Name _____

EE40

Midterm 3

April 24, 2003

PLEASE WRITE YOUR NAME ON EACH ATTACHED PAGE

PLEASE SHOW YOUR WORK TO RECEIVE PARTIAL CREDIT

PLEASE DO NOT LEAVE UNTIL EXAM PERIOD IS OVER

Problem 1: 15 Points Possible _____

Problem 2: 20 Points Possible _____

Problem 3: 15 Points Possible _____

Problem 4: 20 Points Possible _____

Problem 5: 20 Points Possible _____

Problem 6: 10 Points Possible _____

TOTAL: 100 Points Possible _____

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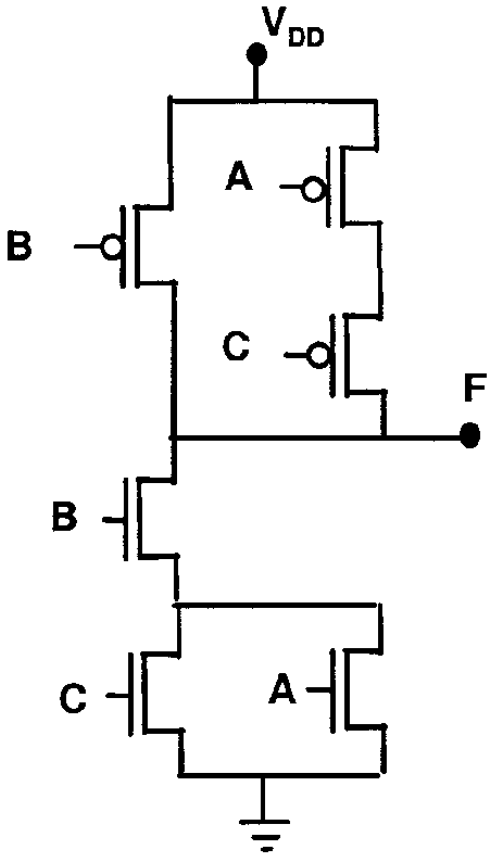
Problem 1: 15 Points Possible

Determine whether the circuit below performs a logical operation. If it does, give the Boolean function it computes. If not, give a set of inputs that results in an invalid output.

For your convenience, 8 copies of this circuit are given on the next page. Assume that all PMOS transistors have source terminal on top, and all NMOS transistors have source terminal on the bottom.



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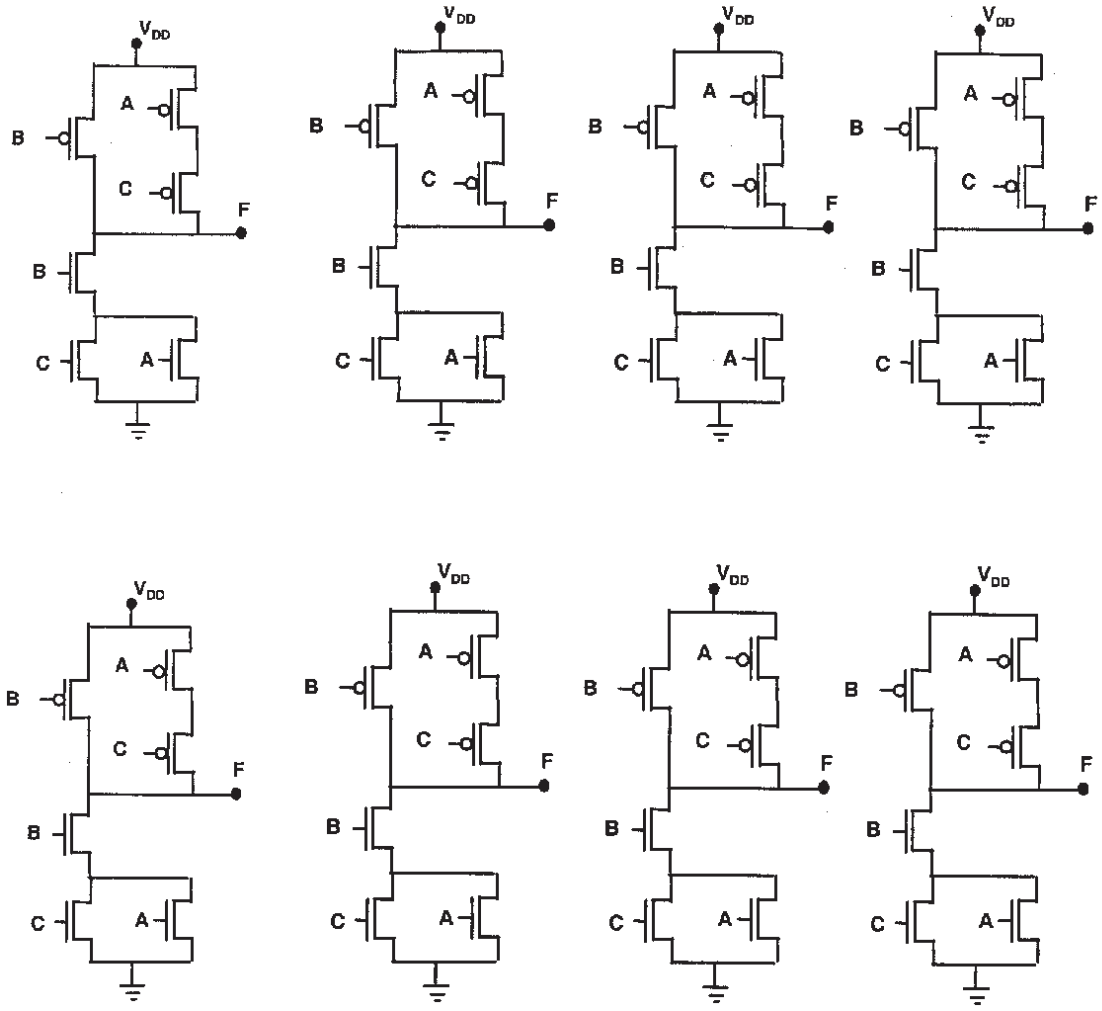
Problem 1 Workspace



