Analog to Digital Converters

- i) Flash A/D converter ✓
- ii) Dual slope converter ✗
- iii) Successive Approx. ADC ✗

Flash A/D Converter:

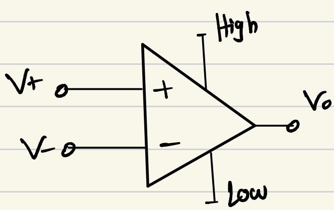
Advantages

- Fastest ADC. It requires one clock cycle to convert the analog to digital data.
  - suitable for large bandwidth applications.
    e.g. Satellite comm., Radar, Oscilloscope.

Disadvantages

- It requires a lot component, cost ↑
- High power consumption.
- Large Die Area
- Limited Resolution (typically up to 8 bit)

Op Amp Comparator



if $V_+ > V_- \rightarrow V_o = \text{High}$
if $V_+ < V_- \rightarrow V_o = \text{Low}$

$V_o \rightarrow$ O/P
$V_+ \rightarrow$ Non inverting i/p
$V_- \rightarrow$ Inverting i/p

Q1 For an analog Signal → $V_{min} = 0V$, $V_{max} = 8V$ (V_{ref})
$n = 3$ bit (i) find the quantization range, quantized value and corresponding Digital signals, (ii) find i/p o/p characteristics.
(iii) Design a 3 bit Flash ADC converter

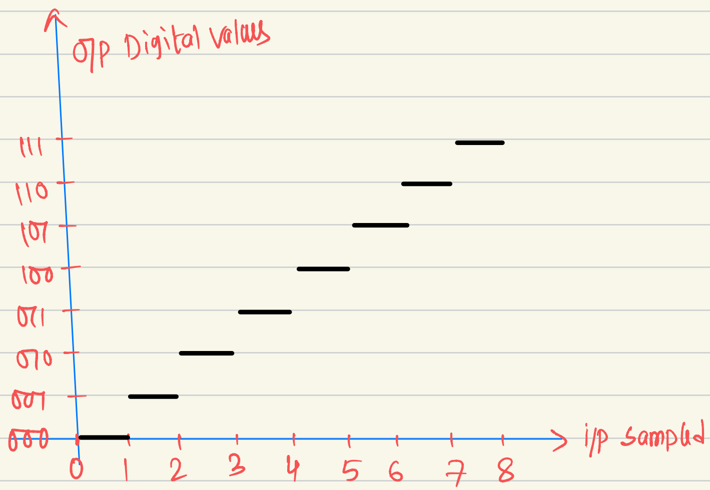
Ans:
$n=3$, $L = 2^n = 2^3 = 8$ levels. Step size, $\Delta = \dfrac{V_{max} - V_{min}}{2^n} = \dfrac{8-0}{8}$

$\Delta = 1$

(i)

Quantization Range	Quantized value	Digital/Encoded
7-8	7	111
6-7	6	110
5-6	5	101
4-5	4	100
3-4	3	011
2-3	2	010
1-2	1	001
0-1	0	000

(ii)



(iii)

Comparator $\rightarrow 2^{N}-1$
Resistors $\rightarrow 2^{N}$
$N \rightarrow$ bit

