Analog to Digital Converters

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

Flash A/D Converter:

Advantages

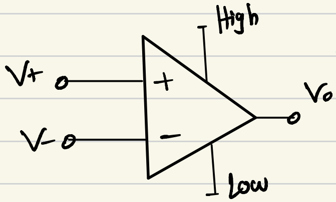
↳ Fastest ADC. It requires one clock cycle to convert the analog to digital data.

↳ 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

Let $V_{min} = 0V,\ V_{max} = 8V,\ n = 2$

$\therefore$ Levels, $L = 2^n = 4$, step size, $\Delta = \dfrac{V_{max} - V_{min}}{2^n}$

$$\Delta = \frac{8-0}{4} = 2$$

Quantization Range	Encoded/Digital signal
6 − 8	11
4 − 6	10
2 − 4	01
0 − 2	00

2-bit Flash ADC

$n = 2$, num of resistors $= 2^n = 4$

num of comparator $= 2^n - 1 = 3$

Priority encoder $2^n : n = 4:2$

Find V_0, V_1, V_2, V_3 using voltage devider Rule

$V_0 = 0V$

$V_1 = \dfrac{R}{R+R+R+R} \times 8$

$= \dfrac{1}{4} \times 8 = 2V$

$V_2 = \dfrac{R+R}{4R} \times 8$

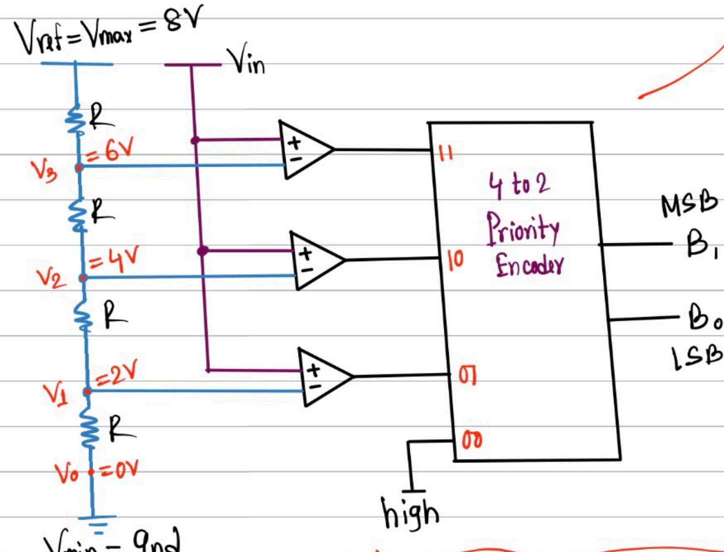
$= 4V$

$V_3 = \dfrac{R+R+R}{4R} \times 8$

$= 6V$

$V_{max} = 8V$

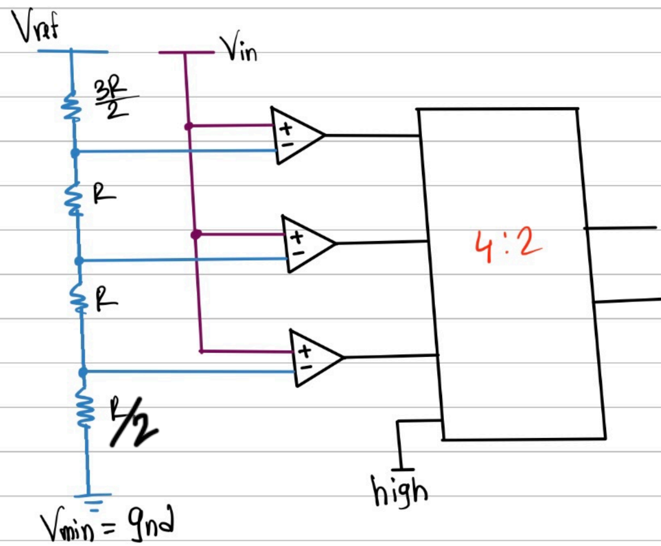
Quantization Range



quantization

Encoding

Practice



For the given Flash ADC, Quantizer range is (0, 8V)
For the following sequences ⟨0.8, 7, 3.4, 5.8, 2.2⟩
write the encoded sequences.

