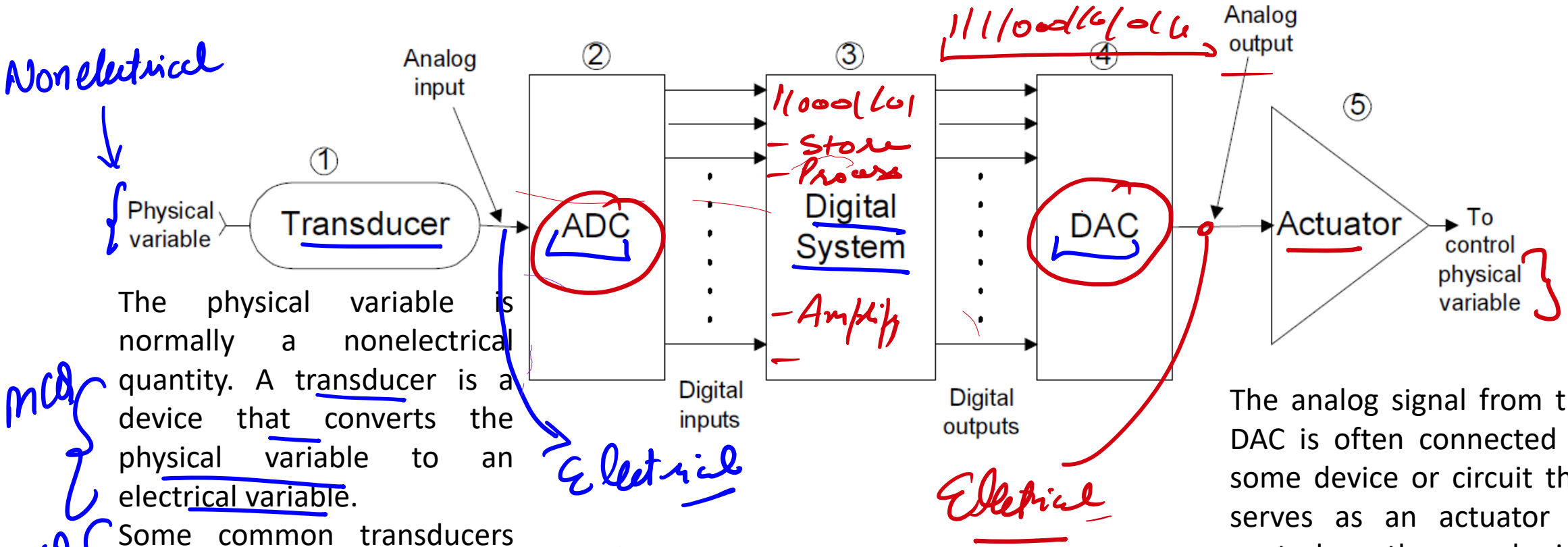
ADC and DAC

Note: CA3 (ECE213) - MCQ
- 30 MCQ, 1 Mark each with 0.25 -ve marking for wrong ans.
- Syllabus: Unit 5 & Unit 6.
- Test date: 8 May 2021 (3-4PM) - (Google form)

Interfacing with the analog world using Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC)



The physical variable is normally a nonelectrical quantity. A transducer is a device that converts the physical variable to an electrical variable.

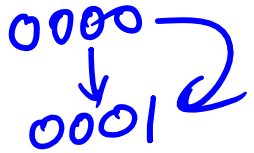
Some common transducers include thermistors, photocells, photodiodes, flow meters, pressure transducers, and tachometers.

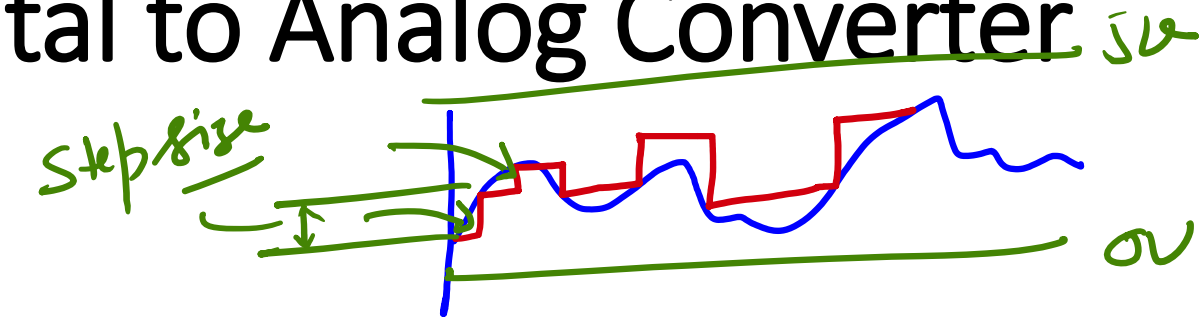
The analog signal from the DAC is often connected to some device or circuit that serves as an actuator to control the physical variable.

Digital To Analog Convertor (DAC)

- The converter which converters the digital form of data in to analog form is called digital to analog converter.
- In this the digital data in the form of 1's and 0's are used to control the switches which are placed in a analog circuit with reference voltage, based on this switch condition (ON/OFF) and position (MSB or LSB) the output analog amplitude is calculated.
- **Types of Digital to Analog Converters**
  - Binary Weighted Resistor DAC or R-2^nR DAC
  - R-2R Ladder DAC

Specifications of a Digital to Analog Converter (DAC)





Resolution

- The resolution of a DAC is the smallest change in the output of the DAC for any change in digital input. i.e. if a input to DAC changes one bit, how much analog output has changed in full scale deflection.

$$\% \text{ resolution} = [\text{Step size} / \text{Full scale output (FSO)}] * 100$$

- In other way the resolution is the number of states into which the full scale output is divided. i.e. if a 8 bit DAC can resolve the FSO up to 255 levels. Each level of output is called step size and for higher number of bits the resolution will be better.

$$\% \text{ resolution} = [1/(2^N-1)] * 100$$

$\frac{1}{255} \times 100$

- Normally the resolution will be in Milli volts.

MCQ

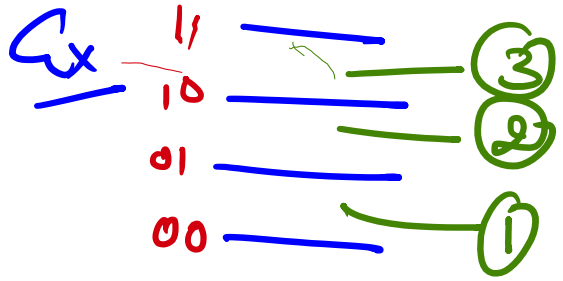
How many equal intervals are present in a 14-bit D-A converter?

a) 16383

b) 4095

c) 65535

d) 1023



$2^2 - 1 = 4 - 1 = 3$

$2^{14} - 1 = 16384 - 1$

$= 16383$

MCQ

$2^6 - 1 = 64 - 1 = 63$

Resolution of a 6 bit DAC can be stated as

a) Resolution of 1 part in 63

b) 6-bit resolution

c) Resolution of 1.587% of full scale $\frac{1}{63} \times 100 = 1.587\%$

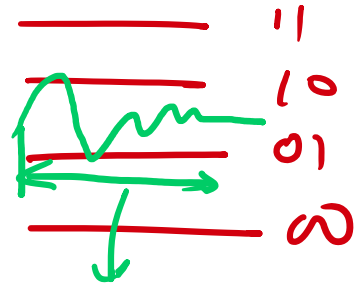
d) All of the mentioned

Specifications of a Digital to Analog Converter (DAC)

Accuracy

- The Accuracy of a DAC is the difference between output practical analog output to the ideal expected output for a given digital input.
- The DAC is contains electronic components where the gain plays a major role which can introduce gain error in the output, Due to the full scale output may differ compared to ideal one.
- For an example if a DAC of 10 V is said to have an accuracy of 0.01% there will be 10mv output deviation.
- The another factor which implicates the accuracy is the zero offset error i.e. for a zero input the output of DAC reflects some offset value.

