UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRONIC ENGINEERING

DIGITAL ELECTRONICS II

COURSE CODE – E441

DECEMBER 2009

DURATION OF THE EXAMINATION - 3 HOURS

INSTRUCTIONS TO CANDIDATES

1. There are FIVE questions in this paper. Answer any FOUR questions only.
2. Each question carries equal marks.
3. Show all your steps clearly in any calculations.
4. State clearly any assumptions made.
5. Start each new question on a fresh page.

Question 1

a) Draw circuit diagrams of clocked R-S Flip-Flop and clocked J-K Flip-Flop and explain the following:

i. Why it is necessary to have clocked circuits?
ii. Illustrating with a characteristic table, explain how a clocked R-S Flip-Flop works.
iii. Explain how a clocked J-K Flip-Flop is said to be an improvement to R-S Flip-Flop.

[15]

b) A sequential circuit has three flip-flops A, B, C; one input x; and one output y. The state diagram is shown in Figure 1. The circuit is designed by treating the unused states as don't-care conditions. Analyze the circuit obtained from the design to determine the effect of the unused states. Use D flip-flops in the design

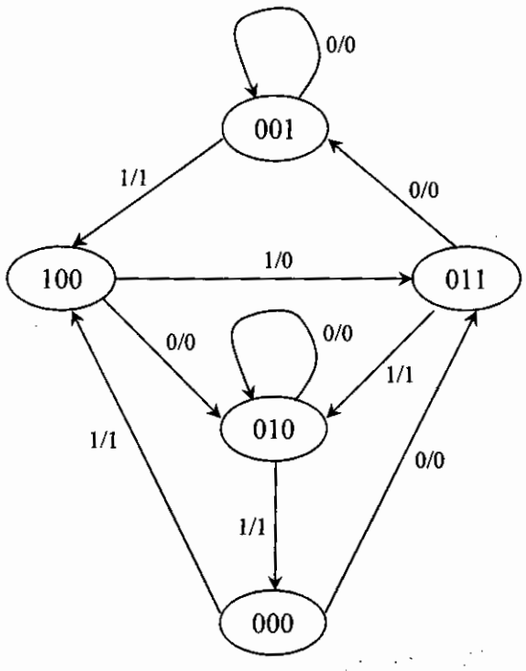

Figure 1. State Diagram of Sequential Circuit

[10]

Question 2

Design a versatile 4-bit shift register capable of operating in the following modes:

(i) converting data from parallel to serial
(ii) converting data from serial to parallel
(iii) shifting data from left to right and from right to left

Explain in detail how your design meets the above requirements. [25]

Question 3

a) Using D flip-flops, design an up-down counter that counts in the following sequence: 0,1,3,5,7. Show all diagrams and working in your design. [16]

b) The circuit in figure 6 shows a 4-bit counter. Derive the truth table and Boolean expressions for the outputs Q1 to Q4. Show how it is possible to arrive at the circuit shown in figure 6.

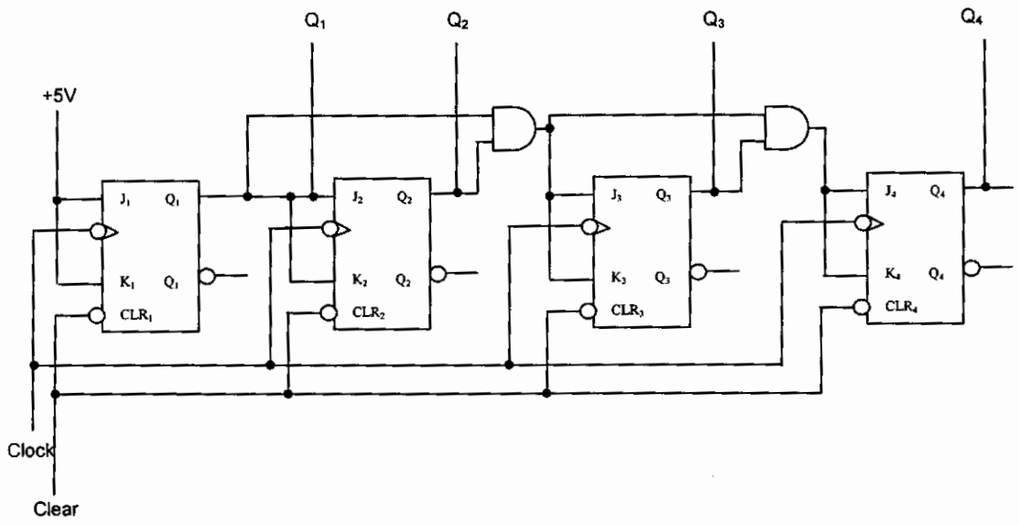

Fig. 6 Decade counter

[9]

Question 4

a) What are the differences between sequential access memories and random access memories?

