Exam IN2305B Embedded Programming
Friday, April 8th, 2011

In order to avoid misunderstanding on the syntactical correctness of code fragments in this examination, we will always assume that we are dealing with pseudo-code (marked as "!! ..."), although we might have syntactically correct code in some cases. We assume that the required variables, semaphores, tasks, timers, etc. are always declared and initialized correctly. Further, we assume the following abbreviations to be known: RR = Round Robin, RRI = Round Robin with Interrupts, FQS = Function Queue Scheduling, RTOS = Real-Time Operating System, IR = interrupt and ISR = interrupt service routine. One system clock tick = 10 ms (if not stated otherwise). "100 us" stands for 100 microseconds.

In this exam, we use the following definitions, unless stated otherwise:

- void delay(int ms) { !! do some CPU computation to the amount of ms milliseconds }
- void random_delay() { !! do some CPU computation for a random amount of ms milliseconds }
- void gets(char *s) { !! fill string s using getchar }
- void puts (char *s) { !! write string s using putchar }

-
  ```
  char getchar() {
    while (!! UART rx buffer empty);
    !! return c from UART rx buffer }
  ```

-
  ```
  void putchar(char c) {
    while (!! UART tx buffer not empty);
    !! send c to UART tx buffer }
  ```

- OSTimeDly(int ticks) – delay system function
- OS_Post(sem) – semaphore "post" system function
- OS_Pend(sem) – semaphore "pend" system function

In order to pass the written exam, you need to answer correctly 20 or more questions. The relationship between the number of correct answers and the mark is:

Nr. correct answers	20	21	22	23	24	25	26	27	28
Mark	6	6.5	7	7.5	8	8.5	9	9.5	10

This table has been computed by discarding one quarter of the questions from the correct answers (to account for guessing). The remainder correct answers were mapped on a linear scale.

If you fail the written exam, you fail the whole module. If you failed the lab (or did not attend), you fail the whole module. If you passed **BOTH** the written exam and lab, then the final mark for this module is computed as the maximum between the (exam mark) and (0.75 * exam mark + 0.25 * lab mark).

Code for Questions 1-3

Given is the following RTOS (pseudo) code. The priority of T2 is higher than the priority of T1, the time for putchar() and context switching is negligible. In this exercise, putchar() is considered to be reentrant:

```
void T1() {
    char x=’e’;
    while (1) {
        putchar(x--);
        OSTimeDly(10);
    }
}
void T2() {
    char x=’5’;
    while (1) {
        putchar(x--);
        OSTimeDly(10);
    }
}
```

Question 1

Which of the following statements is correct? The display shows:

a) 5e4d3c2b ...
b) edcb ...
c) 5432 ...
d) e5d4c3b2 ...

Question 2

The OSTimeDly(10) call is replaced by a delay(10) call. Which of the following statements is correct? The display shows:

a) 5e4d3c2b ...
b) e5d4c3b2 ...
c) edcb ...
d) 5432 ...

Question 3

Consider the original fragment of code. Which of the following sentences is correct?

a) Renaming the variable “x” to “y” in T2 removes the data sharing problem between T1 and T2.
b) The addition of the keyword “volatile” in front of the definition “char x=’1’;” in T2 removes the data sharing problem between T1 and T2.
c) The addition of the keyword “volatile” in front of both definitions “char x=...” removes the data sharing problem between T1 and T2.
d) There is no data sharing problem between T1 and T2.

Code for Questions 4-7

Given is the following (pseudo) code, which reads the current values of 3 different buttons and acts accordingly. The 3 buttons are all mapped to bits 0..2 of the register buttons. The buttons are already debounced; execution time of ISR is negligible.

```
void task1(void) { delay(1000); }
void task2(void) { delay(2000); }
void task3(void) { delay(3000); }
isr_button1() {b1=1}; // arrive here if button 1 is pressed
isr_button2() {b2=1}; // arrive here if button 2 is pressed
isr_button3() {b3=1}; // arrive here if button 3 is pressed

void main (void) {
    while (1) {
        if (b1) { task1(); b1=0; }
        if (b2) { task2(); b2=0; }
        if (b3) { task3(); b3=0; }
    }
}
```

Question 4

None of the buttons has been pressed. Which of the following statements is correct?
The longest time task3( ) takes to fully execute (the time between its release and its completion) is:

a) 3 seconds
b) 6 seconds
c) > 6 seconds
d) undefined

Question 5

None of the buttons has been pressed. Button 3 is pressed and released three times during an interval of 2 seconds. None of the buttons is pressed afterwards. Which of the following is true?

a) task3() is not executed at all.
b) task3() executes only once.
c) task3() executes three times.
d) task3() might not be executed at all.

