AKTU

B.Tech III-Sem

Digital System Design



Unit-5 Lecture-4

EC & EC Allied

GATEWAY CLASSES

Gateway classes

DIGITAL SYSTEM DESIGN

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

Lec 4

Today's Target

- Flash ADC with and without Priority Encoder
- Advantages and Disadvantages of flash type ADC
- Switched Capacitor
- switched-capacitor resistor and its application
- Switched-Capacitor Circuit Advantages
- University Questions

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UNIVERSITY QUESTIONS

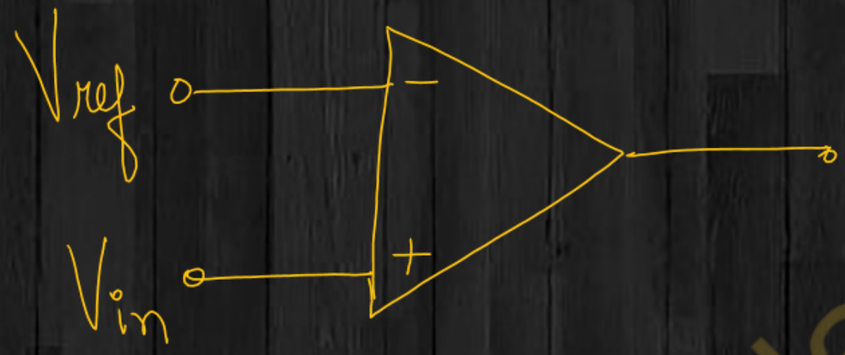
YEAR	QUESTIONS	MARKS
22-23 19-20	What are the advantages and disadvantages of flash type ADC	2 Marks
21-22	Describe switched capacitor and write its applications.	10 Marks
20-21 19-20	With a neat sketch Explain the operation of FLASH ADC.	10 Marks

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Flash ADC

- Also called the parallel A/D converter
- It is formed of a series of comparators, each one comparing the input signal to a unique reference voltage.
- The comparator outputs connect to the inputs of a priority encoder circuit, which then produces a binary output.
- Vref is a stable reference voltage provided by a precision voltage regulator as part of the converter circuit.
- As the analog input voltage exceeds the reference voltage at each comparator, the comparator outputs will sequentially saturate to a high state.
- The priority encoder generates a binary number based on the highest-order active input, ignoring all other active inputs.

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$V_{ref} > V_{in} \Rightarrow$ logic 0

