This is a closed book exam, no notes are allowed. Please leave the cover closed until the time period starts.

Please write your name at the top of each page.

Read the questions carefully. If something appears ambiguous, write down your assumptions.

Rules: You may use the result of a previous problem in your answers even if you have not completed the previous problem. That is, it can be included in a block diagram and assumed to be already designed and available. Total Points: 50

Scoring: Maximum Score 50

Problem 1 (16pts)
Part A (4pts) ____
Part C (4pts) ____
Part B (4pts) ____
Part D (4pts) ____
Total ____

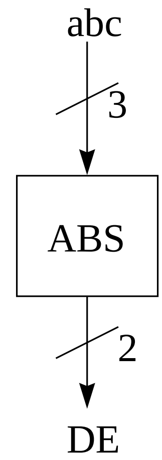
Problem 2 (22 pts)
Part A (7pts) ____
Part B (8pts) ____
Part C (7pts) ____
Total ____

Problem 3 (12 pts)
Part A (6 pts) ____
Part B (6 pts) ____
Total ____

Grand Total _____

Problem 1. Absolute Value

Design a system that converts a 3-bit 2's complement number <a,b,c> into its 2-bit absolute value <D,E> as shown in the figure. Valid inputs are in the range $-(2^n-1)$ to $+(2^n-1)$.



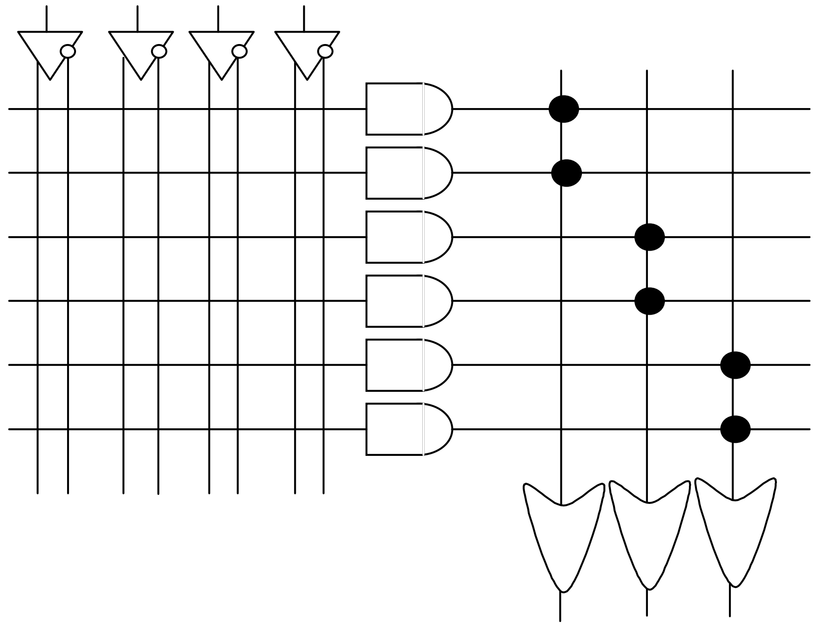
A. Write the Truth Table for the functions D(a,b,c) and E(a,b,c) such that DE = |abc|. **(4pts)**

B. Write the canonical SoP and PoS forms for each function in shorthand notation. **(4pts)**

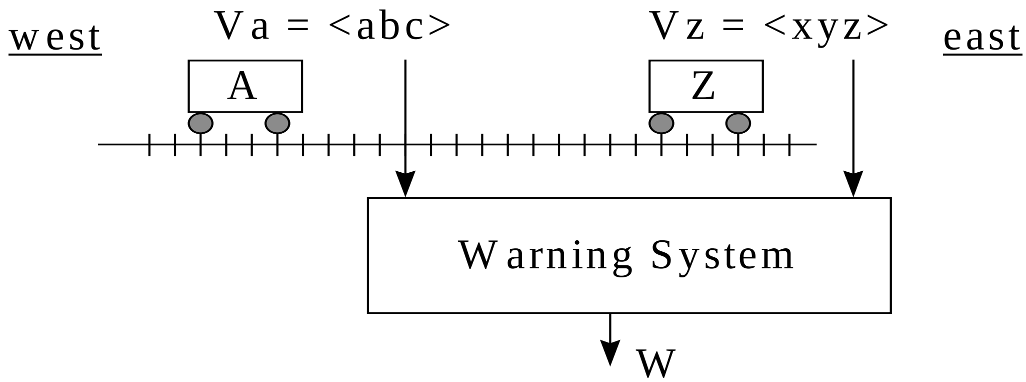
C. Using a K-map, find minimum SoP and PoS expressions for D and E. Using Boolean algebra, verify that your minimum PoS expression for D is equivalent to one of its canonical forms. **(4pts)**

Problem 1 Continued

D. Within the set of valid inputs, does your SoP expression contain a single bit static-1 hazard? If not, explain and program the PAL for D and E. Otherwise identify an input transition that might cause a glitch, and program the PAL with a single-bit static-1 hazard free implementation of D and E. **(4pts)**



Problem 2. Collision Warning System (Bonus Points for Overall Compactness: 4pts)
Train A and Train Z are on the same track and train A is always further west than train Z as shown in the figure. The velocity of each train is represented by a 3-bit 2's complement number from -3 to +3. If the velocity is positive the train is traveling east, otherwise the train is traveling west. The system issues a warning (W) whenever the current velocities of train A and train Z will result in a collision assuming no future velocity changes. There is no need to issue a warning if the trains are going the same speed in the same direction.



A. Write a Pseudo-code or tabular description for the function W in terms of inputs (a,b,c,x,y,z). You may not use addition or subtraction to solve this problem! **(6pts)**

B. Draw a block diagram of your system. Name each block and **provide a one-sentence description for each**. Each block can have no more than 4 input variables. If you are using a previously specified block, then indicate so. Your block diagram must not contain any individual gates. You may use the result from problem 1 as a building block, but that does not necessarily lead to the best result. **(6pts)**

Problem 2 Continued

C. Using truth tables and K-maps as needed, find minimized 2-level implementations for each block and draw the complete final schematic. If you are using the same block more than once, you only need to draw one of them at the gate level, the other(s) can be left as boxes in your final schematic. You do not need to redesign blocks that have been previously designed. **(8pts)**

Problem 3. Generalized Solution to Train Problem. This problem can be done even if you have not done problem 2. Instead of assuming that Train A is always west of Train Z we now have inputs <m,n> and <p,q> which indicate the positions of trains A and Z where position 0 is furthest west and position 3 is furthest east. **Using the "warning system" from problem 2 as a building block**, design a system that computes W(a,b,c,m,n,x,y,z,p,q). Also issue a warning in the case that both trains are in the same position.

A. Draw a block diagram of your system, including the warning system from problem 2. **Your blocks can have any number of inputs**. Your block diagram may contain a few gates to tie things together. Explain each element of your block diagram. **(6pts)**

B. Design the system using gates and/or multiplexors. If you are re-using a block from problem 1 or problem 2, you do not need to design it again. Show your work and draw your schematic. Your schematic can contain boxes to represent duplicate or previously designed blocks. If there are no new blocks, then redraw the block diagram from Part A. **(6pts)**