Soln:

Voltage devider to find V_0, V_1, V_2, V_3

$V_0 =$
$V_1 =$
$V_2 =$
$V_3 =$

Quantization Range	i/p sequences	Encoded seq.

⟨0.8, 7, 3.4, 5.8, 2.2⟩

⟨ ⟩

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, $\boxed{F_s = 2 \times F_{input}}$

→ for n-bit Flash ADC

Hardwares

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

Made with Goodnotes

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:

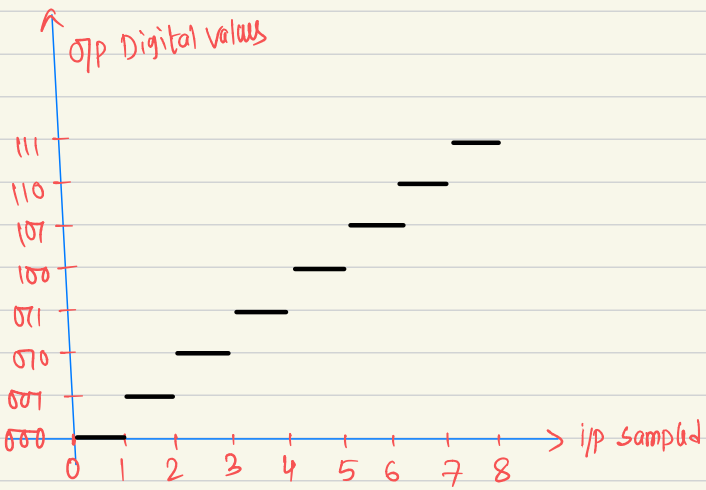
$n = 3$, $L = 2^n = 2^3 = 8$ levels. Step size, $\Delta = \frac{V_{max} - V_{min}}{2^n} = \frac{8-0}{8}$

$\Delta = 1$

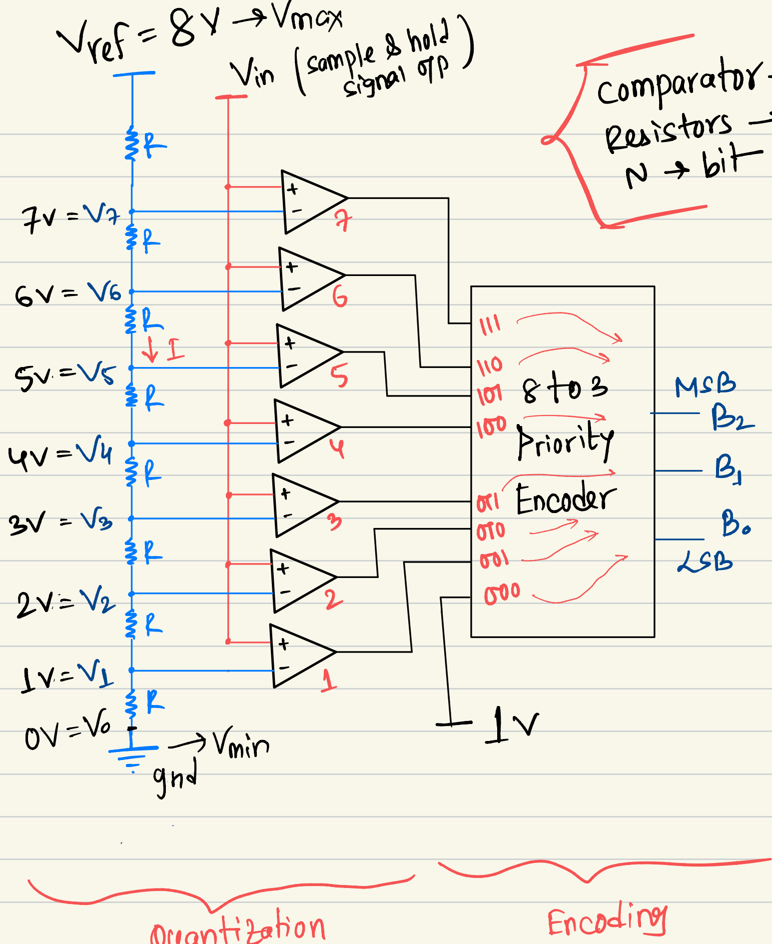
(i)