Specifications of a Digital to Analog Converter (DAC)

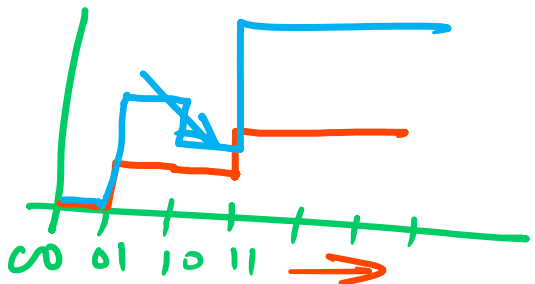


Conversion Speed

- The conversion speed of the DAC is output analog value settling time period for a change in the digital input. This is also called settling time period of DAC. Normally it will be micro seconds and in some advanced micro controller DAC it may be nano seconds.

Monotonicity

- The Digital to Analog Converter is said to be monotonic if its analog value is either increasing or equal to previous value for an LSB change in input digital signal.



Which of the following is a type of error associated with digital-to-analog converters (DACs)?

a) incorrect output codes

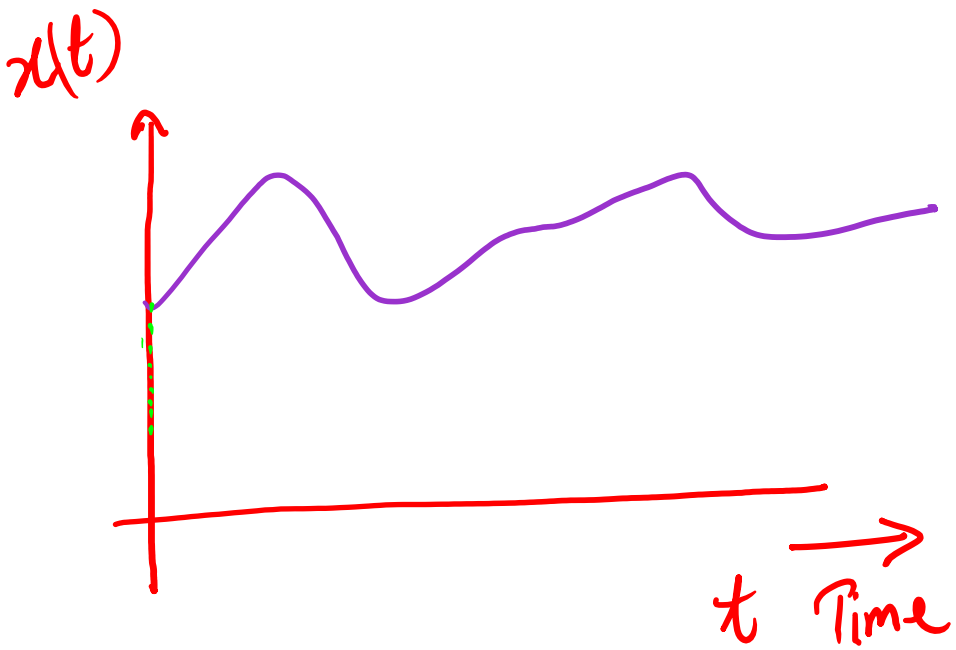
b) nonmonotonic error

c) nonmonotonic and offset error

d) offset error

Analog to Digital Converter(ADC)

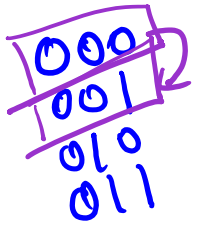
- The data converter which converts the data from analog values to digital values is called Analog to Digital converter in shot it is called ADC.
- In ADC the input signal value is sampled at a particular time interval and compared with the analog value produced by the combination of counter and DAC. If the output of the comparator is zero then the value of the counter will be the output digital value.
- These are very important converters as the environmental analog signals has too be converted in to digital for processing with the digital computer.


x(t)
t Time

Types of Analog to Digital Converters

- Simultaneous or Flash A/D Converters
- Counter-Type A/D Converter
- Tracking-Type A/D Converter
- Successive Approximation Type A/D Converter
- Single-, Dual- and Multislope A/D Converters
- Sigma-Delta A/D Converter

