Czech Technical University in Prague

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Department of Control Engineering

Control of Model of Positioning Device

Bachelor Thesis

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Fundamentals for elaboration:

1. Familiarize with programmable controller ControlLogix by Rockwell Automation.
2. Make a simple model of position device for this controller.
3. Prepare typical tasks of control with this model including visualization by means of RSView 32.
4. Specification of tasks and description of model place on the web of Allen-Bradley Laboratory.

List of special literature: supply head of thesis

Head of bachelor thesis: Ing. Jindřich Fuka

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Abstract

This bachelor thesis was made mainly for education purposes, so that students interested in control using Allen-Bradley programmable controllers can acquaint with the latest so called PACs (Programmable Automation Controllers). Allen-Bradley is a trade mark of Rockwell Automation. Used hardware and software are described in the first chapter. In the second chapter the characteristics of the model of positioning device are depicted. This device was designed and made to be controlled with ControlLogix. The third chapter is dedicated to the explanation of a visualization developed in RSView 32. The models of positioning device are placed in the Allen-Bradley Laboratory at the Department of Control Engineering of the Czech Technical University in Prague.

Declaration

I declare that I made my bachelor thesis by myself. I used only details (literature, projects, SW etc.) which are mentioned on the list of used literature.

Prague …………………. ……………………………….

Signature

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Introduction

Day by day the necessities of human beings are changing and as our thoughts evolve, these necessities force us to think in a better and more efficient ways to satisfy them. As the technology continues to advance in leaps, the impossible is becoming possible, and it also becomes easer to make things that were complicated and inaccessible before into areas where men did not dear to imagine.

Through the years men look for comfort and a good way to obtain it so as to make easier the work for us. Automation is the part of the science that deals with Automatic Control to make lives easier for millions of people around the world. Temperature, Speed, Pressure, Movement and Position; are some of the factors that can be controlled by means of the automatic controllers.

Positioning control for example, is of great importance to us and we can find it in endless number of systems. For this type of control the use of so called PLCs (Programming Logical Controllers) is possible, or still better and more sophisticated PACs (Programming Automation Controllers) can be used as well.

The main purpose of this thesis is to familiarize students with programmable automation controllers from Rockwell Automation (trade mark Allen-Bradley), and make it easier for them to control a device with the appropriated characteristics for beginners as well as for advanced users which are able to work with more advanced methods of control. In this thesis it will be explained what a PAC is, what kind of hardware it is made of, what kind of software we can use with it and how to use this software to control a model of positioning device. For education purposes I made three models of positioning device that are described in this thesis too. There is also a chapter dedicated to a visualization that was made for controlling this model from the computer.

1. Programmable Automation Controllers (PAC)

In this chapter it will be explained what a PAC is, and what are the differences between PACs and PLCs. For that aim information and definitions from different Internet sources are used [1].

A Programmable Automation Controller (PAC) is a compact controller that combines the features and capabilities of a PC-based control system with that of a typical Programmable Logic Controller (PLC). PACs are most often used in industrial settings for process control, data acquisition, remote equipment monitoring, machine vision, and motion control. Additionally, because they function and communicate over popular network interface protocols like TCP/IP, OLE for process control (OPC) and SMTP, PACs are able to transfer data from the machines they control to other machines and components in a networked control system or to application software and databases.

The ARC Advisory Group, an analyst group focused on the manufacturing industry, is generally credited for originating the term "PAC". It was first coined in 2001 as a way to help users of control hardware better define their needs, and to give the leading control hardware vendors a term to more clearly communicate the capabilities of their products.

PAC - PLC Comparison

Generally, PACs and PLCs serve for the same purpose. Both are primarily used to perform automation, process control, and data acquisition functions such as digital and analog control, serial string handling, PID, motion control, and machine vision.

Unlike PLCs, PACs offer open, modular architectures, the rationale being that because most industrial applications are customized, the control hardware used for them needs to allow engineers to pick and choose the other components in the control system architecture without having to worry whether or not they will be compatible with the controller.

PACs and PLCs are also programmed differently. PLCs are often programmed in ladder logic, a graphical programming language resembling the rails and rungs of ladders that is designed to emulate old electrical relay wiring diagrams. PAC control programs are usually developed with more generic software tools that permit the designed program to be shared across several different machines, processors, HMI terminals or other components in the control system architecture. Of course ladder logic is used in PACs.

PAC processing and I/O scanning is also very different. Unlike PLCs, which constantly scan all the I/O inputs in the control system at very high rates of speed, PACs utilize a single tagname database and a logical address system to identify and map I/O points as needed.

Well known control hardware vendors offering PACs include General Electric, National Instruments, Opto 22, ICP DAS, and Rockwell Automation.

1.1. Network Devices (Data Buses)

In Programmable Automation Controllers there are used different data busses to communicate between them and with other instruments, for example computers. Each one serves to different purpose. As it was said before, in this thesis it will be important Data Busses used by Allen-Bradley PACs. The most important Allen-Bradley Data Busses are Ethernet/IP, ControlNet and DeviceNet.

1.1.1. Ethernet/IP

Ethernet/IP (Ethernet Industrial Protocol) is an open industrial networking standard that supports both real-time I/O messaging and message exchange. The name comes from the physical concept of ether. It defines a number of wiring and signaling standards for the physical layer, two means of network access at the Media Access Control (MAC)/data link layer, and a common addressing format.

Ethernet has been standardized as IEEEs 802.3. Its star-topology, twisted-pair wiring form became the most widespread LAN technology in use from the 1990s to the present, largely replacing competing LAN standards such as Coaxial-cable Ethernet, Token Ring, FDDI, and ARCNET. The primary competitor to Ethernet in the Local Area Network market of the present is WiFi, the wireless LAN standardized by IEEE 802.11.

Ethernet/IP represents migration of the upper level CIP (Common Industrial Protocol) common to the ControlNet and DeviceNet networks onto the Ethernet physical media. As a media independent protocol, CIP is capable of migrating to further media such as FireWire or wireless networks. While Ethernet/IP is positioned as a supervisory interface to handle information from plant floor to higher level systems, the protocol will accommodate real time control messages along with non time critical data transfers. Rockwell's introduction of I/O level products such as Flex I/O and MicroLogix controllers emphasizes the real-time capability. The high bandwidth property also lends itself to incorporation of sensors with high data content. Cognex, for example offers a family of Ethernet/IP compatible networked vision sensors.

While Ethernet/IP can accommodate both real-time and non time-critical messages through its encapsulation of both the UDP and TCP protocols, critics contend that this approach creates significant protocol overhead. The Ethernet/IP SIG (Special Interest Group) within ODVA, or the Open DeviceNet Vendor Association, is the keeper of Ethernet/IP-specific objects and device profiles beyond the basic CIP specification. (This information is based on Internet sources) [2].

1.1.2. ControlNet

ControlNet is a real-time control network that provides high-speed transport of both time-critical I/O and interlocking data and messaging data, including upload/download of programming and configuration data on a single physical media link. The ControlNet network’s highly efficient data transfer capability significantly enhances I/O performance and peer-to-peer communication in any system or application where it is used.

ControlNet is highly deterministic and repeatable, and remains unaffected as devices are connected or disconnected from the network. This ensures dependable, synchronized, and coordinated real-time performance [3].