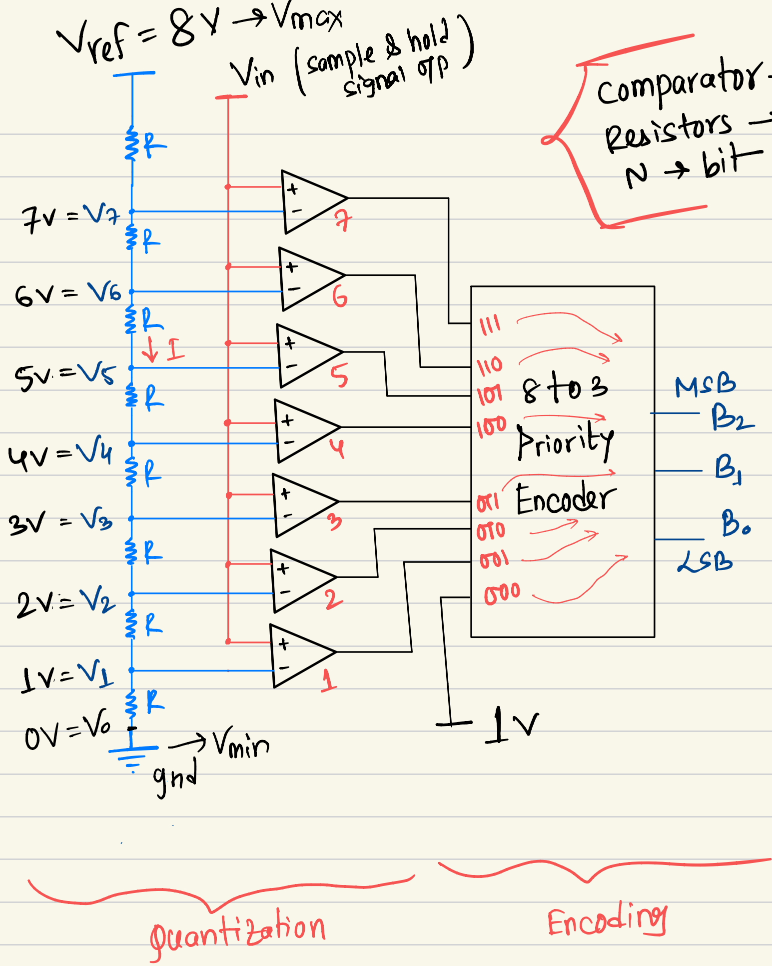


Fig: 3-bit Flash ADC

Using Voltage Divider Rule

$$V_1 = \frac{R}{R+7R} \times V_{ref}$$
$$= \frac{1}{8} \times 8 = 1V$$

$$V_2 = \frac{2R}{2R+6R} \times V_{ref}$$
$$= \frac{2}{8} \times 8 = 2V$$

$$V_3 = \frac{3R}{3R+5R} \times V_{ref}$$
$$= \frac{3}{8} \times 8 = 3V$$

$$V_4 = \frac{4R}{8R} \times 8 = 4V$$

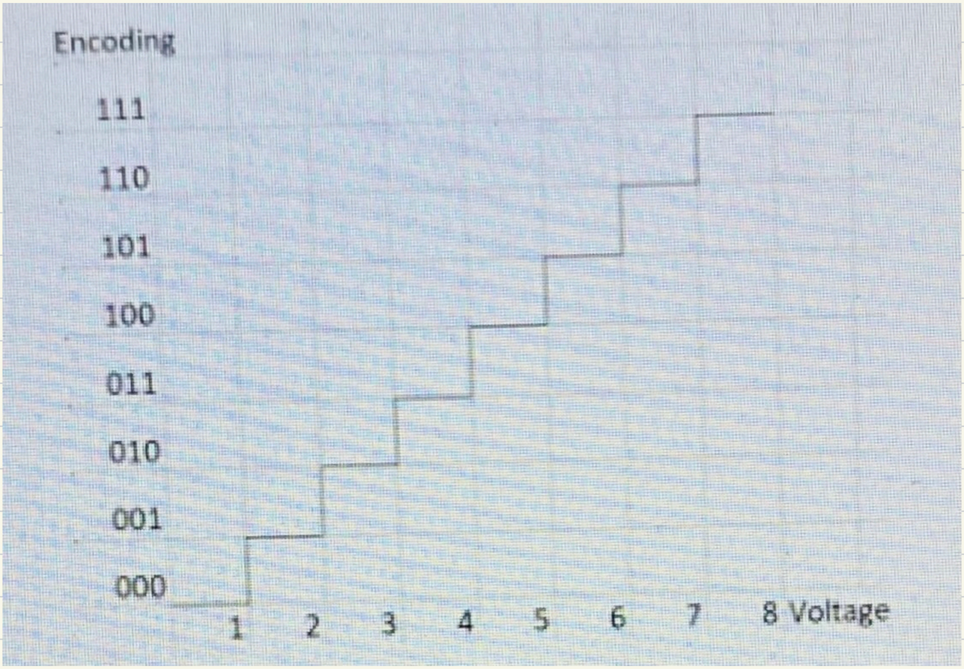
$$V_5 = \frac{5R}{8R} \times 8 = 5V$$

$$V_6 = \frac{6R}{8R} \cancel{\times} 8 = 6V$$

$$V_7 = \frac{7R}{8R} \times 8 = 7V$$

Made with Goodnotes

(11) # Input-Output Characteristics:



Formulas

given → n, V_{max}, V_{min}

→ levels, $L = 2^n$

→ stepsize / resolution, $\Delta = \dfrac{V_{max} - V_{min}}{2^n}$ → 1 LSB value.

