# Homework # 3

Due Thur., Nov. 6, 2014, at 9:45 AM in class. No late homeworks will be accepted except for verifiable illness or similar situations.

1. **Cyclic Combinational Circuits**

   In class we discussed combinational versus sequential circuits. Combinational circuits are "memoryless", i.e., the outputs depend only on the present values of the inputs. Sequential circuits have "memory", i.e., the outputs may depend on the past as well as present input values.

   In class we analyzed the circuit shown in Figure 1. It has three inputs $a$, $b$ and $c$; six gates, each with fan-in 2, arranged in a single cycle; and six outputs, one from each gate. We argued that the circuit is combinational and produces the output functions shown. Note that each function depends on all three input variables. We argued that any acyclic circuit of fan-in 2 gates that implements the same output functions must have at least seven gates.

   Construct a circuit consisting of six fan-in 2 AND/OR/NAND/NOR gates that implements six of the following eight functions (you choose which six!):

$$
\begin{aligned}
f_1 &= b(\bar{a} + \bar{c}) \\
f_2 &= \bar{a}bc \\
f_3 &= \bar{a} + \bar{b} + c \\
f_4 &= a + bc \\
f_5 &= c(a + \bar{b}) \\
f_6 &= c(a + b) \\
f_7 &= \bar{a} + b\bar{c} \\
f_8 &= \bar{a}\bar{c} + \bar{b}
\end{aligned}
$$

   (Multiplication represents AND, addition OR, and a bar negation.) Explain why your circuit is combinational.

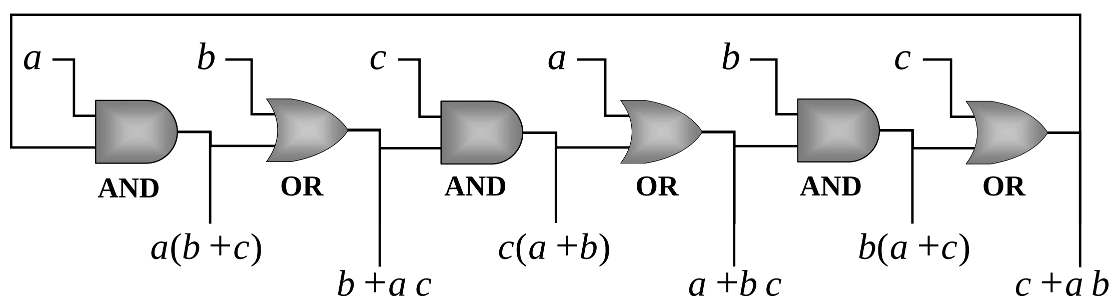


Figure 1: circuit

2. **Analyzing Latches**

   (a) **A Funky Latch**

   Consider the circuit shown in the Figure **??**. Describe its behavior: what are the next values of P and Q for all combinations of the current values of P and Q and assignments to M, N and G? For rows of the transition that are not "well-behaved" – meaning that the result is not predictable, simply indicate this.

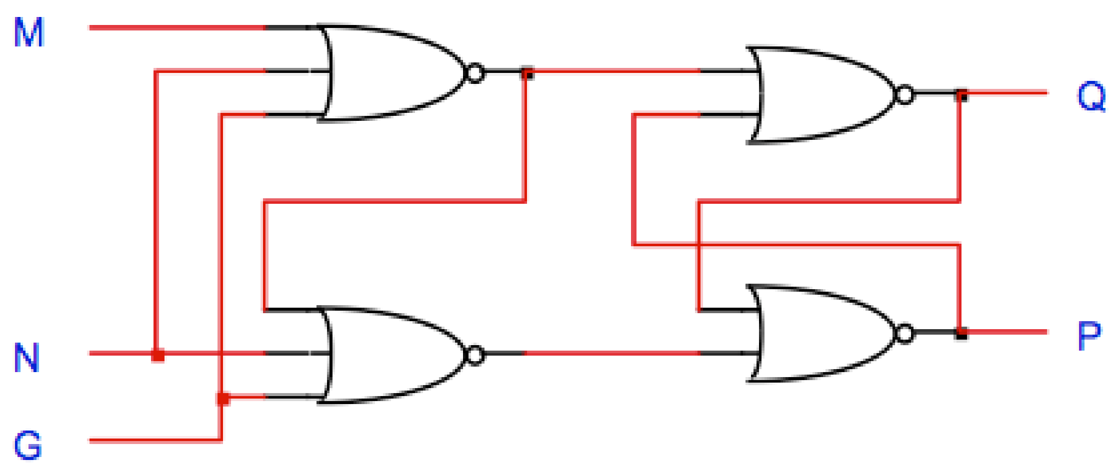


Figure 2: A latch.

   (b) **Another Funky Latch**

   Consider the latch shown in Figure **??**, built from an OR gate, an AND gate, and an inverter.

   i. What restriction must be placed on $R$ and $H$ so that $P$ will always equal the complement of $Q$ (i.e., what is the "bad" input combination)? [*10 points*]

   ii. Indicate this is a "bad" input combination in the table below. For all other input combinations, assume that $P$ is equal to the complement of $Q$. What is the new value of $Q$ that results from applying the input combination? [*15 points*]

| $R$ | $H$ | current $Q$ | new $Q$ |
|---|---|---|---|
| 0 | 0 | 0 | |
| 0 | 0 | 1 | |
| 0 | 1 | 0 | |
| 0 | 1 | 1 | |
| 1 | 0 | 0 | |
| 1 | 0 | 1 | |
| 1 | 1 | 0 | |
| 1 | 1 | 1 | |

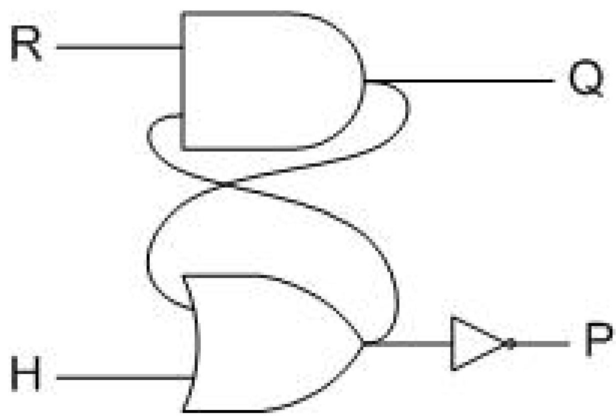


Figure 3: Funky Latch.

3. **Quine-McCluskey**

   For each of the two functions given below,

   (a) Use the Quine-McCluskey procedure (either binary or decimal) to find all prime implicants of the function.

   (b) Construct a prime implicant chart for the function.

   (c) Find all minimum SOP expressions for the function.

$$f(a, b, c, d) = \Sigma m(0, 1, 2, 3, 5, 6, 7, 8, 12, 13, 14, 15)$$
$$g(a, b, c, d) = \Sigma m(5, 6, 9, 12, 13, 14, 15) + \Sigma d(0, 2, 4)$$