The ControlNet network is most often used in these types of configurations as a:

- default network for the ControlLogix platform
- substitute/replacement for the Universal remote I/O (RIO) network, because ControlNet handles large numbers of I/O points
- backbone to multiple distributed DeviceNet networks
- peer communication network
- high-speed I/O network

1.1.3. DeviceNet

The DeviceNet network is an open device level network that provides connections between simple industrial devices (such as sensors and actuators) and higher-level devices (such as programmable controllers and computers). Uses the proven Common Industrial Protocol (CIP) to provide the control, configure, and data collection capabilities for industrial devices. DeviceNet is a flexible network that works with devices from multiple producers [3].

Some of the DeviceNet features are:

- Cost-effective networking solution to simple devices
- Easily access data in intelligent sensors/actuators from multiple third party vendors
- Provides master/slave, Change-of-State, and peer-to-peer capabilities
- Producer/Consumer services let you configure devices, control, and collect information over a single network

- Improves system integration for both safety and standard applications
- Reduces downtime with early detection of system performance problems
- Reduces maintenance costs with diagnostics and automatic device replacement

1.2. ControlLogix System

Recently, coordinated drive control, motion control, process control and sequential control have been each accomplished using disparate hardware and software products. The ControlLogix architecture, on the other hand, paves the road toward integration of these control disciplines in a seamless manner that gives the control designer a common software tool set and a common hardware platform [4].

As part of the Rockwell Automation Integrated Architecture, Logix platforms provide single control architecture for discrete, drives, motion and process control systems. Whether is needed a high-performance control system or a small, value-based control system, these platforms provide the right control system for all applications.

The ControlLogix controllers support intensive process applications and provide fast processing of sequential, motion, process, and drives applications. Multiple controllers, communication modules and I/O can be mixed without restriction. No processor is needed to perform bridging and routing of I/O and, as the system grows, the network permits distributing control to additional chassis [3].

1.2.1. Hardware

ControlLogix System is made up of a main chassis and separated modules. In this chapter will be named and described used modules, for that reason definitions and information from different internet sources will be used [4].

1.2.1.1. Producer/Consumer Model

One of the key features of the ControlLogix system is that communications functions are designed into every layer of the system starting with the backplane and on through to the I/O modules, the processors and, of course, the communications modules themselves. The ControlLogix backplane is a first cousin to the ControlNet network and utilizes the same Producer/Consumer Model that ControlNet does. Producer/Consumer is the name we give to a communication model whereby network nodes or modules on the chassis, each produce data. Other nodes or modules can then consume that data on an as-needed basis without having to make discreet requests. This is vastly different from other models where, for example, a master must manage the communications task by asking each node or module if it has a message to send and arranging the transaction.

For processors, the use of the producer/consumer paradigm allows for the installation of multiple processors in the same chassis. In this way, the backplane itself acts as a high-speed network, which provides communications capabilities between all the modules on the backplane - as well as those that are extended out to other chassis' on ControlNet. For this reason, the capabilities, of the ControlLogix system are also extended well beyond those of the traditional programmable controller. Gateway functionality is a product of this communications architecture. Before the Logix5562 controller was released, the Ethernet, ControlNet and Data Highway Plus (DH+) modules, (along with chassis and power supplies,) were released to form the ControlLogix Gateway product.

The ControlLogix Gateway allows bridging and routing of messages between the various networks without the need for a PLC or other controller to be present in the system. This communications capability is possible because of the backplane's new model of acting as a network itself. Messages can now be routed from one 'link' to another (and in this model the backplane is another 'link' in the path) because of this very flexible and powerful communications model.

Multiprocessor support is also a spin off from the Producer/Consumer Model. Multiprocessing is supported in the chassis for any number of slot locations and for any combination of slots. Since the backplane acts like a high-speed network, each processor is like a node on that network; therefore, any number of processors can communicate to any other, regardless of the slot location of those processors. In this manner, a PLC and DCS processor for instance can co-exist in the same backplane or network, share the field I/0 and exchange data between each other.
A software configuration tool, RSNetworx is used to assign processor ownership output to devices. A given processor operates on the premise that it seamlessly owns all input devices and user designated output devices on the network. Finally, with the Producer-Consumer backplane, many of the boundaries and limitations inherent to older technologies disappear. Since each processor now acts like a node on a high-speed network, there is no single master or bus arbitrator for all communications and control on the backplane. For this reason, any failure of a single processor does not necessarily commit the control system to shutdown. If a given processor is not controlling a mission critical function, the rest of the control may indeed stay running while the processor in question is removed and replaced under Power.

1.2.1.2. Memory

Controller memory is another area where the ControlLogix system offers considerable flexibility, utilizing technologies that outpace other controllers in its class. In adding memory to the Logix5562 controller, there are no fixed areas of memory allocated for specific types of data or for I/O. There is no artificial limit on the number of timers, counters or instructions. Memory is contiguous within any given controller and is utilized 'from top to bottom' as the user develops the application. In the ControlLogix chassis, memory is added specifically to each Logix5562 controller and tags are passed between processors like I/O within the system. This allocation of memory on a processor-by-processor basis is one of the reasons why processors can 'live' in any slot location in a chassis and with any number of processors in a dual chassis.

1.2.1.3. I/O Points

As stated earlier, the ControlLogix system does not impose artificial boundaries on the number of I/O points that a control system can have. When I/O points are configured or when application code is created, memory is used contiguously. Therefore one of the limiting elements for the number of I/O points in the system is, of course, memory. If more memory is needed, the user can add more memory via a memory expansion card or add another processor to the chassis to increase the total number of I/O points in the system. A second factor that may bind the total number of I/O points for a given processor involves the concept of connections. The ControlLogix system uses a connection to establish a communication link between two devices. These devices may be controllers, communication modules, I/O modules, produced and consumed tags or messages.

Connections are quite different from individual I/O points. Each Logix5562 controller, for example, is capable of making 250 connections. In one configuration, a single connection may be made to an entire chassis. Considering the fact that 17 slot chassis are available, and assuming 32 point modules in our calculations, a single processor may actually support up to 128 000 digital I/O points; 4000 analog I/O points can be supported using similar calculations for analog I/O. Although these numbers we large in themselves they double as a second processor is added to a rack - and they triple with the third, etc. Although these numbers may seem extreme when viewed in this manner, the point remains that the ControlLogix architecture does not impose an artificial limit on the total number of I/O points that can be supported for any given application.

1.2.1.4. Used Modules

Let’s see typical configuration of input and output modules in our control application.

Figure 1-1: Used ControlLogix 5562 Modules

Module 1756-IB16ISOE/A (Digital Input)

This is a module with 16 digital inputs and 16 GNDs connected together and to -12 V of DC source in our case. Maximum input voltage is 31.2 V. Logical 0 is defined from 0 to 5 V and logical 1 is defined from 10 to 31.2 V.

Module 1756-OB16IS/A (Digital Output)

The 1756-OB16IS is a 16 point, 10-30 V, sink/source DC output module. It is identical to the 1756-OB16I module except when used with the Motion Arm Output Cam (MAOC) instruction. When used with an MAOC instruction, it provides very accurate and consistent latch and unlatch output events for the first 8 outputs.