Specifications of ADC



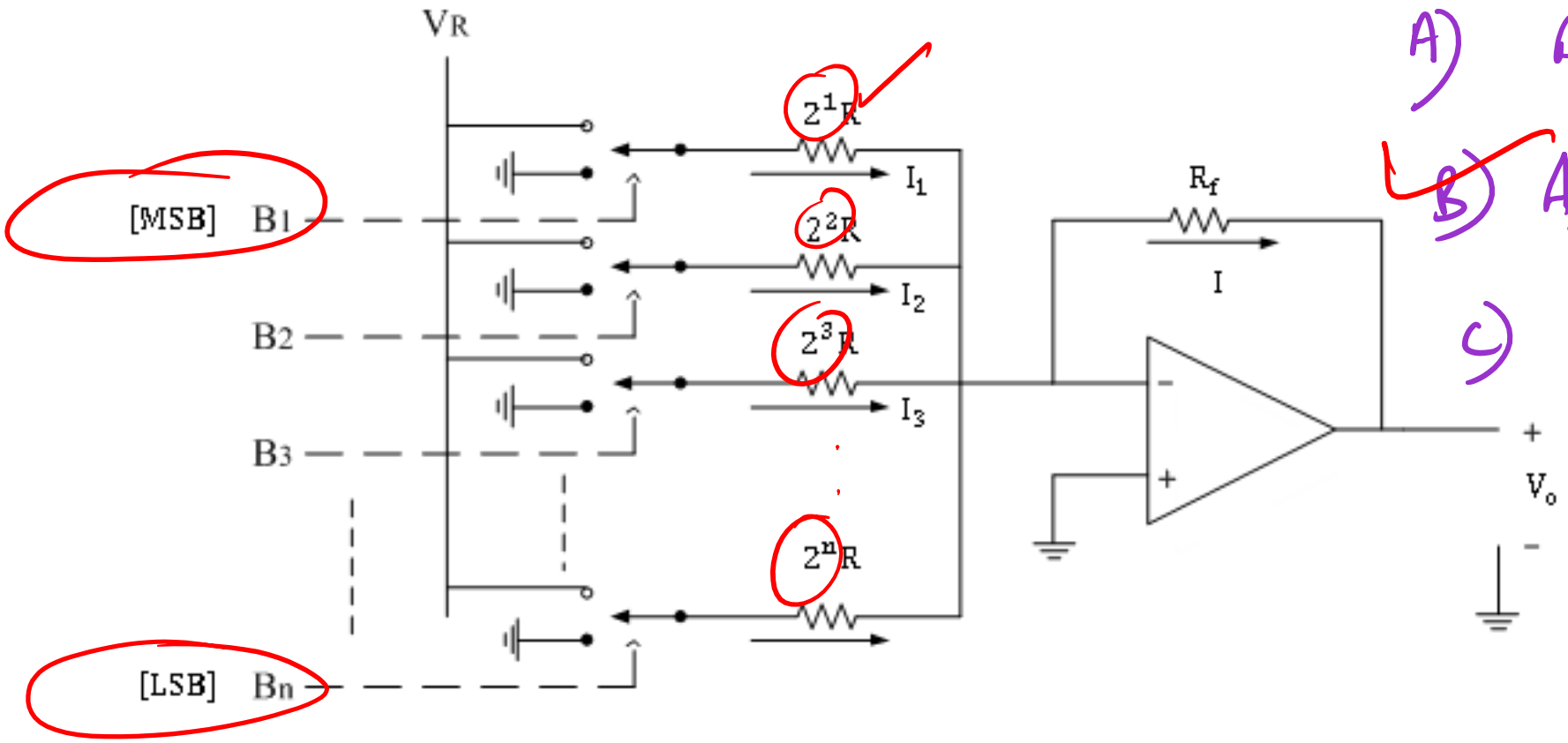
Resolution

- The resolution of an A/D converter is the quantum of the input analogue voltage change required to increment its digital output from one value to the next higher code value.

  i.e. if an n bit ADC then it needs 1/ 2^n-1 of full scaled output to reflect at the output of ADC.

- For example The resolution of an eight-bit A/D converter can be expressed as one part in 255 or as 0.4% of full scale or simply as eight-bit resolution. If such a converter has a full-scale analogue input range of 10 V, it can resolve a 40 mV change in input.

Weighted Resistor DAC



Q: What is the feedback gain of inverting amplifier

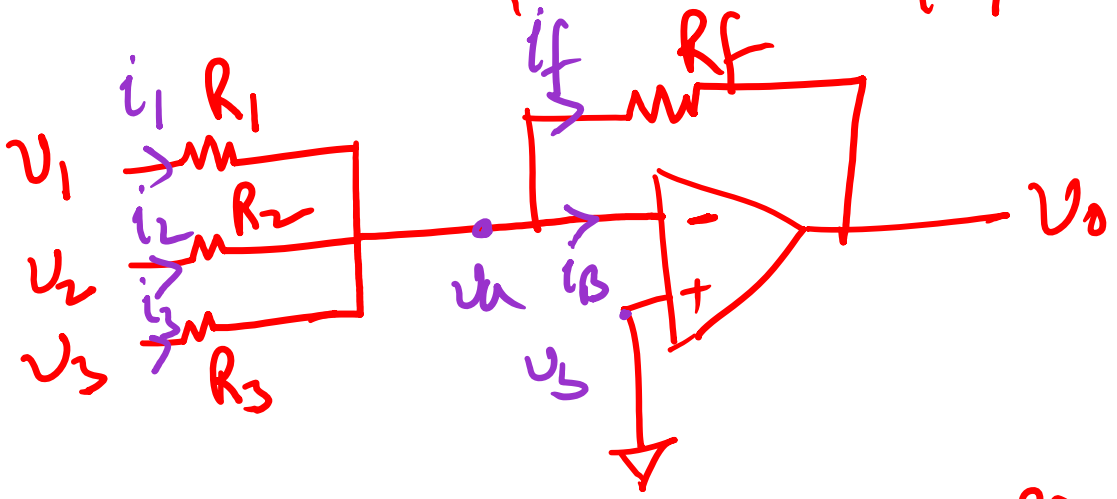
A) $A_f = \frac{R_f}{R_1}$

B) $A_f = -\frac{R_f}{R_1}$

C) $A_f = 1 + \frac{R_f}{R_1}$

D) $A_f = 1 - \frac{R_f}{R_1}$

★ Summing Scaling & Avg Amplifier



Apply KCL at node v_a

$$i_1 + i_2 + i_3 = i_B + i_f$$

Ohm's Law

$$v_0 = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \frac{R_f}{R_3}v_3\right)$$