→ Quantization error $= \dfrac{\Delta}{2}$

$$= \frac{1}{2}\,\frac{(V_{max} - V_{min})}{2^n}$$

→ Sampling period → T_s

→ Sampling Frequency, $F_s = \dfrac{1}{T_s}$

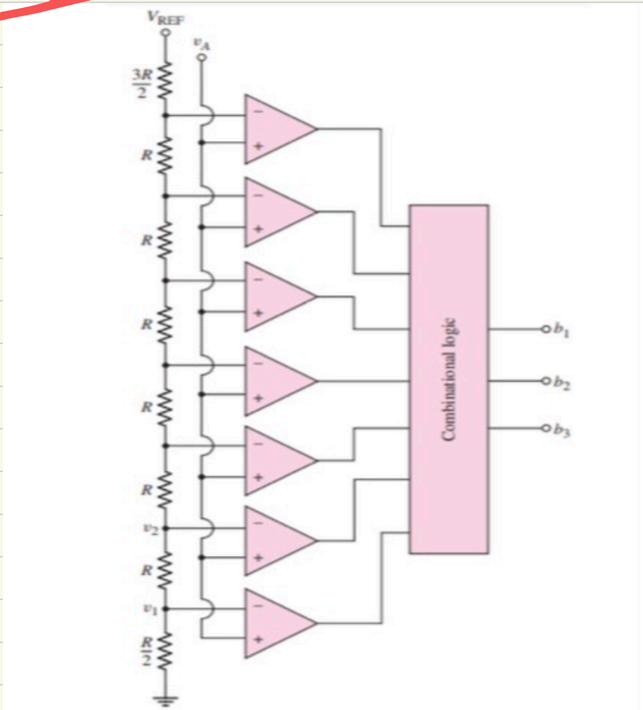
→ Minimum Sampling Frequency, $\boxed{F_s = 2 \times F_{input}}$

Hardwares

→ for n-bit Flash ADC

- → num of Resistors $= 2^n$
- → num of Comparators $= 2^n - 1$
- → $2^n : n$ priority Encoder

Practice Problem



For the given Flash ADC, the reference voltage is, $V_{ref} = 10V$

(a) Calculate the 1 LSB value or each step size or Resolution.

(b) Calculate the quantization range and corresponding Digital / Encoded Signal.

(c) Show Vin vs Vout graph.

(d) Find the ranges where min and max quantization error can occur.

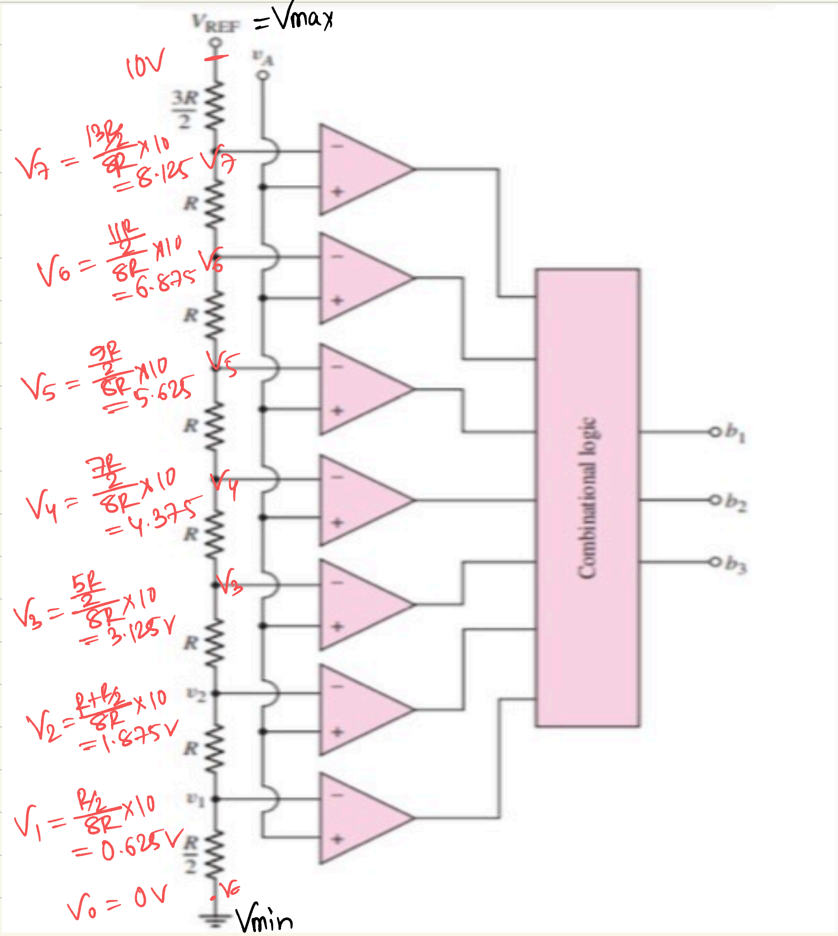
(e) If the input voltage Vin = 7v
   (i) Comment on the quantization range in which the i/p lies.
   (ii) Find the digital o/p for the given i/p.

