# UNIVERSITY OF GHANA



BACHELOR OF SCIENCE IN ENGINEERING
FIRST SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF COMPUTER ENGINEERING
CPEN 403: EMBEDDED SYSTEMS (3 Credits)

INSTRUCTION: *Answer any five (5) Questions of your choice*

TIME ALLOWED: *THREE (3) HOURS*

1. **(a)** State and briefly describe three (3) main characteristics of embedded systems that distinguish such systems from other computing systems. [6 marks]
**(b)** Briefly discuss three (3) major challenges that confront embedded systems of today and state three (3) application areas of embedded systems. For each area, give one (1) sample product that uses the embedded systems. [9 marks]
**(c)** List five (5) key hardware components that can be found on a PLC system and briefly explain the functionality of each component. [5 marks]

2. **(a)** List and explain two (2) design constraints you may consider necessary when designing a tollbooth control system. [4 marks]
**(b)** A temperature sensor monitoring the combustion at the VRA plant is connected to port P1 of a microcontroller board while an LCD device is connected to port P2. Write a simple program to show how bytes of data will be read from P1 and written to P2. Illustrate with a simple diagram. [4 marks]
**(c)** You have been tasked to implement a Fast Fourier Transform (FFT) to process fingerprint images for access control for the Department. You have the option to implement the system using either software on a microcontroller or hardware option using FPGA. Using To use the software option, you will require a clock speed of 300MHz and 450,000 instructions. Assume the software instructions to be executed are as shown in Table 1 below. The hardware approach on the other hand

will require 100MHz clock speed and execution time of 2 pixels per clock.

**(i)** If the size of the fingerprint images is *512 x 512*, find the execution time and the performance of the two FFT system implementation options. [6 marks]

**(ii)** If the voltage requirement by the two systems is 5V and the amount of current drawn by each system is 2A, find the performance/Watt and explain which option you will consider based on this metric. [3 marks]

**(iii)** If the development cost for the microcontroller option is GHc500 and the cost per performance ratio is assumed to be the same for the two options, find how much the FPGA option will cost for implementation. [3 marks]

**Table 1**

| No | Processor instructions | CPI | % Occurrence |
|---|---|---|---|
| 1 | ADD | 1 | 20 |
| 2 | MUL | 2 | 15 |
| 3 | SUB | 1 | 10 |
| 4 | LOAD | 3 | 20 |
| 5 | STORE | 1 | 10 |
| 6 | BRANCH | - | 25% |
| 6a | BRANCH (not taken) | 1 | 35% |
| 6b | BRANCH (taken) | 2 | 65% |

**Q3.** **(a)** What is the difference between a watchdog timer and a counter? An ATM machine on campus that operates at a clock frequency of 16 MHz is connected to a watchdog timer with 16-bit counter. Find the range of the timer and the terminal count value that will be required to measure 5ms interval. [6 marks]

**(b)** Suppose the clock frequency of the system is adjusted to 12 MHz using a pre-scalar and the WDT now needs a reset every 400ns. Find how wide the counter in the WDT should be. [4 marks]

**(c)** Assume a second 16-bit counter is cascaded with the existing counter in the ATM and the clock frequency is maintained at 16MHz. Suppose we want a timeout to occur if the *watchdog_reset* function is not called within 5 minutes. Compute the value that must be loaded on the counters when the watchdog_reset function is called. [4 marks]

**(d)** A motor at the VRA thermal plant at Aboadze operates at 8,050 revolutions per minute (rpm) when its input voltage is 4.45V. The microcontroller that controls the

motor has a PWM whose output port can be set high (5V) or low (0V) and is driven by a 10 MHz clock frequency and a 16-bit counter. Calculate the minimum rpm, the duty cycle required to obtain the 8,050 rpm, and the pulse width and period required to achieve this duty cycle. [6 marks]

4. **(a)** With the support of a diagram, briefly describe the three main functions of an ADC unit on a microcontroller board. State four (4) parameters you will consider important when selecting an ADC/DAC for an application. [6 marks]
**(b)** Suppose an analog input signal from a temperature sensor at the VRA thermal plant has input voltage range from –10 to 10 V. If the ADC on the microcontroller board uses a 12-bit digital encoding system, find the resolution of the conversion and the correct encoding of an input of 6.2V from the sensor. [4 marks]
**(c)** An embedded system has a 10 MHz clock frequency with 12-bit on-chip ADC. The ADC uses a single ramp converter scheme for the conversion and the program loop that processes the input requires 70 instructions with an average execution time of 4 clocks per instruction. Calculate the ADC conversion time, the maximum sampling rate of the signals, and the highest frequency that the sensor system can monitor. [6 marks]
**(d)** If the DAC on the system in Q4 (c) has a full scale of 30mV for 5V maximum output, calculate the accuracy error of the DAC and determine whether this error will be tolerable. [4 marks]

5. **(a)** Embedded systems communicate with outside world via peripherals. Briefly discuss any four (4) synchronous communication interfaces and for each interface, give one (1) common device that is capable of interfacing to the bus. [4 marks]
**(b)**An electronic scoreboard at a stadium is controlled by an embedded system with a board rate of 9600 bps. Find how long it will take to transmit the score information "*Legon CPENG 3*: *KNUST CPENG 2*" on the display unit via UART. If the duration of the transmission is found to be unacceptably long, explain the possible measure that could be taken to resolve it. [6 marks]
**(c)** What are the two (2) main characteristics of memories? Describe the steps you will follow to test memory devices on an embedded board. Explain whether your procedure can be applicable to both RAM and EEPROM. [5 marks]
**(d)** How will you test for missing memory chip on an embedded board? List and briefly describe any three (3) common memory problems. [5 marks]

6. **(a)** Explain the difference between hard real time and soft real time embedded systems. With the support of a diagram briefly describe the embedded system software architecture and the role of the OS. [6 marks]

**(b)** Explain the difference between dynamic priority scheduling and fixed priority scheduling. Briefly describe one algorithm of each type. [6 marks]

**(c)** A real time embedded system has to execute 6 sets of tasks with execution time and deadline shown in the Table 2 below where the deadline of the tasks is the same as the period.

**(i)** Using the rate monotonic scheduling, indicate the priority assignment of the tasks sets. [2 marks]

**(ii)** Determine whether the task sets can be scheduled on time (schedulable) using non-preemptive scheduling. Justify your answer. [3 marks]

**(iii)** Explain how the task sets can be made schedulable in case you found out that they are unschedulable. [3 marks]

**Table 2**

| Tasks | Execution time (ms) | Deadline (ms) | Start time (ms) | End time (ms) |
|---|---|---|---|---|
| T1 | 8 | 25 | 6 | 14 |
| T2 | 25 | 50 | 24 | 49 |
| T3 | 6 | 12 | 0 | 6 |
| T4 | 25 | 100 | 74 | 99 |
| T5 | 10 | 40 | 14 | 24 |
| T6 | 25 | 75 | 49 | 74 |