AKTU

B.Tech III-Sem

Digital System Design



Unit-5 Lecture-1

EC & EC Allied

GATEWAY CLASSES

Gateway classes

UNIT 5 : Digital-to-Analog converters (DAC)

Lec 1

Today's Target

- Digital to Analog Converter
- Weighted Resistor DAC
- R-2R Ladder DAC
- University Questions

Gateway classes

UNIVERSITY QUESTIONS

YEAR	QUESTIONS	MARKS
22-23 20-21 19-20	With neat diagram explain the operation of R-2R DAC	10 Marks
22-23	Explain a Weighted Resistor digital to analog convertor	10 Marks
19-20	The basic step of a 9-bit DAC is 10.3V. if 000000000 represents O Volts, what is the output for an input of 101101111 ?	2 Marks

Gateway classes

Digital to Analog Converter

- A Digital to Analog Converter (DAC) converts a digital input signal into an analog output signal.
- The digital signal is represented with a binary code, which is a combination of bits 0 and 1.
- A Digital to Analog Converter (DAC) consists of a number of binary inputs and a single output.
- In general, the number of binary inputs of a DAC will be a power of two.



Gateway classes

Types of DACs

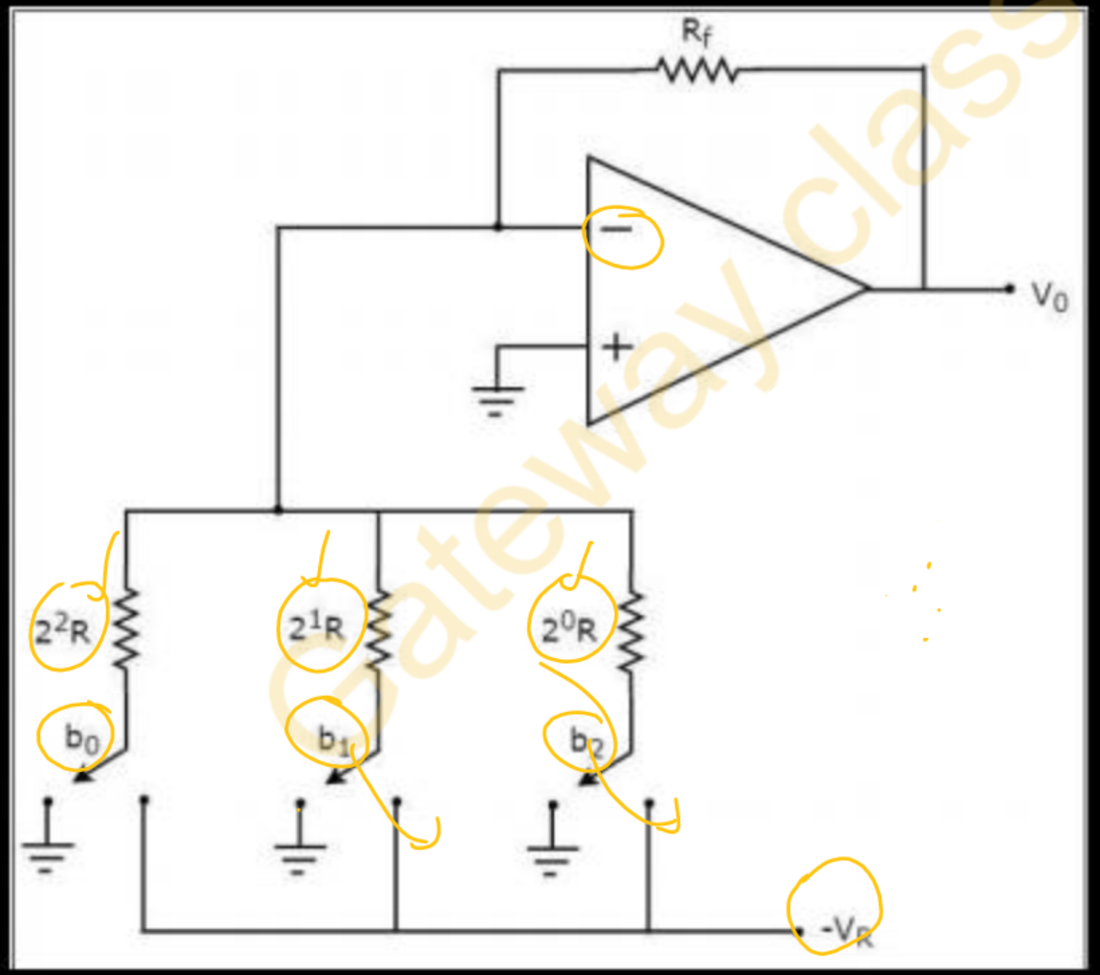
There are two types of DACs

- Weighted Resistor DAC
- R-2R Ladder DAC

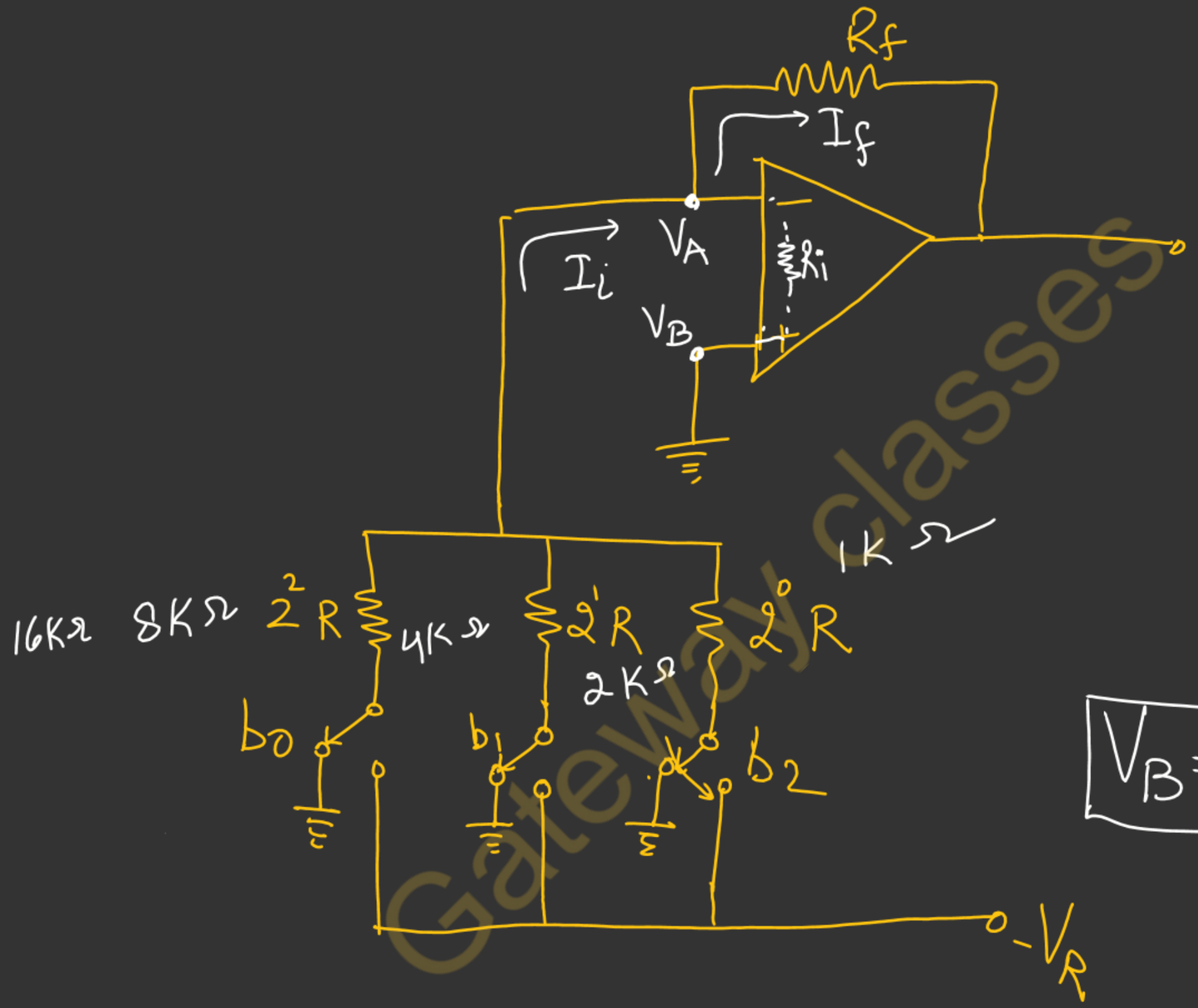
Gateway classes

Weighted Resistor DAC

- A weighted resistor DAC produces an analog output, which is almost equal to the digital (binary) input by using binary weighted resistors in the inverting adder circuit.
- The circuit diagram of a 3-bit binary weighted resistor DAC is shown in the following figure.