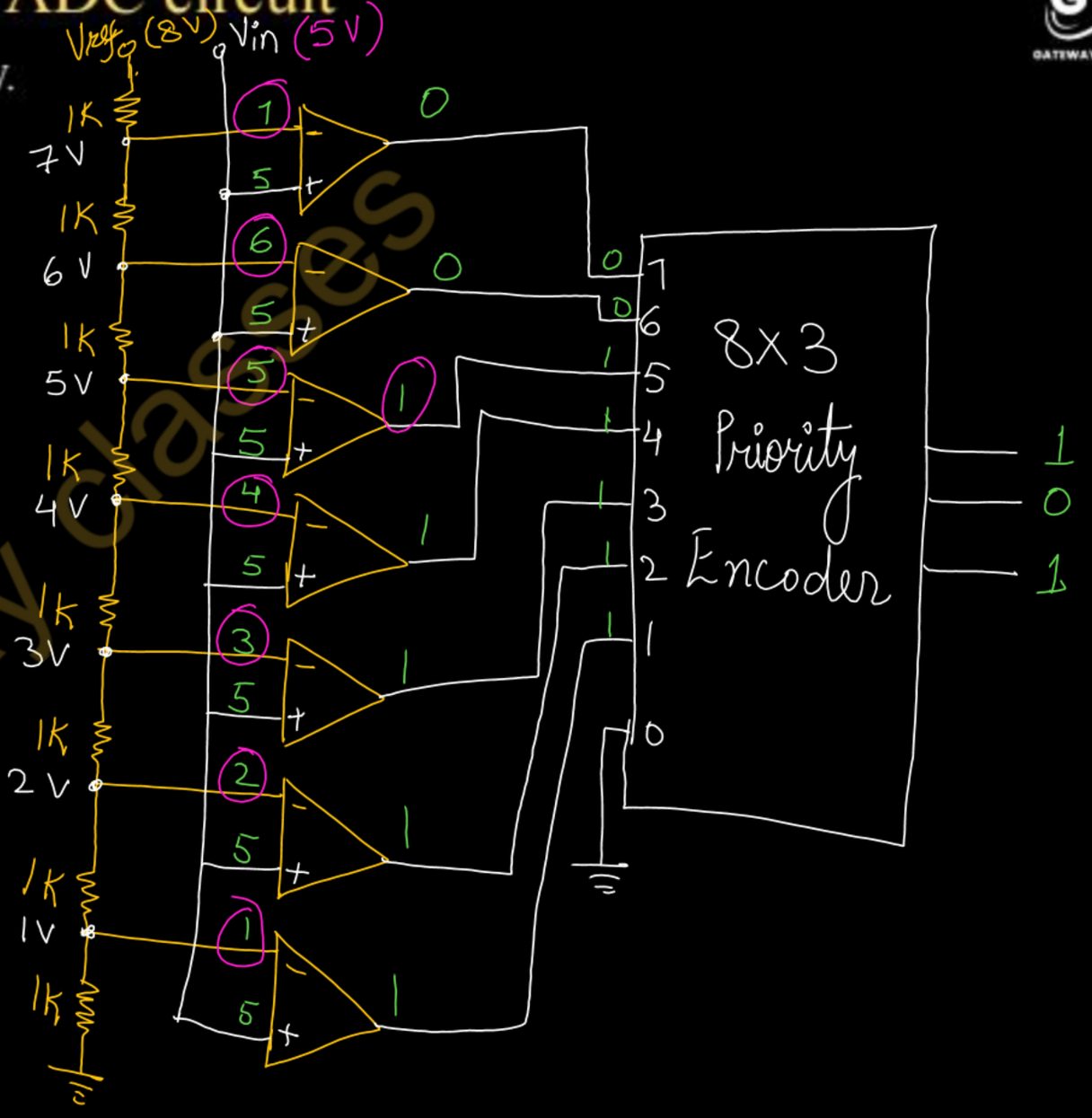
$V_{ref} < V_{in} \Rightarrow$ logic 1

$V_{ref} = V_{in} \Rightarrow$ logic 1

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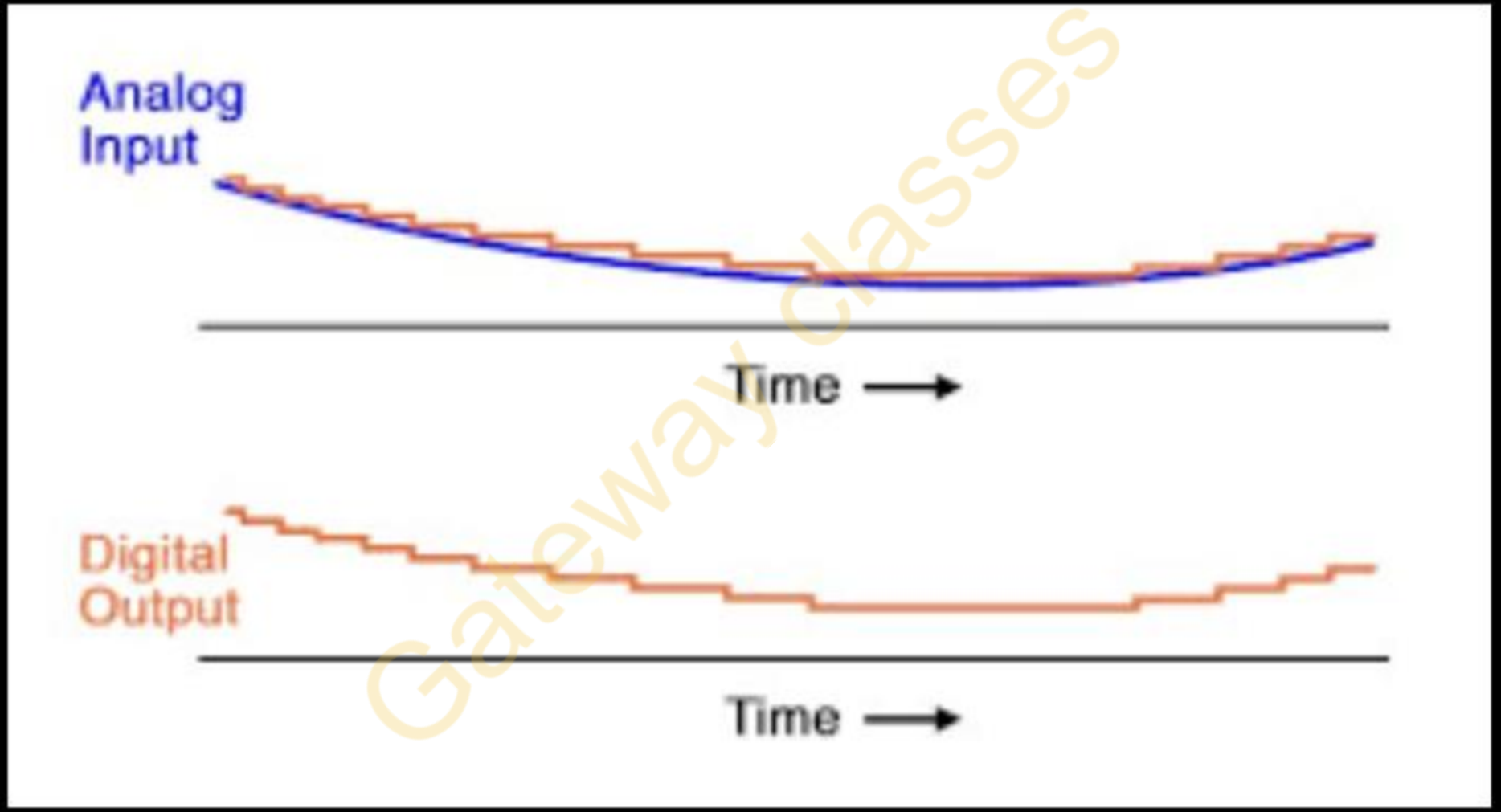
3-bit flash ADC circuit

- The logic diagram for the same is shown below.



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Output of Flash ADC



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Flash ADC without Priority Encoder

