M A S S A C H U S E T T S I N S T I T U T E O F T E C H N O L O G Y
DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

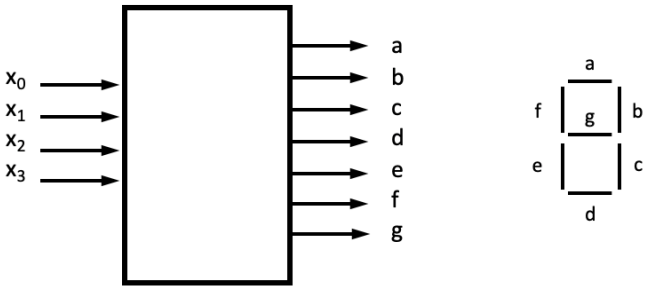
6.111 Introductory Digital Systems Laboratory
Fall 2019

Lecture PSet #1
Due: Tue, 09/10/2019

The goal of the Lpset is to provide examples of problems you may encounter and tools to help find solutions. Since some Lpset solutions will be presented in lecture, Lpset must be submitted as scheduled.

Problem 1 [2 points]. Consider a serial input bit stream that is either 1 or 0. Because of noise, at times the signal glitches, a 1 go to 0 or a 0 goes to 1 momentarily. As a workaround, you sample the incoming data 4x faster (oversample) than the bit stream resulting in 4 samples (x0, x1, x2, x3) for each data bit. For each data bit, if at least 3 samples are the same value, you consider the data valid and set z=1. Give a truth table for this function.

Problem 2 [4 points]. A 4-bit binary-to-seven-segment decoder takes a 4-bit binary number X_3X_2 X_1X_0 as input and produces seven outputs, one for each "segment" in a standard display.



Given the appropriate binary input, this decoder produces outputs that light up the display in the following manner:

An unreasonable professor would ask the student to write a minimized logic for each of the seven segments. But that's not taking advantage of Verilog and the compiler. A more efficient approach is to define a variable for each of the 16 numbers (0 through F) and then use a sum of products to control each of the seven segments.

For example, the variable num0 in Verilog is

assign num0 = $\overline{x_3}$ && $\overline{x_2}$ && $\overline{x_1}$ && $\overline{x_0}$; // num0 is true if all 4 inputs are zero

In Verilog && is the symbol for logical AND with || the symbol for logical OR.

Using a sum of products, write the expressions for controller each of the seven segments:

assign segment_a =

assign segment_b =

assign segment_c =

assign segment_d =

assign segment_e =

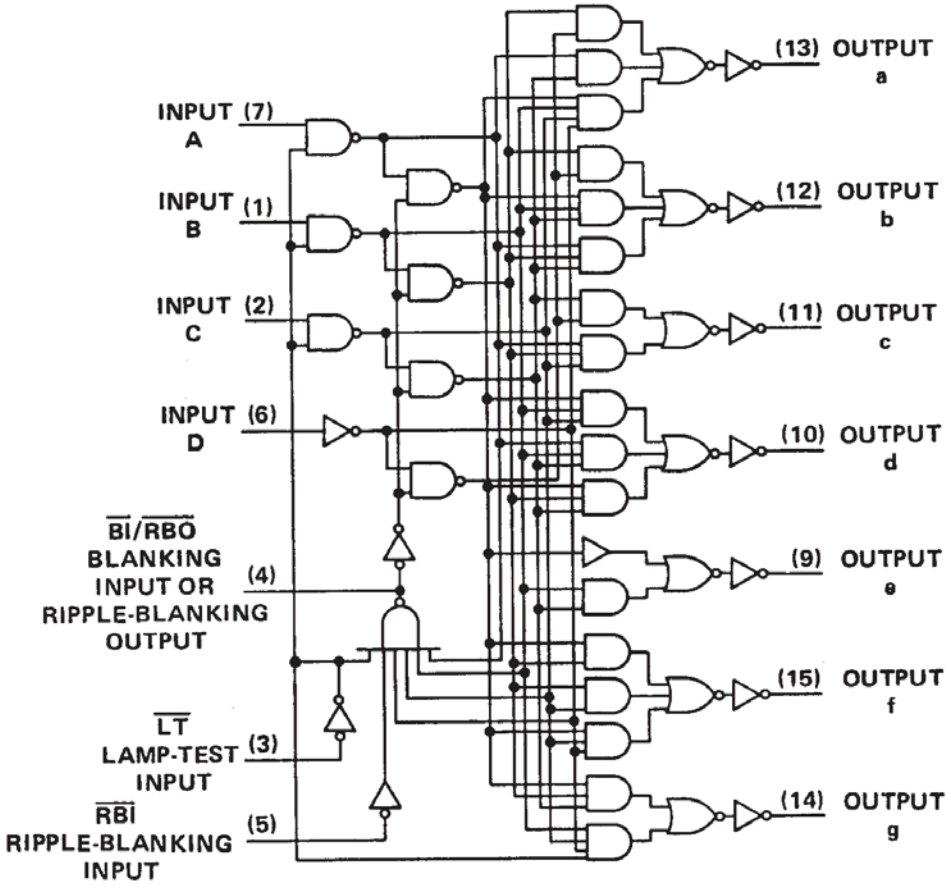
assign segment_f =

assign segment_g =

Notice that segment g requires the sum of 12 product terms. Using a different approach, write the expression for segment g that requires fewer product terms.

assign segment_g2 =

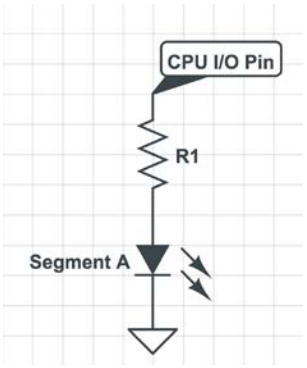
This exact function is implemented in the 74LS47 IC. [used in the pre-FPGA era]



Problem 3 [4 points]. Rather than implement a seven segment decoder with gates, you decide to use an Arduino. The Arduino Uno uses the ATmega328P processor. For many DIY (do it yourself) projects, it's simply plug and play without any need to read the datasheet. When pushing the limits, it's important to understand what it can and can't do.

[This question is typical of the process an engineer goes through in industry. Unlike a lab or lpset where the data for the problem at hand is neatly package and there exists a clean and sometimes unique solution, you will need to hunt through the datasheet to extract the relevant information. Many times you will need to make reasonable assumptions.]

In this problem, you are using an Uno to drive two seven segment displays. For each display, each segment consists of a LED with a forward voltage drop of 1.7V @20mA. There are 14 I/O pins on Arduino processor which are used to drive the segments.



- Operating at 5V and driving the LED using one of the I/O pins, what is the output high voltage (or range) of the processor? [To avoid reading the entire 400 page datasheet, go to p365 and p366. Dedicated engineers may find the entire datasheet interesting – good bed time reading!
- The LED is connected to the I/O pin with a resistor. What resistor value should be used to drive the LED at 20mA max?
- Assuming "88" is displayed, what is the total current for the display? Is this within the processor spec of keeping the DC current at Vcc and GND pins less than 200mA?

- At times a device may lack the pins needed to simultaneously transmit information. A solution is time division multiplexing. With this in mind, if you have only 14 I/O pins, describe how to implement a 4 digit seven segment display. To meet processor specification, the total peak LED currents must be less than 200mA. Hint: what limitation of the end-user can we take advantage of? You may additional semiconductor devices if needed. Draw a diagram of your solution. [A detailed schematic is nice but not required.]

https://web.mit.edu/6.111/volume2/www/f2019/handouts/ATmega328P.pdf