Gateway classes



$$A_d = V_B - V_A$$

$$\frac{V_B - V_A}{A_d} = 0$$

$$V_B - V_A = 0$$

$$V_B = V_A$$

$V_B = 0V \Rightarrow V_A = 0V$ VGC

Gateway classes

$$I_i = I_f$$

$$\frac{V_A-(-V_R)b_2}{2^0 R}+\frac{V_A-(-V_R)b_1}{2^1 R}+\frac{V_A-(-V_R)b_0}{2^2 R}$$

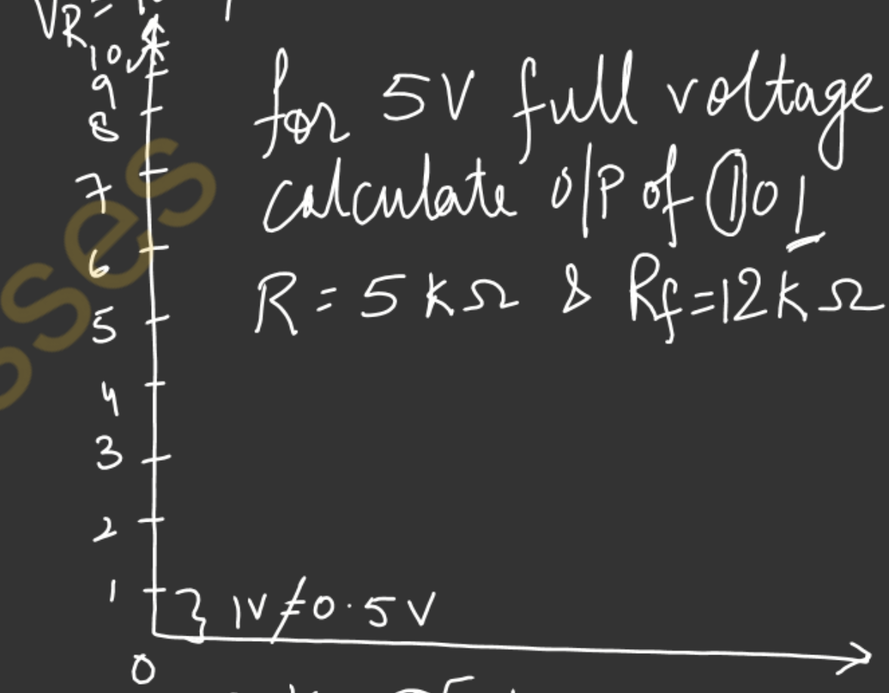
$$=\frac{V_0-V_A}{R_f}$$

$$\frac{V_R b_2}{2^0 R}+\frac{V_R b_1}{2^1 R}+\frac{V_R b_0}{2^2 R}=\frac{V_0}{R_f}$$

$$V_0=\frac{R_f}{R}\cdot V_R\left[\frac{b_2}{2^0}+\frac{b_1}{2^1}+\frac{b_0}{2^2}\right]$$ ✓

If $R = 2R_f$

$$V_0=\frac{V_R}{2}\left[\frac{b_2}{2^0}+\frac{b_1}{2^1}+\frac{b_0}{2^2}\right]$$



5 V

for 5V full voltage calculate o/p of 101

$R = 5\,k\Omega$ & $R_f = 12\,k\Omega$

$$V_0=\frac{12k}{5k}\times 5\left[\frac{1}{2^0}+\frac{0}{2^1}+\frac{1}{2^2}\right]$$

$$=12\left[1+0+\frac{1}{8}\right]$$

$$=12\left[\frac{1}{2}+0+0.25\right]$$

$$=12\times 1.25$$

Gateway classes

- Let the 3-bit binary input is b2b1b0 with b2 = MSB & b0 = LSB
- The digital switches will be connected to ground, when the corresponding input bits are equal to '0'.
- The digital switches will be connected to the negative reference voltage, −VR when the corresponding input bits are equal to '1'.
- The non-inverting input terminal of an op-amp is connected to ground. That means zero volts is applied at the non-inverting input terminal of op-amp.
- According to the virtual short concept, the voltage at the inverting input terminal of op-amp is same as that of the voltage present at its non-inverting input terminal.
- So, the voltage at the inverting input terminal's node will be zero volts.

