Contents

Introduction **7**

1 Exercise L1: PC sequential control **9**
1.1 Introduction . . . 9
1.1.1 State machines . . . 11
1.1.2 Moore machine . . . 12
1.1.3 Mealy machine . . . 12
1.2 Example: Cipher lock . . . 13
1.2.1 Moore machine for a cipher lock . . . 14
1.2.2 Edge detection . . . 15
1.2.3 Time delays . . . 16
1.2.4 Timer TON . . . 16
1.2.5 Mealy machine for the cipher lock after corrections . . . 17
1.3 Visual Studio 2019 . . . 19
1.3.1 Main view . . . 19
1.3.2 Running and debugging a program . . . 19
1.4 Program implementation . . . 21
1.4.1 Moore machine in C++ . . . 21
1.4.2 Mealy machine in C++ . . . 26
1.4.3 Communication with processes . . . 26
1.4.4 Connection with processes . . . 28
1.5 Implementation of the exercise . . . 30

2 Exercise L2: PLC sequential control **31**
2.1 Introduction . . . 31
2.2 PLC programming languages . . . 32
2.3 Example ST Language program: cipher lock . . . 35
2.4 Description of GX Works3 software . . . 39
2.4.1 Creating a new project . . . 39
2.4.2 Types of available programs . . . 41
2.4.3 Variables and labels . . . 43
2.4.4 Code compilation . . . 45
2.4.5 Diagnostics, monitoring of program operation . . . 46
2.5 Implementation of the exercise . . . 48

3 Exercise L3: HMI and SCADA systems **49**
3.1 Introduction . . . 49
3.2 Description of the control system . . . 51
3.3 Implementation of SCADA MAPS visualization . . . 52

3.3.1 Starting SCADA MAPS . . . 52
3.3.2 Agents . . . 53
3.3.3 Behaviors . . . 60
3.3.4 Configuration of spiders . . . 63
3.4 Implementation of the exercise . . . 68

4 Exercise L4: PID control 70
4.1 Introduction . . . 70
4.2 PID controller tuning with SCADA MAPS . . . 81
4.3 Implementation of the exercise . . . 84

5 Exercise L5: Servomechanism 86
5.1 Introduction . . . 86
5.1.1 Structure of the servomechanism . . . 88
5.1.2 The structure of the frequency inverter . . . 93
5.1.3 Safety in working with a laboratory stand . . . 97
5.2 Control of the frequency inverter . . . 99
5.2.1 Task: Setting the inverter parameters . . . 99
5.2.2 Task: Open loop scalar control – Speed setting with analog signal . 99
5.2.3 Task: Closed loop scalar control – position setting . . . 103
5.2.4 Task: Scalar control – execution of homing . . . 106
5.3 MR Configurator2: Basic servo configuration . . . 107
5.3.1 Basic amplifier parameters . . . 110
5.3.2 Basic amplifier diagnostics . . . 112
5.4 MR Configurator2: Basic tuning of the servo motor . . . 112
5.4.1 Basic tuning of the servo motor: parameter preparation . . . 112
5.4.2 Task: Tuning the dynamic response of the servo system . . . 118
5.5 Motion Control: Analog and Digital Interface . . . 130
5.5.1 Task: Control in speed mode . . . 131
5.5.2 Task: Position control mode . . . 139
5.6 Motion Control: Ethernet interface . . . 148
5.6.1 Task: Ethernet interface – amplifier parameterisation . . . 148
5.6.2 Task: Ethernet interface – PLC configuration . . . 149
5.6.3 Task: Ethernet interface – communication with servo . . . 154
5.6.4 Task: Ethernet interface – servo homing . . . 156
5.6.5 Task: Ethernet interface – speed control . . . 156
5.6.6 Task: Ethernet interface – position control . . . 158
5.7 Task: Synchronised knife application . . . 158
5.8 Implementation of the exercise . . . 161

6 Laboratory workstations and processes 162
6.1 Workstation without a motor . . . 162
6.2 Workstation with a motor . . . 164
6.3 Sorting line . . . 166
6.4 Assembly line . . . 168
6.5 Production line . . . 170
6.6 Gripper arm . . . 172
6.7 Punching machine . . . 174