Knight Lights Assignment 3  
Embedded systems Practicum  
Assignment 3

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**Group 13**

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# Abstract

The design and execution of a knight lights system are described in this technical report.   
This is the third assignment of the Embedded Systems 2 practicum. The approach and conclusions are further elaborated below.

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# Introduction

This assignment is all about using registers and direct port manipulation on the Arduino Uno board. For this assignment the students are required to have one Arduino Uno board, 5 LEDs (Light Emitting Diode), 2 Push Switches and 5 resistors. To program the behavior of the board, the students will use the C programming language. Further instructions and a more in-depth description for this assignment are given in the document provided (Hilderink, Assignments, 2022).

The Procedure for building the solution for the presented problem is described in the 'Procedure' section. The designs of the context diagram, state machine and circuit diagram are shown and depicted in the 'Design' section. The closing section is the 'Conclusion' at the end of the document.

# Procedure

The Knight lights assignment was an assignment given by (Hilderink, Assignments, 2022). The needed hardware was given in the document. the students first designed the system with a context diagram to get a nice overview on how the system should work. Then they designed multiple state machines, one for the first part and one for the second part. Lastly, the students created a circuit diagram.

The code written on the Arduino board has the job to run 3 different tasks at the same time (synchronous) without blocking them. At first, the students started designing the context diagram (see [Figure 5](#Figure4_circuit_diagram)). The students did this so they could get a good general overview of the system. Then the students started designing the state machine diagrams, so the students could get a good understanding of how the different systems are triggered and executed (see [Figure 1](#Figure1_default_behaviour), [Figure 2](#Figure2_sweep_a) and [Figure 3](#Figure3_sweep_b)). It took multiple iterations to make sure the system was robust. Then the students designed the circuit diagram to make no mistakes during the building process (see [Figure 4](#Figure4_circuit_diagram)).

After determining how to build the system the students first must make sure the system is safe. They did this by using Ohm’s law and calculating the power in Watts while using the (Semiconductors, 2009) datasheet.   
First the forward current must be calculated it by using the datasheet:

* Ur = 5 – 2,1 = 2,9V

With the forward current and the Amps from the datasheet Ohm’s law could be used to determine the minimal resistance needed:

* R = 2,9 / (30 / 1000) = 96,7 Ω

To know the circuit is safe for sure the power in Watts must be calculated. It can be calculated by using the forward current and Amps:

* P = 2,9 x 0,03 = 0,087 W

0,087 W < 0,250 W, so the circuit is safe. After verifying the circuit is safe it is time to build the system. The Volts and Amps must be measured. With these measurements it can be verified the safety of the system. However, the document expects 470 Ω resistors to be used.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **V** | **mA** | **R** | **P** |
| **LED1** | 1,967 | 9,33 | 1,967 / 0,00933 = 210 Ω | 1,967 x 0,00933 = 0,0184 W |
| **LED2** | 1,972 | 8,97 | 1,972 / 0,00897 = 219 Ω | 1,972 x 0,00897 = 0,0177 W |
| **LED3** | 2,008 | 8,7 | 2,008 / 0,0087 = 230 Ω | 2,008 x 0,0087 = 0,0174 W |
| **LED4** | 1,983 | 8,95 | 1,983 / 0,00895 = 222 Ω | 1,983 x 0,00895 = 0,0177 W |
| **LED5** | 2,005 | 9,11 | 2,005 / 0,00911 = 220 Ω | 2,005 x 0,00911 = 0,0182 W |

And with the accurate values it is confirmed that the circuit is safe as seen in the power column.

Now that 100% of our circuit is safe and reliable, the code is ready to be written. While coding the contracts of the state machine must be kept in mind to ensure user safety.

The development of the code is a bit tricky because both speed and size of the program must be optimized. Furthermore, there are some difficulties with SWEEP B as it is more complex. To do so a reduced amount of “if” statements is present to maintain readability and program speed. All systems are working as described in the assignment document (Hilderink, Assignments, 2022).

# Design

## State machines design

The final design of the state machines is given in figure 1, figure 2 and figure 3. The design of the main flow figure 1 is the start point of all functions(subsystems). If Button A is pressed, the system goes into SWEEP B mode, else it is in SWEEP A while still blinking the LED on pin 8 and reading BUTTON A to toggle the BUILT\_IN LED.

Diagram

Description automatically generated

Figure 1: State machine

The design of figure 2 depicts the flow for SWEEP A. In this mode the lights are changing in the sequence described in the diagram. If Button B is pressed, then this is the end of SWEEP A and the beginning of SWEEP B. The system can be in either SWEEP A or SWEEP B but not both. When Button B is released, the program is sent back to SWEEP A.

Diagram

Description automatically generated

Figure 2: Pseudo of SWEEP A

The design in figure 3 depicts the behaviour of SWEEP B. When Button B is pressed, this is the initiation of SWEEP B and when Button B is released, that’s the end of SWEEP B and the program returns to SWEEP A.

Diagram

Description automatically generated

Figure 3: Pseudo of SWEEP B

## Circuit diagram

The circuit diagram gives a nice overview of how the components should be connected to the two Arduino’s. With this diagram the students already know how the system will look like before even building it. It is also good to have names of the components to refer to them in the measurements table for example.

Diagram, schematic

Description automatically generated

Figure 4: Circuit diagram of knight lights system

## Context Diagram

The context diagram is the starting point of this assignment. While creating the diagram the students must start brainstorming about how the system should look like and what are the key elements of the knight lights system.

Diagram

Description automatically generated

Figure 5: Context diagram of knight lights system

# Conclusion

The collection of diagrams gave a clear view on how the systems should work independently of one another. This made the building process a lot easier.

The creation of the state machines takes a long time with multiple iterations to ensure bottlenecks could not occur. The context diagram on the other hand was simple since there was not that much to say about it.

Before building is was ensured that the circuit was safe and after building the students could also verify it, both with some simple calculations using Ohm’s law and by calculating the power.

Coding with keeping the diagrams in mind is smoother and less error-prone than just starting and changing the code later. After finishing the code and perfecting the communication the system was working as described.

# References

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