Gateway classes

Disadvantages of a binary weighted resistor DAC

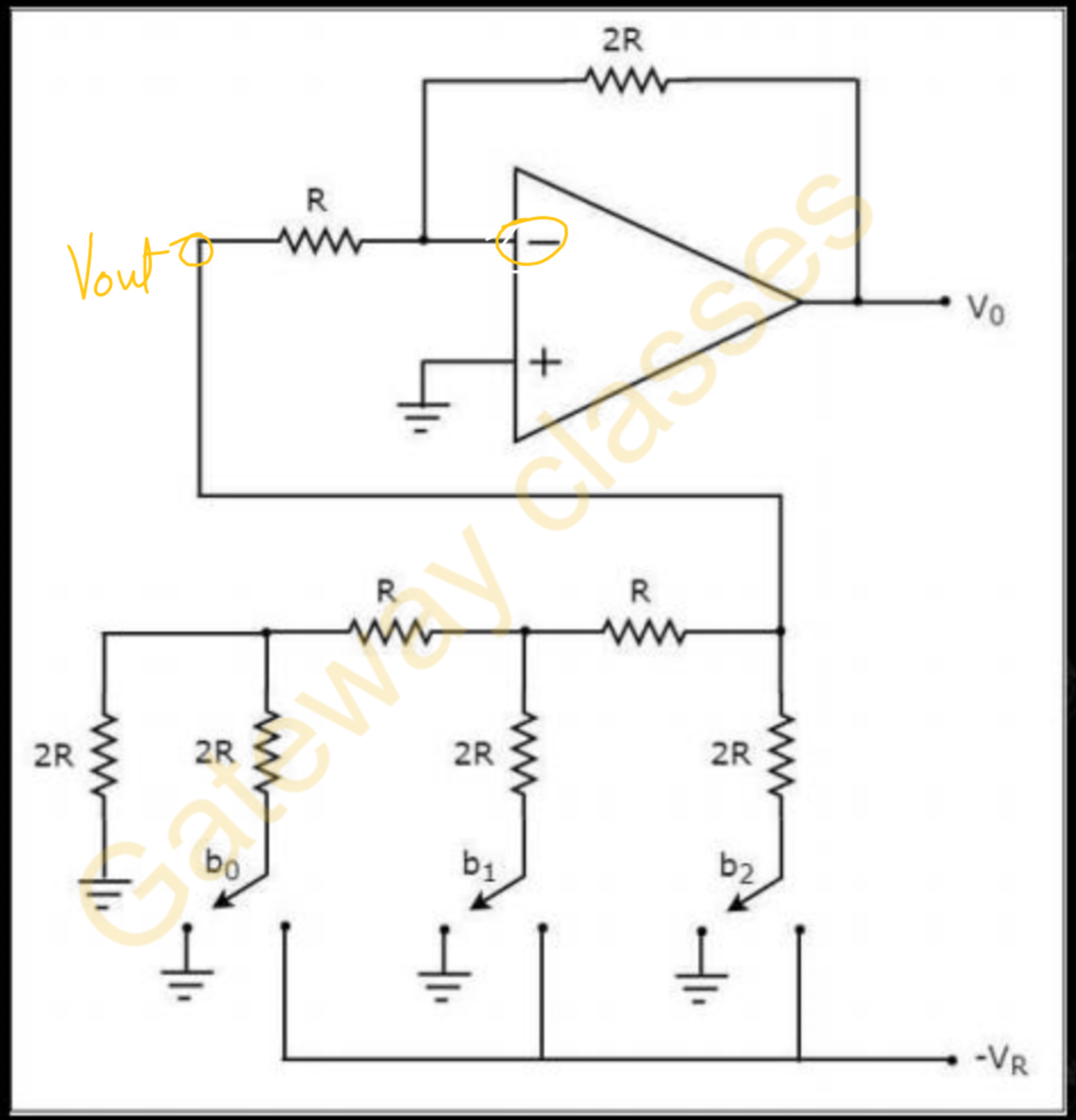
- The difference between the resistance values corresponding to LSB & MSB will increase as the number of bits present in the digital input increases.
- It is difficult to design more accurate resistors as the number of bits present in the digital input increases.