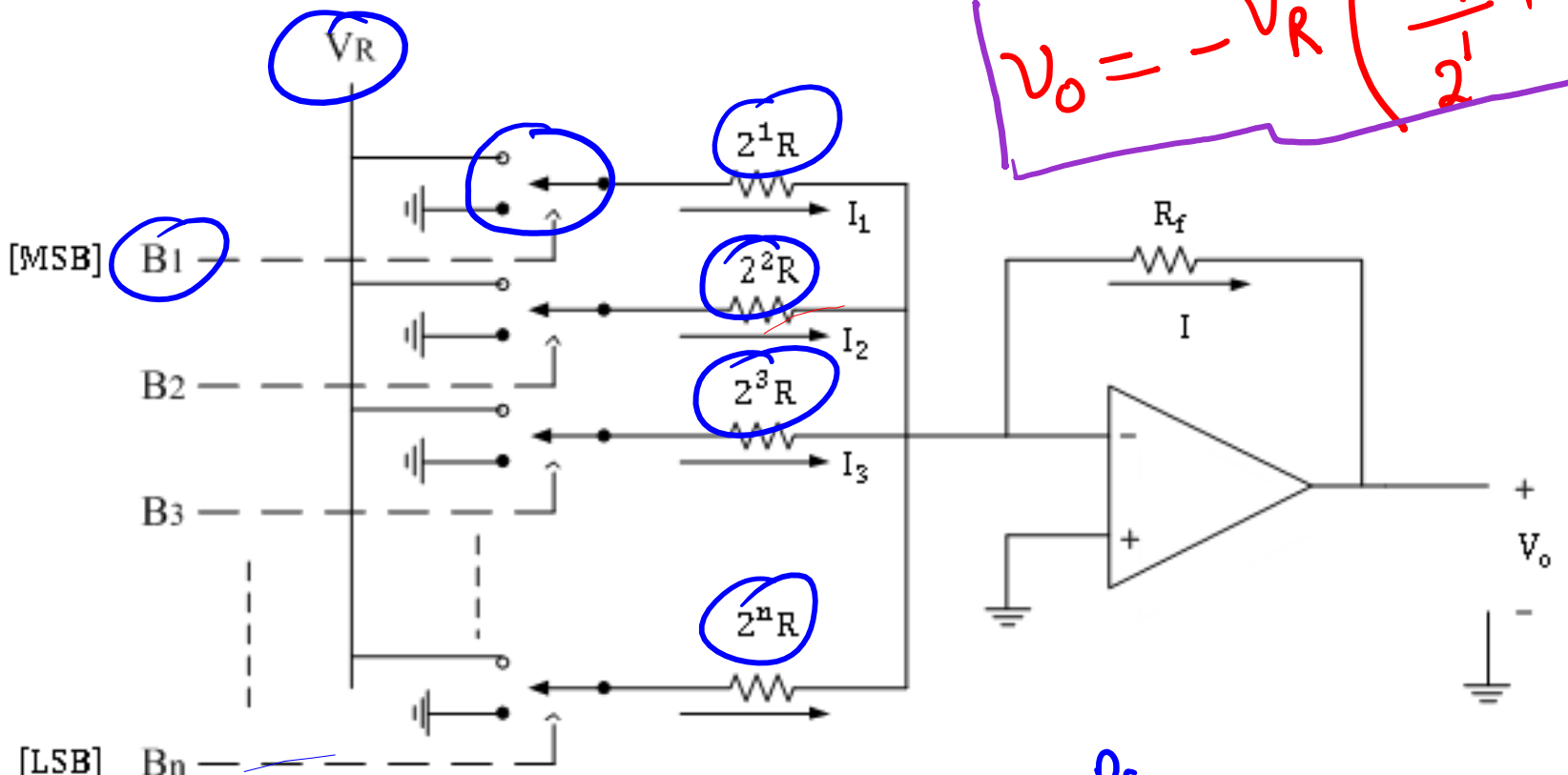
Weighted Resistor DAC

$V_1 = V_2 = V_3 = \cdots = V_n = V_R$

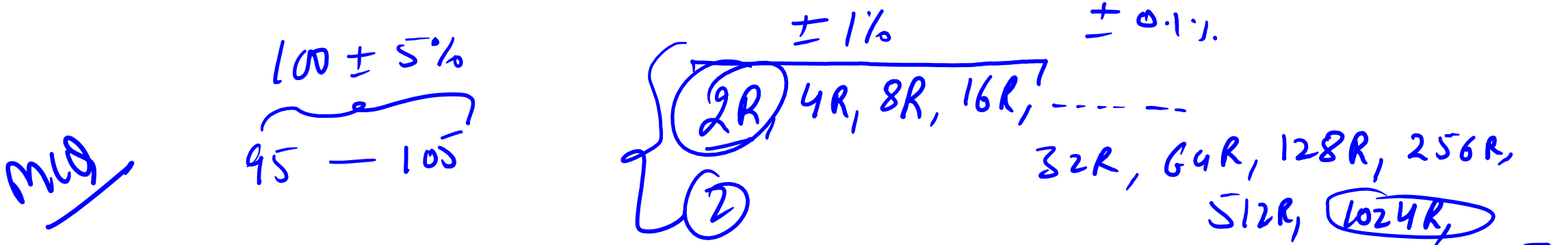
and $R_f = R$

$$V_0 = -V_R\left(\frac{B_1}{2^1} + \frac{B_2}{2^2} + \frac{B_3}{2^3} + \cdots \frac{B_n}{2^n}\right)$$

MCQ



$$V_0 = -\left(\frac{R_f}{2^1R}V_1 + \frac{R_f}{2^2R}V_2 + \frac{R_f}{2^3R}V_3 + \cdots + \frac{R_f}{2^nR}V_n\right)$$



- Disadvantages:
  1) When number of binary input increases, it is not easy to maintain the resistance ratio.
  2) Very wide ranges of different values of resistors are required.
  For high accuracy of conversion, the values of resistances must be accurate.
  3) Different current flows through resistors, so their wattage ratings are also different.
  4) Accuracy and stability of conversion depends primarily on the absolute accuracy of the resistors and tracking of each other with temperature.
  eg. For 10 digit converter
  small resistance value = 10 kΩ and
  large resistance value = 5.12 MΩ
  It is very difficult and expensive to obtain stable precise resistances of such value.
  5) Since 'R' is very large, op-amp bias currents gives a drop which offsets output.
  6) Resistances of switches may be comparable with smallest resistor.

3. Determine the output current for an n-bit weighted resistor DAC?

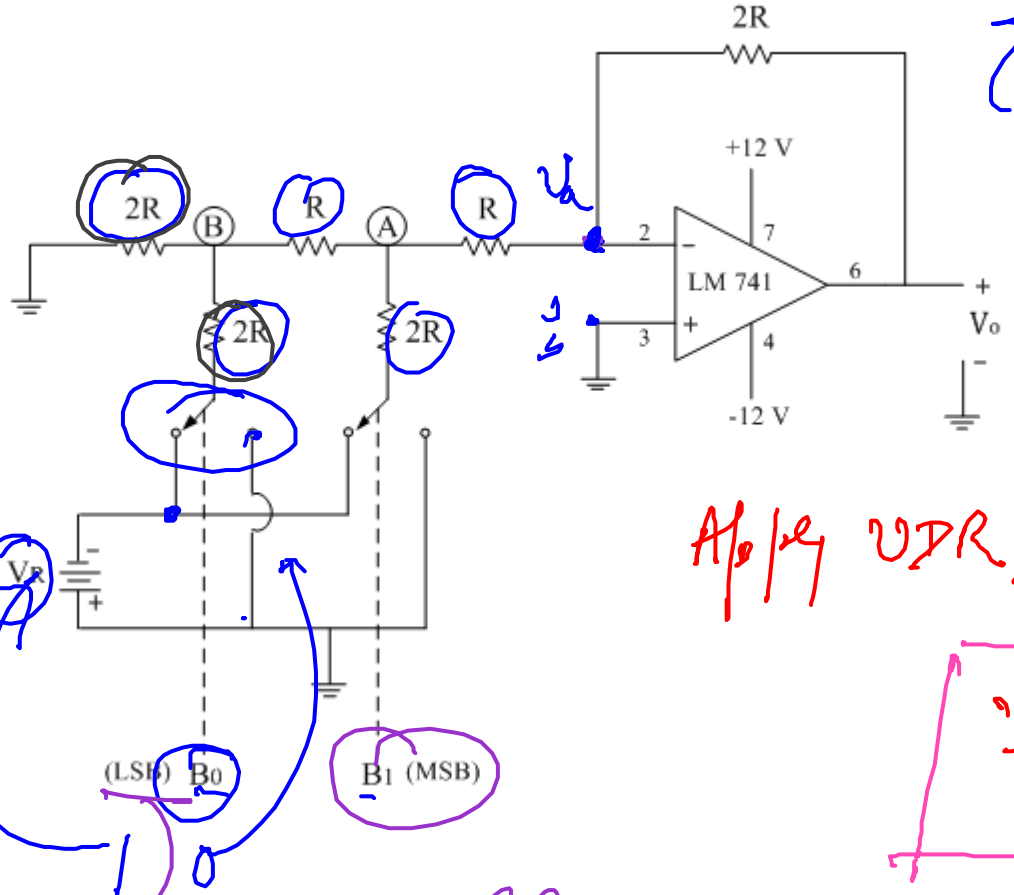
a) $(V_R/R) \times (d_o/2 + d_1/2^2 + \ldots\ldots d_n/2^n)$

