Total: 100 points, 90 minutes

CS2115 Computer Organization

Midterm Exam
October 20, 2020

Student Number: _____

This exam has 4 problems, for a total of 100 points.

• Closed book. No calculators. No electronic devices.
•Write down your answers clearly on your own prepared answer sheets and clearly label them. Sufficient calculations/justifications/intermediate steps should be provided to receive a full mark for a question.
•Please take photos of your answer sheets and upload them to : Canvas → Assignments → Midterm in either **.pdf** or **.png/jpg** form.
•You have an extra **10 mins** to handle the submission.

GOOD LUCK!

Problem	Points
1	
2	
3	
4	
Total	

Problem 1 **Number Systems** (26 points)

a) For the decimal number $(15.75)_{10}$, convert it to the **binary**, **octal** and **hexadecimal** forms, respectively (6 points).

b) For the binary number $(0100, 1110, 0100)_2$, convert it to the **hexadecimal** form and **decimal** form. (4 points).

c) Write the decimal numbers $(11)_{10}$ and $(-6)_{10}$ in signed **5-bit** 2's complement form and signed **8-bit** 2's complement form (6 points).

(Note that this is to write a number A in the 2's complement form, not to write 2's complement of A.)

d) The following binary number is written in IEEE 754 standard for binary floating point numbers (the format is shown as follows). What is the decimal number it represents? Describe your conversion procedure. It's sufficient to write it in form of $a \times 2^b$ (5 points).

1	0001, 0001	0010, 0000, 0000, 0000, 0000, 000

e) Write $(45.375)_{10}$ in the 32-bit binary floating point format (5 points).

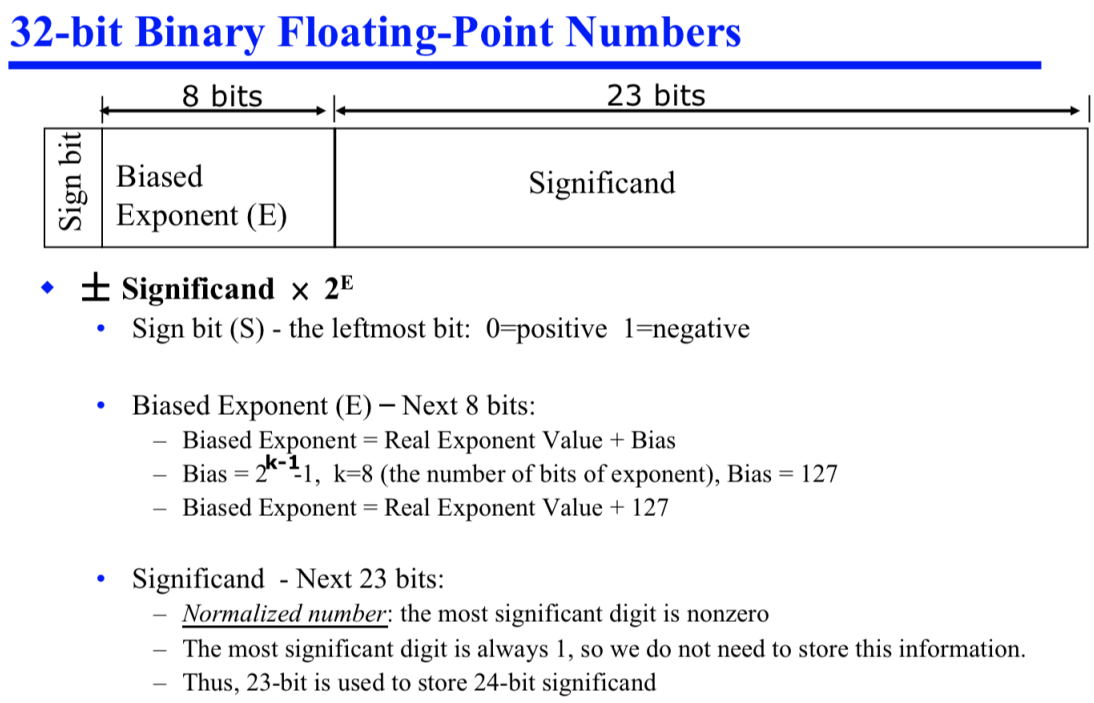


Figure 1: This is a slide from the lecture note for your reference

Problem 2 **Combinational Logic Circuits** (30 points)

For a Boolean function of n variables, we can index a min-term (e.g., $X_1\bar{X}_2\bar{X}_3\bar{X}_4$) by $m_i(i = 0, 1, ..., 2^n - 1)$ and we can determine the index i as follows: we construct a binary number of n bits by putting a 1 corresponding to the positions of a direct term and a 0 corresponding to a complemented term ($X_1\bar{X}_2\bar{X}_3\bar{X}_4 \rightarrow (1000)_2$) then we convert this binary number to the decimal number $i = 8$ ($(1000)_2 \rightarrow 8$).

