THE UNIVERSITY OF THE WEST INDIES
ST. AUGUSTINE

EXAMINATIONS OF December 2015

Code and Name of Course: **ECNG3006 Microprocessor Systems** Paper: **Final**

Date and Time: **2 Dec 2015 9AM** Duration: **Three (3) hours**

INSTRUCTIONS TO CANDIDATES: This paper has 6 pages and 3 questions. Max. Marks: **100**

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Attempt ALL questions.
Questions 1-2 are each worth 25 marks.
Question 3 is worth 50 marks.

Questions Q3.a and Q3.b should be answered on pages 5-6
and the script returned with your exam booklet.

The following reference information is provided:

- Task Information for Process Control System on page 3

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Q1. μCOS-II is an example of a commercial real-time operating system (RTOS) kernel which supports both mutexes and semaphores, as well as both co-operative, and pre-emptive, priority based multi-tasking systems.

(a) Describe the role of the Task Control Block structure within the task scheduling and context switching functions of the μCOS-II kernel. *5 marks*

(b) Compare and contrast the creation and usage of a mutex and a binary semaphore for resource access in μCOS-II. *5 marks*

(c) Compare the performance goal(s) of co-operative priority-based schedulers and pre-emptive priority-based schedulers. Support your answer by identifying at least **one** reason why developers choose to use or not use co-operative scheduling. *5 marks*

(d) Define the term "jitter", and explain how jitter can be observed and quantified for a system designed around μCOS-II. Support your answer by identifying two possible causes of jitter. *5 marks*

(e) *"Multi-tasking provides better average task performance (reduced response-time) than cyclic executives."*

Discuss the validity of the statement. If **true**, why do embedded system designers sometimes prefer cyclic executives? If **false**, why do embedded system designers sometimes prefer multi-tasking solutions? *5 marks*

Q2. An embedded real-time system consists of a PIC18 micro-controller connected to a 4x16 LCD display via an 8-bit interface, as well as a digital temperature sensor which can be configured for 8 to 12 bits of resolution.

(a) Differentiate between sensor linearization and sensor calibration. Explain how each can be used in the temperature sensor in either hardware or software. *5 marks*

(b) Determine the maximum rate at which parallel 8-bit data can be clocked out from a microprocessor whose output pin rise/fall time is $t\mu s$. You should presume a separate clock line is in use. State any assumptions and explain your reasoning. *5 marks*

(c) "If the noise effect rather than quantization predominates, the resolution can be increased by averaging several readings." Explain this statement. Why does averaging not "work" if quantization rather than noise predominates? *5 marks*

(d) "The PIC 16F877 micro-controller is unsuited for real-time systems". Discuss this statement. Show how, under certain restrictions, the PIC can be used for these systems. *5 marks*

(e) Using a sample C-like code, identify the key function calls in the C18 libraries for accessing the LCD. Your answer(s) do not need to be syntactically correct. *5 marks*

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Figure Q3 Description of Process Control System based on Presentation on Selective Catalytic reduction by Kyle Hunte, November 2014

Selective Catalytic Reduction is a process by which exhaust containing nitrous oxides (dangerous emissions) is reacted with ammonia to form nitrogen and water(safe to emit). In this process ammonia is pumped from feed tanks, heated, and combined with exhaust.

System Inputs:	• Ammonia Tank Level Sensor (High/Low) • Temperature Sensor (continuous value)
System Outputs:	• Pump (On/Off) • Heater (On/Off)
System Resources:	**R1** Mutex associated with global variables
Task 1: Ammonia Tank Level Monitoring	Sends signal to Pump Control Task; Runs at 50 ms intervals. **J11, e=5ms** request Mutex R1 **J12, e=5ms** after J11, read Level sensor and store current state in a global variable **J13, e=5ms** after J12, release Mutex R1
Task 2: Pump Control	Toggles state of pump at 100% based on Tank Level; Runs at 100ms intervals. Phase Delay 10ms. **J21, e=5ms** request Mutex R1 **J22, e=5ms** after J21, copy stored Tank Level state to local variable **J23, e=5ms** after J22, release Mutex R1 **J24, e=10ms** after J23, if Tank Level is low turn pump on else turn pump off
Task 3: Temperature Control	Reads the Temperature Sensor, filters data, and turns the Heater on and off appropriately. Runs at 100 ms intervals, but the heater must be triggered within 50ms of the temperature reading. **J31, e=15ms** read and store Current Temperature in local variable and filter Reading (average current and stored readings) **J32, e=5 or 10ms** after J31, if Reading is $> T_{upper}$ then turn on heater (5 ms); else if temperature is $< T_{lower}$ then turn off heater (10ms)

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Q3. A Process Control System is an example of an embedded system with real time requirements. Jobs and tasks for such a system are described on page 3.

