Work package nr 4/ Low level C-programming (Max 11p)

Introduction information for this course week

For this week tasks we will, for some exercises, use a specific web-based IDE environment, **Tinkercad.** TinkerCad supports designing electrical circuits from components (resistors, LED:s , keyboards) and even a CPU board (Arduino Uno). The entire design can then be tested by simulating the system's operation in an associated simulator. You can by this easily test your own software solutions for a specific hardware design. On the canvas page, there are a few videos about that.

Exerc_4_ 1 **(**Filename code.c) (2p)

Pack and unpack variables into a byte. You need to store 4 different values in a byte. The values are:

Name	Range	Bits	Info
engine_on	0..1	1	Is engine on or off . This is bit no 7 (MSB)
gear_pos	0..4	3	Which gear position do we have
key_pos	0..2	2	Which position is the key in
brake1	0..1	1	Are we breaking (provided by sensor 1)
brake2	0..1	1	Are we breaking (provided by sensor 2) = bit no 0 (LSB)

We should store them in a byte like this:

```
[engine_on]  [gear_pos]   [key_pos]     [brake1]     [brake2]
 1 bit       3 bits        2 bits      1 bit        1 bit        (LSB, Least significant bit )
```

(8 bits in total)

Write a program ***code.c*** which takes 5 arguments (more or less than 5 arguments should be treated as an error). The arguments should correspond to the values/variables above.
Example for a start of the program from command line:

```
code    1 2 2 1 1
```

The above should be treated as:

```
Name        Value
------------------------
engine_on   1           Bit no 7
gear_pos    2
key_pos     2
brake1      1
brake2      1           Bit no 0
```

The program should pack these values together in a byte (unsigned char) and print it out to the console in hexadecimal form. For this example, it should be 'AB' corresponding to bits '10101011. After printing out the code to the console, the program should exit. The program should be fail-safe, i.e. if it finds anything wrong (too many/few arguments, faulty input values) your program should print out an error message and exit.

Exerc_4_ 2 (decode.c) (2p)

Write a program ***decode.c*** that takes 1 argument (one argument, hexadecimal number) and prints out the bit positions for the engine, gear, etc. In the example of 'AB' (again, make it fail-safe). The argument should correspond to the decoded byte, e.g. as printed by `code.c`. If your program finds anything wrong (too many/few arguments, faulty input values) your program should print out an error message and exit.

The program should unpack the bytes according to the specification above. Print out the result as below:

```
Name                 Value
-----------------------------
engine_on
gear_pos
key_pos
brake1
brake2
```

For example, start program in the console window :

```
decode AB
```

and the result should be:

```
Name                 Value
-----------------------------
engine_on            1
gear_pos             2
key_pos              2
brake1               1
brake2               1
```

Exerc_4_3 (Filename exerc_4_3.c) (2p)

In this exercise, you shall design a general C-program that reads a smart keyboard including internal 8 bits registers. The keyboard is connected to the CPU and all keyboards registers can be accessed by reading or writing to the register specific address.

The program can read the value of a pressed key on the keyboard as an 8-bit value in a register with a specific address.

The value (0-15) of a pressed key is the value of bit 0 – 3 in the register. If a key is down when the register is read bit 7 (DAV in figure) is zero otherwise the bit 7 is set (1).

In figure the key with the value 6 is down for the moment.

If no key pressed when reading the register DAV bit is set (1).

	DAV				Key nr			
	0	x	x	x	0	1	1	0
Bit nr	7	6	5	4	3	2	1	0

To simulate this reading of the keyboard without any hardware for a general C-program we will use help-functions from the course folder. You can find these at the course homepage in **Files/Course week #4.**

In the file : `bit_manage_func.c` you can find the following functions**:**

`void f_delay(int tenth_sec)` : Gives a time delay for a number of tenths of a second.

`unsigned char random_inport(void)`: Generates a random value 0 – 255.

This will simulate the read value from a 8 bit inport in a system.

