

Exercise Circ09

Consider a CMOS fabrication process with the following process parameters:

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

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

$L_{min} = 0.4 \mu\text{m}$ (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 20% and 30%, 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 an integrated circuit fabricated with the above process have the following sizes:

n -channel transistor: W_n (channel width) = $3 \mu\text{m}$; L_n (channel length) = $0.4 \mu\text{m}$;

p -channel transistor: W_p (channel width) = $9 \mu\text{m}$; L_p (channel length) = $0.4 \mu\text{m}$.

By using the above elementary inverter, we implemented the circuit shown in figure 1, which is a ring oscillator where elementary inverters (equal to the above elementary inverter) are added to drive output lines. Capacitor C_L , which represents the load at node OUT, is equal to 0.8 pF .

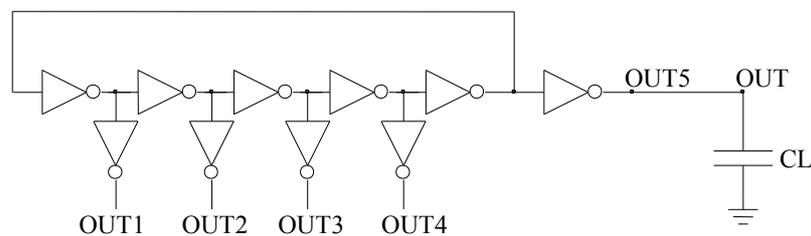


Figure 1

The candidate is asked to:

- a) Calculate the delay time of the elementary inverter in the circuit schematic in figure 1, justifying all the assumptions made, if any.
- b) Estimate the oscillation frequency of the circuit.
- c) Design a buffer to be included between nodes OUT5 and OUT (which are short-circuited in Fig. 1) so as to drive a capacitor C_L equal to 0.8 pF ensuring minimum delay time from node OUT5 to node OUT.
- d) Evaluate the delay time from node OUT5 to node OUT when the above designed buffer (item c) is included.