

Exercise Circ20

Consider a CMOS fabrication process with the following process parameters:

$$k_n' = \mu_n C_{ox} = 90 \mu A/V^2, \quad k_p' = \mu_p C_{ox} = 30 \mu A/V^2,$$

$$V_{th,n} = |V_{th,p}| = 0.6 \text{ V},$$

$L_{min} = 0.5 \mu\text{m}$ (minimum allowed channel length, for both N-channel and P-channel transistors),

$C_{ox} = 2 \text{ fF}/\mu\text{m}^2$ (gate oxide capacitance per unit area),

$t_{ox} = 15 \text{ nm}$ (gate oxide thickness).

The used fabrication technology and the layout are such that, for each transistor, the drain capacitance and the source capacitance turn out to be equal to 25% and 20%, respectively, of the gate capacitance, whereas the overlap/fringing gate capacitance and the capacitances associated to interconnections are negligible.

Supply voltage V_{DD} is equal to 3 V.

The transistors in the elementary inverter used in the circuit shown in Figure 1, fabricated with the above integration process, have the following sizes:

n -channel transistor: W_n (channel width) = $2 \mu\text{m}$; L_n (channel length) = $0.5 \mu\text{m}$;

p -channel transistor: W_p (channel width) = $6 \mu\text{m}$; L_p (channel length) = $0.5 \mu\text{m}$.

Consider the 7-stage ring oscillator in Fig. 1, which has been implemented by using the above elementary inverter.

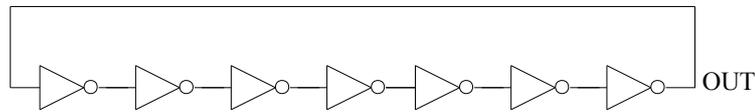


Figure 1

The candidate is asked to:

- a) calculate the delay time of the elementary inverter in the ring oscillator in figure 1, justifying all the assumptions made, if any;
- b) estimate the oscillation frequency of the circuit;
- c) estimate the oscillation frequency of the circuit when a load capacitor C_L of 0.5 pF is connected between the output node OUT and ground, as shown in Fig. 2;
- d) estimate the dynamic power consumption of the circuit in figure 2 (i.e., of the circuit in the presence of the capacitive load $C_L = 0.5 \text{ pF}$), due to charging and discharging capacitances (in other words, neglect leakage and subthreshold currents as well as short-circuit power consumption).

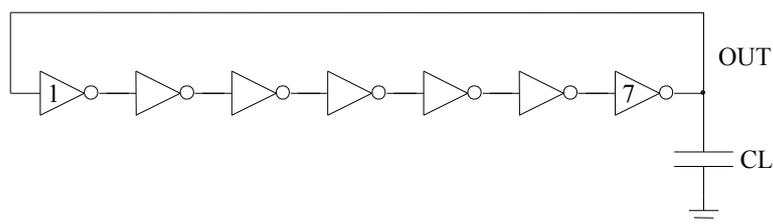


Figure 2