Module 1756-IF4FXOF2F/A (Analogue I/O)

This is a fast analogue module with 4 high-speed, sub-millisecond, differential inputs and 2 high-speed voltage or current outputs, it supports ±10 V of input voltage, on-board data alarming, scaling to engineering units and real-time channel sampling.

Module 1756-CNB/D

This ControlNet network module is an open, state-of-the-art control network that meets the demands of real-time, high-throughput applications. The ControlNet network uses the proven Common Industrial Protocol (CIP) to combine the functionality of an I/O network and a peer-to-peer network providing high-speed performance for both functions.
It gives repeatable transfers of all mission critical control data in addition to supporting transfers of non-time-critical data. I/O updates and controller-to-controller interlocking always take precedence over program uploads and downloads and messaging. It supports from 40 to 48 connections in any combination of scheduled and unscheduled. This Module is not used, but I would be used as well.

Module 1756-ENBT/A

The 1756-ENBT/A ControlLogix EtherNet/IP Module is an enhanced version of the 1756-ENET/A ControlLogix EtherNet/IP Module. This new version of the module communicates at faster rate than its predecessor (10/100 Mbps full duplex vs. 10 Mbps half-duplex) and includes more on-board memory. These enhancements better enable you to transfer large amounts of informational messaging and time-critical I/O and control data simultaneously over a single EtherNet/IP network.

The module displays five-character diagnostic indicators that help to troubleshoot problems much more easily than with simple LED lights – saving time and minimizing any guesswork.

1.2.2. Software

ControlLogix controllers are compatible and can be used with different software, depending on user’s needs. Internet sources [3] and [5] are again used in this chapter.

1.2.2.1. RSLinx

RSLinx is windows based communication software package developed by Rockwell Software to interface to all of the Rockwell and A-B industrial control and automation hardware. RSLinx comes in a variety of different flavors including

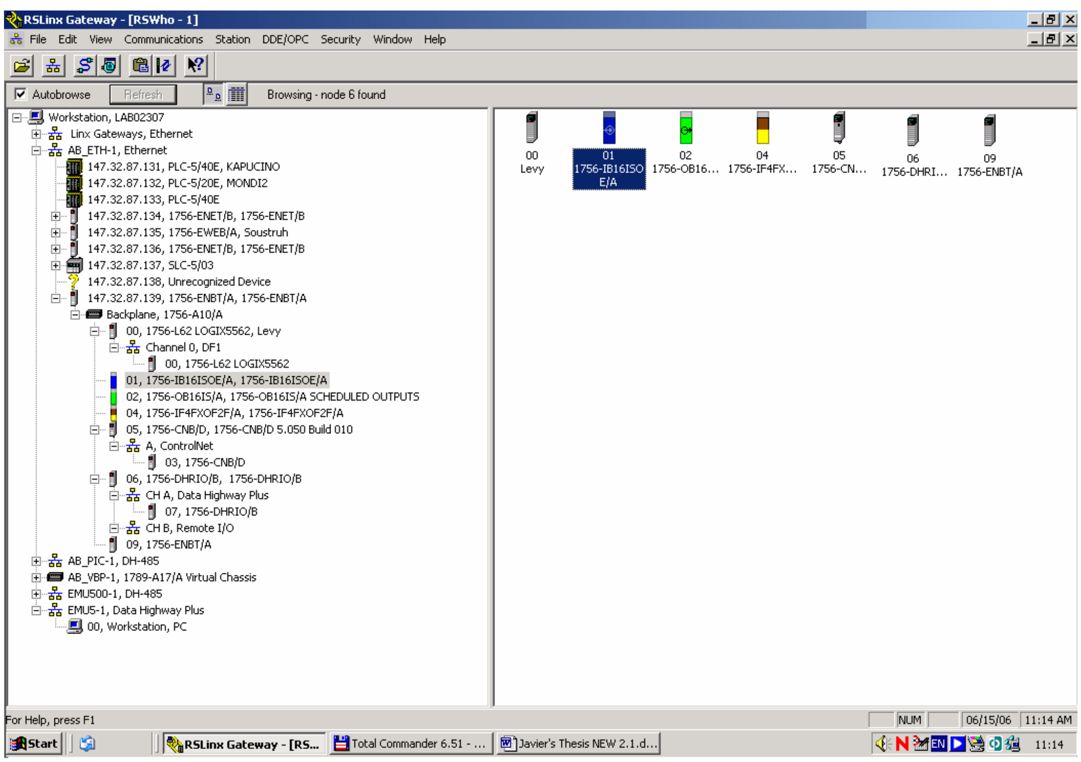

Figure 1-2: RSLinx Configuration

- RSLinx-Lite – PLC Programming software communication interface.
- RSLinx-OEM – Provides DDE capability for Rockwell DDE capable software.

- RSLinx Professional – Provides DDE capability to and DDE capable software.
- RSLinx-Gateway – Communication network bridging, routing, and OPC server.
- RSLinx SDK – Software Development Kit includes the OEM version.

In actuality, all of the RSLinx software packages are the same. What differentiates the software packages from one other is the copy protection software key for RSLinx. If you run RSLinx without a software key the software operates in the lite mode. If you have a key the software operates in the mode that the software key authorizes it to run in.

RSLinx is the intermediary between the communication hardware and the software package that needs data from the communication hardware.

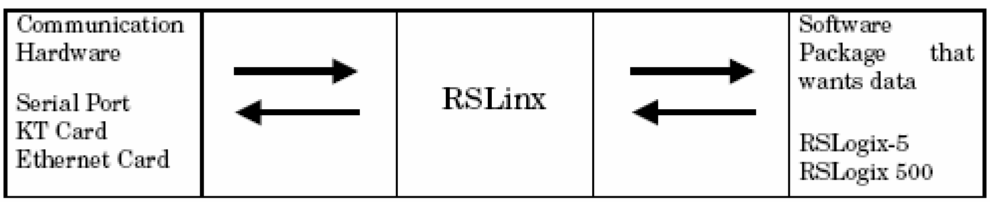

Figure 1-3: RSLinx2 structure

For RSLinx to function it must be configured to use the communication hardware interface of your choice. Choosing the correct communication hardware interface requires a thorough understanding of the device that is to be communicated with. In the case of communicating with a PLC it is important to understand the communication capability of the specific PLC that is being used. Different types, models and revisions of PLCs have different communication capabilities.

For our application we use Ethernet communication. We had to configure Ethernet devices driver {AB_ETH-1, Ethernet} and our communication module has an IP address 147.32.87.139 (Figure 1-2). We can see all modules on local ControlBus network.

1.2.2.2. RSView 32

RSView 32 is software use for monitoring and controlling automation machines and processes. It provides unprecedented connectivity to other Rockwell Software products, Microsoft products, and third-party applications. RSView 32 can be a client/server application that extends the view of data by allowing remote operators to open, run, and interact with RSView 32 graphic displays from virtually any computer on a network. This extends the reach of process control system from the plant floor to the office and beyond. RSView 32 takes advantage of Microsoft Distributed Component Object Model (DCOM) and ActiveX technologies, allowing remote components to appear local and by providing convenient Internet access.