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 → $2^N - 1$
Resistors → 2^N
N → bit

Fig: 3-bit Flash ADC

Using Voltage Divider Rule

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

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

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

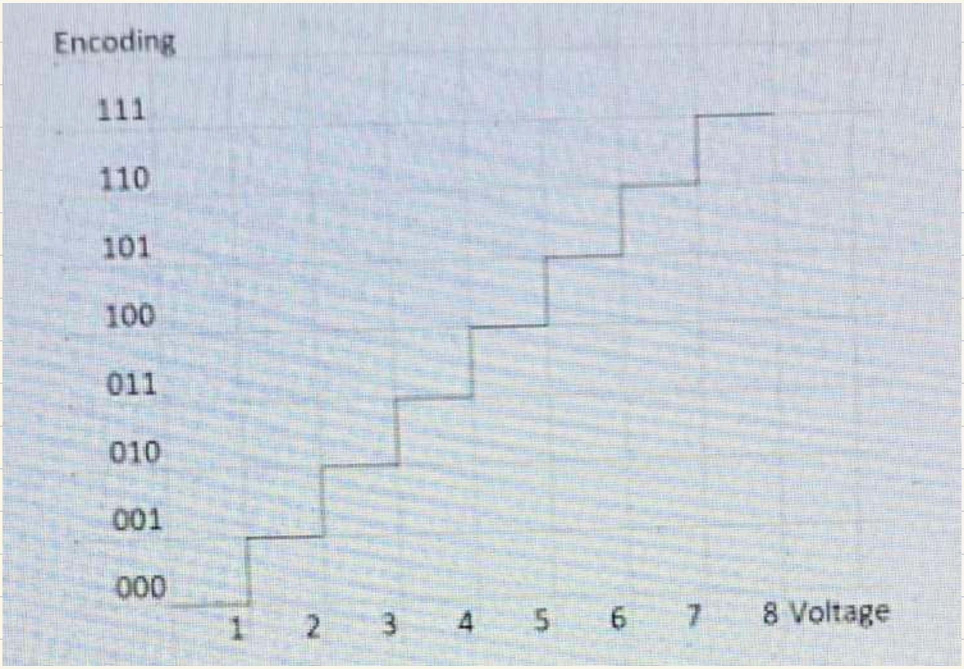
$$V_4 = \frac{4R}{8R} \times 8 = 4V$$

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

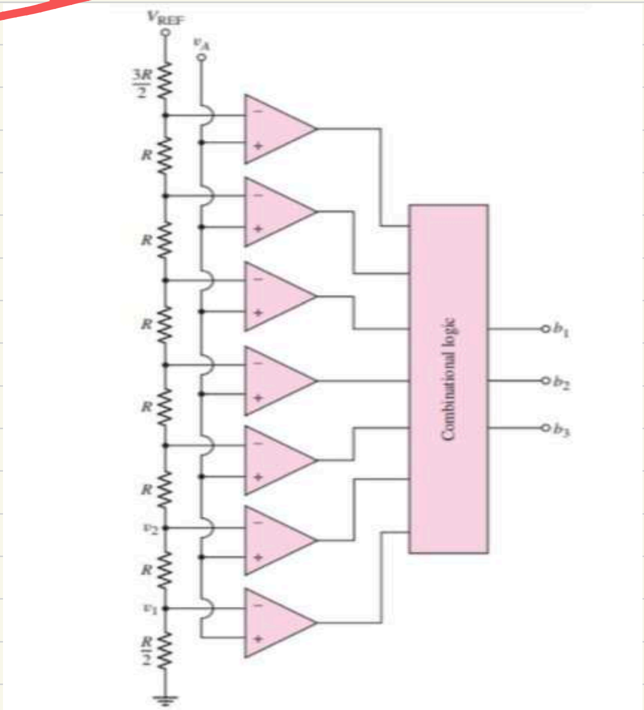
$$V_6 = \frac{6R}{8R} \times 8 = 6V$$

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

(11) # Input-Output Characteristics:



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 $V_{in} = 7V$

(i) Comment on the quantization range in which the i/p lies.