***`void printport(int portvalue)`* :** Prints out the binary pattern and the decimal value for a char of value 0 – 255.

In reality, the keyboard is controlled by a hardware, and to read a pressed key number you read the 8-bit value in a register at a specific address. In our case, in this exercise, we simulate this by call the function ***random_inport()****.*

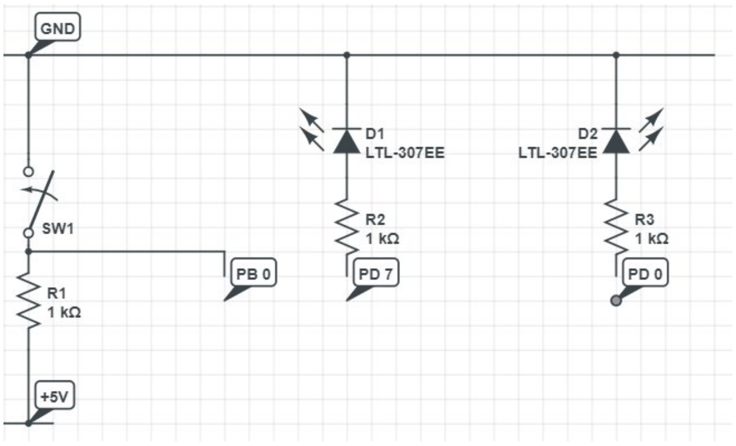
The value in the register should be interpreted as follows: If bit no 7 is zero there is a key pressed and the key nr (0 – 15) can be read as bit 0 to 3 in the value. The value on bit no 4 to 6 is of no interest and its value should not affect the program function.

Write a program that periodically (e.g. once every half second) reads the keyboard register (the random number). If a key is pressed (bit-7) read the key nr and print it out on the console in hexadecimal form 0 – 9, A- F. If no key pressed there shouldn't be any printout.

Exerc_4_4 **(** File name exerc_4_4.c**)** **(2p)**

In ThinkerCad you should draw a new circuit as the figure on next page shows. In the circuit PD0-PD7 is used as output bits and connected to the LED:s anode side via a resistor (1kOhm). Bit PB0 is used as an in-bit reading the status from one side of a DIP switch. The value to PB0 will be either 1 or 0 depending on if the DIP switch is on or not.

The circuit is designed as figure to right shows. A high (1, (5V)) value on an out-bit on PD will light up the diode.



Write a program with the function described below that uses out- and in-port as described above. The code should be written in C (even though one could use a block-diagram in TinkerCad).

The program should work as follows:

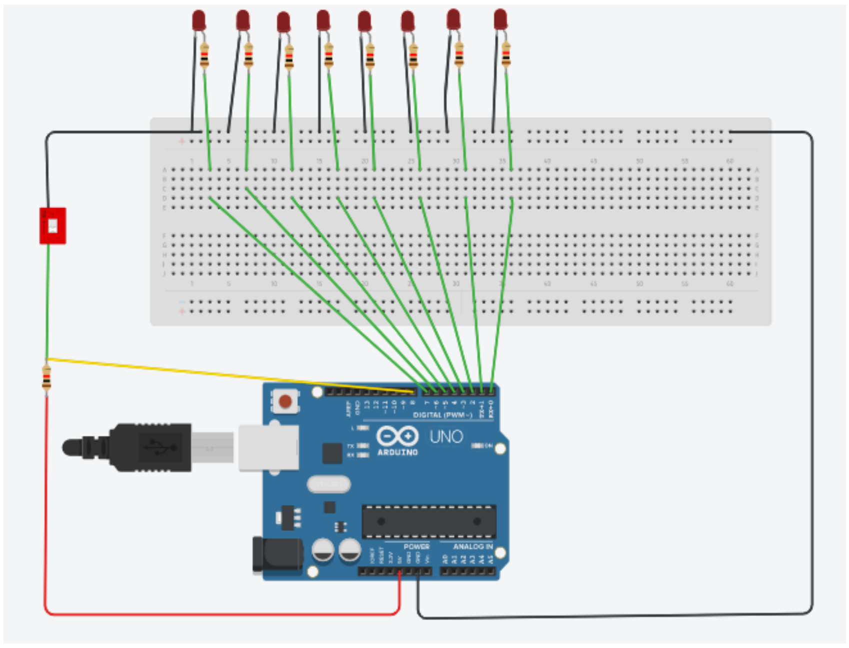
```
1.  Configure the PORTB as input port and PORTD as output port.
2.  Write 3 (binary 0000 0011) to PORTD.
3.  In an infinitive loop:
    Read bit PB0 on the IN_PORTB
     - If bit is set (1) rotate the content on OUT-port one step left. If bit 7 on PORTD is
set before the left shift bit 0 should be set after the shift (we rotate the content).
          - If bit is clear (0). Do not change the value on OUT-port.
```

