UNIVERSITAT POLITÃLCNICA DE CATALUNYA
BARCELONATECH
Escola PolitÃlcnica Superior d'Enginyeria de Manresa

Final examination

June 13, 2023 | Embedded Systems - iTIC Degree | 120 MINUTES

FAMILY NAME:

GIVEN NAME: ENROLLMENT GROUP:

Question 1 [2 points]. *ADC and serial port with C*

Regarding the 10-bit analog-to-digital converter (ADC) of the ATmega328P AVR microcontroller answer the next questions considering that we have selected $V_{ref} = 1.1\,\text{V}$ as the ADC reference voltage.

a) Compute the value given by the ADC, x_{ADC}, if the voltage at the input is $v_{in} = 0.6\,\text{V}$. Mark the true answer/answers.

- ○ $x_{ADC} > 559$
- ○ $x_{ADC} = 558$
- ○ $x_{ADC} = 558.5$
- ○ $x_{ADC} = 140$
- ○ None of the previous answers is true.

b) Justify the previous answer

c) x_{ADC}, sampled at $f_s = 11\,\text{kHz}$, must be send through the serial port (1 start bit, 1 stop bit) with serial data rate $serial_{dr}$. Mark the true sentence/sentences.

- ○ The serial data rate $serial_{dr} = 115\,200\,\text{bps}$ can be used
- ○ There is a $serial_{dr} < 200\,000\,\text{bps}$ that can be used
- ○ The serial data rate $serial_{dr} = 132\,000\,\text{bps}$ can be used
- ○ None of the previous answers is true

d) Justify the previous answer.

Question 2 [3 points]. *Fixed-point arithmetic*

In one of our projects, we need to compute $y = a * x$, where a is a fixed coefficient and x is a value given by the 10-bit analog-to-digital converter (ADC) of the ATmega328P AVR microcontroller. In the next questions consider $a = 1.175$ and $x = 47$.

a) Consider the following C code:

```
uint16_t read_ADC(void);
uint16_t x,y;
x = read_ADC();
y = 1.175 * x;
```

Mark the true sentence/sentences.

- ○ $y = 55.225$
- ○ $y = 47$
- ○ $y = 56$
- ○ $y \geq 55$
- ○ In the last line there is at least one implicit type conversion, i.e a promotion.
- ○ The value of y is not computed because the last line needs an explicit type conversion (type casting) to work

b) If you think that the previous code will not work, write below the correct code.

c) Write a C code that only uses fixed-point arithmetic. To codify a use $\{B, F\} = \{B, 3\}$.

d) Regarding the fixed-point arithmetic code, mark the true sentence/sentences.

- ○ $y = 55$
- ○ $y = 53$
- ○ $y = 56$
- ○ $y > 52$
- ○ None of the previous answers is true

e) Justify the previous answer.

Question 3 [3 points]. *FPGA and VHDL: synchronizing clock enable with data*

A signal called `clk_en_in` is high the first rising edge of `clk` after `data_in` is ready and is low the next rising edge. We want to design an entity in order to update `data_out` from `data_in` every two `clk_en_in` in the following way; if `data_in` (coded as unsigned) is lower than 8 then `data_out` is equal to `data_in`, otherwise all bits of from `data_out` take the value one. In addition, a signal called `clk_en_out` must be high the first rising edge of `clk` after `data_out` is ready and must be low the next rising edge.

The following `VHDL` code tries to do that.

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity se_exam_2023 is
  port (clk, clk_en_in : in std_logic;
        data_in : in std_logic_vector(3 downto 0);
        clk_en_out : out std_logic;
        data_out : out std_logic_vector(3 downto 0));
end entity;

architecture arch_1 of se_exam_2023 is
  signal n : unsigned(1 downto 0):= to_unsigned(0,2);
begin
  process(clk)
  begin
    if rising_edge(clk) then
      if clk_en_in = '1' then
        clk_en_out <= '0';
        if n = 2 then
          if unsigned(data_in) < 8 then
            clk_en_out <= '1';
            data_out <= data_in;
            n <= to_unsigned(0,n'length);
          else
            data_out <= (others => '1');
          end if;
        end if;
        n <= n+1;
      end if;
    end if;
  end process;
end architecture;
```

a) Unfortunately, `clk_en_out` is not well generated. Draw the actual digital waveform (`clk`, `clk_en_in` and `clk_en_out`). Consider that there is one `clk_en_in` for every three `clk`, and that `data_in` is "0000".

b) Modify the code. Make the modifications next to the code of this page.

c) Draw the correct digital waveform.

Question 4 [2 points]. *Qualifiers and fixed-width integer types in C*

The next code, $code_1$, belongs to one of your classmates who is taking the *PBN* subject. The code is used in one of the modules of the course project.

```
#include ...
#define ...

typedef enum { ABoff, Aclear, Bclear, AtoB, BtoA } state_t;
static volatile uint8_t ticks;
static volatile state_t state;
static semaph_t semaphA, semaphB;

ISR(TIMER1_COMPA_vect) {
    ticks++;
    if (ticks == 20) {
      if (state == AtoB) state = Bclear;
        if (state == BtoA) ...
    } else if (ticks == 80) {
        if (state == Aclear) ...
    } else if (ticks == 100) {
    ...
}

void control_init(void) {
  ticks = 0;
  state = ABoff;
  ...
}

void control_force(street_t t) {
  if (state == ABoff){
    state = ...
    ticks = ...
    ...
}
...
```

This other code, $code_2$, belongs to another of your classmates.

```
#include ...
#define ...

static int ticks = 0;
static enum {Aclear, AtoB, Bclear, BtoA, ABoff} state;
static semaph_t SemA;
static semaph_t SemB;
```

```
ISR(TIMER1_COMPA_vect){
  --ticks;
  if(ticks == 0){
    if(state == Aclear){
      ...
      ticks = ...
      state = ...
    }
    else if ...
}

void control_init(void){
  ticks = 0;
  state = ABoff;
  ...
}

void control_force(street_t t){
  if(state != ABoff){
    ...
      if(state == Bclear){
        ticks = ...
        state = ...
        ...
}
...
```

First, focus on the variable *ticks*.

a) Comment on the validity of this sentence: *the variable ticks should be uint*8*_t and not int*. Ignore this difference in all the remaining questions.

Next, focus on the definition of the variables *ticks* and *state* and answer the following questions:

a) Mark the true sentence/sentences:

- ◯ If both codes prove to work as expected then both definitions are correct
- ◯ None of the codes will work because the definitions are not correct
- ◯ One of the codes will work and the other will not work
- ◯ One code will work and the other cannot be said
- ◯ None of the previous sentences is true

b) Justify your previous answer.

c) Mark the FALSE sentence/sentences:

- ◯ The definitions in one code are fine and the definitions in the other code are not
- ◯ The definitions in one code are fine and the definitions in the other code cannot be said
- ◯ The definitions in both codes are fine
- ◯ One or more of the previous sentences is false

d) Justify your previous answer.

Draft area