b) $(V_R/R) \times (d_1/2^1 + d_2/2^2 + \ldots\ldots d_n/2^n)$

c) $(V_R/R) \times (d_0^2/2 + d_1^2/2^2 + \ldots\ldots d_n^2/2^n)$

d) None of the mentioned

R-2R Ladder DAC



LSB MSB

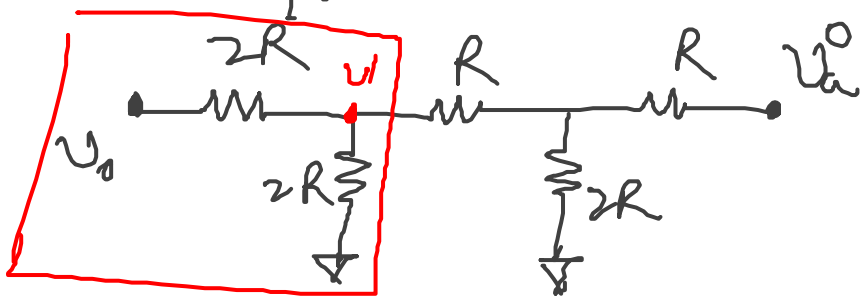
V_0 V_1

Thevenin's th.

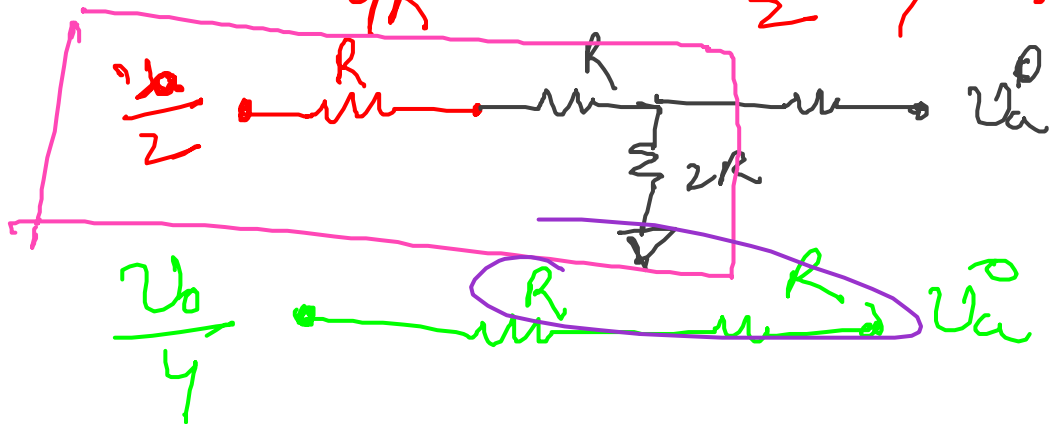
Superposition th.

$V_a = V_a^0 + V_a^1$

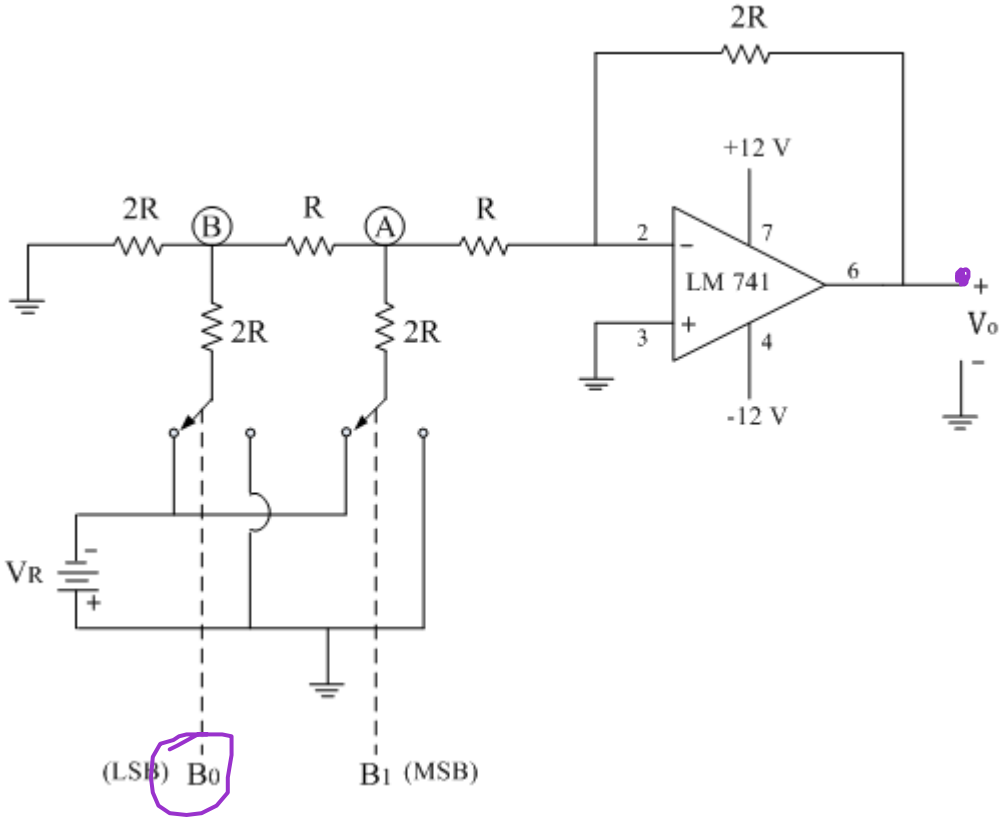
$\Rightarrow$ Turn off V_1, i.e. $V_1 = 0$ (GND)