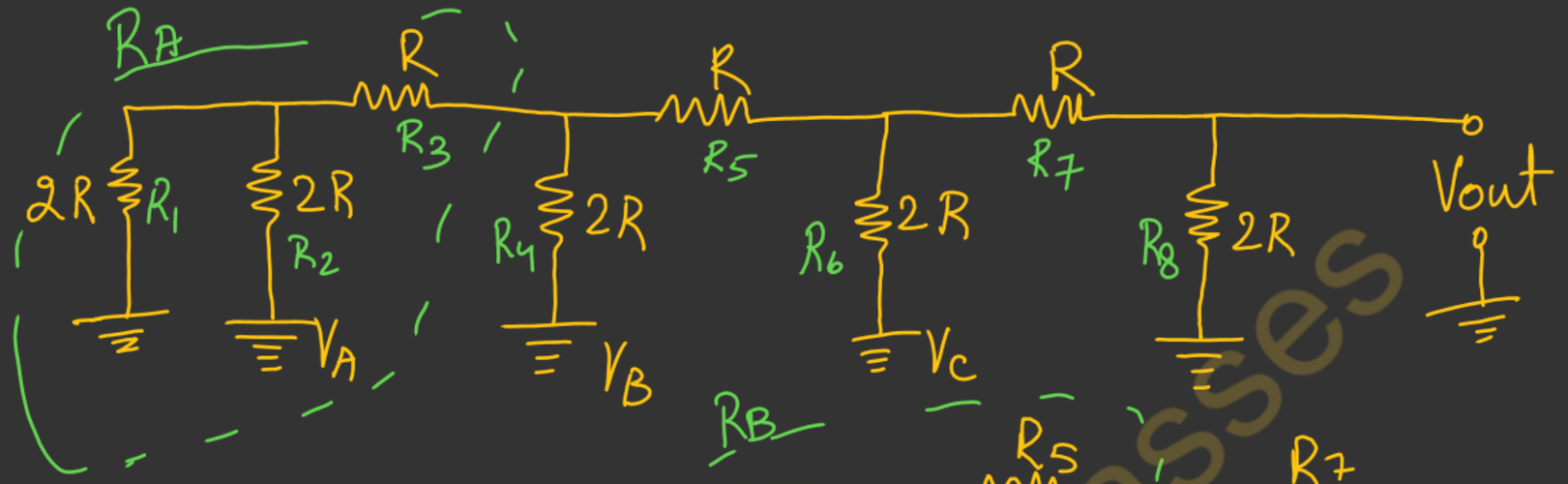
Gateway classes

R-2R Ladder DAC

- It overcomes the disadvantages of a binary weighted resistor DAC.
- R-2R Ladder DAC produces an analog output, which is almost equal to the digital (binary) input by using a R-2R ladder network in the inverting adder circuit.