(a) i. Fill in the missing job parameters and precedence arrows on the precedence graph on page 5. *5 marks*

ii. Use the precedence graph on page 5 to determine the effective release times and deadlines for jobs J21 and J31. Justify your answer.

iii. Use the graph paper on page 6 to construct a **cyclic schedule** for the execution of these jobs where the minor cycle is 10ms. *5 marks*

(b) Use the graph paper on page 6 to construct appropriate **task and resource timelines** for the execution of these jobs assuming that they are scheduled using a pre-emptive priority based scheduler, with a 10ms tick, where Task 3 has the highest priority, and Task 1 has the lowest priority. *10 marks*

(c) Compare the task performance achieved using the cyclic executive, and the pre-emptive priority based scheduler. Your answer should clearly identify at least **two** criteria you could use for comparison, and explain which system you would prefer to implement and what adjustments (if any) you would make. *10 marks*

(d) You have been asked to modify the implementation so that a foreground-background system may be used. To do so, the Ammonia Tank Level sensor will deliver an interrupt-on-change signal when the Ammonia level goes from low-high or high-low.

In the revised system, Task 3 runs in the background, and J24 is called in the interrupt handler (foreground) for the Ammonia Tank Level Sensor interrupt on change. Task 1 and Jobs J21, J22, J23 are not used.

Assess whether the suggested scheme is feasible, and if it offers any benefits. Your answer should identify all resources and procedures you would require to detect and/or address any subsequent issues. *15 marks*

END OF QUESTIONS

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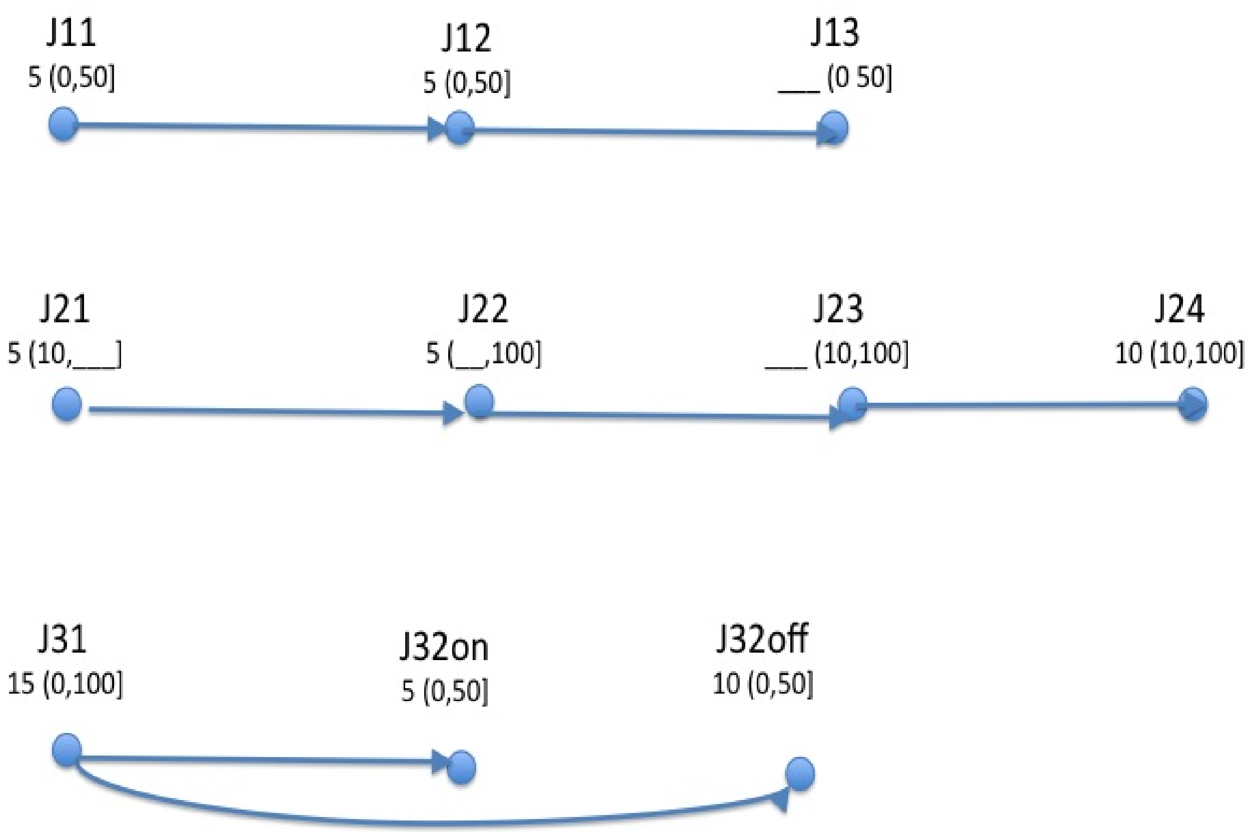

