LSU EE 3755 Homework 3 Due: 9 October 2013

Problem 1: A Verilog description of yet another population count module appears below.

```
module ya_pop(p,a);
   parameter N = 256;
   input [N-1:0] a;
   output        p;
   reg [8:0]     p;
   integer       i;

   always @( a ) begin
      p = 0;
      for ( i=0; i<N; i = i+1 ) p = p + a[i];
   end

endmodule
```

(*a*) Sketch the synthesized hardware when `N` is 4.

(*b*) Estimate the cost in terms of gates when `N` is 4 assuming that a ripple adder was inferred for the `+` operator and that reasonable optimizations were made. For this problem assume that an XOR, and other basic gates have a cost of 1.

(*c*) Making the same assumptions as in the previous part, determine the delay for arbitrary `N` and for `N=4`. In particular assume that optimizations were made to reduce cost but that the circuit was not re-organized to improve performance (see the next part). In your delay model use 2 for the delay of an XOR and 1 for other gates.

Problem 2: As the previous problem hinted, it is possible to obtain faster performance from the population counter (than is possible from a synthesis program that does not apply the technique described below). Faster performance can be obtained by using use several smaller population counters and adding their sums.

(*a*) Briefly describe why this would result in faster performance.

(*b*) Write a Verilog behavioral description of a 256-bit population count module which instantiates four 64-bit `ya\_pop` modules.

(*c*) Write a Verilog behavioral description of an `N`-bit population count module with parameters `N` and `M`, where `N` is a multiple of `M`. Unlike the module from the previous part, the module for this part should not instantiate any other modules. In procedural code it should determine the population in `M` parts and add them together. Solution to this problem may require Verilog's equivalent of arrays, called *memories*. See page 46 of the Verilog XL manual linked to the course's references page, `http://www.ece.lsu.edu/ee3755/ref.html`.