Consider the following function:

$$F = f(A, B, C, D) = m_0 + m_1 + m_2 + m_3 + m_5 + m_8 + m_{15} \tag{1}$$

a) Construct the truth table. (4 points)

b) Write the function in SOP and POS form. (5 points)

c) Using K-Map to simplify the function and write the simplified function. (6 points)

d) Draw the circuit according to the function you wrote in c) only use **AND, OR, NOT** gates. (5 points)

e) Consider the function :

$$G = g(A, B, C, D) = A + AB + A\,\overline{D} + B + BD + B\,\overline{CD} \tag{2}$$

Simplify the function (using logic properties or the K-map) to the most simplified form and draw the circuit with **only NAND** gates. (10 points)

Hint: DeMorgan's Theorem $\overline{XY} = \overline{X} + \overline{Y}$.

Problem 3 **Sequential Logic Circuits** (28 points)

a) Given the following circuit of the SR latch in Fig. 2, please complete the below function table (you can use '0', '1', 'No change', or 'Indeterminate'). (4 points)

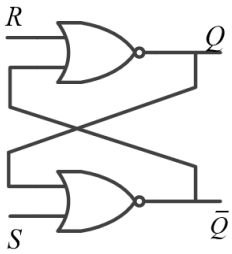


Figure 2: The circuit of the SR latch.

R	S	Q	$\bar{Q}$

b) Given the SR latch in Fig. 2, we can construct a D flip flop in Fig. 3. Please complete the timing diagram according to Fig. 3. (6 points)

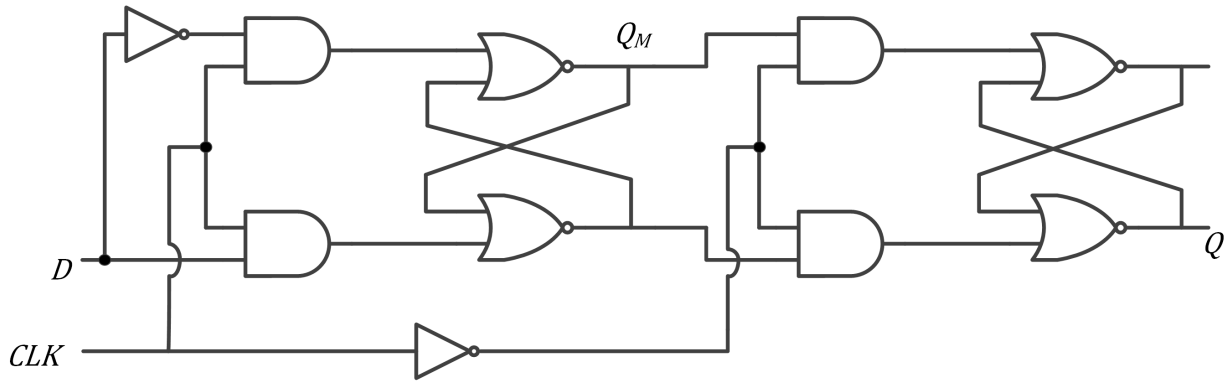
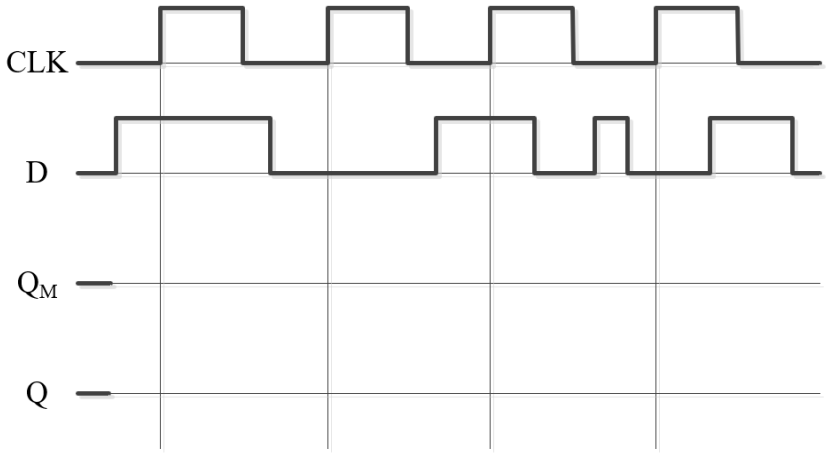


