Input/Output Systems
Proposed exercises

Exercise 1. A hard disk has an average seek time of 4 ms, a rotation speed of 15000 rpm and 512 byte sectors with 500 sectors per track. You want to read a file that consists of 2500 sectors with a total of 1.22 MB. Estimate the time needed to read this file in two scenarios:

- The file is stored sequentially, that is, the file occupies the sectors of 5 consecutive tracks.
- The sectors of the file are distributed in a random way by the disk

Exercise 2. A disk has 600 sectors per track, a rotation speed of 7200 rpm and an average seek time of 2 ms. Calculate the average time to access a sector.

Exercise 3. A 32-bit computer with the RISC-V32 instruction set and a common input/output map has a sensor that measures the height, width and length of a part. The sensor has the following 32-bit registers:

- Data register 1 (with address 0x108). It stores the height of the part.
- Data register 2 (with address 0x112). It stores the width of the part
- Data register 3 (with address 0x116). It stores the length of the part.
- Control register (with address 0x104). When the value 0x2 is written in the register, the sensor is instructed to make a measurement of the dimensions of a part.
- Status register (with address 0x100). If the register value is 0, no measurement has been performed. If the value is 1, the values are already available and the sensor has in the data logs the values of height, width and length.

Write the code for the ReadMeasures function: This function reads the measurements of a part. The function returns three results: the height, the width and the length of the piece.

Exercise 4. A 32-bit computer with the RISC-V32 instruction set and a common input/output map has a sensor with the following three 32-bit registers:

- Data register (with address 0x108). It stores the read temperature value.
- Control register (with address 0x104). When the value 0x2 is written in the register, the sensor is initialised. The sensor is initialised when a 1 is stored in the status record as long as there is a 0 value, the record is not considered initialised.
- Status register (with address 0x100). If the register value is 0, no reading has been done. If the value is 1, a temperature reading has been taken and the sensor has the temperature value in the data log. If the value is -1, an error has occurred and the reader has to be reset (the reader has to be reset only once, unless an error occurs).

Write the code of two functions, which strictly follow the convention of passage of parameters:

a) `SensorInit`: This function does not accept arguments or return any results. The function initializes the sensor and returns when the sensor is initialized.
b) `ReadTemperature`: this function reads the temperature value. The function returns two results: the read value and a code: 0 if it has been correctly read and -1 in case of error.

Exercise 5. Consider a barcode scanner driver. The driver has 3 registers:

- Data register (address 0x1000), 32-bit register that stores the read barcode.
- Control register (address 0x1004), 32-bit register When the value 111 is written in the register, the barcode reader is initialized.
- Status register (address 0x1008), 32-bit register. If the value of the register is 0, no reading has been done. If the value is 1, a reading has been made and the controller has the product code in the data register.

If the computer to which this controller is connected has a common I/O map and memory and has the RISC-V32 instruction set, write a program that: initializes the reader and then indefinitely reads barcodes. Every time a new barcode is read, the value will be stored in the memory position 0xA0000000.

Exercise 6. A controller for a traffic light is to be developed. The controller has a 32-bit CPU, separate I/O map, and RISC-V32 instruction set. Two I/O modules are connected to this CPU. The first is a stopwatch and the second is the I/O module which controls the operation of the traffic light. The timer module has the following three registers:

- Register with address 1000. In this register the value corresponding to the countdown in seconds is loaded.
- Register with address 1004. In this register a 1 is loaded when you want to start the countdown.
- Register with address 1008. When the countdown reaches 0, a 1 is loaded in this register..

The I/O module that controls the traffic light has three register:

- Register with address 1012. In this register the value corresponding to the traffic light color is coded: 100 for red, 010 for yellow and 001 for green.

Write the assembly program that controls the operation of this traffic light. The traffic light always starts on red. The duration of the red and green light is 90 seconds and 20 seconds in yellow.