RSView 32 allows:

- View and interact with real-time, animated graphics
- Manage and control alarms, trends, and set-points
- Manage and acknowledge global alarms
- Centrally manage configuration files, graphic display files, databases, and RSView 32 security
- Centrally administer the RSView 32 security system
- Automatically deploy client software through your network from the Microsoft Internet Explorer browser on a client
- Automatically establish client sessions with an alternate server if the primary server fails
- Use RSView 32 Active Display with Microsoft Windows Terminal Services to reduce total cost of ownership. Combine RSView 32 Active Display and Terminal Services to use thin clients, such as the Microsoft Windows CE-based RAC6182 and MobilView that remotely access RSView 32 information.

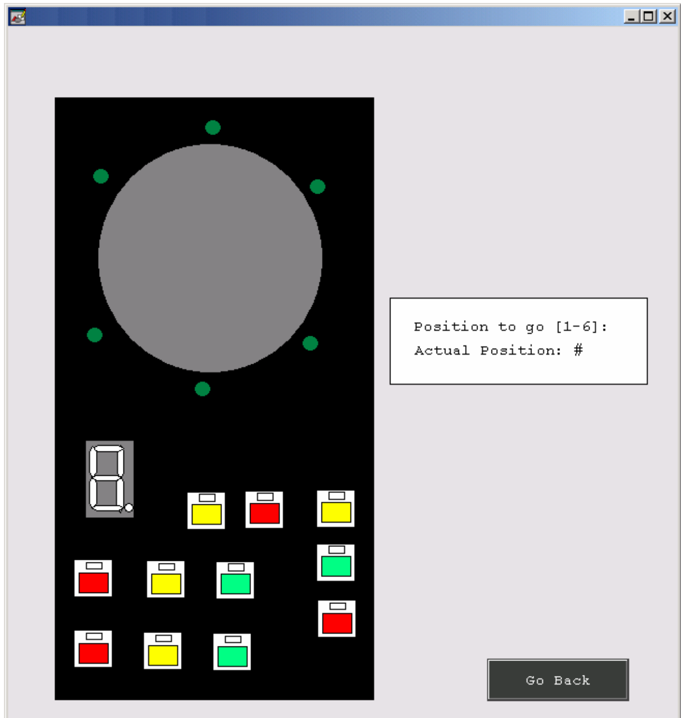

Figure 1-4: Example of visualization of the model in RSView 32

1.2.2.3. RSLogix 5000

RSLogix 5000 is windows based communication software developed by Rockwell Software and designed to work with the Rockwell Automation Logix platforms: ControlLogix, CompactLogix, FlexLogix, SoftLogix5800 and DriveLogix.

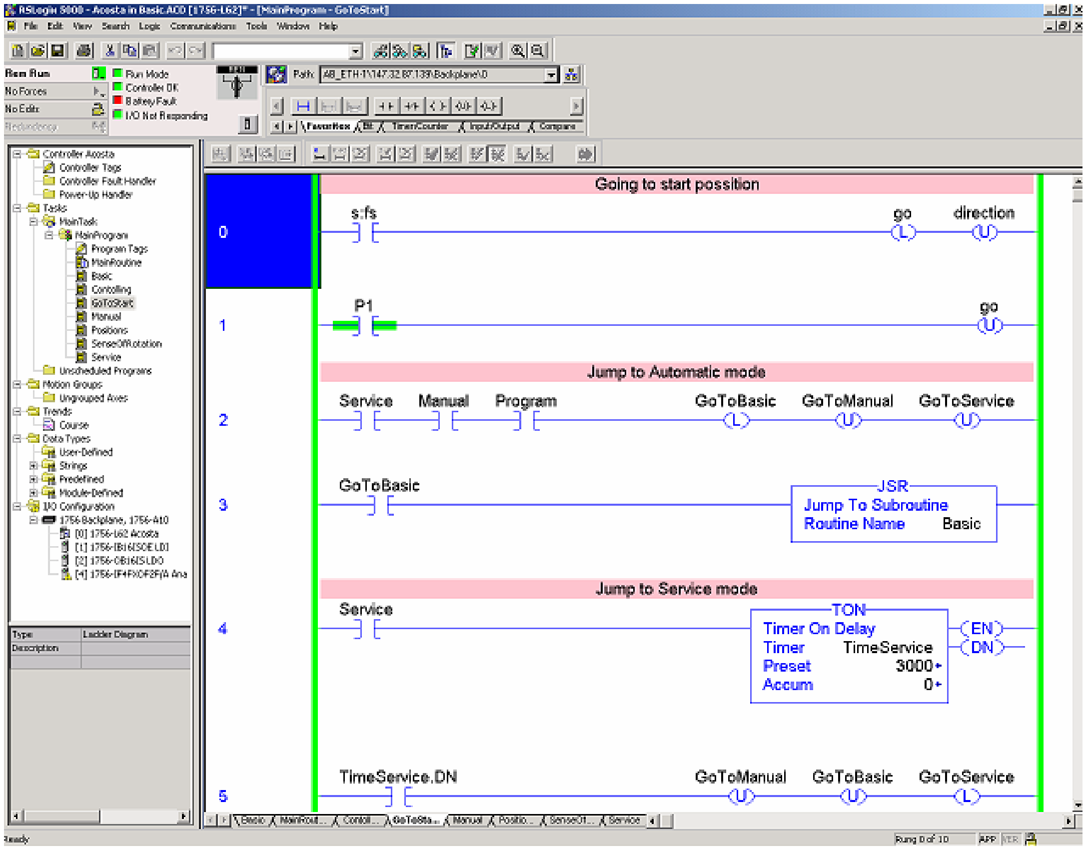

Figure 1- 5: Program in RSLogix 5000

The RSLogix 5000 environment offers an interface simple to use, symbolic programming with structures and arrays, and a comprehensive instruction set that serves many types of applications. It supports relay ladder, structured text, function block diagram, and sequential function chart editors for you to develop application programs.

RSLogix 5000 fully uses function drag and drop; it increases speed and effectiveness of writing programs. Of course there is a possibility of showing variables in a graph. Translating module for transformation of programs of controllers SLC500 and PLC5 is content of software RSLogix 5000. Using this module considerably reduce costs and spend time.

2. Model of Positioning Device

An important part of this work consists of the design and construction of a model of a positioning device. The device will be connected to and controlled by the ControlLogix system. I designed and made three models. For the design of the electronic circuit, I improved a previous design made by Mr. Karasek in his thesis [6].

Figure 2-1: Overview of the Model

2.1. Overview

The outside of the model of the positioning device consists of a black box that has two levels. The first level contains 6 buttons and 5 switches with its respective LEDs (each one of a different color (green, yellow and red), and also there is a seven segment display. In the second level, there are 6 LEDs separated by the same distance from the center (25 mm). These LEDs are arranged in a circle with the adjacent LEDs making a 60 degree sector angle. The LED display is covered by circular glass that enables us to see the inside of the box. There is metallic rotating disk which is placed between six sensors. The disc is driven by a small DC motor with gearing.