Apply VDR $V' = \frac{2R}{4R} V_0 = \frac{V_0}{2}$; $R_{TH} = 2R \| 2R = R$

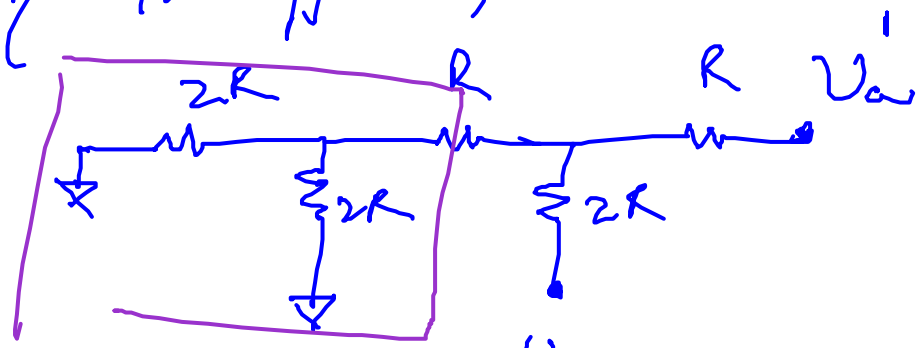


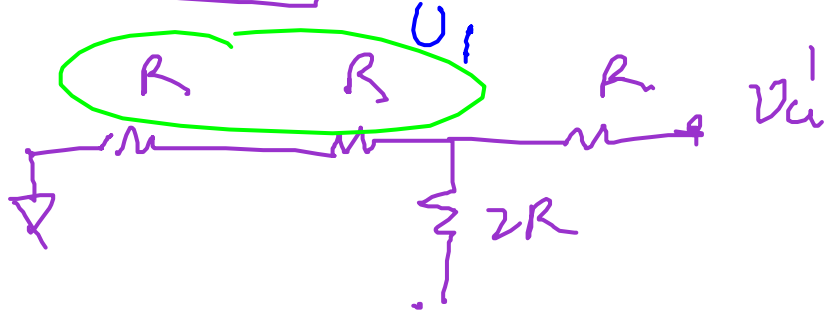
R-2R Ladder DAC



$V_0 = B_0 V_R$, $V_1 = B_1 V_R$

★ Turn off V^0, i.e $V^0 = 0$





$\frac{V_1}{2}$

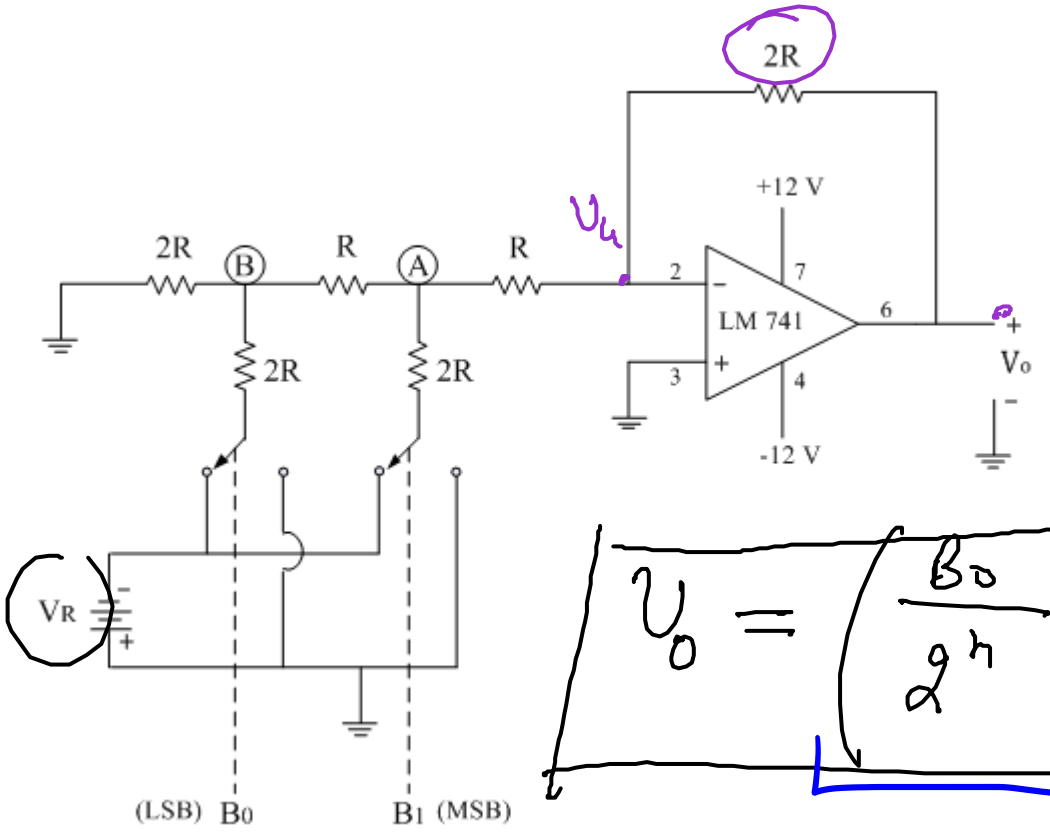
$$V_a = \frac{V_0}{4} + \frac{V_1}{2}$$

$$\Rightarrow V_a = V_R\left(\frac{B_0}{2^2} + \frac{B_1}{2^1}\right)$$

R-2R Ladder DAC

$$V_o = -\frac{R_f}{R_1} V_a$$

$$V_o = -\frac{2R}{2R} V_R \left(\frac{B_0}{2^2} + \frac{B_1}{2^1} \right)$$



$$V_o = \left(\frac{B_0}{2^n} + \frac{B_1}{2^{n-1}} + \frac{B_2}{2^{n-2}} + \cdots \frac{B_{n-1}}{2^1} \right) V_R$$

0-1

Which of the following statement is TRUE?

a) R-2R ladder DAC requires high precision resistors

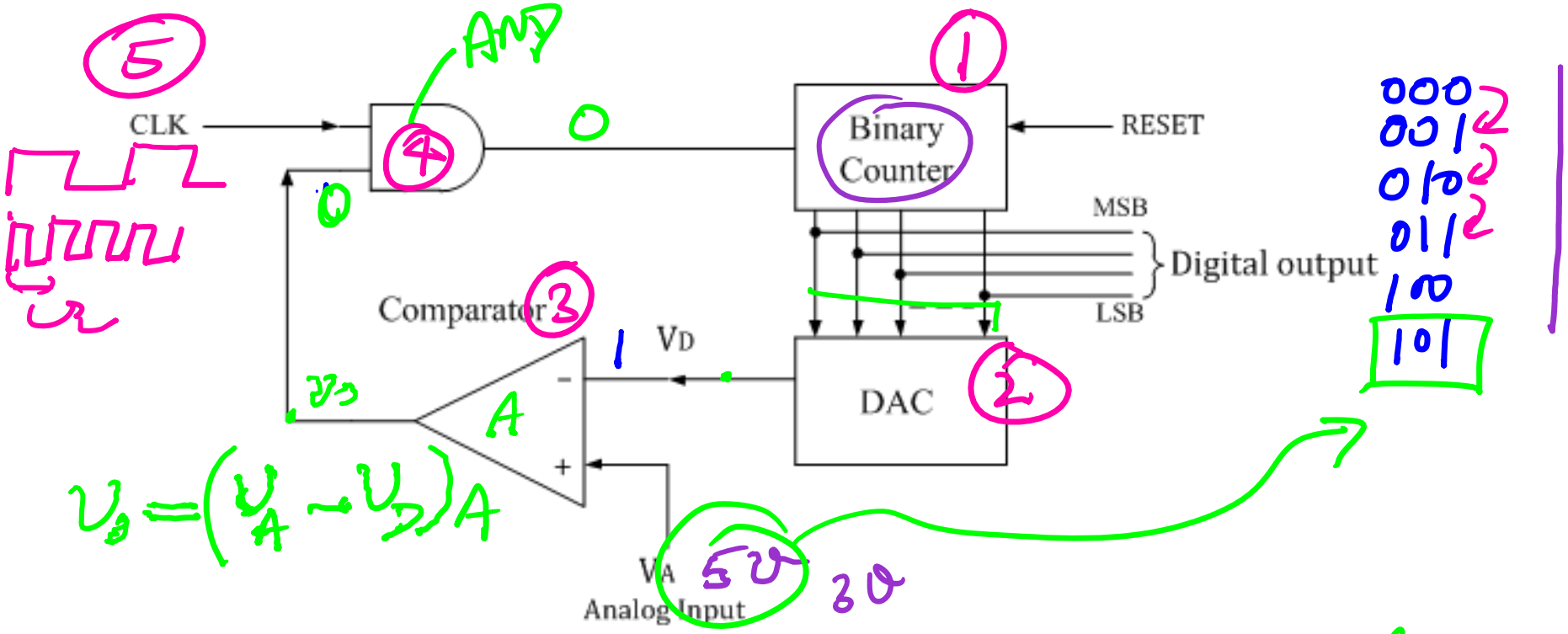
b) Binary weighted resistor DAC conversion time is high