Figure 3: D flip flop.



c) (**Finite State Machine**) Given the circuit in Fig. 4, let us consider the input to be X, output to be Z, and state to be $Q1, Q0$. Write the state equation (write the output and the next state as functions of the present state and the input), the state table (contain present state, input, next state, output) and draw the state transition diagram (clearly label the states, inputs, and outputs). (18 points)

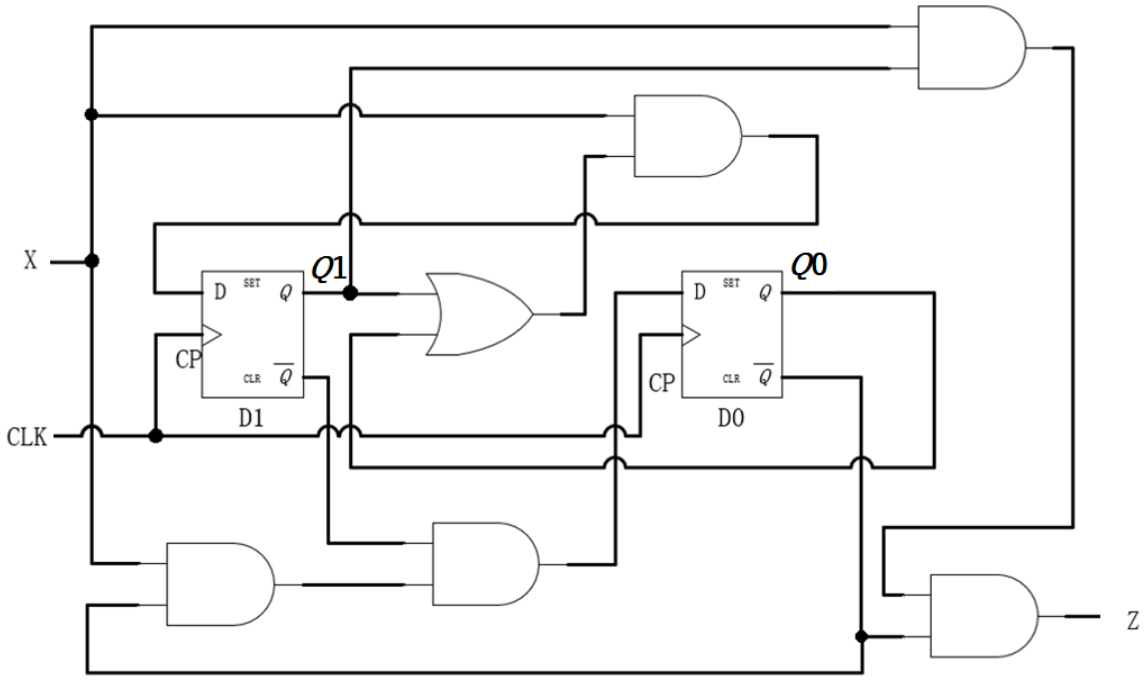


Figure 4: The circuit.

Problem 4 **Computer Architecture Overview** (16 points)

Answer the following questions. **Be concise and to the point.**

a) What are the five components in the von Neumann Architecture? Please briefly describe each component's function. (5 points)

b) What is the key difference between combinational logic circuits and sequential logic circuits? (2 points)

c) What is the key difference between asynchronous sequential logic circuit and synchronous sequential logic circuit? What is the key difference between latches and flip flops. (4 points)

d) How to solve the mismatch between processor speed and DRAM speed? Please list at least three points. (3 points)

e) You have learned many different number systems in this course, but only binary is wildly used in modern computer systems. What makes binary system so special compared with other number systems? (2 points)