2.2. Specifications

The model consists of six sensors arranged in a circular shape with the sector angles 60, 120, 180, 240, 300 and 360 degrees, respectively. Each sensor is placed 25 mm from the center. These position sensors are optical sensors: TCST 1013. The sensor consists of the light-emitting source and the detector that are placed face-to-face on the same optical axis approximately in 3 mm distance. It allows to place between them an obstacle to prevent the light of the emitter diode to be detected by the phototransistor.

In my work, I used metallic disc of width 1 mm and diameter 50 mm that rotates between sensors. The disc, that has a hole of 5 x 5 mm in the outer edge, is placed in such form, that it prevents the sensors detect the light of their respective emitter. When the disc rotates and the hole passes through a sensor, the phototransistor detects the light of the LED and sends a signal to the controller which enables to find the position of the hole. At the same this sensor indicates the position of the hole by switching on the LED placed just upon the sensor. There are altogether 6 LEDs, each one just upon its respective sensor.

In order to rotate the metallic disc between the sensors, I decided to use a small servomotor Hitec HS-311 with gearing in a plastic box which can rotate in both directions: clockwise and counter-clockwise. The switching-on, switching-off, direction of rotation and the number of revolutions of the motor, are controlled by the controller (ControlLogix).

The internal circuit of the model works with +12 Volts DC, GND and -12 Volts DC. It consists of an amplifier (to load the motor), a circuit for switching-on and switching-off of the motor, a circuit for the operation of the sensors and LEDs and a circuit for the operation of buttons, switches and a seven segments display. The seven segment display is controlled by the ControlLogix and can be programmed to indicate the position number. It is also possible to control the motor manually by pushing the “Manual-B1” button, but in this case current flows and the motor starts moving only in one direction, though the sensors and LEDs work normally.

2.3. Construction of the Real Model

I used small and big plastic boxes for body of the model. The small one (29x65x90 mm) is placed over the big one (49x90x200 mm). This arrangement permits to place the motor with its gearing in to lower part. The upper part is ideal for placing the sensors and the rotational disk. Inside the big box there are placed the electronic circuits of the motor and the voltage divider which controls the direction of rotation of the motor. The circuits of the sensors and LEDs are placed inside the small box.

2.3.1. Sensors and LEDs

Sensors have a compact construction where the emitting-light source and the detector are located face-to-face on the same optical axis. The operating wavelength is 950 nm. The detector consists of a phototransistor and the emitter is an LED. In the model, I used 6 sensors, all placed in a circle with an angle between them of 60 degrees. The connection of the circuit for these sensors and their corresponding LEDs (LEDs indicates when phototransistor detects light from emitter) were made according Mr. Karasek’s thesis [6].

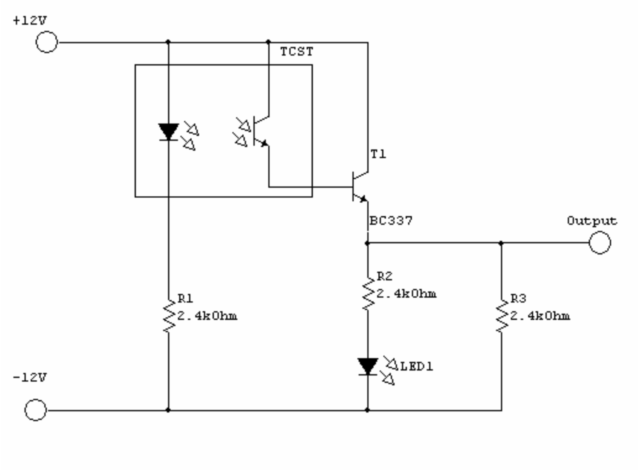

Figure 2-2: Sensor's circuit

When the hole of the rotating disk passes through a sensor, light opens inner transistor of the sensor. Due to transistor T1 also opens. Current flows through the LED, which illuminates, and also output is on.

2.3.2. Motor

The used motor is a small servo motor Hitec HS-311 Servo Motor. In the motor I did some changes: first of all I removed the electronic circuit included to control the motor (I didn't need it any more because I made my own). Next step was to eliminate a part of the potentiometer that does not allow the motor to rotate more than 270 degrees.

Direction of the motor

To control the direction of the motor I made a voltage divider with input of ±12 V and output of ±4 V approximately. For that reason there were placed also two variable resistors that can be set to a different value to increase or decrease voltage if needed (Figure 2-3).

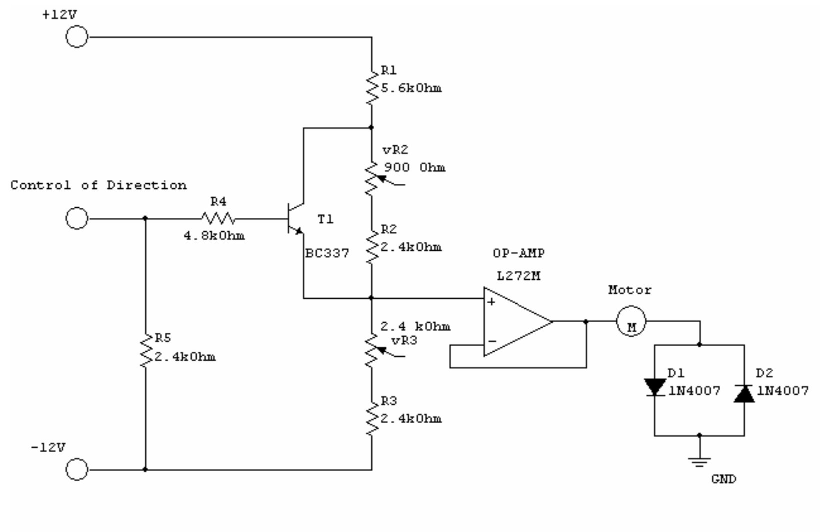

Figure 2-3: Circuit of the Motor's direction

Switching on/off circuit

For switching motor I use two transistors that work like switches when current passes trough them. There must be also two diodes connected to the transistors to improve switching process.

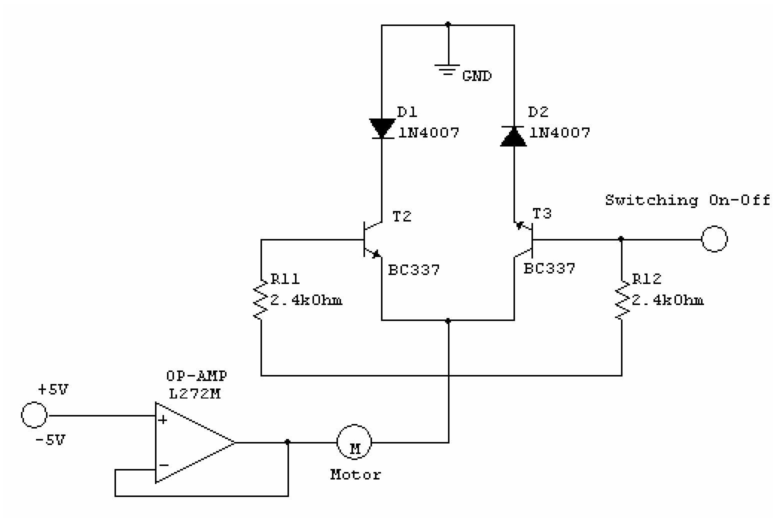

Figure 2-4: Circuit of switching on/off motor

Control of the Switching on/off of the motor is controlled by the ControlLogix.