Question 6

None of the buttons has been pressed. Button 3 is pressed and immediately released. After 2 seconds, button 2 is pressed and immediately released. After 2 more seconds, button 2 is pressed and immediately released. Which of the following is true?

a) none of the above
b) task2() preempts the execution of task3()
c) task2() executes once
d) task2() executes twice

Question 7

Which of the following statements is correct?
This source code is an example of a ...

a) RR architecture
b) RRI architecture
c) FQS architecture
d) RTOS architecture

Code for Questions 8-11

Given is the following RTOS (pseudo) code. The priority P(isr_2) > P(isr_1), RS232 speed is 1 char per 100 us, the timer ticks every 1000 us. The time to process an IRQ is negligible:

```
void f1(void) { // do something that takes between 30 … 60 us }
void f2(void) { // do something that takes between 10 … 30 us }
void f3(void) { // do something that takes between 30 … 60 us }
void isr_1 (void) { // arrive here if RS232 input char (IRQ1)
    !! service IRQ takes 10 us CPU time }
void isr_2 (void) { // arrive here if timer expires (IRQ2)
    !! service IRQ takes 10 us CPU time }
void task (void) {
    while (1) {
        f1();
        !! disable IRQ1 here
        f2();
        !! enable IRQ1 here
        f3()
    }
}
```

Question 8

Which of the following statements is correct? The minimum time interval between the arrival of a character on the RS232 interface and the moment its processing is finished (as in isr_1{} execution completes) is:

a) more than 20us.
b) 0 us.
c) 10 us.
d) 20 us.

Question 9

Which of the following statements is correct? The maximum time interval between the arrival of a character on the RS232 interface and the moment its processing is finished (meaning isr_1{} execution completes) is:

a) 30 us .
b) 40 us.
c) 50 us.
d) 60 us.

Question 10

Which of the following statements is correct? The maximum time interval between the start of the execution of the f2() function and the end of the execution of the f2() function is:

a) 30 us.
b) 40 us.
c) 50 us.
d) 60 us.

Question 11

Imagine that the CPU clock frequency is increased ten times, meaning that all the previous execution times are decreased ten times, including the period of the timer. The speed of the RS232 interface (number of characters per second) remains unchanged. Which of the following statements is correct?

a) The number of correctly processed characters coming from the RS232 interface increases 10 times.
b) The number of correctly processed characters coming from the RS232 interface remains the same.
c) f2() is executed more often.
d) f2() is executed significantly less often.

Code for Questions 12-15

Given is the following RTOS (pseudo) code with priority T1 > T2. Event #1 triggers “sem1” and event #2 “sem2”.

```
void T1(void) {
    while (1) {
        OSSemPend(sem1); // event #1 may unblock any time
        f(1);
        OSTimeDly(1);
    }
}
void T2(void) {
    while (1) {
        OSSemPend(sem2); // event #2 may unblock any time
        f(-1);
        OSTimeDly(1);
    }
}
void f(int i) {
    OSSemPend(mutex);
    counter = counter + i; // modify some global counter
    OSSemPost(mutex);
}
```

Question 12

Which of the following statements is correct?

a) function f() is not reentrant
b) there is a potential data sharing problem between T1, T2
c) the usage of semaphores “sem1” and “sem2” can trigger priority inversion
d) there is no data sharing problem

Question 13

Which statement is correct? For the program to work correctly, the mutex needs to be initialized with...

a) 0
b) 1
c) 2
d) any value will work

Question 14

The order of events is #1, #1, #2, #2, #2 and they occur within 10ms from each other. Which of the statements is true?

