

Programme Code : TU856
Module Code : CMPU1019
CRN:22387

TECHNOLOGICAL UNIVERSITY DUBLIN
CITY CAMPUS

TU856 – BSc. (Honours) in Computer Science

Year 1

SEMESTER 2 EXAMINATIONS 2021/22

Microprocessor Systems

Internal Examiners

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Instructions:

Answer 3 out of the following 4 questions

Special Instructions/Handouts:

Numbers that are prefixed with ‘0x’ are in hexadecimal

Question 1 (33 marks)

- (a) What output will be produced when a C program executes the following instructions:

```
a. printf("%x", 0xabcd1234 | 0x1234abcd);  
b. printf("%x", 0xabcd1234 ^ 0x1234abcd);  
c. printf("%x", 0xabcd1234 & ~0x1234abcd);
```

[6 marks]

- (b) What is the unsigned numeric range of the following C types:

```
a. uint8_t  
b. uint32_t
```

[4 marks]

- (c) What value will the variable X have after the following code is executed?

```
uint8_t X=125;  
X = X + 5;
```

[5 marks]

- (d) A serial communications link operates at a speed of 115200 bits per second and uses odd parity checking.

- What parity bit will be sent when a byte with a value of 65 (decimal) is transmitted?
- This serial link sends a parity bit, a stop bit and a start bit for each byte transmitted. In other words it takes 11 bits to send a byte. How long will it take to send 1024 bytes of data over this link?

[4 marks]

- (e) A little-endian computer system stores the C-string "1234" in memory starting at address 100. It also stores the 16 bit integer value 0x1234 starting at address 200. What values are stored in memory addresses 100 to 104 and memory addresses 200 to 204. The ASCII code for '1' is 49.

[4 marks]

- (f) The Arm Cortex M0+ executes most instructions in a single clock cycle. If the clock speed is 16MHz, how many nanoseconds will it take to execute a function with 10 instructions?

[2 marks]

- (g) An STM32L031 has a 12 bit analogue to digital converter with an input voltage range of 0 to 3.3V. What number will it output if the input voltage is 1V?

[4 marks]

- (h) What role do each of the following play in a computer system?

- Address bus
- Data bus

[4 marks]

Question 2 (33 marks)

An STM32L031 MCU is wired to a button and two LED's as follows:

Green LED Port A, Bit 0

Red LED Port A, Bit 1

Button Port A, Bit 2

A '1' in a port bit turns on an LED. When the button is pressed, the pin to which is connected is pulled down to '0' otherwise it defaults to '1'.

- (a) What roles do the following registers play in the STM32L031 General Purpose Input Output system:
- a. ODR
 - b. IDR
- [4 marks]
- (b) Write C code that will turn on the Green LED without affecting the Red LED
- [4 marks]
- (c) Write C code that will turn off the Red LED without affecting the Green LED
- [4 marks]
- (d) Write C code that will wait for the button to be pressed.
- [4 marks]
- (e) A C-function called **eputchar** that outputs a single character over the USART in an STM32L031 is shown below.
- a. What is the purpose of the line starting with the **while** keyword?
 - b. Write a C-function that uses **eputchar** to send a C-string.

```
#define TX_COMPLETE 6
void eputchar(char c)
{
    while( (USART2->ISR & (1 << TX_COMPLETE)) == 0 );
    USART2->TDR = c;
}
```

- [8 marks]
- (f) The SysTick timer in Arm Cortex-M microcontrollers can be used to generate a periodic interrupt.
- a. Outline how this timer operates
 - b. What is meant by the phrase 'interrupt' in this context?
 - c. A SysTick timer has an input clock frequency of 32MHz. What value should be placed in its Reload Value Register (RVR) to cause it to generate an interrupt every millisecond?

[9 marks]

Question 3 (33 marks)

- (a) The STM32L031's CPU core is an Arm Cortex M0+. It does not allow data transfers directly from one memory location to another. If a symbol 'X' is declared as shown below, write the Arm-Thumb (assembler) instructions necessary to read the value stored at X into register R0

```
                AREA DATA
X                DCD                10
```

[4 marks]

- (b) The MOVS instruction provides an efficient way of loading a limited range of values into a Cortex M0+ register. What range of values is allowed?

[2 marks]

- (c) Listing Q3a is the assembly language code for a version of the **memcpy** function commonly used in C programs. The function copies 'n' bytes from the source location ('src') to the destination location ('dest').

- a. What happens when each line of this function is executed?

[10 marks]

- b. Identify an example of each of the following addressing modes in this function:

- i. Immediate
- ii. Register indirect

[4 marks]

- c. If the stack pointer contains 0x20002000 on entry to this function, what address will the PUSH instruction save a copy of the link register to?

[2 marks]

- d. You have a 32 byte block of data at memory address 0x20000100 that you would like to copy to address 0x20000200. How would you set up the registers and call upon this function to do this for you.

[6 marks]

- e. How would you modify this function so that it returns the address of the destination buffer in R0.

[5 marks]

```

; void memcpy(uint8_t *dest, uint8_t *src, uint32_t n);
; on entry R0 = dest, R1 = src, R2 = n
memcpy
    PUSH        {LR}
memcpy_loop
    CMP         R2,#0
    BEQ         memcpy_exit
    LDRB        R3,[R1]
    STRB        R3,[R0]
    ADDS        R0,R0,#1
    ADDS        R1,R1,#1
    SUBS        R2,R2,#1
    B           memcpy_loop
memcpy_exit
    POP         {PC}

```

Listing Q3a

Question 4 (33 marks) CPU architecture

(a) What are the functions of the following Arm Cortex M0+ registers?

- a. PC
- b. SP
- c. LR

[6 marks]

(b) The Arm Cortex M0+ has 4 ALU flags. What are they and what calculations causes each of them to be set to 1?

[4 marks]

(c) Listing Q4a shows how a translation of a simple C function to assembler. The local variable X is allocated on the stack. Referring to the assembler code, explain how this operates.

[6 marks]

(d) Local variables can be subject to “Buffer overflow” attacks. What is meant by this term and what risks does it pose?

[7 marks]

(e) Modern microprocessors typically include additional hardware to accelerate their performance. Describe what is meant by each of the following and how they increase performance.

- a. Instruction Pipeline
- b. CPU Cache

[10 marks]

<pre>void f() { int X; X = 1; }</pre>	<pre>F push {r7, lr} sub sp, sp, #8 add r7, sp, #0 movs r3, #1 str r3, [r7, #4] add sp, sp, #8 pop {r7, pc}</pre>
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Listing Q4a