

Massachusetts Institute of Technology  
Department of Electrical Engineering and Computer Science

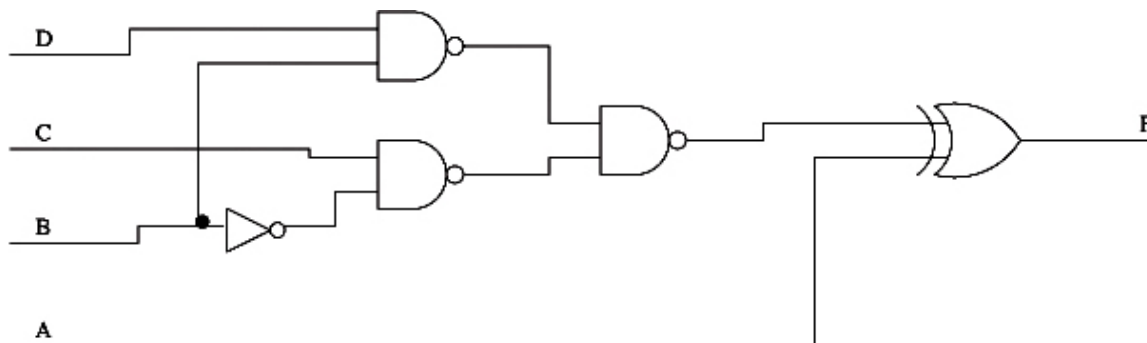
6.111 - Introductory Digital Systems Laboratory, Spring 2003  
Problem Set 2

Issued: February 12, 2003

**Due: February 19, 2003**

**Problem 1: Combinational Logic**

(a) Write the truth table for the combinational logic circuit shown below. Use 'A' as the most significant bit and 'D' as the least significant bit. Explain what the circuit does.



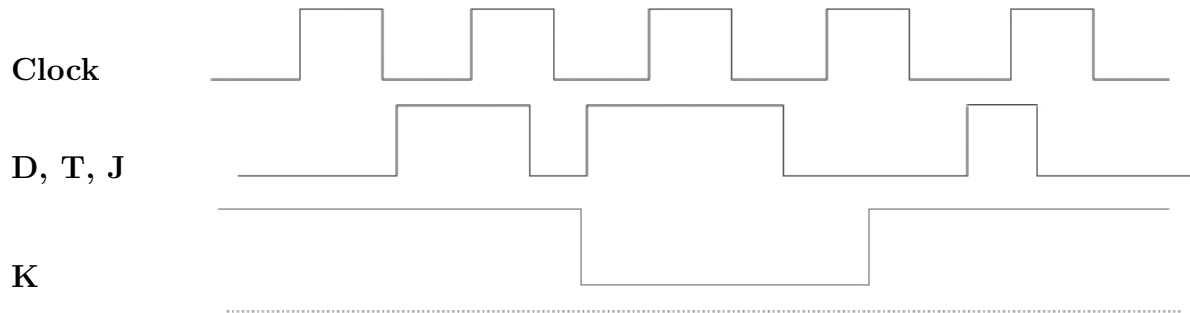
(b) Draw the Karnaugh map for the circuit. Circle appropriate groups to find a minimal sum of products expression and write the expression.

(c) Is the MSP expression from (b) free from hazards? Why or why not?

(d) Write a VHDL file that implements the function F. Compile and simulate it using Max+plus II. Be sure to include your VHDL code and a print-out of the simulation screen.

**Problem 2: Know your Flip-Flops**

Using the following timing diagram, draw the output of Q for a positive edge-triggered D flip-flop, a positive edge-triggered T flip-flop, and a positive edge-triggered JK flip-flop. Assume that Q starts as a 0.



Q(D flip-flop).....  
 .....  
 Q(T flip-flop).....  
 .....  
 Q(JK flip-flop).....

**Problem 3: Counters**

- (a) The '163 is a synchronous counter while the '393 is a ripple counter. What are the differences between these two counters in terms of design and performance.
- (b) There are multiple ways to create an 8-bit counter from two '163 chips. One might try wiring the RCO of the first counter to the clock of the next counter. Why is this a bad way to cascade two counters? What is a better way?
- (c) MIT's Physical Plant has hired you to design a circuit to count the number of inches of snow that has fallen on a given day. You are provided with a sensor that emits a logic 1 pulse each time an inch of snow has fallen. Using '163 counters, draw a circuit that can count up to 24 inches of snow. The circuit should reset to 0 once more than 24 inches of snow have fallen (i.e. if 25 inches have fallen, it should indicate 0; if 26 inches have fallen, it should indicate 1, etc).
- (d) Code the design from (c) in VHDL using a bottom-hierarchy. First create a VHDL file that emulates a '163. After verifying its functionality, use your '163 in a top level file to implement the snow counter.