[2]

b) Specify the size of a ROM (number of words and number of bits per word) that will accommodate the truth table for the following combinatorial circuit components:
   a. A binary multiplier that multiplies two 4-bit numbers;
   b. A 4-bit adder subtractor;
   c. A quadropole 2-to-1 line multiplexers with common select and enable inputs; and
   d. A BCD-to-seven-segment decoder with an enable input.

[8]

c) Figure 8 depicts an intersection between two roads. Traffic through Road 1 is one way and in the direction shown by the arrow labeled 1. This traffic is controlled by traffic light

TB. Traffic through Lane A flows in the direction shown by the arrow labeled 3. This traffic is controlled by traffic light TA. Each traffic light module has three lights (RED, GREEN, and AMBER).

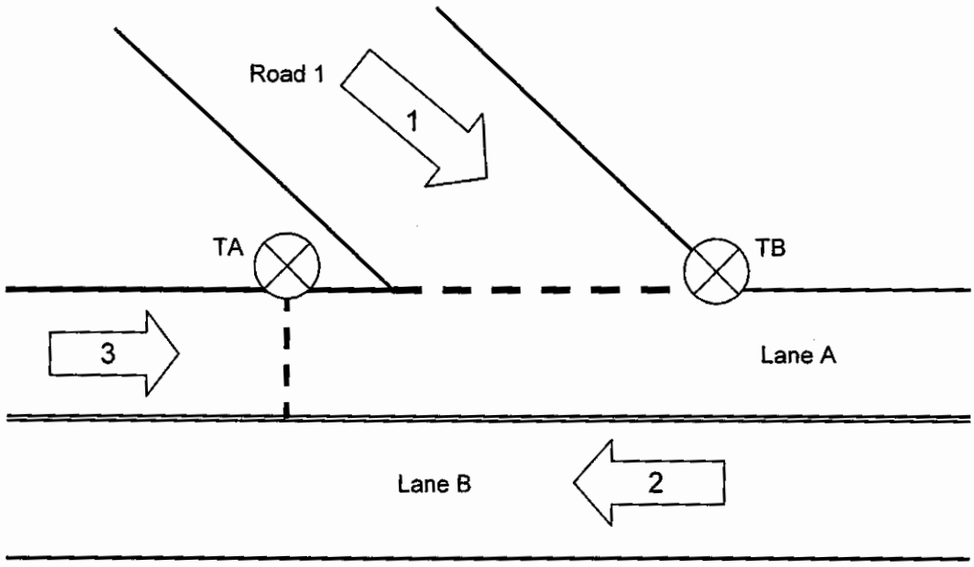

Figure 8. Road intersection for question 4

Design a traffic controller that ensures an orderly flow of traffic in Road 1, Lane A, and Lane B, using a suitable counter and a ROM. Assume that it a clock frequency of 1Hz is used for driving the counter. [15]

Question 5

a) Figure 8 below shows the basic architecture of a microcontroller. Explain in detail the function of each module. [7]

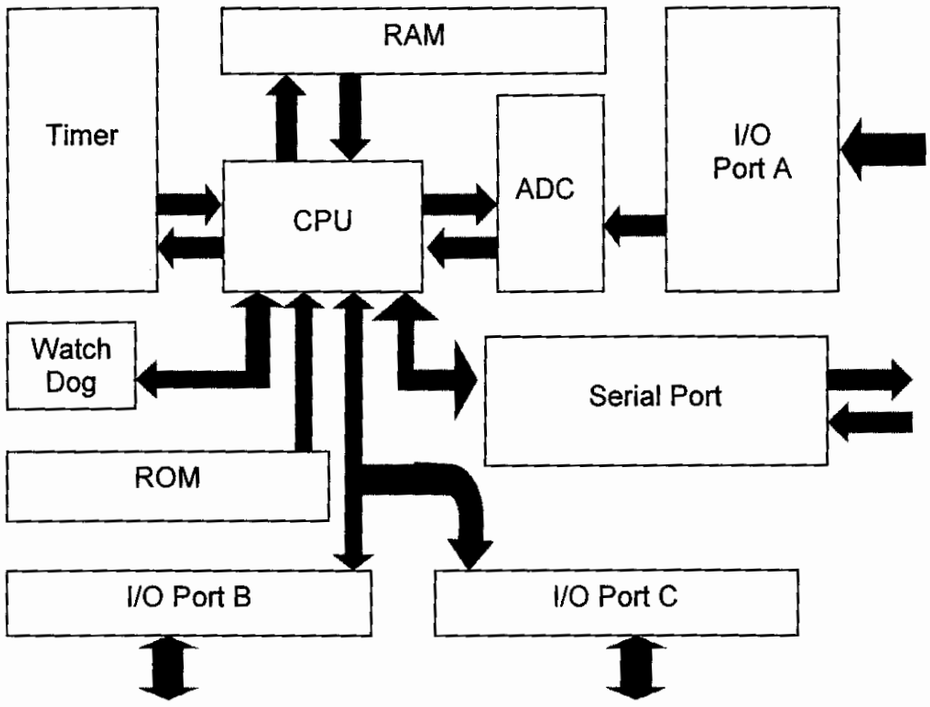

Figure 8. Basic architecture of a microcontroller

b) Compare and contrast the features of Microcontrollers and microprocessors? [6]

