3-3.5	b_1 | 1	1	0.25
3.5-4	b_1 | 1	0.625	0.625



Final $V_{c1} = V_{c2} = \frac{10}{16} V_{REF} = 0.625\, V_{REF}$

4.

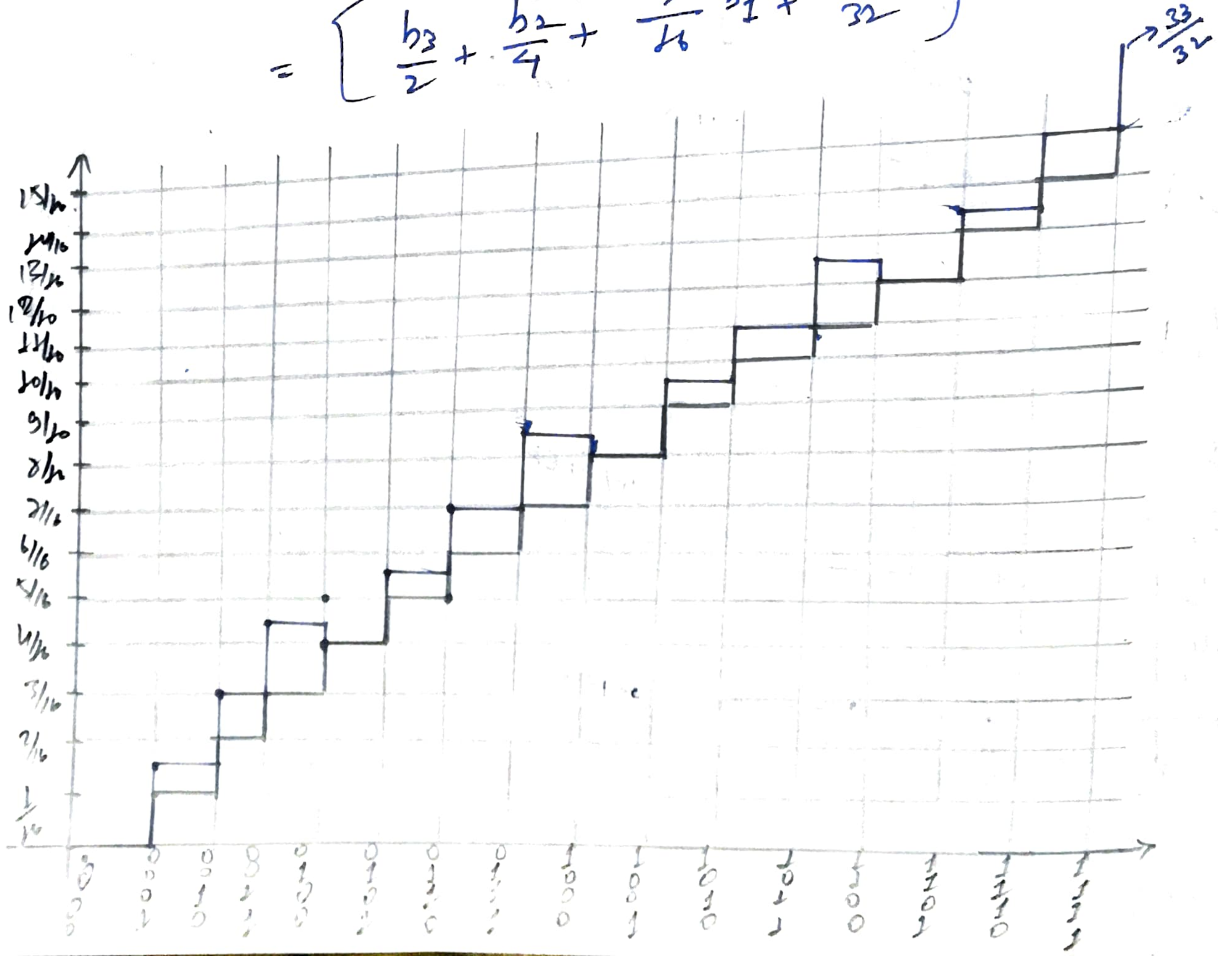


$$V_{o1} = \left(\frac{b_3}{2} + \frac{b_2}{4}\right) V_{REF} = \left(\frac{b_3}{2} + \frac{b_2}{4}\right) V$$

$$V_{o2}' = \frac{3}{8}\left[\frac{b_1}{2} + \frac{b_0}{4}\right] V_{REF} = \left[\frac{3}{16} b_1 + \frac{3}{32} b_0\right] V$$

$$V_{out} = V_{o1} + V_{o2}'$$

$$= \left[\frac{b_3}{2} + \frac{b_2}{4} + \frac{3}{16} b_1 + \frac{3}{32} b_0\right] V$$



$1\,LSB = \frac{1}{16}\,V$

Transition	Jump (LSB)	DNL (LSB)	INL (LSB)
0000 - 0001	1.5	0.5	0.5
0001 - 0010	1.5	0.5	1
0010 - 0011	1.5	0.5	1.5
0011 - 0100	-0.5	-1.5	0
0100 - 0101	1.5	0.5	0.5
0101 - 0110	1.5	0.5	1
0110 - 0111	1.5	0.5	1.5
0111 - 1000	-0.5	-1.5	0
1000 - 1001	1.5	0.5	0.5
1001 - 1010	1.5	0.5	1.0
1010 - 1011	1.5	0.5	1.5
1011 - 1100	-0.5	-1.5	0
1100 - 1101	1.5	0.5	0.5
1101 - 1110	1.5	0.5	1.0
1110 - 1111	1.5	0.5	1.5

DNL = 0.5 LSB & −1.5 LSB

INL = +1.5 LSB

This DAC is not monotonic as the value decreases as the digital input increases.