There are three different possibilities to control the motor:

1. Digital Manner

When controlling in digital form, we use the ControlLogix with digital modules 1756-IB16ISOE/A and 1756-OB16IS/A. In this case, the ControlLogix controls motor's switching on/off and direction. It allows moving in both directions at the constant speed (See figure 2-3 and 2-4).

2. Analogue Manner

When controlling by analogue manner we use also ControlLogix analogue module 1756-IF4FXOF2F/A. It allows controlling not only the direction but also the speed of the motor by increasing or decreasing voltage (max/min voltage ±10 V) (Figure 2-5). For the control with analogue module it was necessary to design a circuit to stabilize voltage to ± 10 V. This voltage supplies potentiometer which is connected to rotational disk. It allows analogue measuring of the position of the hole.

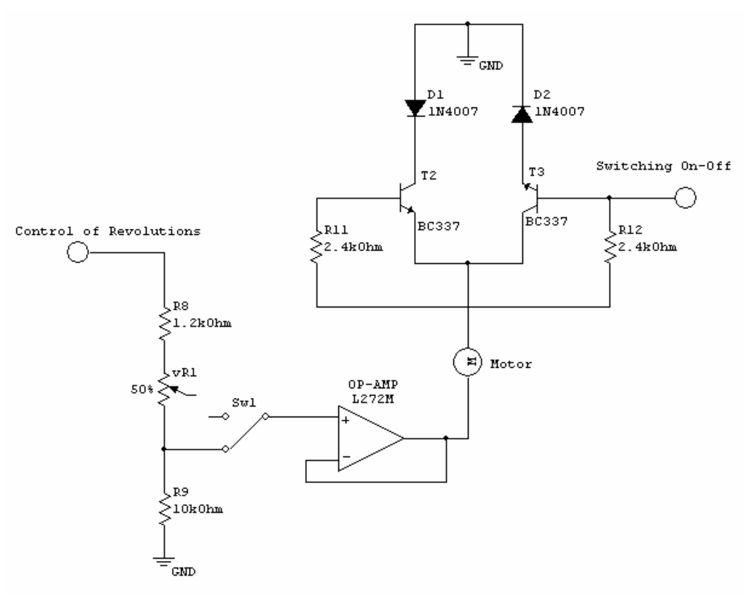

Figure 2-5: Circuit of the motor controlled by analogue mode

3. Pushing "Manual-B1" Button:

The positioning device can be controlled without ControlLogix by pushing "Manual-B1" button. It is needed just to connect the model to a source of ±12 V. In this case the motor can rotate only in one direction at the same speed.

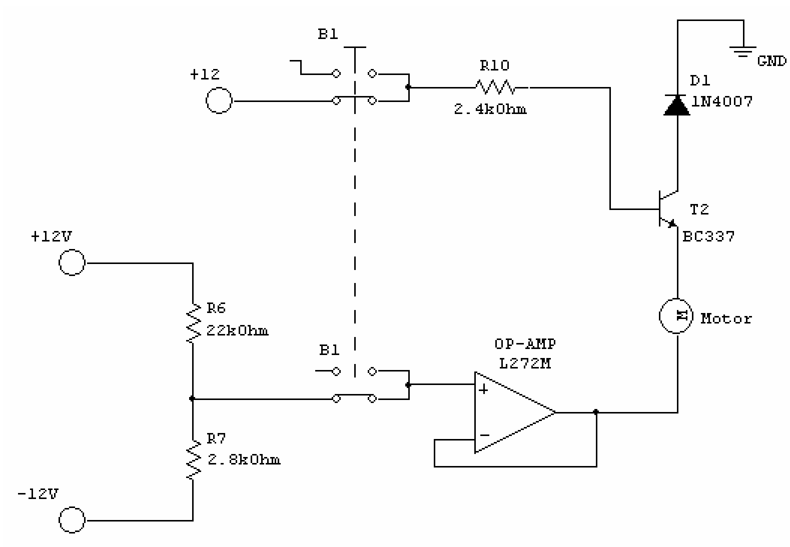

Figure 2-6: Manually controlled circuit

Figure 2-7 presents the complete design of the circuit:

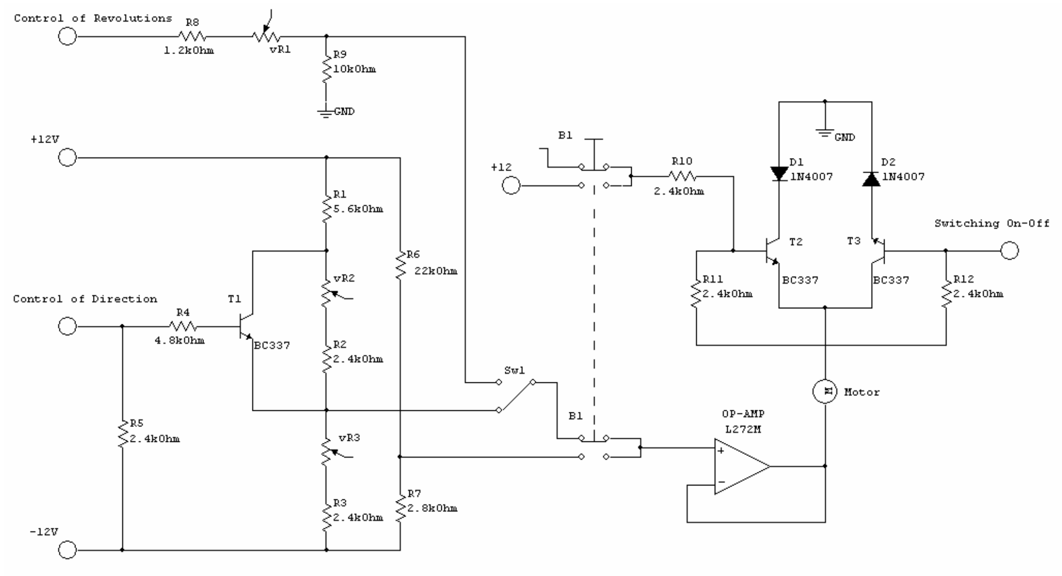

Figure 2-7: Final circuit of model of positioning device

2.3.3. Buttons and Switches

The model has 6 buttons and 5 switches; Button 1 can control the position, without controller, Button 2 and Button 3 is Start and Stop Button respectively. Buttons 4, 5, and 6 are respectively Program, Manual and Service Buttons. These buttons are for switching between different modes. The Switch 1 switches between Analogue and Digital mode, switch 2, 3, 4 and 5 can be use for programming purposes.

Label	Name	Function
B 1	Button 1	B1-Manual
B 2	Button 2	Start
B 3	Button 3	Stop
B 4	Button 4	Program
B 5	Button 5	Manual
B 6	Button 6	Service
SW 1	Switch 1	D/A Switch
SW 2	Switch 2	Free
SW 3	Switch 3	Programmable
SW 4	Switch 4	Programmable
SW 5	Switch 5	Programmable

Table 1: List of buttons and switches

Figure 2-8: Placement of buttons and switches

2.3.4. Voltage Source

The model is powered by two voltage sources of 12 V / 0.5 A in series. The +12 V output of one power supply is connected to common terminal of another power supply. The connection is used like analog GND or 0 V. The common of the first power supply is used like -12 V for the analogue part of circuitry and also as digital GND. Then +12 V of the second power supply is 24 V for the digital part.

