Exam IN2305-B Embedded Programming Monday, January 18, 2009 (time 14.00-17.00)

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, 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 routing . One system clock tick = 10 ms (if not stated otherwise).

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
}

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

void gets(char *s) {
  !! fill string s using getchar
}

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

void puts (char *s) {
  !! write string s using putchar
}
```

Question 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:

```
void T1() {
   char x='a';
   while (1) {
      putchar(x++);
      OSTimeDly(10);
   }
}
void T2() {
   char x='1';
   while (1) {
      putchar(x++);
      OSTimeDly(10);
   }
}
```

Question 1

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

a) abcdefgh …
b) 1a2b3c4d …
c) 12345678 …
d) a1b2c3d4 …

Question 2

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

a) a1b2c3d4 …
b) 1a2b3c4d …
c) 12345678 …
d) abcdefgh …

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.

Question 4

Which of the following statements is correct? A reentrant function …

a) may not call other reentrant functions
b) may only call other reentrant functions
c) may call non-reentrant functions
d) may not be called by different tasks

Question 5

Which of the following is correct?

Disabling task switches by a task in a RTOS:

a) affects the functionality of interrupts
b) affects the functionality of semaphores
c) can be used to protect shared data between tasks
d) is considered an “illegal operation”

Question 6

Which of the following statements is correct?

The X32 platform …
a) uses one interrupt priority level
b) permits IR preemption
c) prohibits IR preemption
d) prohibits IR priorities

Question 7-10

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 7

None of the buttons has been pressed. Which of the following statements is correct?

The longest time task3( ) takes to fully execute is:
a) 1 second
b) 3 seconds
c) 6 seconds
d) < 1 seconds

Question 8

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

Question 9

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

Question 10

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

Question 11

Which of the following is correct?

All interrupt service routines are supposed to…
a) restore the context and return
b) disable the non-maskable interrupts
c) restore the lowest-priority interrupt
d) increase the program counter

Question 12

Which of the following is correct?

Using interrupts may affects:
a) system response time
b) task response time
c) requirements of the embedded system
d) processor response time

Question 13-14

Given is the following (pseudo) code:

```
void isr_timer (void) {
   puts("t ");
   delay(2000);
}

void isr_buttons (void) {
   f();
   delay(500);
}

void f(void) {
  puts("b ");
  delay(500);
}

int main ( ) {
   …
   X32_timer_per = 2000 * CLOCKS_PER_MS;
   …
}
```

Question 13

Interrupt priority for isr_buttons is set to 11. Interrupt priority for isr_timer is set to 10. Which of the following statements is correct?

a) If a button is pressed, a ‘b’ will appear in the output after 2 seconds
b) If a button is pressed a ‘b’ may appear sometimes.
c) If a button is pressed, a ‘b’ will always appear in the output.
d) No ‘b’ will appear, even if a button is pressed.

Question 14

Interrupt priority for isr_buttons is set to 10. Interrupt priority for isr_timer is set to 0xff. Which of the following statements is correct?

a) If a button is pressed and immediately released, a ‘b’ will appear in the output after 1 second
b) Ifa button is pressed and immediately released, a ‘b’ will appear in the output after 2 seconds
c) If a button is pressed and immediately released, two ‘b’s will show up
d) No ‘b’ will appear, even if a button is pressed and immediately released

Question 15

Priority inversion occurs when:

a) the “volatile” and “static” keyword are wrongly used inside a task or interrupt
b) one semaphore is shared and wrongly used by several tasks
c) one semaphore is shared and wrongly used by several interrupts
d) several semaphores are shared and wrongly used by several tasks

Question 16

An interrupt vector table contains:

a) the code of the interrupt vectors
b) the addresses of the interrupt vectors
c) the code of interrupt service routines
d) the addresses of interrupt service routines

Question 17

The “Embedded Software Crisis” refers to:

a) the “year 2000” bug
b) the rising price of the embedded systems
c) the lack of correct code for the increasing number of embedded systems
d) the decrease in the number of manufactured embedded systems

Question 18

Which of the following sentences is NOT correct:

The interrupt latency of an interrupt depends on:
a) the longest period of time interrupts are disabled
b) the period of time taken by the execution of interrupts with higher priority
c) the time taken by the processor to do the necessary operations to transfer control to the ISR
d) the time taken by the RTOS to switch between the active task and the interrupt

Question 19

Given the following code on top of a RTOS:

```
int done=0;

void isr_button(void) {
  if (!! Button pressed)
     done=1;
}

void task1(void) {
  while(1) {
    f();
    OSTimeDly(10);
  }
}

void task2(void) {
  while(!done) {
    f();
    OSTimeDly(10);
  }
  printf(“program done\n”);
  return;
}
```

Question 19

This program is uploaded to an embedded system in the conventional way. Which of the following statements is correct?
a) This program finishes only if the button is debounced
b) This program never ends
c) This program ends only if priority of task2 is higher than priority of task1
d) None of the above statements is correct

Question 20

Which of the following statements is correct?

a) a RRI architecture is less responsive than a FQS architecture
b) FQS does not provide interrupt preemption, while an RTOS does
c) IR and IRS can sometimes be available as part of the RR architecture
d)a RRI architecture has less shared data problems than the RR architecture

Question 21

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 22-25

Given is the following RTOS (pseudo) code with priority T1 > T2 :

```
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(3);
   }
}
void f(int i) {
   OSSemPend(mutex);
   counter = counter + i; // modify some global counter
   OSSemPost(mutex);
}
```

Question 22

Which of the following statements is correct?

a) function f() is not reentrant
b) there is a shared data problem between T1, T2
c) priority inversion can occur in this case
d) there is no data sharing problem

Question 23

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 24

The order of events is #1, #2, #1, #2, #1 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 25

Assume that we change “OSTimeDly(1);” with “delay(20);”. 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 26

An alarm system constantly monitors the binary output of several motion detector sensors in a house. If a breach is detected then an intermittent alarm sound is triggered. What is the minimally required architecture?

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

Question 27

For which kind of software architecture for embedded systems is the worst response time for a task equal to the total execution time for all tasks code plus the execution time for interrupt routines?

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

Question 28

Which of the following statements is correct?

Interrupts can be disabled in order to …

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

Question 29

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 30

Given the following RTOS (pseudo) code (priorities of Task1 is greater than priority of TASK2):

```
void isr_buttons(void) {
  if (!! Buttons pressed)
    OS_Post(event);
}

Void Task1(void) {
  while (TRUE) {
    OS_Pend(event); // wait for event
      !! some functionality
    OS_Post(event);
  }
}

Void Task2(void) {
  while (TRUE) {
    OS_Pend(event); // wait for event
      !! some functionality
    OS_Post(event);  }
}
```

Question 30

In the case in which the user presses (and immediately releases) the button twice, which of the following statements is true? (the button is debounced)

a) the "!! some functionality" in both Task1 and Task2 are executed twice
b) the "!! some functionality" in Task1 is executed twice
c) the "!! some functionality" code in Task 2 is never executed
d) the behavior of this code cannot be predicted