Faculty of Electrical Engineering, Mathematics, and Computer Science
Delft University of Technology

exam – **Embedded Software** – TI2726-B
April 19, 2018 13.30 - 15.00

This exam (6 pages) consists of 60 True/False questions.
Your score will be computed as: $max(0, \frac{\#correct}{60} - \frac{1}{2}) \times 2 \times 9 + 1$
It is **not** allowed to consult the book, handouts, or any other notes.

Instructions for filling in the answer sheet:
- You may use a **pencil** (erasures are allowed) or a **pen** (blue or black, **no** red, **no** strike outs).
- Fill in the boxes **completely**.
- Answer **all** questions; there is no penalty for guessing.
- Do not forget to fill in your **Name** and **Student Number**, and to **sign** the form.

The following abbreviations are assumed to be known:

- RR (Round Robin)
- RRI (Round Robin with Interrupts)
- FQS (Function Queue Scheduling)
- RTOS (Real-Time Operating System)
- ISR (Interrupt Service Routine)
- UART (Universal Asynchronous Receiver Transmitter)

One system clock tick = 10 ms (unless stated otherwise).

We make use of the following definitions:

```
void delay(int ms) {
   !! do some CPU computation to the number of ms milliseconds
}

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
}
```

1. Embedded programming is more difficult than "classical" programming because of the lack of support for recursion. true/false

2. A defining characteristic of embedded systems is the usage of a rich user interface. true/false

3. Because embedded software engages the physical world, it has to embrace time and other non-functional properties, which requires a view that is significantly different from the prevailing abstractions in computation. true/false

4. Finite State Machines can be coded in VHDL.
- An advantage of doing so is that it results in a fast and predictable process executing on dedicated hardware. true/false

5. Interrupts cannot only be generated by hardware, but also by software.
- A software interrupt is a synchronous signal to indicate the need for a change in the execution flow. true/false

6. An embedded program can be coded as a finite state machine.
- When for every state S the number of incoming transitions (arcs) equals the number of outgoing transitions (arcs), the code is free of deadlocks. true/false

7. Besides Finite State Machines other models of computation suitable for embedded systems include Symbolic Execution and Discrete Events. true/false

8. The size of an `int` is architecture dependent, but defined to be larger than a `short`. true/false

9. Memory allocated by the `malloc()` function is located on the data heap above the code. true/false

10.

```
typedef void (* resolve)(void *old, void *new);
```

The definition above declares `resolve` as a pointer to a function that takes two arguments of type `void *` and returns a void pointer as result. true/false

11.

```
int main(void)
{
   int c;
   statefp state = before;
   while((c = getchar()) != EOF) {
      state = (statefp) (*state)(c);
   }
   return 0;
}
```

The above driver loop for a FSM follows a round-robin architecture. true/false

12. Specifying the type of `statefp` is difficult in C because it is recursive and types cannot be referenced before being fully defined. true/false

13. GDB is programming tool that provides controlled execution of an executable.
- it also provides post mortem inspection when a core file is generated. true/false

14. Using interrupts improves system response time. true/false

15. An interrupt service routine should restore the context upon exit. true/false

16. To guarantee atomicity critical sections must be disabled. true/false

17. An ISR can **not** be interrupted by another ISR. true/false

18. When a processor is powered up, the state of the interrupt controller needs to be initialized before the RTOS can be invoked. true/false

19.

```
static int iSeconds, iMinutes;
void interrupt vUpdateTime(void)
{
   ++iSeconds;
   if (iSeconds>=60) {
      iSeconds=0;
      ++iMinutes;
   }
}
long lSeconds(void)
{
   disable();
   int now = iMinutes*60+iSeconds;
   enable();
   return(now);
}
```

The above pseudo code correctly dis-/enables the interrupts to solve the shared-data problem. true/false

20. An interrupt vector table contains the code of the interrupt service routines. true/false

21. Given 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 button register. The buttons are already debounced.

```
void f1(void) { delay(1000); }
void f2(void) { delay(2000); }
void f3(void) { delay(3000); }

void main (void) {
   while (1) {
      if (buttons & 0x01) f1();
      delay(1000);
      if (buttons & 0x02 ) f2();
      delay(1000);
      if (buttons & 0x04 ) f3();
   }
}
```

This code is an example of an RR architecture. true/false

22. When none of the buttons have been pressed, the longest time that button #3 must be pressed to activate f3() once is 4 seconds. true/false

23. When the system is in an arbitrary state, button #1 must be pressed at most 10 seconds to activate f1(). true/false

24. The worst-case latency for servicing an interrupt is a combination of factors, including the time taken for higher priority tasks. true/false