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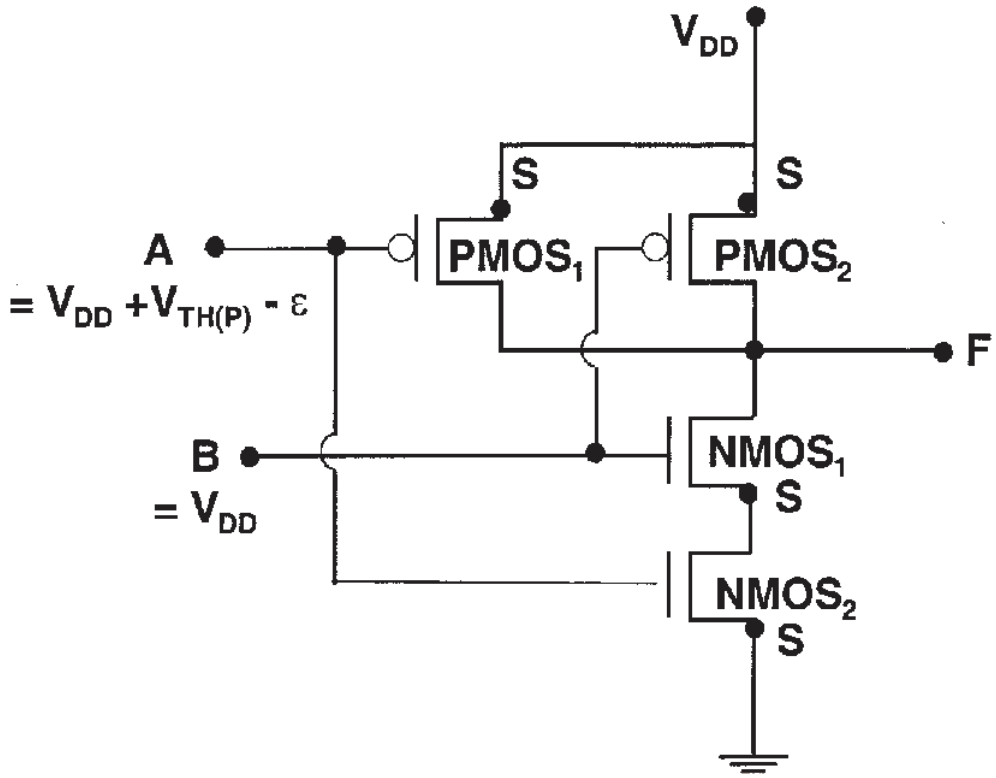
Problem 2: 20 Points Possible

For the CMOS logic circuit below, determine the most probable mode of operation for each transistor. Assume that ε is a very small positive number, and V_{DD} is much larger in magnitude than either V_{TH} .



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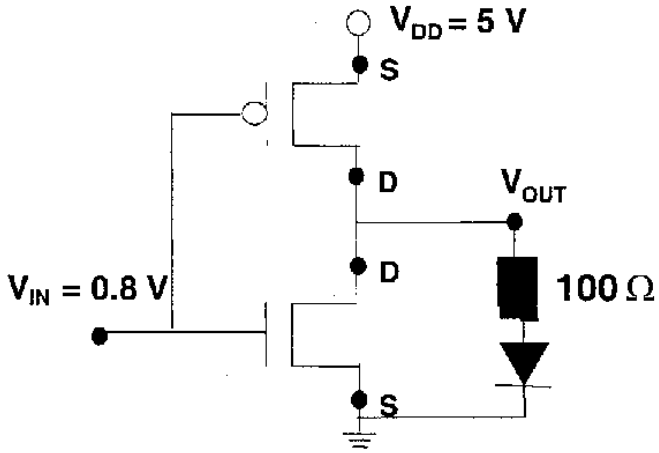
Problem 3: 15 Points Possible

Consider the inverter at right, which turns on an LED when the output voltage is high.



