THE AUSTRALIAN NATIONAL UNIVERSITY
First Semester Examinations 2008

ENGN3213
Digital Systems and Microprocessors

Writing Period: 2 hours
Study Period: 15 minutes duration

Permitted Materials: Pens

Total 50 Marks (20% of Subject)

You must attempt all 5 questions
Q1. Fixed point arithmetic (10 marks; 20% Total)

Evaluate the following (1 mark each),

(a) \( 130_{10} = X_2, \Rightarrow X = \)

(b) \( 123_{16} = Y_5, \Rightarrow Y = \)

(c) \( 0111 + 011 = \)

(d) \( 0110 - 0001 = \)

(e) \( 0101 \times 0011 = \)

(f) \( 1100111100_2 = X_{16}, \Rightarrow X = \)

(g) \( 1100111100_2 = Y_8, \Rightarrow Y = \)

(h) What is the integer value of the C variable A defined by,

\[
\text{signed char A = 133;}
\]

(i) Compute \( 4_{10} + (-6)_{10} \) using two’s complement arithmetic.

(j) If \( \text{unsigned short } Y = X \times X \), where \( X = 257 \) what does \( Y \) evaluate to? You may assume that an \textit{unsigned short} has a width of 16 bits.
Q2. General Knowledge (20 marks; 40% Total)

(a) Describe how a PIC microcontroller executes a branch instruction such as a subroutine call. (3 marks)

(b) Explain using diagrams how a Schmitt Trigger can debounce a switch. (3 marks)

(c) (1) Draw the truth table of a T flip-flop. (2 marks)
    (2) Sketch a circuit implementation of the T flip-flop using one D-flip-flop. (3 marks)

(d) The D flip-flop shown in the following figure is applied the input signals shown in the traces.
    (1) Define in words the meaning of setup and hold time (2 marks)
    (2) Redraw the traces in the figure in your script books and label the setup and hold times of the flip-flop (2 marks).

![D flip-flop diagram]

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(e) In terms of the functional blocks shown in the following figure of a simplified microcontroller, describe in detail the steps involved when the microcontroller adds two numbers stored in RAM and outputs them to an IO port. (5 marks).

PC = Program Counter (register)
W = Working Register
SR = Status Register
Q3. Logic Synthesis and Karnaugh Maps (6 marks; 12% Total)

Given the following expression representing a detector for prime numbers lower than 16,

\[ F = \Sigma_{A,B,C,D} (1, 2, 3, 5, 7, 11, 13) \]  

(1) Write out the SOP representation of this expression. (1 mark)

(2) Draw the truth table. (1 mark)

(3) Draw the Karnaugh map from the truth table. (1 mark)

(4) On the Karnaugh map loop out the logical adjacencies. (1 mark)

(5) Write down the minimised Boolean logic expression arising from the Karnaugh map. (1 mark)

(6) Draw the circuit implementation. (1 mark)

Q4. State machines and VERILOG (10 marks; 20% Total)

A synchronous system has an input X and an output Y where the output will only be '1' when the number of 1's received is even and the number of 0's received is odd respectively. Assume initially that no 0's or 1's have been received.

(1) Design a synchronous state machine and input logic to perform this task. Use any convenient flip flop arrangement for its implementation. (6 marks)

(2) Write VERILOG code that implements this system in HDL. (4 marks)
Q5. C Programming (4 marks; 8% Total)

The code below demonstrates the use of pointers in C. Answer the following questions.

(1) What are the values of the array “Dorian” after execution of the function “image” (2 marks).

(2) Describe how data is passed from the main routine to “image” (2 marks).

```c
void image(unsigned char * Gray, int len) {
    unsigned char * tmp = malloc(len);
    int up = 0;
    int down = len;
    while(down--) {
        *(tmp + up) = *(Gray + down);
        up++;
    }
    for(up=0; up<len; up++){
        *(Gray+up) = *(tmp+up);
    }
}

static int length = 10;
int main() {
    unsigned char * Dorian = malloc(length);
    int nchars;
    for(nchars = 0; nchars < length; nchars++) {
        *(Dorian+nchars) = nchars;
    }
    image(Dorian, length);
    return 1;
}
```