Exercise 7. A computer is connected to a mouse that must be consulted at least 30 times per second in order to update its position on the screen. The routine that consults its position and redraws the pointer on the screen requires 2000 cycles to be executed. If the computer has a frequency of 2.7 GHz, what is the overload of the mentioned interruption treatment routine, that is, what percentage of time does the computer spend to execute this routine.

Exercise 8. There is a computer that has a sensor connected that measures the temperature of an oven and an alarm. The temperature sensor is connected to the computer through an I/O module that has the following three registers:

- Control register (address: ST_REG_CONTROL). This register is used to indicate the operation to be performed on the sensor. Two operations can be indicated:
  - Device initialization. The device is initialized with the value 0
  - Temperature reading. This operation is indicated by the value.
- Data register (address: ST_REG_DATOS). This record stores the temperature value taken by the sensor.
- Status register (address: ST_REG_ESTADO). This record can store two values:
  - Ready (value 1): when the device has been initialized or a valid temperature measurement is available.
  - Busy (value 0): when the device is initializing or taking a measurement.

The alarm is connected to an I/O module that has two register:

- Control register (address: A_REG_CONTROL). This register is used to activate or deactivate the alarm.To activate the alarm the value 1 is written in this register. To deactivate it the value 0 is written.
- Status register (address: A_REG_ESTADO). This log allows to know the alarm status. If the value of this register is 0, the alarm is disabled. If the value stored is 1, the alarm is activated.

The computer has a separate I/O map and two I/O instructions:

- in RegProcessor, RegI/O which loads into the RegProcessor register the data stored in the register of an I/O module with RegI/O address.
- out RegProcessor, RegI/O which loads into the I/O module register with regI/O address the data stored in the RegProcessor register.

All the registers of the I/O modules are 32-bit registers. Use the MIPS assembly to write a program that continuously reads the oven temperature. If the temperature exceeds 100°C, the alarm should be activated and left on as long as the temperature is above 100°C. When the temperature falls below 100°C, the alarm should be deactivated.

Exercise 9. Consider a computer that runs a program in 1 hour. Of that time it is known to spend 20% on disk access and the remaining 80% on processing time. If you change the disk for another one that allows disk access operations to be performed in half the time. Determine what fraction will be dedicated to disk access when the program is run again. If this new disk is used, what will be the fraction of disk access in case of changing the processor to another one 50% faster?

Exercise 10. Consider a 32-bit computer with byte addressing and separate address maps for memory and input/output. Its architecture offers the RISC-V32 instruction set plus the in and out instructions, which allow reading and, respectively, writing to the I/O module register:

```
in rdest, addr
out rsrc, addr
```

A Px water level sensor is connected to this computer with, among others, the following characteristics:

- The module or I/O unit has the following registers:

Name	Address	Width
Control Reg.	R_CONTROL_Px	32 bits
Status Reg.	R_STATUS_Px	32 bits
Data Reg.	R_DATA_Px	32 bits

- It only has two commands: ON (activates the sensor) and OFF (deactivates the sensor).
- The Status Reg. has three possible values: MEASURING, NEW and ERROR.
- The operation mode of the sensor is as follows: when it is activated it sets its status initially to MIDDLE, from that moment on it will return (in its Data register) a new measurement (32 bits) of the water level every time it detects a variation in the level higher than a certain threshold. When you supply a new measurement in the Status Register, the value NEW appears, and when it detects that it has been read (from the Data Register) it changes its value to MIDDLE, until the arrival of a new measurement. Besides, it is possible that some anomaly may occur in the sensor, stopping its operation, which is indicated by the ERROR value in the Status Register.

Answer:

a) Write a program (driver) to operate this peripheral through programmed I/O with the following operation:
   1. The sensor is activated.
   2. Until a total of 100 measurements are completed, each time a new one arrives it must be stored in the next position of the assigned Memory area, which starts at address M_WAREHOUSE.
   3. If at any time, an error is detected in the operation of the peripheral device, the reading of the 100 measurements must be interrupted and the value TROUBLES must be written to the memory position M_CODE.
   4. If the 100 measurements are completed, the value ALL_OK will be written in the memory position M_CODE.

b) Indicate what disadvantages there are in using this Scheduled or Direct I/O technique here and how the Interrupt I/O technique could be used instead. Briefly indicate the benefit of using it in this case.