c) Binary weighted resistor DAC requires large range of resistors

d) R-2R ladder DAC is the faster conversion time compared to weighted resistor type DAC

R, 2R, 4R, 8R, 16R, 32R, 64R, - - - -

Counter-Type A/D Converter



$V_0 = (V_A - V_D)A$

Ex 3-bit ADC
0–7 V →

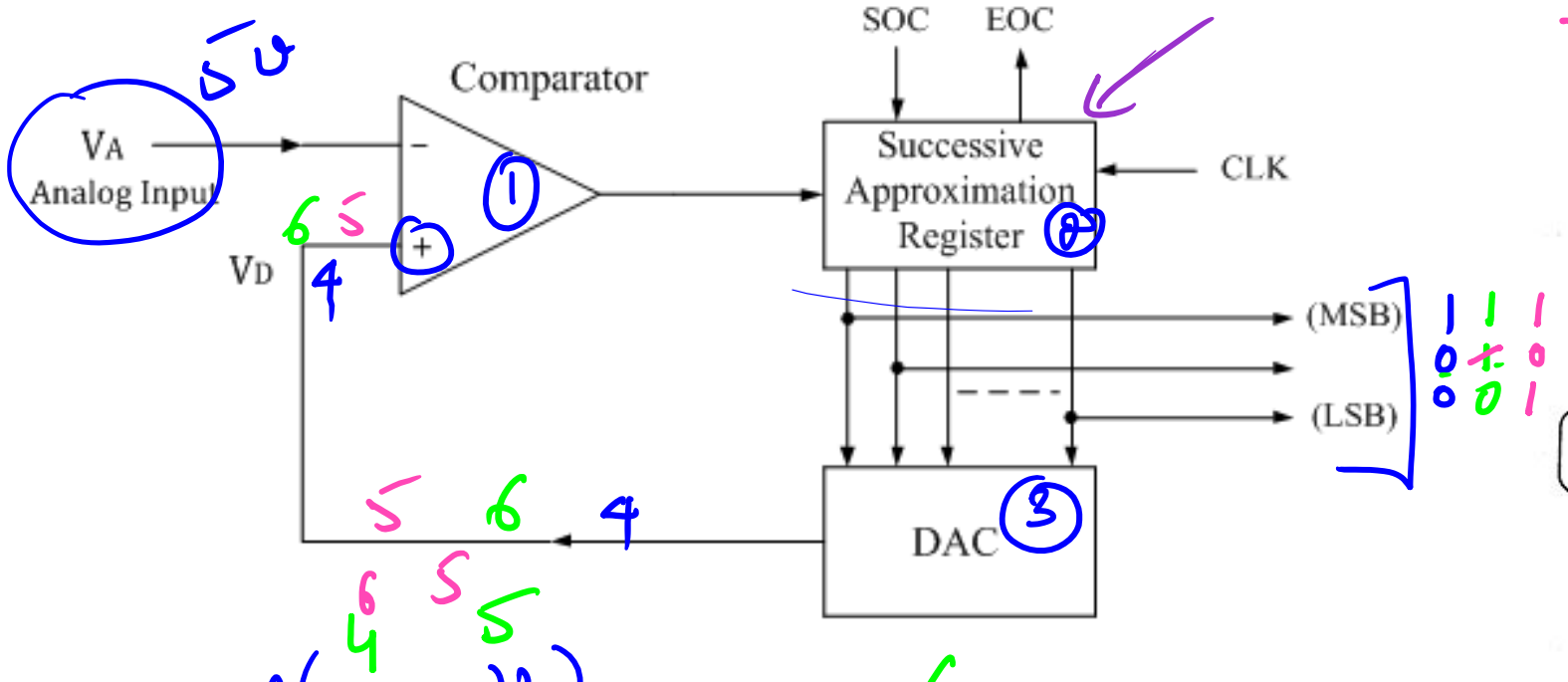
if $V_A > V_D$ → V_0 +ve (high)
if $V_A = V_D$ → $V_0 = 0$ (low)
if $V_A < V_D$ → V_0 −ve (low)

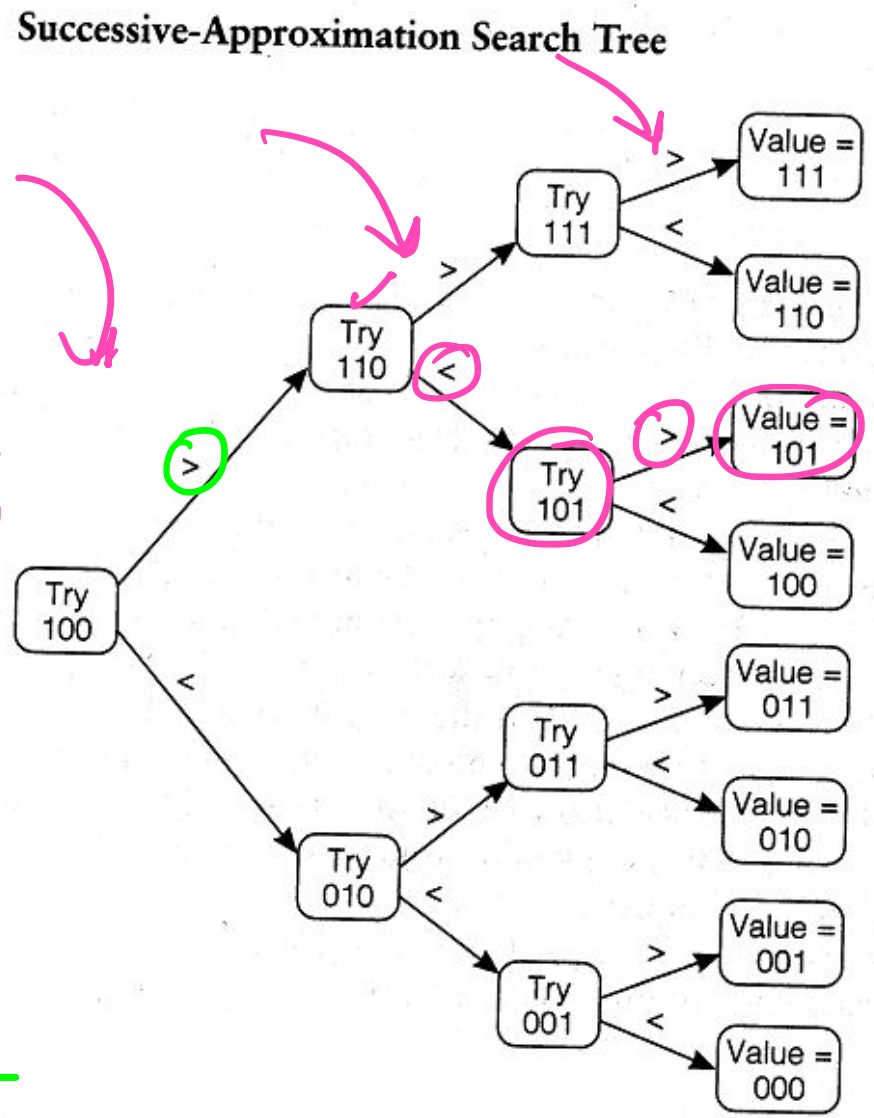
If one i/p of the and gate is high then the o/p is same as 2nd input