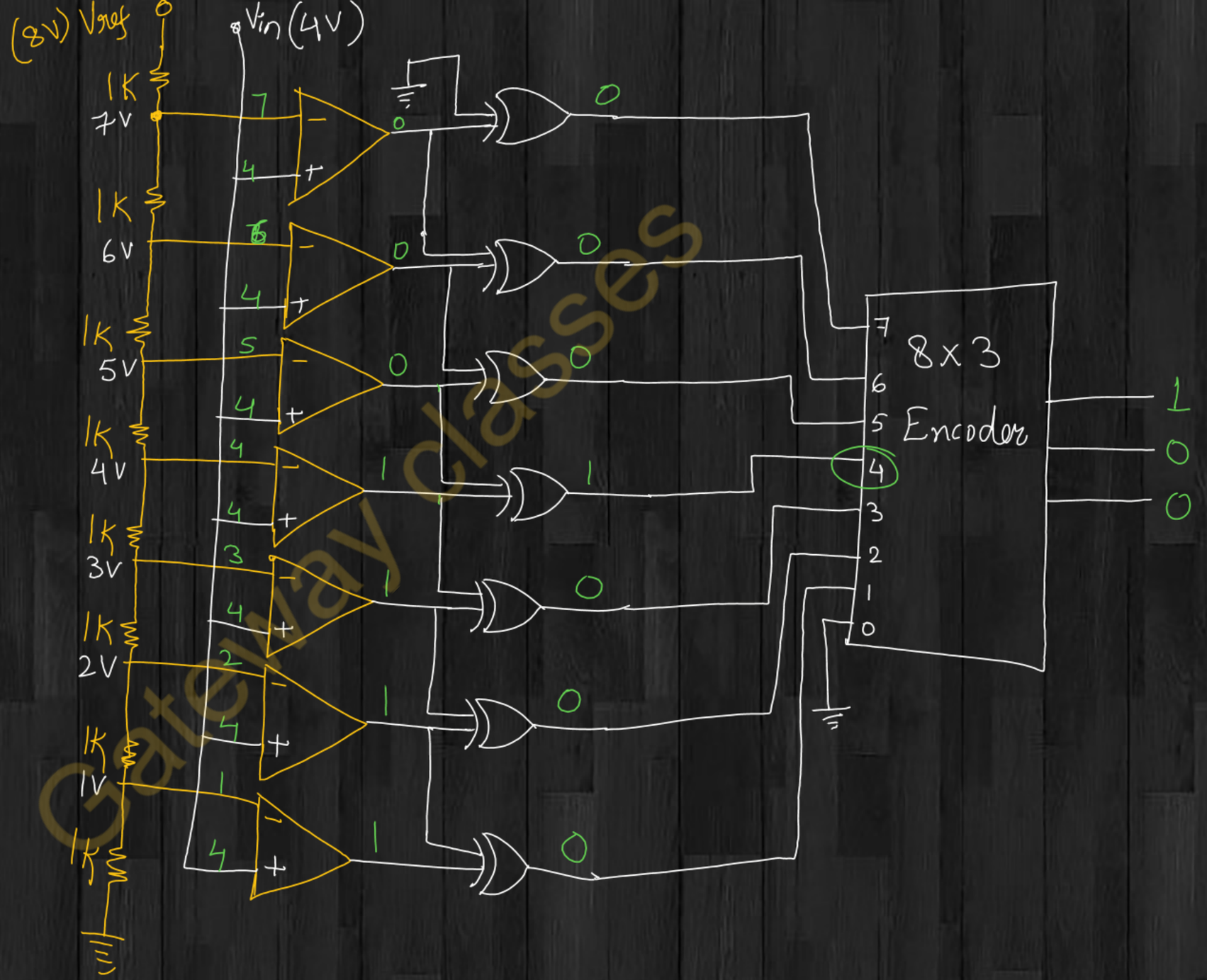
- For this particular application, a regular priority encoder with all its inherent complexity isn't necessary.
- Due to the nature of the sequential comparator output states (each comparator saturating "high" in sequence from lowest to highest), the same "highest-order-input selection" effect may be realized through a set of Exclusive-OR gates, allowing the use of a simpler, non-priority encoder:

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Ex-OR

$Y = \bar{A}B + A\bar{B}$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0



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Advantages and Disadvantages of flash type ADC

- Flash ADCs offer many advantages such as high speed and low latency.
- They also have some drawbacks such as high power consumption, large size, and limited resolution.
- These drawbacks can be mitigated by using sub-ranging or folding architectures, as well as interpolation techniques

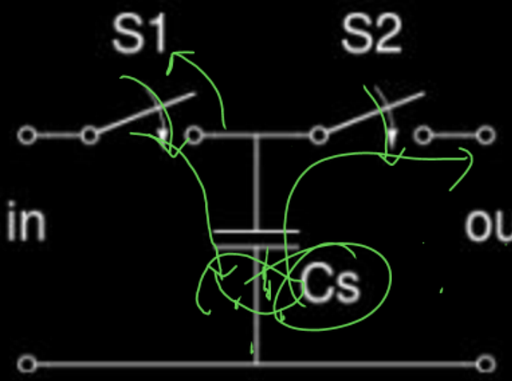
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Switched Capacitor

- A switched capacitor (SC) is an electronic circuit element implementing a filter.
- It works by moving charges into and out of capacitors when switches are opened and closed.
- Usually, non-overlapping signals are used to control the switches, so that not all switches are closed simultaneously.
- This makes them much more suitable for use within integrated circuits, where accurately specified resistors and capacitors are not economical to construct.