NOTE: all the identifiers (symbolic names) that appear in the statement will have a certain value (not specified here) and always correspond to 32-bit data.

Exercise 11. We want to develop a controller for a microwave oven. The controller has a 32-bit processor, common I/O map and RISC-V32 instruction set. I/O, which controls the operation of the oven. The module has the following five 32-bit registers:

- Register with address 1000. In this register the value corresponding to the countdown in seconds is loaded.
- Register with address 1004. In this register a 1 is loaded when you want to start the countdown. As long as there is a 0 the countdown does not start.
- Register with address 1008. When the countdown reaches 0, the controller stores a 1 in this register.
- Register with address 1012. The value corresponding to the desired power is loaded in this register. The value is a 32-bit integer in addition to two.
- Register with address 1016. When the value 1 is loaded in this register, the microwave starts working with the power stored in the previous register. When a 0 is loaded in this register, the microwave stops regardless of whether the end of the countdown has been reached.

Write a function in RISC-V32 Assembly, called Controller that allows to control the operation of the oven. This function will receive two input parameters: an integer value indicating the number of seconds the oven is to remain on and an integer value representing the power of the oven. The function will program the previous controller with the power and seconds spent as parameters, taking care of starting the oven and turning it off when the necessary time has elapsed. The function will return the following possible value:

- A value equal to 0 that represents that there has been no error and will be returned when the function has stopped the oven.
- - A value equal to -1, when the power passed as a parameter is less than 100 and greater than 1000. In this case the oven controller does not have to be programmed and the function must immediately return the value -1.

Answer:

a) Indicate in which registers the parameters are to be passed and in which register the result is to be returned.
b) Invoke the previous function for a power value of 800 W and a duration of 90 seconds. Then, write the code that allows the result returned by the function to be printed on the screen.
c) Write the code corresponding to the function Controller.

Exercise 12. We want to develop a controller for a device that measures a person's blood pressure. The voltage meter I/O module is connected to a computer that has a 32-bit processor, common I/O map and RISC-V32 instruction set. The module has the following 32-bit register:

- Register with address 1000. When the value 1 is loaded in this register, it indicates to the module that you want to start a voltage measurement.
- Register with address 1004. When the measurement has finished in this register, a 1 is stored, while the device is performing the measurement, its value is 0.
- Register with address 1008. When the device has finished measuring the pressure, the value corresponding to the systolic pressure is stored in this register.
- Register with address 1012. When the device finishes measuring the pressure, the value corresponding to the diastolic pressure is stored in this register.

Write a function in RISC-V32 assembly ly, called Controller that allows you to control the operation of this equipment. This function will not receive any input parameters. The function will take care of a blood pressure measurement and will return as output parameters the value of the systolic data and the value of the diastolic data.

Exercise 13. You wish to acquire a high performance hard disk for an online multimedia server, dedicated to distribute high quality movies. Two alternatives are available, whose specifications are shown below:

Specification	Disk A	Disk B
No. of plates (plates/disc)	16	32
Surfaces per plate	2	2
Tracks (track / surface)	512.000	256.000
Track size (sectors / track)	64	64
Sector size (bytes / sector)	512	512
Rotation speed (RPM)	5400	7200
Average seek time (seconds)	0.001	0.003
Purchase cost (Euro/Mbytes)	0,01 €	0,2 €

Give a reasoned answer to each of the following questions:

a) Calculate the total size in MB of each of the above hard disks.
b) For hard disk A, calculate the average access time assuming that users access movies whose average size is 4096 MBN. We assume that the movies are stored sequentially on the hard disk.
c) Which of the two disks is cheaper?
d) In case of reading hard disk A randomly, sector by sector, how long would it take to access a movie?