Assignment 11

Solution to GATE EC2016, question 17

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Question

Assume that all the digital gates in the circuit shown in the figure are ideal, the resistor $R = 10\ k\Omega$ and the supply voltage is 5 V. The D flip-flops D_1, D_2, D_3, D_4 and D_5 are initialized with logic values 0, 1, 0, 1 and 0, respectively. The clock has a 30% duty cycle.

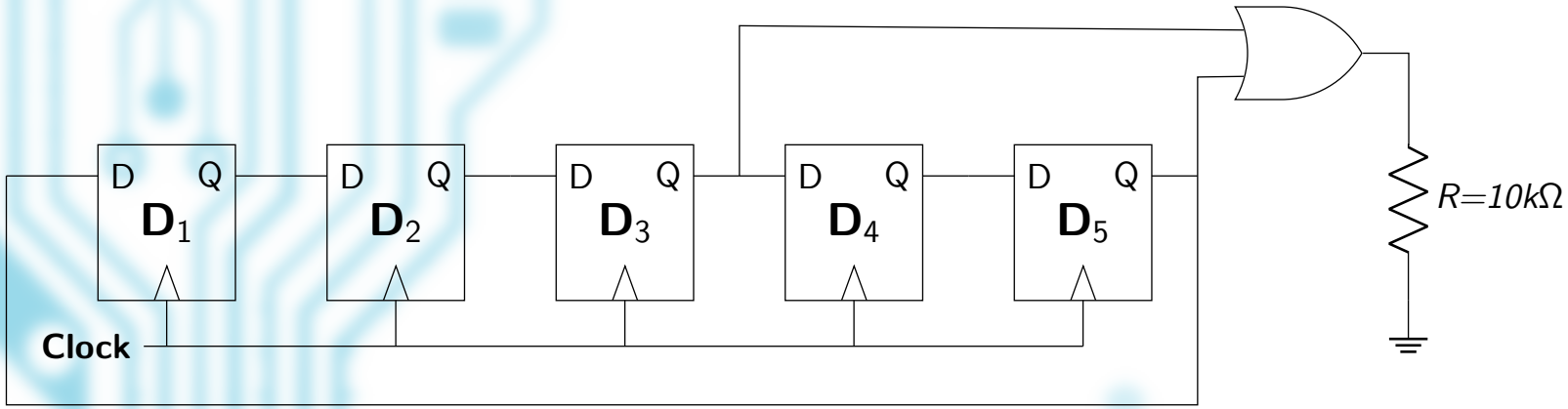

Figure: *Question figure*

The average power dissipated (in mW) in the resistor R is _____

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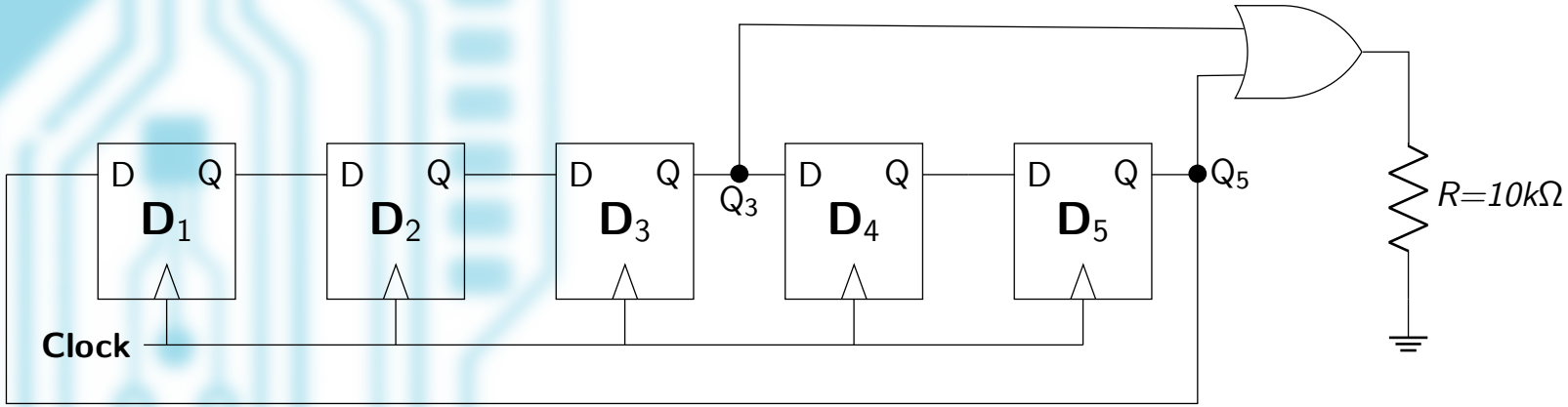
Solution / Pretext



Let the output waveform be represented by Y. Then, we can infer from the question figure that

$$Y = Q_3 + Q_5 \tag{1}$$

We can also infer that the given Flip-Flops are negative edge triggered since they have a bubble (can be seen as a triangle) on the clock input.

