

Table of Contents

1. Introduction

- 1.1 General 1
- 1.2 Microprocessors and Microcontrollers 2
- 1.3 Microcontroller structural components 7
- 1.4 Microcontroller applications 9
- 1.5 Popular microcontrollers 13
- Exercise Sheets 13

2. General Features of the AVR Microcontrollers

- 2.1 Introduction 17
- 2.2 Architecture 18
- Exercise Sheets 27

3. The basic Assembly instruction set of the microcontroller

- 3.1 Introduction 35
- 3.2 Loading instructions 36
- 3.3 Arithmetic instructions 53
- 3.4 Logical instructions 65
- 3.5 More arithmetic and other instructions 69
- 3.6 Bit manipulation 77
- 3.7 Developing complete and functional programs 86
 - 3.7.1 Embedding INC files 86
 - 3.7.2 The basic Assembler directives 87
- Exercise Sheets 89

4. Implementing basic programming structures

- 4.1 Introduction 101
- 4.2 Comparison and branch instructions 101
 - 4.2.1 Basic programming structures 101
 - 4.2.2 Implementing single control flow structures (selection) 103
- 4.3 Iteration structures 112
 - 4.3.1 Iteration structure do-while 112
 - 4.3.2 Iteration structure while-do 114
 - 4.3.3 Nested loop (iteration structure) 115
 - 4.3.4 Implementing a loop without comparison 118
 - 4.3.5 Defining the iterations number beyond the register limit 119
- 4.4 Absolute and relative jump 121
- 4.5 The stack 124
- 4.6 Time features of code execution and delay programs 128
- 4.7 Macroinstructions 132
- 4.8 Program coding in memory 135
- Exercise Sheets 137

5. Basic Programming of the Input/Output (I/O) Ports

- 5.1 Introduction **145**
- 5.2 Elementary electrical-electronic circuits **145**
 - 5.2.1 Circuit with resistor **145**
 - 5.2.2 Circuit with diode **147**
 - 5.2.3 The LED diode **148**
- 5.3 Basic manipulation of digital ports **150**
- 5.4 LED manipulation through microcontroller ports **157**
- 5.5 General purpose switch circuits **158**
 - 5.5.1 Operation methods **158**
 - 5.5.2 Simplified switch circuit **159**
- 5.6 Implementing a time delay **159**
 - Application 5.1 – Activating eight LEDs **161**
 - Application 5.2 – 8 LED activation and deactivation with time delay **161**
 - Application 5.3 – Successive LED activation with logical shift **163**
 - Application 5.4 – Traffic light control **165**
 - Application 5.5 – Controlling a LED with a button **169**
 - Application 5.6 – Button circuit simplification using the internal Pull-Up resistor **172**
 - Application 5.7 – Direct LED control using buttons **173**
- LABORATORY EXERCISE 1 - Basic electrical circuits **176**
- LABORATORY EXERCISE 2 - Time Delay **182**
- LABORATORY EXERCISE 3 - Switch circuits **184**

6. Display units manipulation

- 6.1 Seven segment display manipulation **187**
 - Application 6.1 – Testing the SSD unit operation **189**
 - Application 6.2 – Displaying the numbers 0 to 9 **192**
 - Application 6.3 – Controlling the SSD unit by using multiplexing **194**
 - Application 6.4 – Display four digits on multiple SSD units **197**
 - Application 6.5 – Automated three digit number display **201**
- 6.2 LCD screen **214**
 - Application 6.6 – Using the LCD screen (16x2) **217**
- LABORATORY EXERCISE 4 - Seven Segment Display (SSD) units **228**
- LABORATORY EXERCISE 5 - Using an LCD 16x2 screen (1602) **231**

7. Switch circuits for user input

- 7.1 Introduction **233**
- 7.2 The keyboard layout **233**
 - Application 7.1 – Developing a keyboard for displaying the digits 0 to 7 on SSD units **236**
 - Application 7.2 – Displaying the digits 0 to F on SSD units using the keyboard **247**
- LABORATORY EXERCISE 6 - Keyboard development **255**

Appendix A - Simulating assembly source code in Atmel Studio 7	257
Appendix B – Instruction summary	265