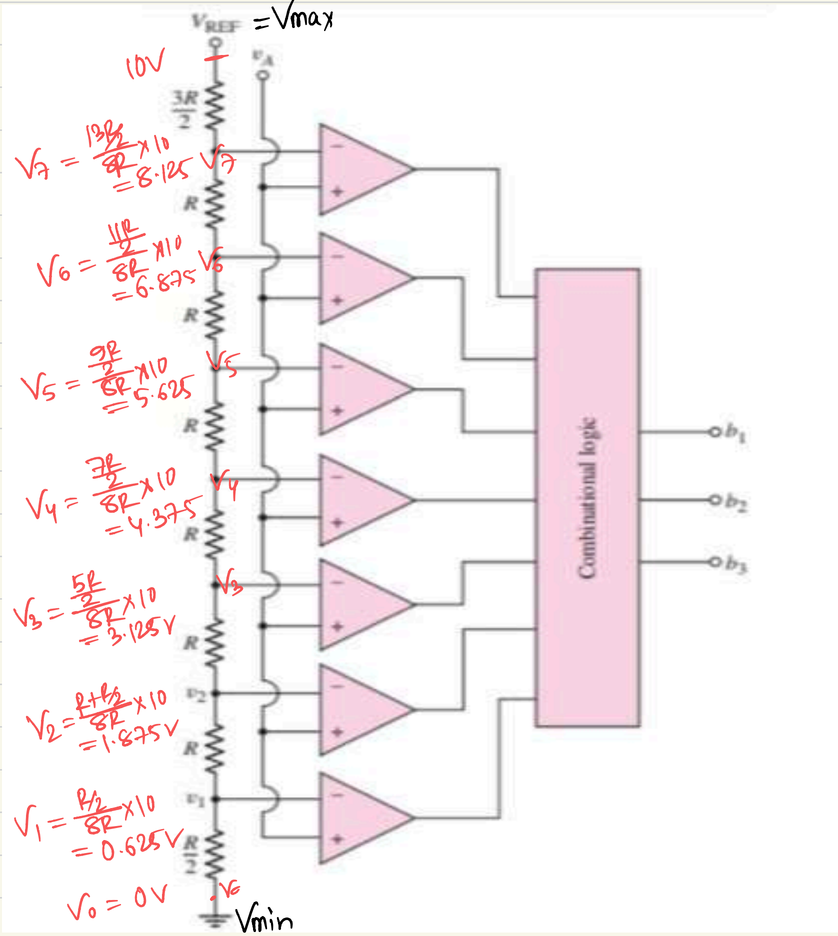
(ii) Find the digital o/p for the given i/p.

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

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

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

(b)



