CpE401 – Exam I, F03

Name ____________________

Show all your work in the space provided. Answers with a simple "yes", "no", or a single number are typically incomplete and will not be given full credit. Answers in non-reduced form, like (a+sqrt(b))/c, are fine where appropriate. Good English on essay/short answer questions is required. ON MULTIPLE CHOICE QUESTIONS, IF YOU'RE NOT SURE GUESS CAREFULLY– you will get points off for wrong answers. If you know part of an answer, write what you know for partial credit.

1. (20 Points) One approach to scaling interconnect is "constant resistance" scaling, where the resistance of the interconnect remains constant as feature-size scales. If the width of the wire, W, and the thickness of the insulation between layers, t_{ins}, scales with 1/k, where k is the scale factor, answer the following questions:
    a. (5 Points) Assuming we are working with an aluminum wire (not some other material), what parameter must scale to maintain a constant per-unit-length resistance and how must it scale? (Your answer to this part is important to the next parts of this question. If you do not know the answer, I will give it to you but you will lose the points).

    b. (5 Points) Approximately how does per-unit-length wire delay, τ_w, scale in this case? (As an approximation, you may ignore fringing capacitance).

    c. (5 Points) Unfortunately, this type of scaling also causes some bad side-effects. What undesirable side-effects result from this type of scaling?

    d. (5 Points) Is there any other way to achieve the same effect (low resistance interconnect) without these drawbacks of the scaling given in part a above?

2. (15 Points) V_{dd} and V_T are both scaled with device size. There are (unpleasant) consequences to this scaling, but the parameters <u>must</u> be scaled. Why must these parameters be scaled? What are the consequences?

3. (11 Points) Short-answer questions from student presentations:
   a. (2 Points) What is IBIS used to model?

   b. (2 Points) What is the main advantage of a vertical transistor:

   c. (2 Points) What is the main challenge to systems-on-a-chip (SOC)?

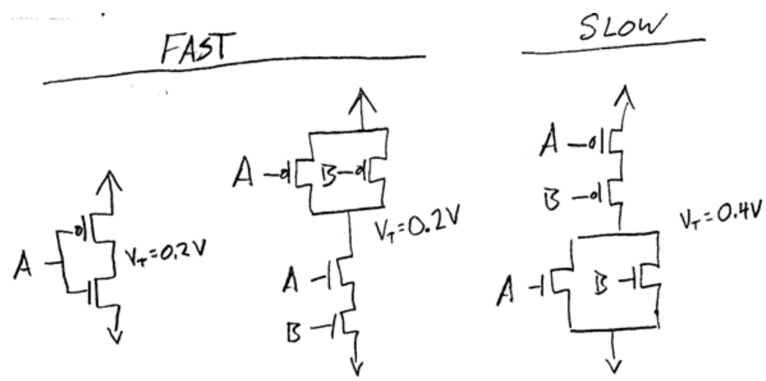
   d. (2 Points) What are the three main types of power-distribution?

   e. (3 Points) Is a read-access to DRAM memory destructive? Why?

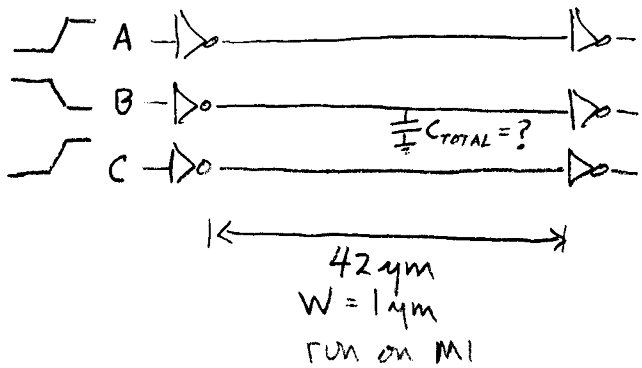
4. (16 Points) The following three circuits appear within a chip. The two circuits on the left are critical to performance and so have a low V_T. The circuit on the right in not critical so has a high V_T. It just so happens that the inputs A and B are both 0.
   a. Approximately how much leakage current does the fast NAND gate and slow NOR gate draw in relation to the inverter (i.e. find X for $I_{0,NAND} = X*I_{0,INV}$)?
   b. Which circuit draws the least amount of leakage current?

Assume "average" characteristics for a 0.25 micron process.

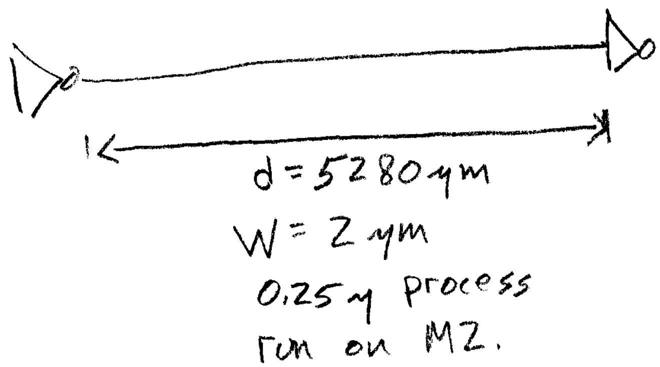
A=0
B=0



5. (18 Points) Three signal wires run next to one another as shown below. We want to find the <u>total</u> capacitance driven by the buffer on line B. The wires are made from M1 (Al1), are 1 micron wide, are fabricated in a 0.25 micron process, and run for 42 microns in length. The input capacitance to the buffers is 1fF. The signals A and C both transition from low to high at the same time that signal B transitions from high to low, as shown in the figure. What is the <u>total</u> capacitance driven on line B?



6. (20 Points) A signal wire runs from one gate to another using metal 2 (Al2) in a 0.25 micron process. The signal wire is 2 microns wide, 0.9 microns thick, and runs a distance of 5280 microns from one gate to the other. For this signal wire, which is more important at 40 GHz: the skin effect or the lumped inductance associated with the wire's loop area? Show your calculations.



<u>Convenient parameters</u>
for SiO_2, $\varepsilon\mu = 4.3\text{x}10^{-17}$ FH/m^2
($\varepsilon_o = 8.85\text{x}10^{-12}$ F/m
$\varepsilon_{SiO2} = 3.9$
$\mu_o = 4\pi\text{x}10^{-7}$ H/m
$\mu_r = 1$).
$C_{area,\ M2} = 13$ aF/μm^2
$C_{fringe,M2} = 25$ aF/μm
$\rho_{Al} = 2.7\text{x}10^{-8}$ Ωm
$\rho_{Al}\pi\mu = 1.1\text{x}10^{-13}$ΩH