For the delay use the delay function as shown in the program skeleton below.

You should use the predefined macros for reading/writing to the registers and in/out ports. You should use PORTx when writing out values and PINx for reading the same port if configured as input port. Just like we used the pins during the lecture.

You shall use the predefined structure with the two functions setup() and loop().

Run the program in the simulator to test the function.

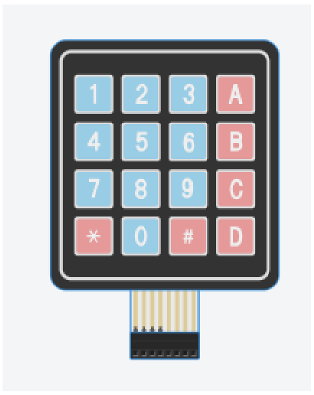


Note : If you get some problems it can help using the debugger. Before start set a break point. There is also a possible to connect a Multimeter to any part of the circuit. Depending of our use of bit PD1 and PD0 we can´t use the serial monitor for printing.

When ok you just copy the code to any editor and add necessary information in the program head, save it and hand it in as usually together with the other solutions.

```
// ---- Program template for Arduino in Tinkercad VT 2021
#include <avr/io.h>
#include <util/delay.h>

/* --- Macros predefined for the compiler
DDRB  Data direction register B
PORTB Outport B
PINB  Inport B
DDRD  Data direction register D
PORTD Outport D
PIND  Inport D
*/
unsigned char input;
void setup() {
  Serial.begin(9600); // If using the Serial monitor and in that case
needed Port D bit 1,0 to be set as out/in
  DDRD = 0xFF  To set all Port D bits as outbits.
  DDRB=  ……. (Set all to inbits)

}

void loop() {
  // ------ Main loop-------


  delay(500); // Wait for 500 millisecond(s)


}
```

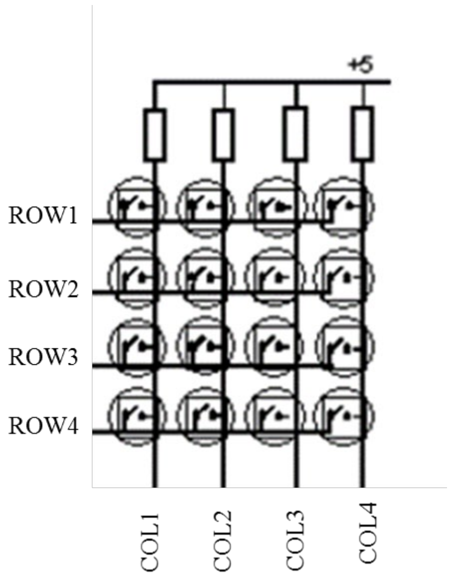
Exerc_4.5 (Filename: exerc_4_5.c): Keyboard scanning. (3p)



Some cheap keyboards are not connected to a supporting hardware with register for reading the key number. This simpler device is a bit harder to read. In TinkerCad you can connect such a simple keyboard (Figure) to Arduino Uno and then design a program that reds a pressed key number.