a) the final value of the counter will be decreased by 1
b) the final value of the counter will be the same
c) the final value of the counter will be increased by 1
d) the final value of the counter will be undefined

Question 15

Assume that we change "OSTimeDly(1);" with "delay(10);". Which of the following is true?

a) the final value of the counter will be decreased by 1
b) the final value of the counter will be the same
c) the final value of the counter will be increased by 1
d) the final value of the counter will be undefined

Question 16

Which factor determines the least delay until the execution of an interrupt?
The shortest period of time ...

a) it takes to execute any higher priority ISR
b) during which the interrupt is enabled
c) during which the context of the current task is restored
d) during which another higher priority task is executing

Question 17

In the event-driven paradigm, with respect to time, the program running on an embedded system should:

a) produce events that will wake up the system after each sleep period.
b) poll for events and execute the code associated with them.
c) alternate between running intervals and sleep times and never stop.
d) stop at a predefined moment.

Question 18

Which of the following statements is correct? The X32 platform ...

a) provides non-interruptable interrupt routines.
b) prohibits interrupt nesting.
c) uses one interrupt priority level only.
d) permits preemption of ISR.

Question 19

Which of the following statements is correct? An interrupt is ...

a) a synchronous signal from the processor to ask for hardware time.
b) a synchronous signal from the hardware to ask for processor time.
c) an asynchronous signal from the processor to ask for hardware time.
d) an asynchronous signal from the hardware to ask for processor time.

Question 20

We assume a system clock tick of 20ms. Assuming the function call itself consumes a negligible amount of time, executing the sequence:

```
OSTimeDly(1); OSTimeDly(2); OSTimeDly(2);
```

a) causes a delay smaller than 80ms.
b) causes a delay of exactly 100ms.
c) causes a delay between 80ms and 100ms.
d) causes a delay larger than 100ms.

Question 21

Which of the following sentences is correct? An interrupt vector table ...

a) contains information about the interrupt addresses and their status.
b) can have its size changed dynamically at runtime.
c) can be considered not-initialized immediately after a reset.
d) needs to be filled by the user with information about the interrupt priorities.

Question 22

In which of the following architectures the worst wait time for the highest-priority task is the length of the task code functions plus the execution time of any interrupt routines that might happen?

a) RR b) RRI c) FQS d) RTOS

Question 23

Which of the following is true?

a) Timeliness is a characteristic of programming abstractions for embedded systems.
b) Liveness is not a characteristic of programming abstractions for embedded systems.
c) Security is a characteristic of programming abstractions for embedded systems.
d) Reactivity is not a characteristic of programming abstractions for embedded systems.

Question 24

Which of the following is true?

a) In the rendezvous mechanism, a process does not have to stall until the second process is ready.
b) In publish-subscribe models, components are connected via named event streams.
c) In a discrete-event system, the order in which the events occur is not important.
d) The data flow model is the best available model for the design of embedded systems.

Question 25

Which of the following statements is correct? Interrupts can be disabled in order to ...

a) disable a critical section.
b) enable context switches.
c) make a critical section atomic.
d) protect task code from shared data.

Question 26

Which of the following statements is false? A logic analyzer is preferred to an in-circuit emulator because:

a) an in-circuit emulator will not be able to replace different types of processors.
b) the logic analyzer must be connected to all connectors of the processor.
c) logic analyzers are easier to use.
d) logic analyzers are less invasive than in-circuit emulators.

Question 27

Which of the following principles of RTOS-based design is false?

a) Short interrupt routines are needed for a responsive system
b) More tasks help sometimes encapsulate data more efficiently
c) Turning time-slicing off decreases the throughput of the processor
d) It is recommended to use just the minimum necessary functionality from an RTOS

Question 28

Which of the following sentences is correct?

a) The in-band data collection method allows only small amounts of debug information to be gathered.
b) The local logging data collection method allows online inspection of debug data.
c) The online sniffing data collection method requires an additional hardware attached to each device.
d) The out-of band data collection method allows only offline inspection of the debug data.