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The switched-capacitor resistor



- The simplest switched-capacitor (SC) circuit is the switched-capacitor resistor, made of one capacitor C and two switches S_1 and S_2 which connect the capacitor with a given frequency alternately to the input and output of the SC.
- Each switching cycle transfers a charge q from the input to the output at the switching frequency f.
- The charge *q* on a capacitor *C* with a voltage *V* between the plates is given by: $q = CV$
- where *V* is the voltage across the capacitor.
- Therefore, when S_1 is closed while S_2 is open, the charge stored in the capacitor C_S is: $q_{IN} = C_S V_{IN}$
- When S_2 is closed (S_1 is open - they are never both closed at the same time), some of that charge is transferred out of the capacitor, after which the charge that remains in capacitor C_S is: $q_{OUT} = C_S V_{OUT}$

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The switched-capacitor resistor

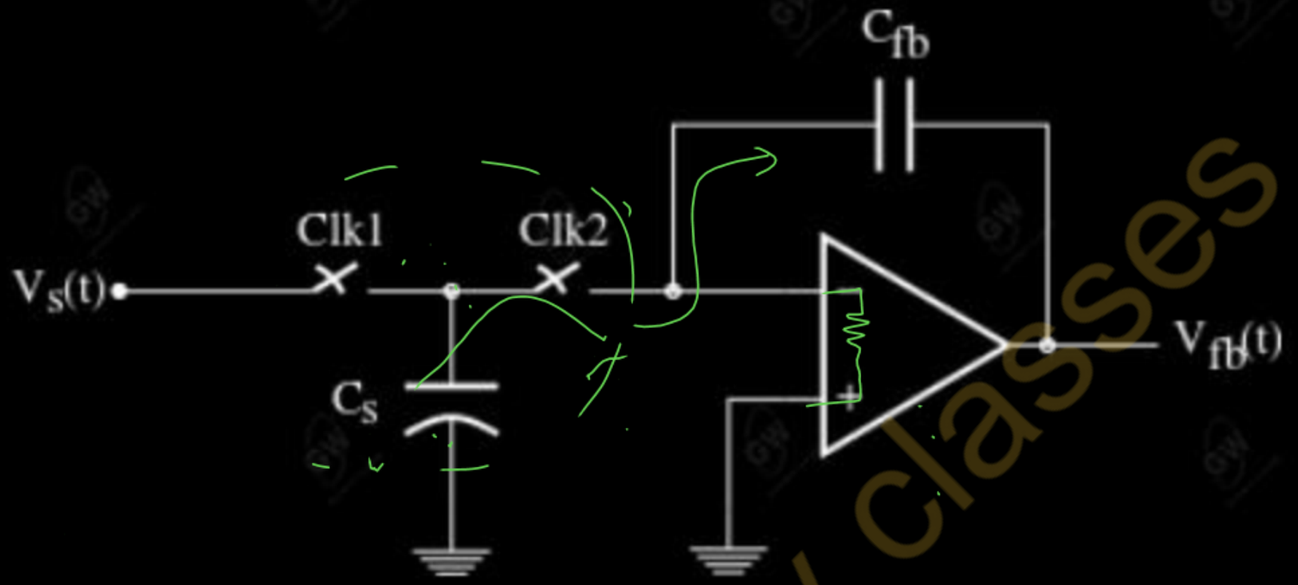
- Thus, the charge moved out of the capacitor to the output is: $q = q_{IN} - q_{OUT} = C_S [V_{IN} - V_{OUT}]$
- Since this charge q is transferred at a rate f, the rate of transfer of charge per unit time is: $I = qf$
- A continuous transfer of charge from one node to another is equivalent to a current, so

  $$I = C_S [V_{IN} - V_{OUT}] f$$

- Let V be the voltage across the SC from input to output. So: $V = V_{IN} - V_{OUT}$
- So the equivalent resistance R (i.e., the voltage–current relationship) is: $R = V/I = 1/(C_S f)$
- Thus, the SC behaves like a resistor whose value depends on capacitance C_S and switching frequency f.
- The SC resistor is used as a replacement for simple resistors in integrated circuits because it is easier to fabricate reliably with a wide range of values.
- It also has the benefit that its value can be adjusted by changing the switching frequency (i.e., it is a programmable resistance).

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The parasitic-sensitive integrator



- Often switched-capacitor circuits are used to provide accurate voltage gain and integration by switching a sampled capacitor onto an op-amp with a capacitor C_{fb} in feedback.
- One of the earliest of these circuits is the parasitic-sensitive integrator developed by the Czech engineer Bedrich Hosticka.