Counter-Type A/D Converter

- Advantages:
  1 Simple construction.
  2 Easy to design and less expensive.
  3 Speed can be adjusted by adjusting the clock frequency.
  4 Faster than dual slope type ADC.

Successive Approximation ADC





Successive Approximation ADC

- **Advantages:**
  1 Conversion time is very small.
  2 Conversion time is constant and independent of the amplitude of the analog input signal VA.
- **Disadvantages:**
  1 Circuit is complex.
  2 The conversion time is more compared to flash type ADC.

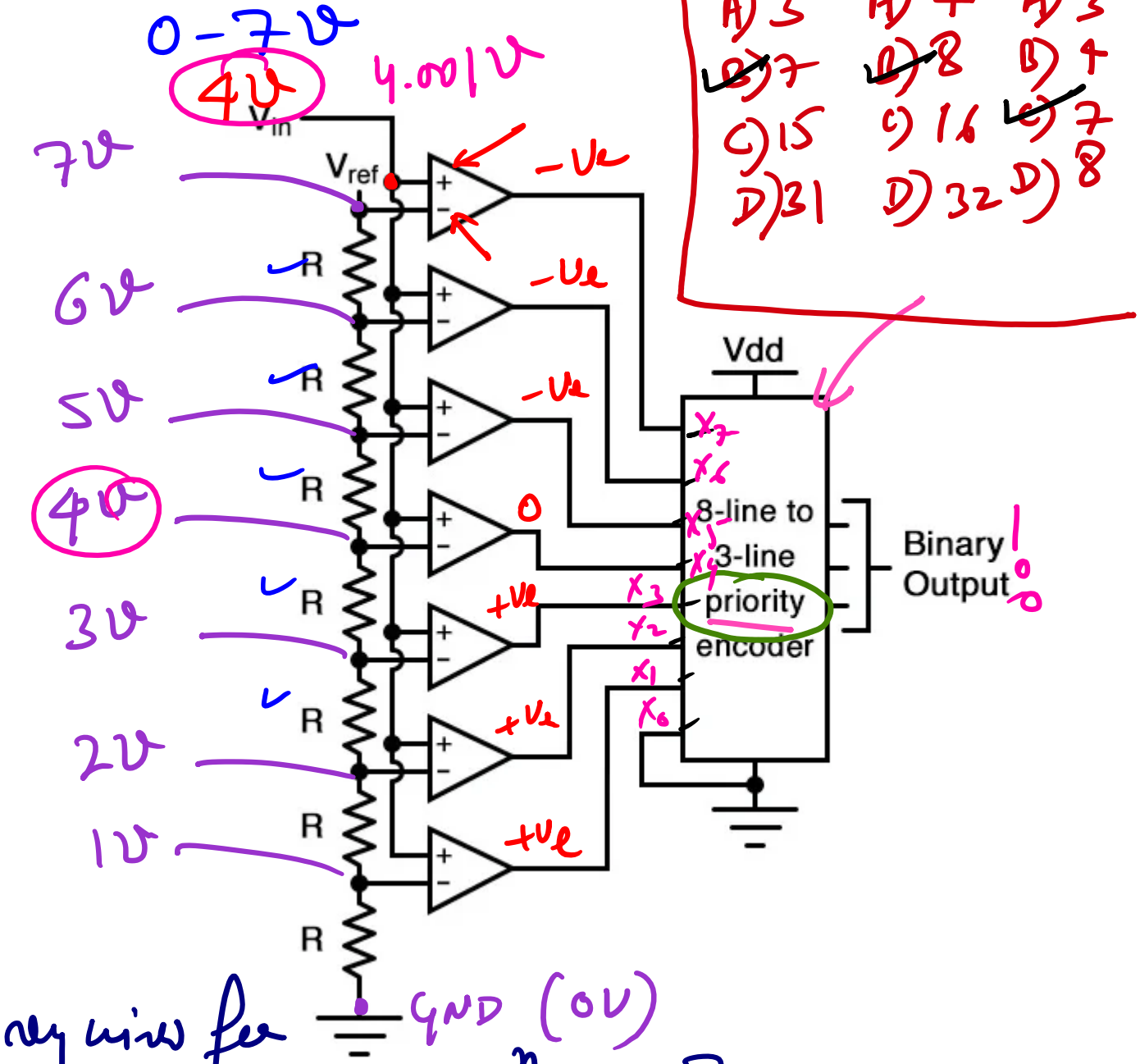
Flash type ADC

- Voltage divider ckt
- Comparator

-Ve (low logic), 0 (low logic)

+Ve (high logic)

X_7	X_6	X_5	X_4	X_3	X_2	X_1	X_0	Y_2	Y_1	Y_0
1	0	0	0	0	0	0	0	1	1	1
0	1	0	0	0	0	0	0	1	1	0
0	0	1	0	0	0	0	0	1	0	1
:	:	:	:	:	:	:	:	:	:	:
1	1	0	1	0	1	1	0	1	1	1
0	0	0	1	0	0	1	1	1	0	0



A) 3 A) 4 A) 3
B) 7 B) 8 D) 4
C) 15 C) 16 C) 7
D) 31 D) 32 D) 8

Q: How many op-amp (comparator) are required for 3-bit flash type ADC?

Ans: $2^n - 1 = 7$

Flash type ADC

- **Advantages:**
  1)It is the fastest type of ADC because the conversion is performed simultaneously through a set of comparators, hence referred as flash type ADC. Typical conversion time is 100ns or less.
  2)The construction is simple and easier to design.

- **Disadvantages:**
  1)It is not suitable for higher number of bits.
  2)To convert the analog input voltage into a digital signal of n-bit output, $(2^n - 1)$ comparators are required. The number of comparators required doubles for each added bit.

4-bit, 2^4-1, 16:4 (64)

#-bit	3	4	5	6	7	8
	7	15	31	63	127	255