3. RSView 32 Visualization of Positioning Device

Important part of this thesis is to prepare typical tasks of control using the model of positioning device including visualization by means of RSView 32. I prepared tasks that consist of two parts: a program in RSLogix 5000 software and visualization in RSView 32 software. The task that is attached in Appendix C, can be found on webpage of the Allen-Bradley's Laboratory.

3.1. Settings

Before starting with the RSView 32 it is necessary to set parameters in RSLinx so that it can point to our work. We can do that by choosing the option "DDE/OPC" and then clicking on "Topic Configuration…" option.

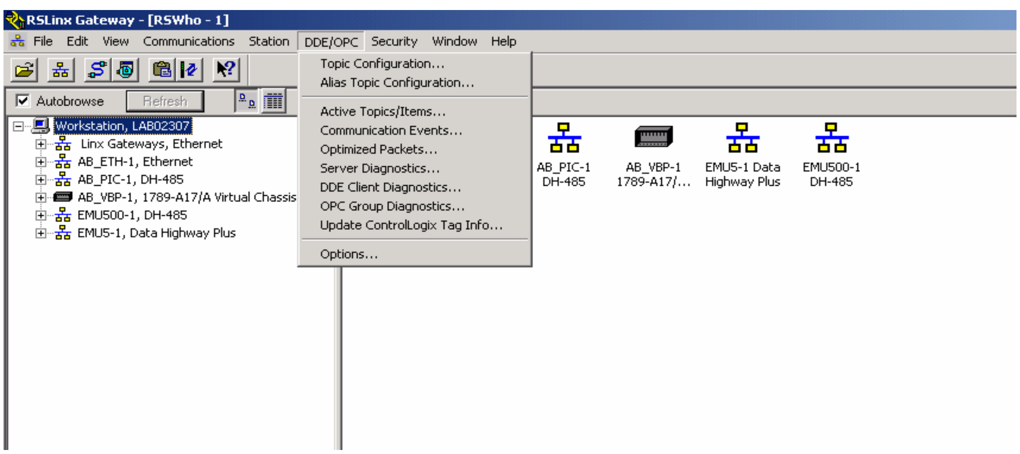

Figure 3-1: Set parameters in RSView 32 (Topic Configuration)

In the appearing window we can make a new topic list and set the way that points to our project in ControlLogix processor or we can use an exiting Topic with parameters already defined. Figure 3-2 depicts topic "Krab" for my project.

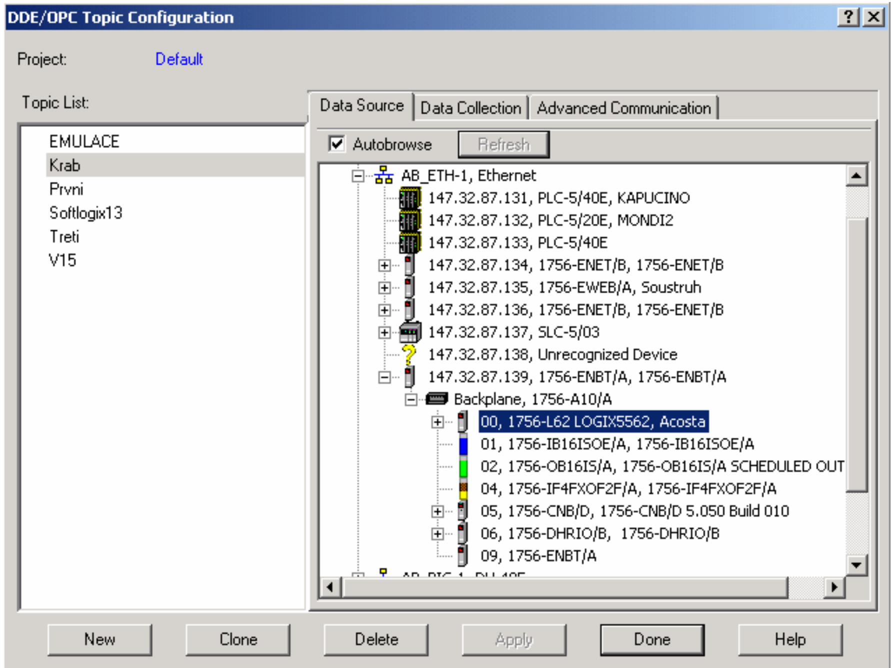

Figure 3-2: Set parameters in RSView 32 (Topic Configuration 2)

3.2. Visualization

When designing the view of our visualization it is very important to take in account that it has to be user friendly entourage so that it will be easy to use. Since the used methods for doing visualization is up to students, it is recommendable to separate processes and modes of control in different windows. An example of how can be it done is to create a main window containing a menu in which can be placed links to individual control modes Automatic Mode, Manual Mode, and Service Mode.

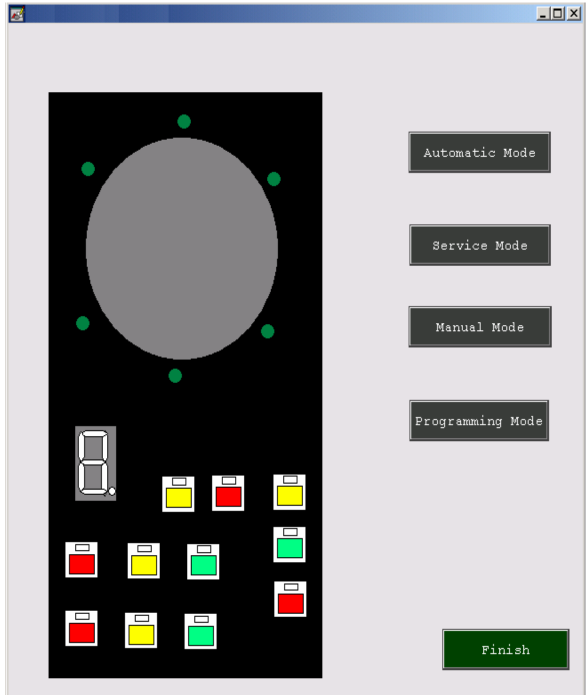

Figure 3-3: Visualization in RSView 32

Conclusion

The first objective of this Bachelor Thesis was to familiarize with programmable automation controller ControlLogix from Rockwell Automation. I have explained structure of PACs and PLCs, data busses, used software and hardware, and components like I/O modules.

Further it was required to design and make a model of positioning device which is connected and controlled by the ControlLogix controller. Three models were successfully designed, made and tested. The circuit of the model and a picture of it can be seen in Figure 2-7 and Figure 2-1 respectively.

Typical tasks of control for students using the model of positioning device and the ControlLogix controller were also prepared (See appendix D). For solving these tasks is necessary to use software installed in the Allen-Bradley Laboratory: RSLinx, RSLogix 5000 and of course RSView 32 for visualization. The task was satisfactory tested on my model. The model can be used for other tasks from simple one (start and stop motor) to much complex (control of traffic lights).