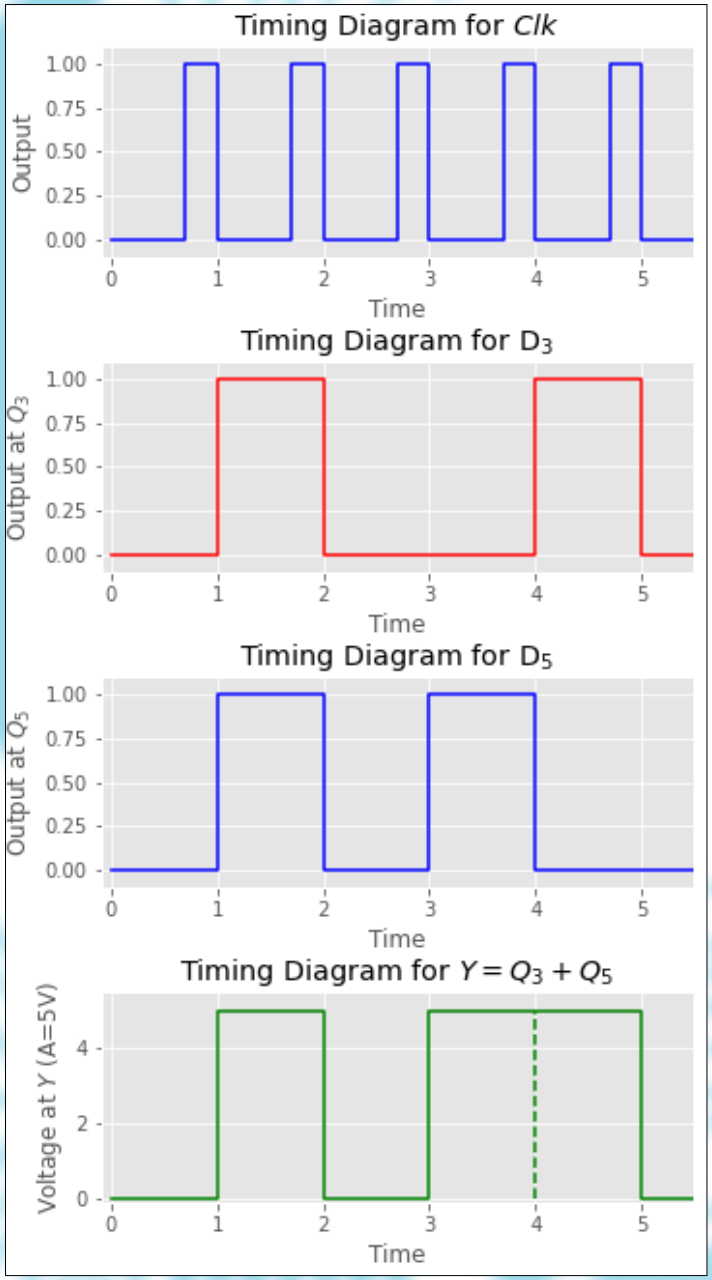
Solution / Truth Table

Clk	Q_1	Q_2	Q_3	Q_4	Q_5	$Y = Q_3 + Q_5$
0	0	1	0	1	0	0
1	0	0	1	0	1	1
2	1	0	0	1	0	0
3	0	1	0	0	1	1
4	1	0	1	0	0	1
5	0	1	0	1	0	0

Table: *Truth Table for the Circuit Diagram given in the Question Figure*

Now, using the truth table, we can make the timing diagram as given on the next slide.

Solution / Timing Diagram



Here, the time 0 to 5 represents five time periods of the clock. Since the given Flip-Flops are negative edge triggered, each of them changes their value when the output of the clock falls to 0.

From the timing diagram for Y, we can see that out the output voltage is non-zero for 3 time periods.

Solution / Calculation

We can thus calculate the average power over time using the general formula:

$$\textit{Average power dissipated} = P_{avg} = \frac{1}{T}\int_0^T VI\,dt \tag{2}$$

In the current context, we are calculating the average over 5 time periods. Hence, the equation now becomes:

$$P_{avg} = \frac{1}{5T}\int_0^{5T} VI\,dt \tag{3}$$

writing I in terms of V $(5V)$ and R $(10k\Omega)$, we get:

$$P_{avg} = \frac{1}{5T}\frac{V^2}{R}\int_0^{5T} dt \tag{4}$$

Solution / Calculation

placing the value of integral, we get:

$$P_{avg} = \frac{1}{5T}\frac{V^2}{R}3T \tag{5}$$

finally, placing the values of V and R, we get:

$$P_{avg} = \frac{3}{5}\frac{5^2}{10000} \tag{6}$$

$$\boxed{P_{avg} = 1.5\ mW} \tag{7}$$

Thank you.