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- In capacitors, charge = capacitance × voltage
- when S1 opens and S2 closes we have the following:
  - Because C_S has just charged: $Q_S(t) = C_S \cdot V_S(t)$
  - Because the feedback cap, C_{fb}, is suddenly charged with that much charge (by the op amp, which seeks a virtual short circuit between its inputs): $Q_{fb}(t) = Q_S(t-T) + Q_{fb}(t-T)$
  - Now dividing 2) by C_{fb}: $V_{fb}(t) = [Q_S(t-T)/C_{fb}] + V_{fb}(t-T)$
  - And inserting 1): $V_{fb}(t) = [C_S / C_{fb}]V_S(t-T) + V_{fb}(t-T)$
  - This last equation represents what is going on in C_{fb} - it increases (or decreases) its voltage each cycle according to the charge that is being "pumped" from C_S (due to the op-amp).
  - However, there is a more elegant way to formulate this fact if T is very short.
  - Let us introduce $dT \leftarrow T$ and $dV_{fb} \leftarrow V_{fb}(t) - V_{fb}(t-T)$ and rewrite the last equation divided by dt: $dV_{fb}(t)/dt = f[C_S / C_{fb}]^* V_S(t)$
  - Therefore, the op-amp output voltage takes the form:
  - $V_{OUT}(t) = -V_{fb}(t) = -[1/\{(1/f C_S) * C_{fb}\}]^* \int V_S(t)dt$
  - This is an inverting integrator with an "equivalent resistance $R_{eq} = 1/f C_S$
  - This allows its *on-line* or *runtime* adjustment.

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Switched-Capacitor Circuit Advantages

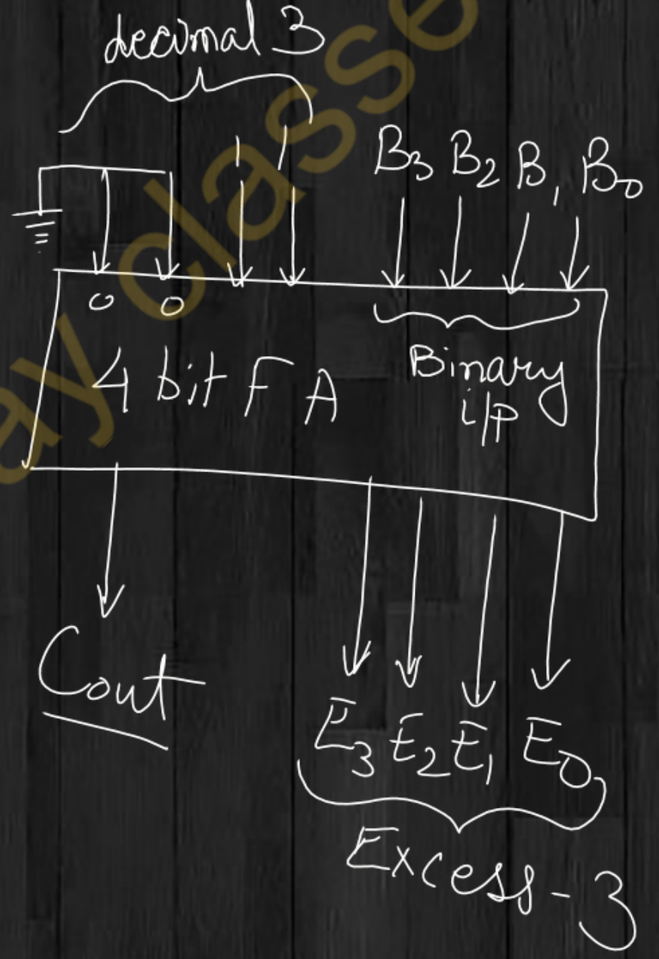
- Saves space while achieving high resistance values.
- Achieve a frequency response accuracy of the order of 0.1%.
- Matching similar IC components(such as capacitor to capacitor) instead of two different components(such as capacitor to resistor) allows for this level of precision.
- Easier to reliably implement with a broader range of values, making it an ideal replacement for traditional resistors in any integrated circuit application.
- Possible to adjust the equivalent resistor value by changing the clock speed.

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Binary to Excess-3 using FA

Bin + 0011 $\Rightarrow$ Excess 3

dec 3



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Thank You