Figure Q3.a Precedence graph for Job set $J11...J32$

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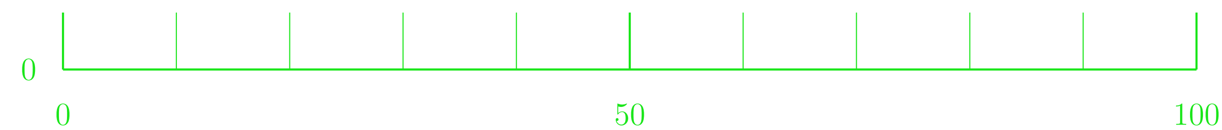

Figure Q3(a)iii Grid for Cyclic Schedule for Job set $J11 \ldots J34$

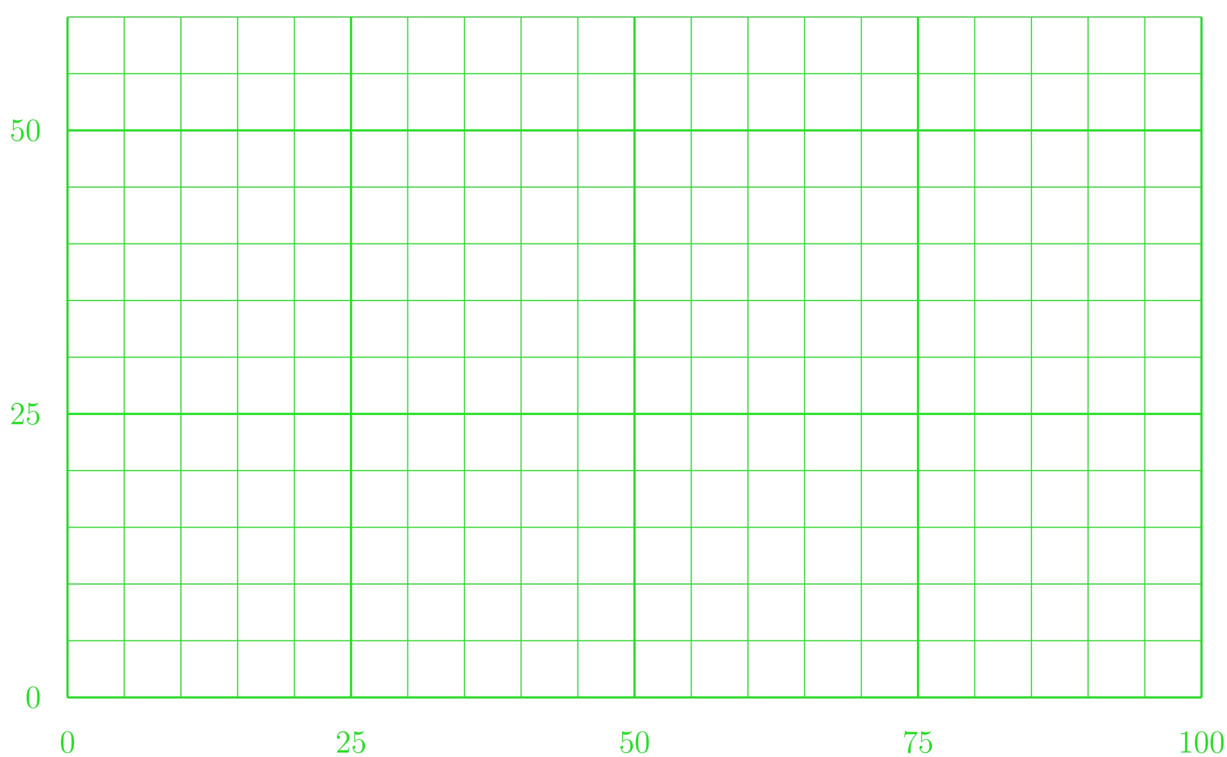

Figure Q3.b Grid for Pre-emptive Priority Timeline(s) for Job set $J11 \ldots J34$

END OF EXAM PAPER