5c

8 bit ADC, $V_{ref} = 4\,V$

$$V_{LSB} = \frac{V_{ref}}{2^N} = \frac{4}{2^8} = 15.625\,mV$$

$$V_{Q(RMS)} = \frac{V_{LSB}}{\sqrt{12}} = \frac{1}{64\sqrt{12}} = \frac{1}{128\sqrt{3}}\,V$$

$$= 4.51\,mV$$

Full Scale Sine Wave

$V_{p-p} = V_{ref} =$

$\therefore V_{rms} = \frac{V_{ref}}{2\sqrt{2}} = \frac{4}{2\sqrt{2}} = \sqrt{2}\ V$

$SNR_{full} = \frac{1.414\ V}{4.51\ mV} = 313.53$

$SNR_{full}(dB) = 20\log(313.53)\ dB$

$= 49.92\ dB$

Half Scale Sine Wave

$V_{pp} = 4V_{ref}/2$

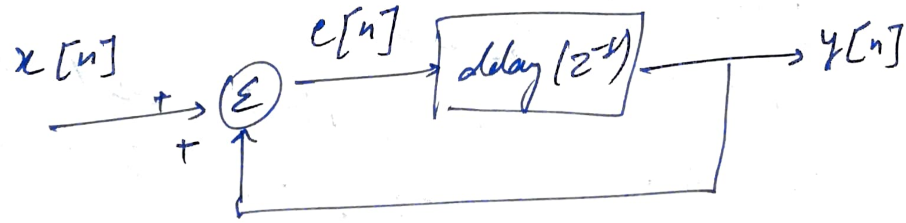
$\therefore V_{rms} = \frac{V_{ref}}{4\sqrt{2}} = \frac{1}{\sqrt{2}} V = 0.707\ V$

$SNR_{half} = \frac{0.707\ V}{4.51\ mV} = 156.76$

$SNR_{half}(dB) = 20\log(156.76)$

$= 43.90\ dB$

6c
I



$e[n] = x[n] + y[n]$

$y[n] = e[n-1]$

$\therefore y[n] = x[n-1] + y[n-1]$

Applying z-transform

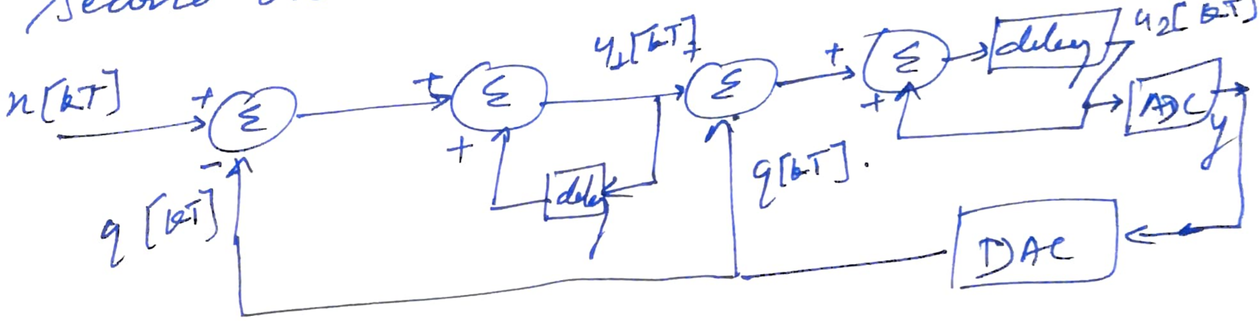
$Y[z] = z^{-1} X[z] + z^{-1} Y[z]$

$$\Rightarrow \quad \frac{Y[z]}{\alpha[z]} = \frac{z^{-1}}{1-z^{-1}}$$

z^{-1} is the delay part & $\frac{1}{1-z^{-1}}$ is the Integrator T-F.

$\therefore$ Given block performs an integration function.

7. Second-Order $\Sigma-\Delta$ modulator



We have,

$$Q_e[kT] = q[kT] - u_2[kT]$$

$$y[kT] = q[kT] \qquad (\because 1 \text{ bit ADC})$$

$$y[kT] = q[kT] = Q_e[kT] + u_2[kT]$$

$$= Q_e[kT] + \left[u_1[kT-T] - q[kT-T] + u_2[kT-T]\right]$$

$$y[kT] = Q_e[kT] + u_1[kT-T] - Q_e[kT-T]$$

$$u_1[kT] = x[kT] - q[kT] + u_1[kT-T]$$

$$u_1[kT-T] = x[kT-T] - q[kT-T] + u_1[kT-2T]$$

$$= x[kT-T] - \left[Q_e[kT-T] + u_1[kT-2T] - Q_e[kT-2T] + u_1[kT-2T]\right]$$

$$u_1[kT-T] = x[kT-T] - Q_e[kT-T] + Q_e[kT-2T]$$

$$y[kT] = x[kT-T] + Q_e[kT] - 2Q_e[kT-T] + Q_e[kT-2T]$$