I have put a resistor in series with the LED to limit the current so the LED doesn't burn.

But, the LED needs a current of at least 20 mA to light up.

I want the LED to light up for an input voltage as high as 0.8 V.

Will the LED light up for an input of 0.8 V?

$W/L\ \mu\ C_{OX}$ = 100 mA/V^2 for both transistors,
$V_{TH(N)} = -V_{TH(P)}$ = 1 V,
λ = 0 V^{-1} for both transistors,
V_F = 2 V for the LED (use large-signal model).

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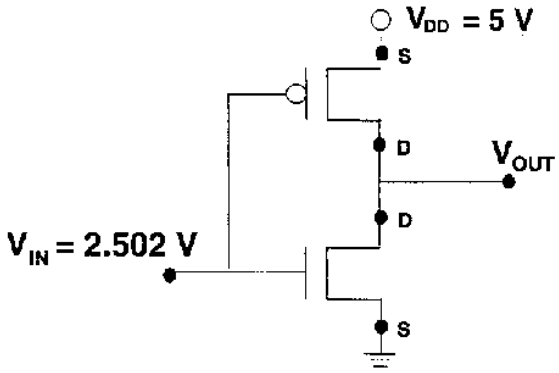
Problem 4: 20 Points Possible

Consider the CMOS inverter at right, with

W/L μC_{OX} = 1 mA/V^2 for both transistors,
$V_{TH(N)} = -V_{TH(P)}$ = 1 V,
λ = **0.01 V^{-1} for both transistors.**

For this inverter, V_M = 2.5 V.



a) Find V_{OUT} for V_{IN} = 2.502 V. Hint for guessing modes: Notice that V_{IN} is close to V_M.

b) Find the slope of the V_{OUT} vs. V_{IN} curve in this region, given by

$$\frac{\Delta V_{OUT}}{\Delta V_{IN}} = \frac{V_{OUT}(\text{for } V_{IN} = 2.502\text{ V}) - V_M}{2.502\text{ V} - V_M}$$

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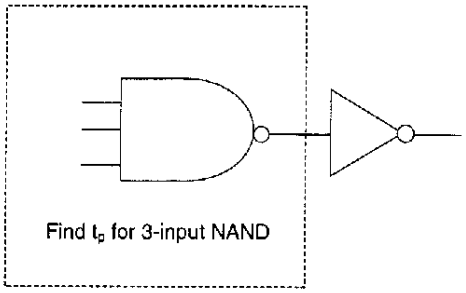
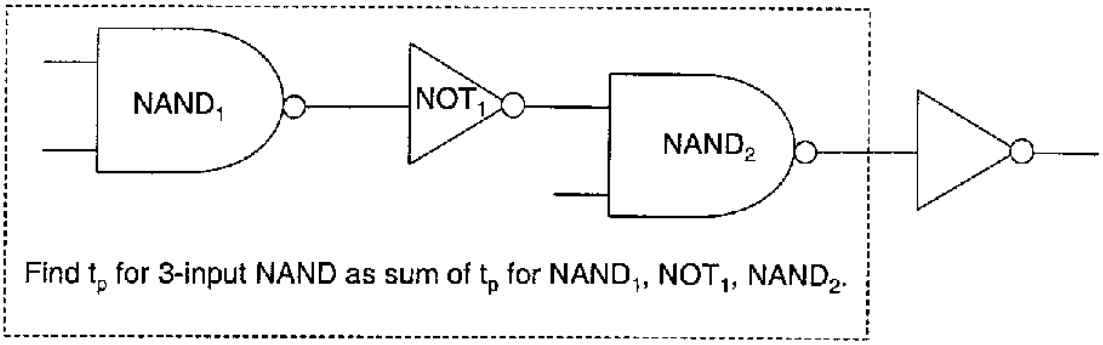
Problem 5: 20 Points Possible

Find the propagation delay for this 3-input NAND gate with inverter load,



where the 3-input NAND is implemented using two 2-input NAND gates and an inverter:



Compute the propagation delay t_p for the 3-input NAND as the sum of the worst-case propagation delays of the individual gates inside.

Use R_N = 1 kΩ, R_P = 2 kΩ, and C_G = 10 fF per transistor. Ignore interconnect capacitance.

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Problem 6: 10 Points Possible

Design a circuit, using only NMOS and PMOS transistors (and a power supply), that performs the 3-input NAND function with **shorter** worse-case propagation delay than the implementation given in Problem 5, when a single inverter is attached as the output load.

Assume that your transistors have the same characteristics as those I Problem 5.

Use R_N = 1 kΩ, R_P = 2 kΩ, and C_G = 10 fF per transistor. Ignore interconnect capacitance.

Provide your design and its worst-case propagation delay with single inverter output load.

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Fun Corner

It's picture time again! If you finish early, please don't get up and disturb students in your row. Instead, show off your artistic/comedic ability here.