The principle for the keyboard and reading a key.

The keyboard is built up by four row connectors and four column connectors. At the 16 crosses between raw and column there is normally no electrical connection. At each cross there is a key and if a key is pressed there will be an electrical connection between the column and raw. (See figure below)



The rows (row 1 to row 4) is possible to connect to anything via the four left bits in the flat connector. On the four right bits the four columns are possible to connect to anything.

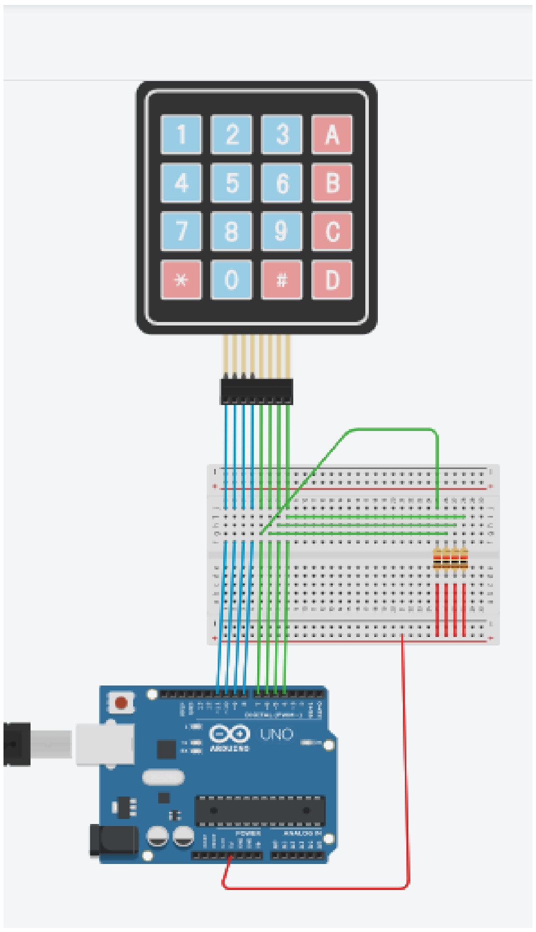
The keyboard can be connected to any of Arduino´s IO-ports. One possibility is to connect all 8 row/columns to Port D and configure the port D as 4 bit out/four bit in.

If we chose this way of connecting the keyboard it will be a bit more tricky than necessary to develop the program for reading the keyboard. This is depending of the possibility to use the same physical IO-port as IN or OUT on bit level. We will also lose the possibility to use the serial monitor for printing out some control text.

Instead we chose to connect the keyboard by connecting the rows to Arduino Port B (bit 0 – 3) and the Columns to Port D (bit 0 – 3) . By this we can use Port B as outport and Port D as inport.

To ensure the level (electric) of the columns, when no key is pressed, you normally connect them to 5V via a resistor (so called “pull up resistor”). You can see this in the figure above.

Your task:



In Tinkercad you should design a new circuit as described above and shown in the figure to right. We will later expand the circuit so it´s good to design it as the figure shows.

You should then, also in Tinkercad, develop a program reading the keyboard system above. The program should print out the key number in the serial monitor if a key is pressed. If no key is pressed there should be nothing printed out.

The program structure should be as below. You should also use the predefined macros as in earlier exercises.

You can use the function `Serial.println()` for printing on the monitor.

```
-----------------------------------------------------------------------
- configure the IO ports
- in an infinity loop
    Call a function checking if any key is pressed and if it
          should return it´s value.
    If a key was pressed print out the key value ( 0-9 ,
        A-F) on the serial monitor.
    Delay for one second.
 -----------------------------------------------------------------------
```

Demonstrate for TA and hand in the solution as for exercise 4_4 .

IMPORTANT! You are not allowed to use <keypad.h> library in this exercise!