c) Figure 9 shows a two lane busy road that passes over a narrow bridge. Due to the narrow bridge, traffic coming from opposite directions (Traffic A and B) cannot pass over the bridge at the same time. To ensure an orderly flow of traffic over the bridge, the traffic control lights have been introduced. Each traffic light has a RED, AMBER, and GREEN lamps.

The traffic control lights are required to operate so that traffic flows as follows: Traffic B is allowed 1 minute to pass through, while traffic A is allowed 2 minutes. Traffic A is allowed to pass through the bridge when the GREEN light in Control Lights A is ON, otherwise the Traffic A is stopped. Similarly traffic B can only pass through the bridge when the GREEN lamp in traffic control B is on. When a traffic control light turns from GREEN to RED, for 3 seconds it flashes the AMBER light and then switch on the RED lamp. Assume that, initially (before the control regime come into effect), all traffic is stopped for 10 seconds.

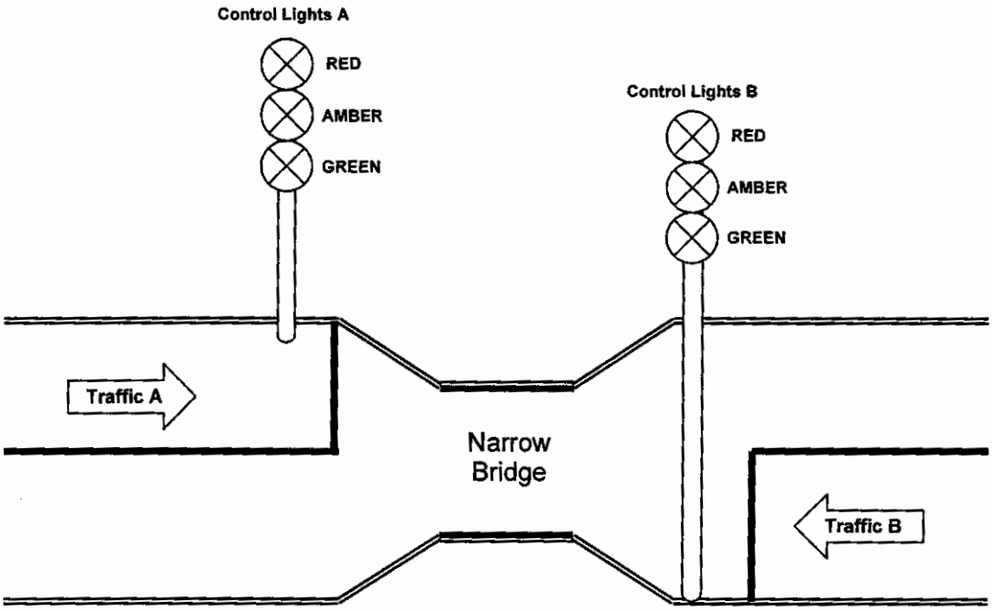

Figure 9. Traffic control lights diagram for Question 5 (c)

You are required to design a machine language-based program that when executed by a microprocessor would make sure that the control lights control the traffic through the bridge according to the above control regime. As part of your solution produce the following artefacts:

(i) An ASM chart modeling the behaviour of the traffic control system. **[4]**

(ii) A truth table that shows a sequence of how the six lights would be switched ON and OFF. **[4]**

(iii) Write a machine code program (to be executed by the microprocessor) based on the table in (iii) to meet the requirements of the traffic lights control regime. **[4]**

In writing your program assume that the instruction set of the microprocessor has ONLY the following low-level instructions:

```
CC CX
DE DX
F5 XXXX
```

The meanings of the above instructions are as follows:

- The instruction CC sends control data to turn ON and OFF the traffic lights. It takes as an operand the hexadecimal control value defined in CX, converts it into a binary equivalent, and send it to output port B, where the traffic control interface is connected.
- The instruction DE delays execution of the next instruction in the program for a time period equivalent to the seconds stated in the hexadecimal operand DX.

- Instruction F5 is a GOTO instruction which redirects program execution to the address specified by hexadecimal address XXXX. For example, the following instructions will redirect program execution to start at address 1005:

```
F5
10
05
```

Also assume that the execution of your program starts at address 1000 and that immediate addressing is used.

State clearly any other assumptions you have made in your solution.

END OF PAPER