UNIVERSITY OF GHANA

BACHELOR OF SCIENCE IN ENGINEERING
FIRST SEMESTER EXAMINATIONS: 2017/2018

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)** What is an embedded system? State four main characteristics that distinguish embedded systems from other computing systems. [5 marks]
   (b) Give four application areas of embedded systems and for each application area, list one product type that uses the embedded technology. [4 marks]
   (c) State and briefly describe two models commonly used for embedded system design. Enumerate the steps you will follow for the design and development of an elevator system for the School of Engineering Sciences building. [6 marks]
   (d) A temperature sensor monitoring activities at a plant is connected to port P1 of a PIC microcontroller while an LCD system is connected to port P2. Sketch the connection diagram. Write a code to show how a sensed signal with decimal value of 35 on P1 is read and written to P2. Use the BCD bit format. [5 marks]

2. **(a)** An embedded system for a driverless car is to be implemented using software approach by writing to a microcontroller or VHDL using FPGA hardware. To use the microcontroller, a clock speed of 450 MHz and 600,000 instructions would be required for execution (see Table 1 below). Using the FPGA will require a clock speed of 600 MHz and an array size of 256 x 256 with execution time of 2 pixels per clock. Calculate the following:
   (i) execution time and performance for the two systems. [7 marks]
   (ii) performance/watt for each system and explain its implication on the systems.

Assume the microcontroller system requires a voltage of 5V and draws a current of 4A while the FPGA requires 3.5V and 6A. Which of the two options you will recommend for implementation based on this metric. [6 marks]

(iii) cost for implementing the FPGA hardware option if the cost for implementing the microcontroller option is GHc8000 and the cost per performance is assumed to be the same for the two options. [3 marks]

(b) Using the simple loop structure, show the code structure you will implement on the controller for the air-condition system of a vehicle. [4 marks]

Table 1 – Microcontroller operational data

No	Instructions	CPI	% Occurrence
1	ADD	5	35
2	MUL	4	20
3	SUB	2	15
4	LOAD	6	12
5	STORE	3	8
6	BRANCH	-	10
6b	BRANCH (taken)	3	65
6a	BRANCH (not taken)	2	35

3. **(a)** Explain the difference between a timer and watchdog timer (WDT). State three functions of a timer on an embedded system. [5 marks]

(b) An LED on a microwave is connected to pin P2.3 of a PIC microcontroller that is driven by a 4 MHz clock. The LED is to blink at a rate of 5 KHz without using a timing loop (delay). Sketch the connection diagram and determine the number of bits (in hex format) that is written on the timer register for the blinking operation. Assume the timer has a 16-bit register. [6 marks]

(c) A vending machine has an embedded device that is driven by a clock frequency of 15 MHz, which is connected to a WDT with a 16-bit counter. Find the range of the timer and the terminal value that is required to measure 5ms interval. How often should the system signal the WDT to let it know that it is alive? [5 marks]

(d) To adjust the speed, a pre-scalar is used to change the frequency to 12 MHz. If the WDT needs a reset every 200ns, find how wide the counter in the WDT should be to achieve the required reset. [4 marks]

4. **(a)** List four parameters you will consider necessary when selecting an ADC/DAC for an embedded application. [4 marks]

(b) An input signal monitored from an elevator has a range of -5V to 5V. If the ADC/DAC on the embedded device uses a 12-bit encoding system, find the correct encoding using the BCD format for an input voltage of 4.2V. [4 marks]

(c) Suppose the embedded device on the elevator is driven by a 16 MHz clock and has 12-bit on-chip ADC that uses the successive approximation register (SAR) architecture for the analog signal conversion. The ADC program that processes the input requires 300 instructions with average execution time of 4 clocks per instruction. Find the ADC conversion time for signals and the maximum frequency that the system can monitor. [8 marks]

(d) Find the accuracy error of the DAC on the embedded device if the full-scale range is 20mV for 5V maximum output. Will you consider this error tolerable? Explain your answer. [4 marks]

5. **(a)** List and briefly explain two transmission media that are commonly used in embedded systems. For each transmission medium, give two device types on the embedded board that could be used for the purpose. [6 marks]

(b) What is UART? Give two reasons why UART is used in embedded devices. A 16 x 2 LCD system is connected to an embedded board via UART for monitoring operations at the TOR plant. The baud-rate on the embedded board is set at 9600 bps. How long will the system take to display the message "*current chamber temp = 780°C*" on the LCD? [4 marks]

(c) Suppose the microcontroller in 6 (b) is used to control a motor at the plant via the PWM whose output port can be set high (5V) or low (0V). The microcontroller is driven by a clock rate of 10 MHz and 16-bit counter with pre-scale timer setting of 4. The motor operates at 5,000 revolutions per minute (rpm) when its input voltage is 3.5V. Find the following:

(i) duty cycle required to achieve the 5,000 rpm and pulse width. [3 marks]

(ii) values for the *smod* and TH1 register required to generate a baud rate of 9600 for the microcontroller. (NB: *smod* is 2 bits and TH1 is 8 bits). [3 marks]

(iii) PWM period and frequency for maximum value of period register. [4 marks]

6. **(a)** State and briefly explain two key characteristics of memories. [2 marks]

(b) What is the difference between EEPROM and NVRAM? Which of the two memory devices will you consider suitable for an embedded system if you want to

store critical system information? [4 marks]

(c) What is the difference between SRAM and DRAM? Which of the two memory devices will you consider suitable for an embedded application and why? State four parameters you will consider when selecting memory device for an embedded application. [5 marks]

(d) Describe the steps you will follow to test memory on an embedded board and explain whether the process will be suitable for RAM and EEPROM. [3 marks]

(e) Draw a diagram of a processor, memory and peripheral connected to a system bus in which the peripheral gets serviced using vector interrupt. Assume servicing moves data from the peripherals to the memory. Show all relevant control and data lines of the bus. Provide a timing diagram to illustrate what happens over the system bus during the interrupt. [6 marks]

7. **(a)** Define the following terms: *real-time system; hard real-time system; soft real-time system; interrupt; and real-time operating system.* [5 marks]

(b) State and describe one static and one dynamic real-time scheduling algorithm that is used in embedded systems. Give one example of each type. [4 marks]

(c) An elevator controller system has to execute six sets of tasks with execution times and deadlines shown in the Table 2 below using non-preemptive scheduler. The deadline of the tasks is assumed to be the same as the period.

(i) Using the deadline monotonic and rate monotonic scheduling, indicate the order in which the tasks will be assigned for execution. [4 marks]

(ii) Determine whether all the tasks can meet their deadlines when the earliest deadline and the rate monotonic scheduling schemes are used. [7 marks]

Table 2 – Tasks sets scheduling information

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