Introduction to Arduino, ATmega microcontroller and TinkerCad

To test the solution of the exercises exerc_4.4 and 4.5 and later some more we will use a web environment Tinkercad and a hardware build around an Arduino Uno card. Before you start solving the exercises you need some information about things around the environment, hardware and how we should design the hard- and software.

Arduino CPU board

Arduino is a small computer board designed to make it easy and quickly to develop small embedded systems. The various Arduino boards are designed with different ATmega microcontrollers. Arduino

Uno, which we will use for some exercises in this course, is equipped with an ATmega 328 microcontroller.

The Arduino system also includes its own development environment (IDE) which, with help of extensive associated library functions, facilitates software development and makes it easy for a beginner to develop the software for a hardware system in the program language C supplemented by all Arduino's own library functions and without knowing much about lots of low-level details.

The Arduino IDE is a freeware and the only thing you need to bay is an Arduino CPU board (from 250 skr) and the additional electronic components you need for your specific own hardware system.

In this course we will not use the real Arduino CPU board, but we will build electronic circuits including Arduino Uno CPU board in a virtual environment supported by Tinkercad.

You may need some information of developing C-programs for an Arduino system in the following exercises. You find all this information on the Arduino homepage (https://www.arduino.cc/).

Tinkercad

In some of the exercises in WP # 4 and 5 we will use the development environment, **Tinkercad**, which makes it possible to virtually build an electronic system around an Arduino card computer and then write the software for the system. The entire design can then be tested by simulating the systems function in an associated simulator. You can easily test your own software solutions for a specific hardware design.

Tinkercad is a web-based development environment which makes it independent of the user's own computer environment. To use Tinkercad you only need to create an account on their website. You can if you want create one common account for your work group.

Link to Tinkercad: https://www.tinkercad.com/

Under the menu **Circuits** you will find the development environment that we will use in the exercises. In this IDE you can design many electric circuits with help of a selection of electronic components and an Arduino CPU board. When choosing the components, you should choose **all in menu** to find the needed components.

To design the circuits in the virtual environment you need to use a virtual **breadboard** that you also find in the component list.

If you never used a breadboard se the first 5 to 6 minutes of this video:

https://www.youtube.com/watch?v=oiqNaSPTI7w

To start develop a circuit.

Log in to your account in Tinkercad. You can study a lot of electronic circuits in the Gallery/Circuits and you can copy them to your own account to study and test.

From Tinkercad home page, chose Circuits in left menu and then Create new. In right menu Components chose view all. From the list you can chose any listed component, breadboard, Arduino CPU bord and then start connecting the components with wires. Normally it´s very easy to connect with wires but it can sometime look like a connection but it isn´t connect to each other. To test you can try to move the component and if the wire follows the component it´s ok.

Briefly about the ATmega 328 microcontroller

First some general about micro controllers. A Micro controller is a bit different designed in comparison to a more general processor. They use to have ready-made IO ports for both digital and analog signals. They also often have built-in modules for AD/DA converters, timer circuits, etc. The different IO ports have fixed addresses. IO-ports and the internal modules are easily configured by writing bit patterns in special registers. ATmega 328 has many digital 8 bits IO ports (On Arduino one 8 (PORTD) and one 6 bits digital IO PORTB) as well as many analog inputs and outputs with associated AD and DA converters, respectively.

The digital IO ports are configured for In or Out on bit level by writing 1 or 0 in the corresponding bit in a so-called **data direction register DDRD and DDRB** respectively. Writing and reading can be done if you know the address of the ports. In Arduino's IDE you can, via simple functions call or use of so-called Macron, configure the ports to the desired function and then easily read and write on the IO ports.

You can find a pin-layout picture fort the use of ATmega328 on the Arduino Uno computer board at:

https://i2.wp.com/marcusjenkins.com/wp-content/uploads/2014/06/ARDUINO_V2.png

On the course homepage in the file archive you can find some documents regarding Arduino and the ATmega microcontroller. One pdf describes the controller and it´s memory and register structure.