(f) If the o/p is '010' what is the max and min value of VA that produces this o/p?

(g) If 1 bit was increased from this 3 bit Flash ADC, comment on the hardware changes required.

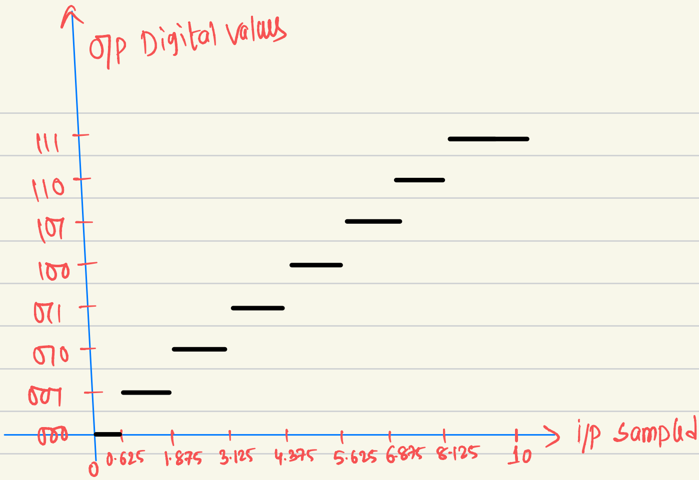
(a) $\Delta = \frac{V_{max} - V_{min}}{2^n} = \frac{10-0}{8} = 1.25$

(b)



Quantization Range	Encoded Signal
8.125 – 10	111
6.875 – 8.125	110
5.625 – 6.875	101
4.375 – 5.625	100
3.125 – 4.375	011
1.875 – 3.125	010
0.625 – 1.875	001
0 – 0.625	000

(c)



(d) min quantization error range → $\boxed{0 - 0.625}$

max " " " → $\boxed{8.125 - 10}$

quantization error $= \frac{\Delta}{2} = \frac{1.25}{2}$

(e) (i) → 6.875 to 8.125

(ii) → 110

(f) min VA = 1.875 V

max VA = 3.125 V

(g) $n = 3+1 = 4$ bit

∴ number of Resistors $= 2^n = 2^4 = 16$

number of comparators $= 2^n - 1 = 2^4 - 1 = 15$

$2^n : n$ Priority Encoder → 16 : 4

PP-2

An analog signal $8 \sin 4000\pi t$ is to be converted into Digital signal with a quantization error less than or equal to 0.781% of the input voltage range.

i) Find the required number of bits

ii) Determine the minimum sampling frequency and sampling Period.

Ans:

(i) We know $q.error = \frac{\Delta}{2} = \frac{1}{2} \frac{(V_{max} - V_{min})}{2^n}$

given $q.error = 0.781\% \; (V_{max} - V_{min})$

$$\therefore \frac{1}{2} \frac{(\cancel{V_{max} - V_{min}})}{2^n} = \frac{0.781}{100} (\cancel{V_{max} - V_{min}})$$

$$\frac{1}{2^{n+1}} = \frac{0.781}{100}$$

$$\therefore \boxed{n = 6}$$

(ii) $2\pi f_{i/p} t = 4000\pi t$

$\therefore f_{i/p} = 2000\,Hz$

$\therefore$ min sampling frequency $\rightarrow f_s = 2 f_{i/p}$

$$\boxed{f_s = 4000\,Hz}$$

Sampling Period, $T_s = \frac{1}{f_s} = \frac{1}{4000}$ sec