ECE9047/ECE9407
Final Examination Sample Questions

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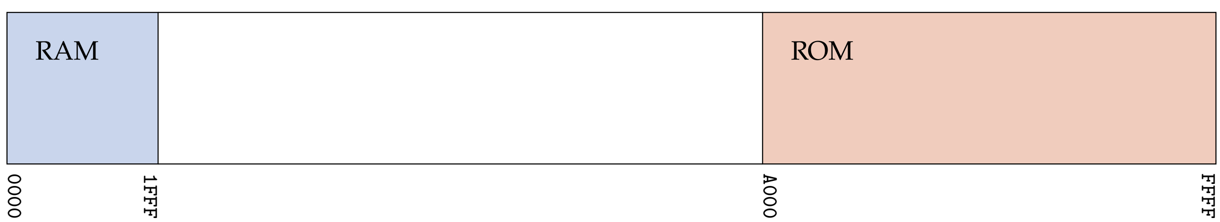
Memory Mapping

For all problems, the system has an address space of 64 kB with 8 bit memory cells. (Note that the ARM Cortex®A9 has a much larger 32-bit address space, but there is no need to write out such long address numbers to demonstrate understanding of the concept of memory mapping, so we will use a smaller address space.)

1. Design the memory decoding scheme (minterms) for the memory map shown. All RAM and ROM chips are $8\,\text{k}{\times}8$.



2. Design a memory map using two $4\,\text{k}{\times}8$ RAM chips, occupying a contiguous block starting at address `0000`, and one $8\,\text{k}{\times}8$ ROM chip ending at address `FFFF`. Draw the memory map, showing the boundaries of each individual memory chip, and design the memory decoding scheme.

3. For this memory map, we want the RAM to occupy the memory space `0000` to `5FFF`, and the ROM to occupy the memory space `C000` to `FFFF`. We have only two $8\,\text{k}{\times}8$ ROM chips, two $8\,\text{k}{\times}8$ RAM chips, and two $4\,\text{k}{\times}8$ RAM chips. Draw the memory map, showing the boundaries of each individual memory chip, and design the memory decoding scheme.

4. Design 4 kB of memory starting at address `0000`. Due to suburban families hording supplies during the pandemic, we only have access to two $4\,\text{k}{\times}4$. Draw the memory map and shown the boundary of each memory chip. Remember, these memory chips are only half as wide (4 bit) as needed.

5. Use two $8\,\text{k}{\times}8$ ROM chips in a contiguous block ending at address `FFFF`, two $4\,\text{k}{\times}8$ ROM chips occupying a contiguous block starting at address `A000`, and four $4\,\text{k}{\times}4$ RAM chips in a contiguous block starting at address `0000`. Draw the memory map and shown the boundary of each memory chip, and design the memory decoding scheme. Show how the CPU lines (16-bit address bus and 8-bit data bus) are connected to each chip.

Assembly Language Programming

Implement the following programs in ARMv7 assembly language. Where necessary, use the memory mapped peripherals on a DE1 SoC, as given by the online simulator we used in lab 1.

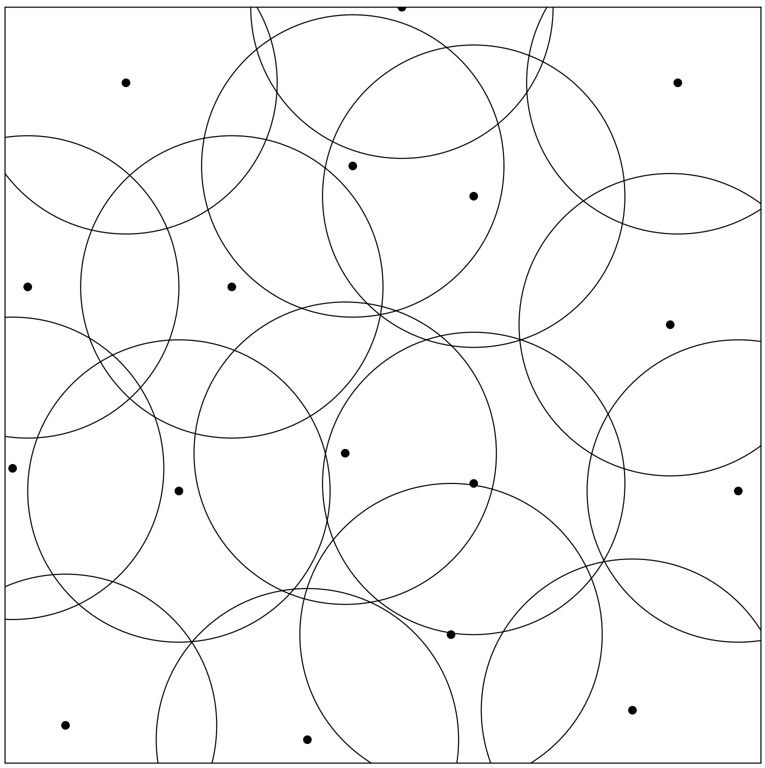
1. Generate the first 100 Fibonacci numbers and store them in memory in one sequential array.

2. Write a subroutine to find the largest number in a continuous array of numbers stored in memory.

3. Write a program to that allows the user to flip the switches (address `FF200040`) and light up a corresponding LED (address `FF200000`).

Wireless Sensor Design

Consider a square area of size $L \times L$ with a semi-randomly distributed set of 17 sensor nodes, as shown. The detection area of each sensor node is circular, with a radius of $0.2L$. The communication area of each sensor node is also circular, with a radius of $0.4L$.



1. What is the k-coverage of the WSN?
2. What is the k-connectivity of the WSN?
3. In your opinion, which sensor node is the most critical — i.e., which node, if it fails, will cause the WSN to degrade the most?
4. Sketch your best guess for the path that traces the maximal breach distance of the WSN. Justify your answer.
5. Sketch your best guess for the path that traces the maximal support path of the WSN. Justify your answer.
6. Would a regular grid of sensor nodes produce a better or worse WSN? Explain your answer by referring to k-coverage, k-connectivity, number of nodes, reliability of the network, and any other concepts discussed in class that you think are relevant.

If you wish to redraw the map of the WSN precisely using your favourite software, the coordinates of the nodes, expressed as fractions of the side length L, are (0.01,0.39); (0.03,0.63); (0.08,0.05); (0.16,0.9); (0.23,0.36); (0.3,0.63); (0.4,0.031); (0.45,0.41); (0.46,0.79); (0.525,1.0); (0.59,0.17); (0.62,0.37); (0.62,0.75); (0.83,0.07); (0.88,0.58); (0.89,0.9); (0.97,0.36).

Relay Ladder Logic

Implement the following control mechanisms using relay ladder logic.

1. Walk signals at an intersection with traffic lights. The walk signals should turn on, and remain on, when a pedestrian presses the button and the main traffic light is green. The walk signal should turn off as soon as the light turns red. If no pedestrian presses a button, the walk signal should remain off.

2. A 2-floor elevator. User controls must include the floor buttons and door open or close buttons. An emergency stop can optionally be implemented. Mechanical signals include whether the doors are in motion opening or closing, or stationary open or closed, and whether the elevator is moving up or down, or stationary at the first or second floor. Appropriate feedback controls need to be used so that the doors don't open while the elevator is moving, and so that the elevator doesn't start moving while the doors are open. (*This example is more challenging than I would put on an exam.*)