Specification of task and description of model were prepared but due to reconstruction of the web of the Allen-Bradley Laboratory, they will be updated later there. It will be possible to find them at <http://dce.felk.cvut.cz/ab>.

Literature

[1] Wikipedia, Free Encyclopedia <http://www.wikipedia.org>

[2] Ethernet, Industrial Networking, the online Industrial Ethernet Book <http://www.ethernet.industrial-networking.com>

[3] ControlLogix Digital I/O Modules User Manuals, March 2001 <http://www.ab.com>

[4] Allen-Bradley ControlLogix, Woodrow, <http://www.woodrow.co.za>

[5] PLC archive, <http://www.control.com>

[6] Milan Karásek, Thesis (Diplomová Práce) Prague 2002, Czech Technical University in Prague (C.T.U.), Department of Control Engineering.

Abbreviations

LED	Light emitting diode
PAC	Programmable Automation Controller
PLC	Programmable Logic Controller
i.e.	Id est (That is)
e.g.	Exempli gratia (for example)
IP	Internet Protocol
OLE	Object Linking and Embedding
I/O	Input/Output
SMTP	Simple Mail Transfer Protocol
PID	Proportional Integral Derivative
CIP	Common Industrial Protocol
MAC	Media Access Control
UDP	User Datagram Protocol
TCP	Transmission Control Protocol
SIG	Special Interest Group

Table 2: List of Abbreviations

Attachments

Appendix A: Lists of the Addresses and Tags in the ControlLogix

Input Module

Input Elements	Address in the ControlLogic	Name of Tag
Stop Button 'Red'	Local:1:I.Data.0	Stop
Start Button 'Green'	Local:1:I.Data.1	Start
Program Button 'Green'	Local:1:I.Data.2	Program
Manual Button 'Yellow'	Local:1:I.Data.3	Manual
Service Button 'Red'	Local:1:I.Data.4	Service
Bit Switch 1 'Green'	Local:1:I.Data.5	SWGreen
Bit Switch 2 'Yellow'	Local:1:I.Data.6	SWYellow
Bit Switch 3 'Red'	Local:1:I.Data.7	SWRed
Free Switch 'Red'	Local:1:I.Data.8	
Position 1 from sensor	Local:1:I.Data.9	P1
Position 2 from sensor	Local:1:I.Data.10	P2
Position 3 from sensor	Local:1:I.Data.11	P3
Position 4 from sensor	Local:1:I.Data.12	P4
Position 5 from sensor	Local:1:I.Data.13	P5
Position 6 from sensor	Local:1:I.Data.14	P6
Not used	Local:1:I.Data.15	

Table 3: Input Module Elements

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Output Module

Output Elements	Address in the ControlLogic	Name of Tag
Switch On-Off Servo-Motor	Local:2:O.Data.0	Motor
Control of motor's direction	Local:2:O.Data.1	Direction
Program LED 'Green'	Local:2:O.Data.2	Lprogram
Manual LED 'Yellow'	Local:2:O.Data.3	Lmanual
Service LED 'Red'	Local:2:O.Data.4	Lservice
7 segment display a	Local:2:O.Data.5	Sega
7 segment display b	Local:2:O.Data.6	Segb
7 segment display c	Local:2:O.Data.7	Segc
7 segment display d	Local:2:O.Data.8	Segd
7 segment display e	Local:2:O.Data.9	Sege
7 segment display f	Local:2:O.Data.10	Segf
7 segment display g	Local:2:O.Data.11	Segg
7 segment display point	Local:2:O.Data.12	Segp
Green LED	Local:2:O.Data.13	Lstart
Red LED	Local:2:O.Data.14	Lstop
Yellow LED	Local:2:O.Data.15	Lyellow

Table 4: Output Module Elements

Appendix B: List of Used Electronic Components (in one model of positioning device):

Resistors:		**Pieces**
	5k6	1
	2k4	34
	10k	1
	22k	1
	2k8	1
	1k2	1
Diodes:		
	1N4007	2
Transistors:		
	BC337	9
Sensors:		
	TCST 1003	6
LEDs:		
	L-HLMP-1503	6
Buttons:		
	P-0SRB	6
Switches:		
	P-1SEB	5
Servo Motor:		
	Hitec HS-311	1
Variable resistors:		
	-	3
Op-Amp:		
	L272M	1
Voltage sources:		
	12 V	2

Table 5: Used Electronic Components

Appendix C: Canon 37 Connector Pins Wiring

Pin 1	+ 12 V.		Pin 20	Out 5
Pin 2	GND		Pin 21	Out 6
Pin 3	- 12V.		Pin 22	LED 3
Pin 4	Seven Segment 7		Pin 23	LED 1
Pin 5	Seven Segment 4		Pin 24	LED 2
Pin 6	Seven Segment 1		Pin 25	LED 5
Pin 7	Seven Segment 3		Pin 26	Button 2
Pin 8	Seven Segment 8		Pin 27	Button 3
Pin 9	Seven Segment 5		Pin 28	Button 4
Pin 10	Seven Segment 2		Pin 29	Button 5
Pin 11	Seven Segment 6		Pin 30	Button 6
Pin 12	Motor on		Pin 31	Switch 5
Pin 13	Analogue control		Pin 32	Switch 4
Pin 14	Direction control		Pin 33	Switch 3
Pin 15	LED 4		Pin 34	Switch 2
Pin 16	Out 1		Pin 35	Analogue position
Pin 17	Out 2		Pin 36	Free
Pin 18	Out 3		Pin 37	LED 6
Pin 19	Out 4			

Table 6: Canon Connector

Appendix D: Task

Write a program for the automatic controller ControlLogix that is connected to the model of positioning device. The program will provide motion of model in three different control modes. Make visualization of the system by means of software RSView 32.

The device operates in three working modes. The automatic mode is designed for automatic repeated production. Manual mode is determined for single-part production. Service mode is used for repairing device. Choice of working mode is determined by Manual, Automatic and Service buttons and is signalized by LED diode placed over each button. The program can be operated either directly from model or from RSView 32. Description of modes:

- Automatic: In this mode the system remembers up to 10 required positions that must be fulfilled in order of setting. 3 switches and 3 buttons should be used to enter 6 different positions. The system waits 2 seconds in the required position and then continues to the next pre-selected position in the shortest way. The number of the position that is going to is displayed on the seven-segment display. By pushing Start button the sequence starts.

- Manual: The number of required position is submitted by means of switches, the number is given in binary number system. After pushing one button, the system goes to the required position in the shortest way. Next run happens after new setting of the position.

- Service: This mode is only available when controlling from model. The motor runs by pushing Start button and stops by pushing Stop button. The sense of the direction is set by the Yellow switch.

The current operation can be canceled and the device must be stopped when Stop button is pushed in any mode longer than 5 seconds.

The controller is equipped with digital diagnostic modules IB16D and OB16D. Study the characteristics of diagnostic of these modules. The model has the possibility to interrupt the circuit of one input and one output. In the controller program include the testing of disconnecting of input and output circuits and the reaction on this type of fault.

If using analog control of speed, control the speed of motor by means of voltage change.

As a basis for your program you can use a copy of prepared exemplary programs with prepared database of basic variables.