Gateway classes


2R
R
Vout
V0
R
R
2R
2R
2R
2R
b0
b1
b2
-VR



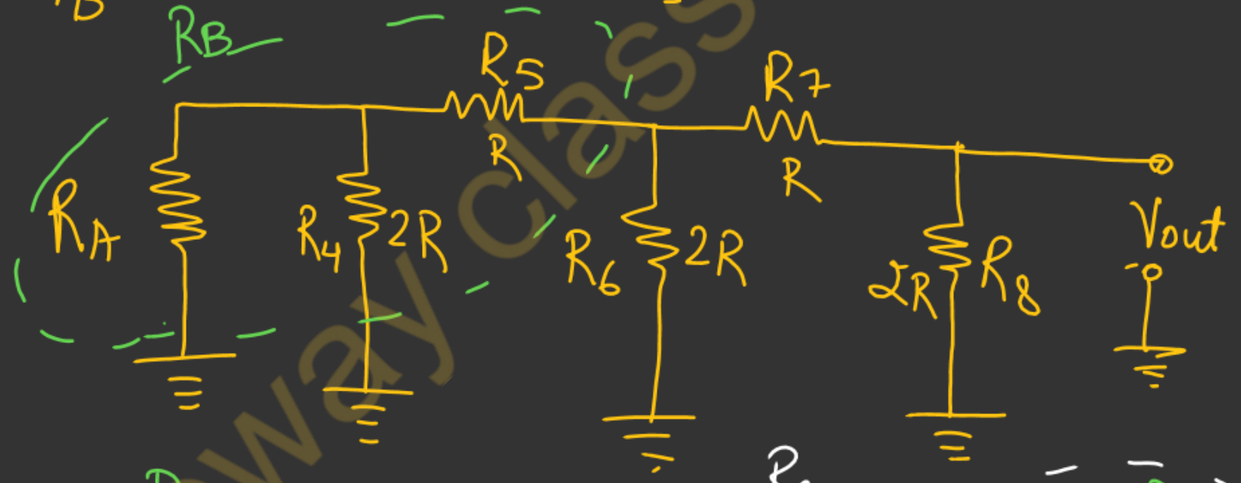
Bit = 0000

$$R_A = \frac{R_1 R_2}{R_1 + R_2} + R_3$$

$$= \frac{2R \times 2R}{2R + 2R} + R$$

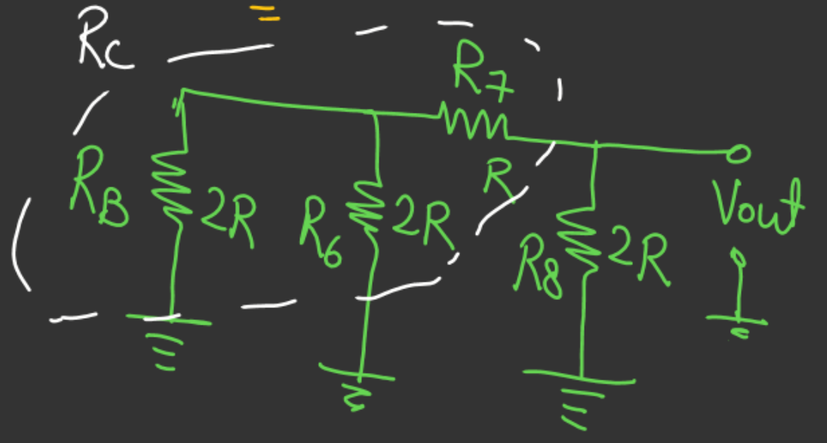
$$= \frac{4R^2}{4R} + R$$

$$R_A = 2R$$



$$R_B = \frac{R_A R_4}{R_A + R_4} + R_5$$

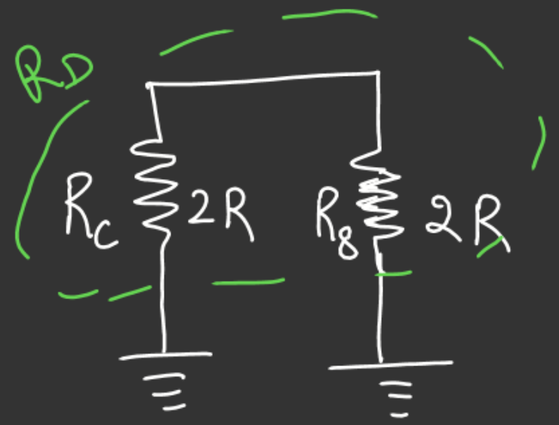
$$R_B = 2R$$



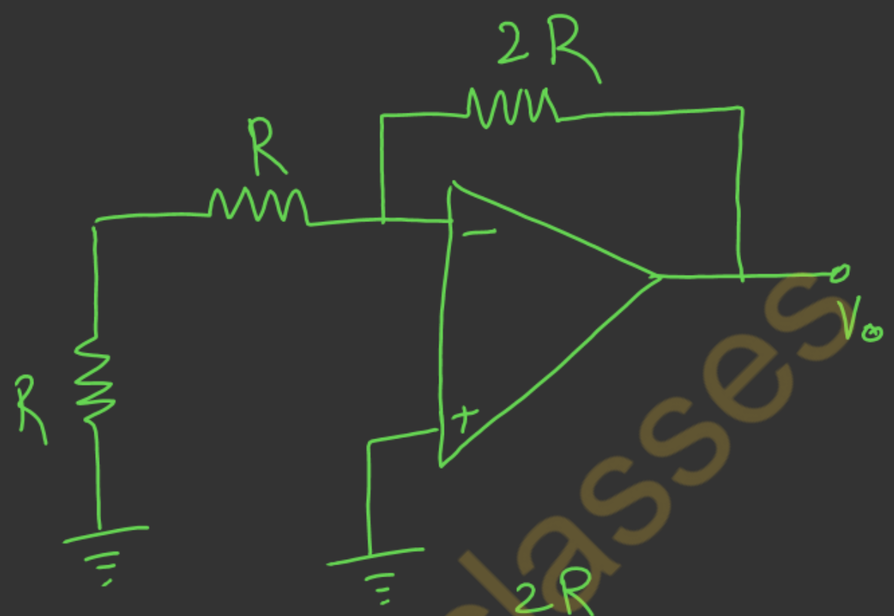
Gateway classes

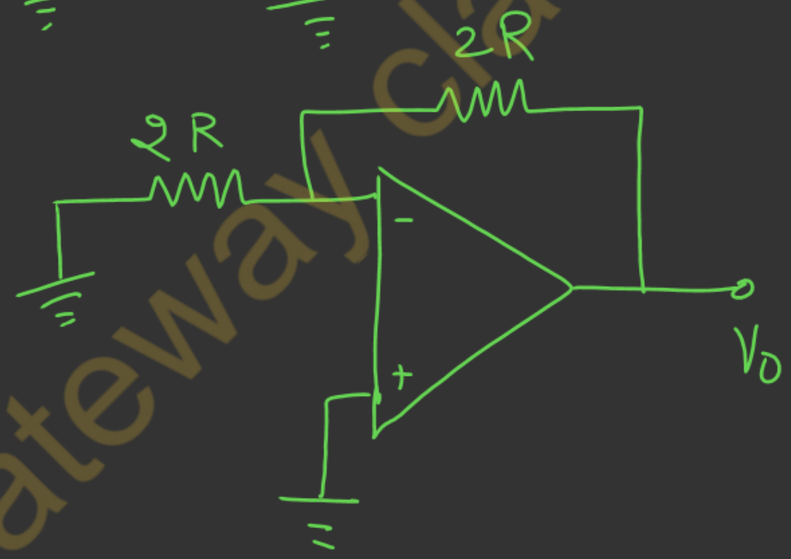
$$R_C = \frac{R_B R_6}{R_B + R_6} + R_7$$