25. The number of interrupts is limited by the number of GPIO pins on the processor. true/false

26. Mutual exclusive access can also be accomplished by disabling interrupts, which has the advantage of faster context switching compared to using RTOS primitives like semaphores and mutexes. true/false

27. **Priority inversion** requires a minimum of 3 tasks of different priority and 3 semaphores to occur. true/false

28. The **primary** shortcoming of an RRI architecture is that all tasks have the same priority. true/false

29. An FQS architecture supports priority-based ISRs. true/false

30. The response time to an external event in an FQS architecture depends on the longest task in the system. true/false

31. An RR architecture is most robust to code changes. true/false

32. Consider an alarm system that constantly monitors the digital output of several motion detector sensors in a house. If a breach is detected then an intermittent alarm sound is triggered.
- That alarm system can be implemented with an RR architecture. true/false

33. When detecting a car crash an airbag should not be inflated instantly.
- An RTOS provides functionality to support such delayed actions. true/false

34. When upgrading to an RTOS, signaling between ISRs and tasks may still be done through flags residing in global memory. true/false

35. Semaphores can be used for signaling between ISRs. true/false

36. A reentrant function may **not** reference variables labeled `extern`. true/false

37. A semaphore used for guaranteeing mutual exclusive access to shared resources must be initialized to 1. true/false

38. A high-priority task must **not** invoke an RTOS function that may block. true/false

39. The 'alternating buffers' technique addresses the shared-data problem by having the RTOS control when to switch between buffers. true/false

40. In the implementation of the `OS_Pend()` primitive, the RTOS first switches the state of the current task to BLOCKED, and then looks for a task in the READY queue.
- if the READY queue is empty the processor may be put into sleep mode to save energy when idling. true/false

41.

```
int f (int x) {
   disable_int();

   !!  read some global variables
   !!  do some processing, call some functions
   !!  write some global variables

   enable_int();
}
```

Function `f()` disables/enables interrupts to address the shared-data problem.
- However, when `f()` calls itself recursively, it is no longer reentrant. true/false

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

```
void T1(void) {
   while (1) {
      OS_Pend(sem1); // event #1 may unblock any time
      f(1);
   }
}

void T2(void) {
   while (1) {
      OS_Pend(sem2); // event #2 may unblock any time
      f(-1);
   }
}

void f(int i) {
   delay(10); // do some computation
   counter = counter + i ; // modify some global counter
   printf("%d\n", counter) ; // print result
}
```

The function `f()` is reentrant. true/false

43. If `counter` is set to 15 when event 2 occurs, and event 1 follows 3 ms later, then the first value printed is 16. true/false

44. If the call to `delay` is replaced with `OSTimeDly` the output will be different. true/false

45. An RTOS usually provides two types of delay functions: polling-based and timer-based.
- polling-based delays are more efficient as other tasks can run while the caller is waiting for the specified time to pass. true/false

46. Assume that one system clock tick = 10 ms.
- Calling the function `OSTimeDly(5)` causes a delay between 40 and 50 ms. true/false

47. To address the shared-data problem, many RTOSs provide communication primitives like queues, mailboxes, and pipes.
- a common advantage is that they allow pointers to be passed from one task to another. true/false

48. The advantage of queues over pipes is that messages/items can be of variable length. true/false

49. Even when an RTOS is aware of which task is using which semaphore, it cannot prevent deadlock. true/false

50. Tasks in an RTOS are often structured as state machines with states stored in private variables and messages in their queues acting as events. true/false

51. The memory footprint of a program grows linearly with the number of tasks. true/false

52. Printing from an ISR is to be avoided except when the RTOS provides a reentrant primitive to do so. true/false

53. Time slicing between tasks of equal priority is to be avoided as it compromises the predictability of their response times. true/false

54. A semaphore S used by task A must be initialized before A is created. true/false

55. It is recommended to use just the minimum necessary functionality from an RTOS. true/false

56. Code coverage tools help in thorough testing.
- a 100% coverage implies a bug-free program. true/false

57. A logic analyzer is preferred to an in-circuit emulator because it is easier to install; not all signals need to be connected. true/false

58. Debugging through scripting test scenarios can only be used to test HW-independent code. true/false

59. A large study of outdoor sensor-network deployments [Beutel:2009] has shown that the most underestimated problem has been securing the power supply of the sensor nodes. true/false

60. When debugging code for a distributed sensor network, collecting the (debug) output of the nodes can be arranged in different ways.
- A **wireless** testbed requires **no** physical instrumentation (i.e. wiring) of the sensor nodes. true/false