

## EHB322E Digital Electronic Circuits Homework 2

Deadline: 21/04/2014 (before the lecture)

Consider a Boolean function shown below.

$$f = x_1 \overline{x_2} x_3 + x_1 \overline{x_4} + x_2 x_3 \overline{x_4}$$

**1) CALCULATION:** Use the following parameters for your calculations.

*Equivalent resistor for all NMOS transistors:  $R_N=10\text{k}\Omega$*

*Equivalent resistor for all PMOS transistors:  $R_P=13\text{k}\Omega$*

- a) Implement  $f$  with “a CMOS Complex Gate Circuit”, “an NMOS Pass Transistor Logic Circuit”, and “a CMOS Pass Transistor Logic Circuit”. For pass transistor logic select an ordering of  $x_1, x_2, x_3$ , and  $x_4$ . There should be total of **three** circuits/implementations.
- b) Suppose that a load capacitor of 10pF is connected to the output of each circuit. Calculate the worst case propagation delays  $t_{PLH}$  and  $t_{PHL}$  for each implementation. There should be total of **six** delay values.

**2) SIMULATION:** Construct each of the three circuits implemented in **1)-a)** using SPICE. Select  $V_{DD}=5\text{V}$  (logic 1) and ground=0V (logic 0) for inputs. Connect body terminals of transistor to their source terminals. Select  $W_P=2\mu$ ,  $L_P=1\mu$  for all PMOS transistors; select  $W_N=1\mu$ ,  $L_N=1\mu$  for all NMOS transistors. Use T15DN and T15DP spice models for NMOS and PMOS transistors, respectively (for details refer to Homework 1).

- a) Statically test your implementations by applying two cases  $x_1=1, x_2=0, x_3=1, x_4=1$ , and  $x_1=0, x_2=1, x_3=0, x_4=1$ . For each case sketch  $V_{OUT}$  in time domain. There should be total of **six** Spice figures.
- b) Connect a load capacitor of 10pF to the output of each circuit. Apply square pulse waves with frequency of 10kHz to required inputs. Find the worst case propagation delays  $t_{PLH}$  and  $t_{PHL}$ , by sketching  $V_{IN}$  &  $V_{OUT}$  in time domain, for each implementation. There should be total of **six** delay values and Spice figures. Compare your results with those in **1)-b)**; justify your answer.

*Grading: 1(a)20%, 1(b)20%, 2(a)20%, 2(b)40%*

*Note: Do not forget to attach SPICE **output file** prints to your homework!*