$$= 2R$$



$$R_D = R$$





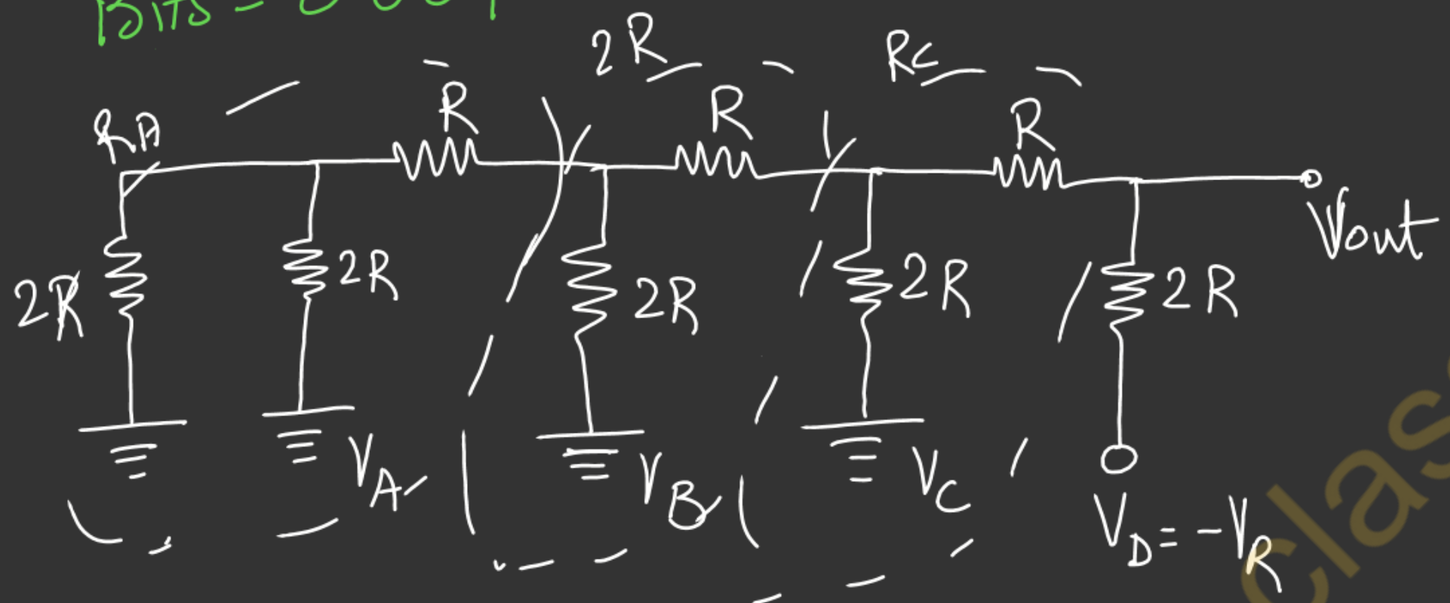
$$V_0 = \frac{R_f}{R} V_{in}$$

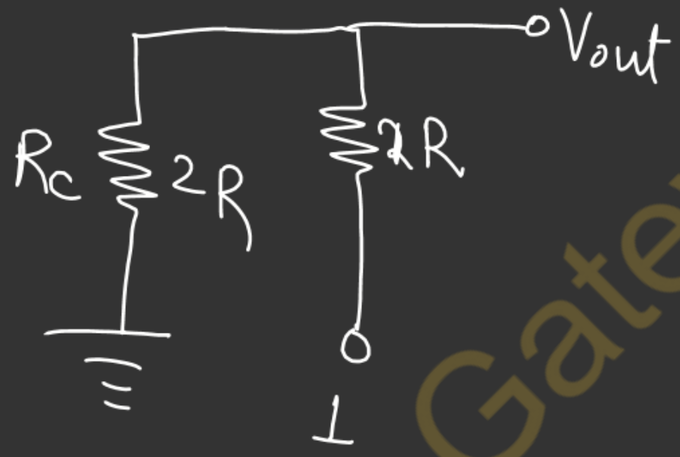
$$= \frac{2R}{2R} \times V_{in}$$

$$= 0\ V$$

Gateway Classes

Bits = 0 0 0 1





$V_R = 5V$

$V_{out} = \frac{5V}{16} \times 1 = 0.3125\ V$

$= 312.5\ mV$

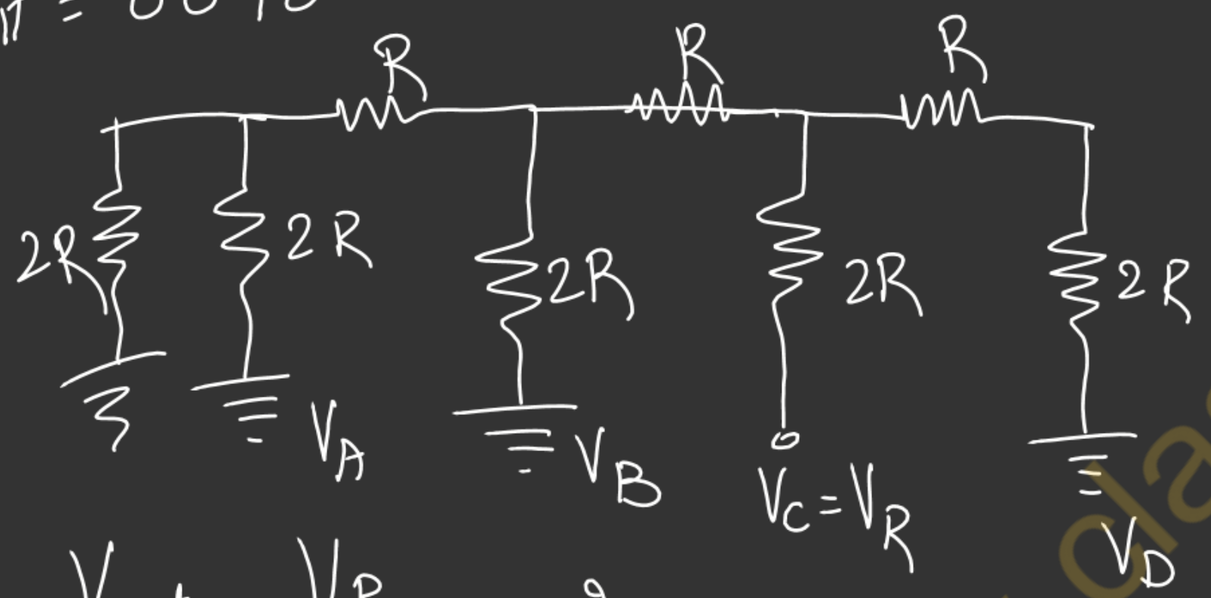
$V_R = 10V$

$V_{out} = \frac{10}{16} \times 1$

$=$

Gateway classes

bit = 0010



$$V_{out} = \frac{V_R}{16} \times 2$$

$$= \frac{5\,V}{16} \times 2$$

$$= 625\,mV$$

$$\text{Resolution} = \frac{V_R}{2^n}$$

Gateway classes

$n = 9$ bit DAC

000 000 000 = 0 V

111 111 111 = 10.3 V

$^{8}1\ ^{7}0\ ^{6}1\ ^{5}1\ ^{4}0\ ^{3}1\ ^{2}1\ ^{1}1\ ^{0}1$ = ?

$$V_0 = V_R \left[\frac{b^{n-1}}{2^1} + \frac{b^{n-2}}{2^2} + \frac{b^{n-3}}{2^3} + \cdots \frac{b_0}{2^{n-1}} \right]$$

$$= 10.3 \left[\frac{1}{2^1} + \frac{0}{2^2} + \frac{1}{2^3} + \frac{1}{2^4} + \frac{0}{2^5} + \frac{1}{2^6} + \frac{1}{2^7} + \frac{1}{2^8} + \frac{1}{2^9} \right]$$

$$= 7.383 \text{ V}$$

Gateway classes

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Thank You