10V

$V_7 = \dfrac{13R/2}{8R} \times 10 = 8.125$

$V_6 = \dfrac{11R/2}{8R} \times 10 = 6.875$

$V_5 = \dfrac{9R/2}{8R} \times 10 = 5.625$

$V_4 = \dfrac{7R/2}{8R} \times 10 = 4.375$

$V_3 = \dfrac{5R/2}{8R} \times 10 = 3.125\,V$

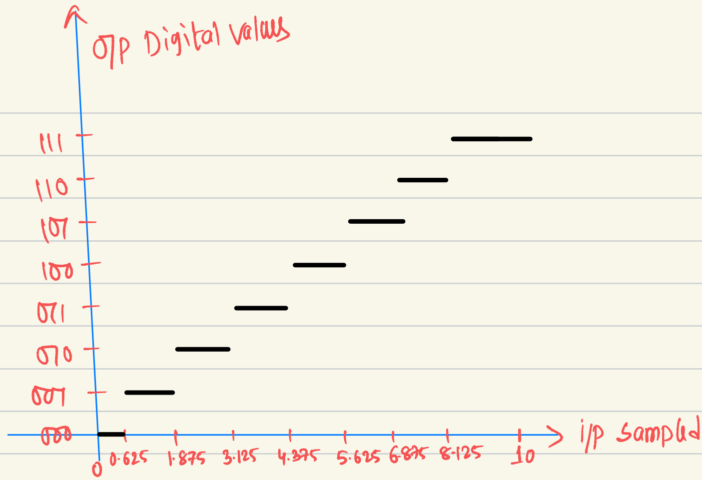
$V_2 = \dfrac{R + R/2}{8R} \times 10 = 1.875\,V$

$V_1 = \dfrac{R/2}{8R} \times 10 = 0.625\,V$

$V_0 = 0\,V$

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 $V_A = 1.875$ V

max $V_A = 3.125$ V

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

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

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

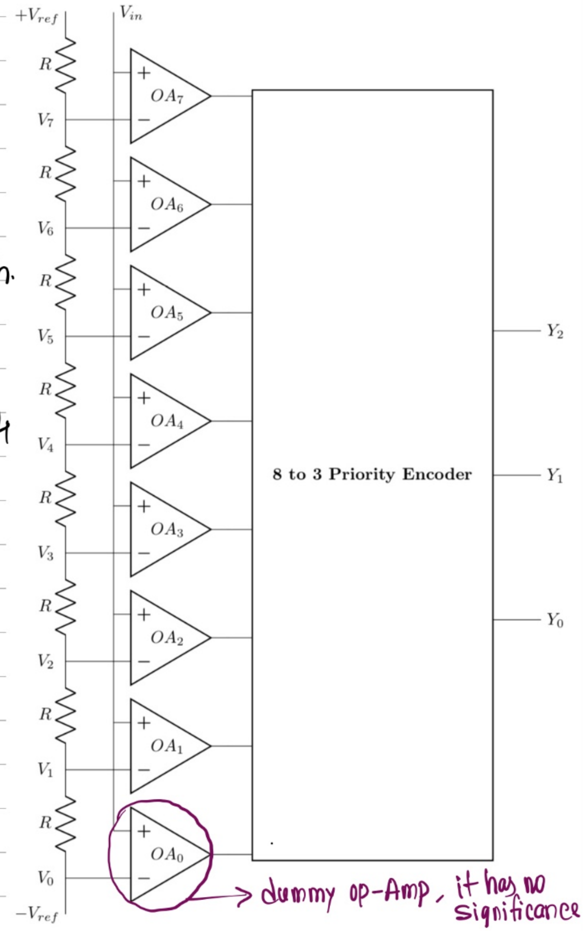
$2^n : n$ Priority Encoder → 16 : 4

Made with Goodnotes

Q. For the given Flash ADC $V_{ref} = 16V$.

(a) Find the quantization range and corresponding digital signal.

(b) Draw the $V_{i/p}$ vs $V_{o/p}$ graph.



→ dummy op-Amp, it has no significance

Soln:

(a) here, $V_{max} = +V_{ref} = 16V$

$V_{min} = -V_{ref} = -16V$, $n = 4$

$V_0 = -V_{ref} = -16V$

$$\boxed{V_j = \frac{\sum R_i}{\sum_n R}(V_{max} - V_{min}) + V_{min}}$$

$V_1 = \frac{R}{8R}(16-(-16)) - 16 = -12V$

$V_2 = \frac{2R}{8R}(16+16) - 16 = -8V$

$V_3 = \frac{3R}{8R}(32) - 16 = -4V$

Similarly, $V_4 = 0V$, $V_5 = 4V$

$V_6 = 8V$, $V_7 = 12V$

quantization Range	Encoded Signal
12 to 16	111
8 to 12	110
4 to 8	101
0 to 4	100
−4 to 0	011
−8 to −4	010
−12 to −8	001
−16 to −12	000

(b)