Gate 2023- Instrumentation Engineering

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Question 60: In the circuit shown, the input voltage $V_{in} = 100mV$. The switch and the opamp are ideal. At time $t = 0$, the intial charge stored in the $10nF$ capacitor is $1nC$, with the polarity as indicated in the figure. The switch S is controlled using a $1KHz$ square-wave voltage signal V_s as shown. Whenever V_s is 'High', S is in position $'1'$ and when V_s is 'Low', S is in position $'2'$.
At $t = 20ms$, the magnitude of the voltage V_o will be

Solution: As $f = 1KHz$ its time-period is $1ms$.

Parameter	Value	Description
V_{in}	$100mV$	Input voltage
q_{10nF}	$1nC$	Intial charge on $10nF$
f	$1KHz$	Frequency of V_s
V_o		Output voltage

TABLE 0
INPUT PARAMETERS

So, for $0.5ms$ the switch will be at position 1 and then shift to position 2 for the other $0.5ms$ and this continues in cycles.

In the first $0.5ms$ the switch will be at position 1. The $1nF$ capacitor gets charged to $0.1nC$.

In the second $0.5ms$ the switch shift to position 2. So, the op-amp's $-ve$ terminal gets virtually shorted then the charge across the $1nF$ capacitor should be zero.

To maintain the charge across the $1nF$ to be 0, it transfers the charge of $0.1nC$ to the $10nF$ capacitor.

As the polarity across the $10nF$ capacitor is opposite to the which the $1nF$ capacitor transfers the charge the charge gets subtracted.

So, effectively in a cycle of $1ms$ time-period $-0.1nC$ charge is transfered to the $10nF$ capacitor. In 20 cycles it transfers $-2nC$.

At $t = 20ms$ the effective charge on the $10nF$ capacitor is $-1nC$ and voltage across it is V_o.

$$V_o = \frac{-1nC}{10nF} \tag{1}$$

$$= -100mV \tag{2}$$