INVESTIGATION AND DEVELOPMENT OF ELECTRONIC INSTRUMENTS FOR PLC PROGRAMMING TRAINING

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Programmable logic controllers have been gaining popularity on the factory floor and nowadays are the most common choice for manufacturing controls. Because of the nature of a specific industrial object or manufacturing process it is impossible by reason of security the program adjustment to be performed in real conditions. Thus simulators are designed to mimic real-world environments and they can provide a safe and risk-free platform for job training, project testing, design engineering and troubleshooting. The goal of the present project is a simulator for PLC programming training to be developed.

Keywords: PLC, simulation, test, training

1. INTRODUCTION

The complex manufacture automation is a modern direction in the technology development. It is not enough separate machines to be automated. The requirements for combining more flexibility with better efficiency could be satisfied only when the separate machines are integrated in the whole system. Modern machinery consists of both mechanical and electronic parts. Overall functionality is determined by "*balance*" between these components [1]. Application of electronics leads to great changes in industrial objects control. New directions in industrial measurement and control are created. Programmable logic controllers (PLC) are used widely in automation problems solution. Their application allows a definite machine or process functioning to be started, controlled and monitored. Because of the nature of a specific industrial object or manufacturing process it is impossible by reason of security the program adjustment to be performed in real conditions. Thus the necessity of simulators generating signals with parameters completely matching those obtained from the object in real conditions occurs. Such simulators are used in PLC programming training.

Simulation and modeling are investigations approaches which take place in different fields of scientific and applications developments [7, 8]. First the behavior of a circuit or module is simulated and the parameters are adjusted and then they are verified by investigation over real object.

Complex systems control requires complete cover of the behavior of every industrial object and process in all working regimes. This could be achieved using the possibilities of the simulation and modeling. These methods have wide application in industry areas like electric power production, chemical manufacture, machine

building and etc. where interruption and accident regimes creation in order to adjust the control equipment are impermissible.

2. APPLICATION OF SIMULATION IN PLC PROGRAMMING TRAINING

PLCs have been gaining popularity on the factory floor and will probably remain predominant for some time to come [2]. This is because of the advantages they offer. The main ones are:

- cost effectiveness for controlling complex systems;
- flexibility – i.e. the ability to be reapplied to control other systems quickly and easily;
- intelligence - allowing more sophisticated control;
- programming simplicity reduce downtime;
- reliability - the operation period is years before failure.

PLC usage has become the most common choice for manufacturing controls. Thus the need to teach the staff how to program them arose. Simulator systems are ideal tools for this purpose. Designed to mimic real-world environments they can provide a safe and risk-free platform for job training, project testing, design engineering and troubleshooting. The simulator systems allow:

- training reinforcement;
- skill testing;
- system troubleshooting;
- instrumentation test and calibration;
- program testing and debugging;
- back-up spare parts;
- on-the-job training;
- HMI screen development;
- system integration testing;
- network testing.

After a program has been written it is important to verify that it works as intended, before it is used in production. In a simple application this might involve running the program on the machine, and looking for improper operation. In a complex application this approach is not suitable. In these cases simulators allow the programs to be tested without the actual machine. The use of a simulator typically follows the basic steps below:

- the machine inputs and outputs identification;
- a basic model of the system development in terms of the inputs and outputs, including items such as when sensor changes are expected, what effects actuators should have, and expected operator inputs;
- a system simulator configuration with some combination of specialized software and hardware;
- the simulator action verification for the expect operation of the developed system;

- software testing and operation verification of the developed system using the simulator.

The goal of the present project is a simulator for PLC programming training to be developed. The goal will be achieved after completing the following tasks:

- investigation of the electrical and functional characteristics of the input and output circuits of the PLC;

- investigation of electronic circuits for signals generation simulating the PLC operation in real environment;

- design and verification of an electronic system for generation input signals to and receiving output signals from the PLC.

3. INVESTIGATION OF THE ELECTRICAL AND FUNCTIONAL CHARACTERISTICS OF THE PLC INPUT AND OUTPUT CIRCUITS

Inputs to, and outputs from, a PLC are necessary to monitor and control a process. Both inputs and outputs can be categorized into two basic types: digital and analog.

Inputs come from sensors that translate physical phenomena into electrical signals. Typical examples of sensors with digital transfer characteristics are listed below in relative order of popularity:

1) Proximity switches - use inductance, capacitance or light to detect an object logically.

2) Switches - mechanical mechanisms will open or close electrical contacts for a logical signal.

There is a variety of ranges for input voltages - 12-24 Vdc, 100-120 Vac, 10-60 Vdc, 12-24 Vac/dc, 5 Vdc (TTL), 200-240 Vac, 48 Vdc, 24 Vac. The most popular are 24 Vdc and 200-240 Vac.

Outputs to actuators allow a PLC to cause something to happen in a process. Popular actuators with digital (logical) performance are:

1) Solenoid valves - logical outputs that can switch a hydraulic or pneumatic flow.

2) Lights - can often be powered directly from PLC output circuits.

3) Motor starters - basically large relays.

Typical values of the output voltage are 120 Vac, 24 Vdc, 12-48 Vac, 12-48 Vdc, 5Vdc (TTL), 230 Vac. The common used of them are 24 Vdc and 230 Vac.

Some PLC have digital in-/outputs, which may be used for technological functions respectively as standard periphery. Such is the *Count* submodule of the CPU 313C from Siemens. It functions in three modes:

• Continuous count, e.g. for position decoding with incremental encoder;

• Single count, e.g. for unit decoding to a maximum limit;

• Periodical count, e.g. for applications with repeated counting operations.

The maximum frequency is up to 30kHz.

The possibilities for connection to the technological functions are:

• 24V incremental encoder, equipped with two tracks with 90° phase offset;

• 24V pulse generator with direction signal;

• 24V proximity switch (e.g. BERO or light barrier).

For each counter the following inputs are available:

Channel$_x$ *(A)* - pulse input for count signal res. track A of an encoder;

Channel$_x$ *(B)* - direction signal res. track B of the encoder;

Hardware gate$_x$ - this input allows opening the HW gate with a high peek and thus starting a count process;

Latch$_x$ - with an edge 0-1 at this input the recent counter value is stored in a memory.

Typical analog inputs for PLCs are:

1) Oven temperature.

2) Fluid pressure.

3) Fluid flow rate.

The reasonable ranges for the input voltage are 0V to 5V, 0V to 10V, -5V to 5V, -10V to 10V and for the input current are -20mA to 20mA, 0mA to 20mA, 4mA to 20mA.

The PLCs have analog inputs measuring resistance in ranges 150Ω, 300Ω, 600Ω and etc.

They have analog inputs for direct connection of thermocouples and resistance thermometers (Pt100).

Distinctive examples for control using analog outputs are:

1) Fluid valve position.

2) Motor position.

3) Motor velocity.

The most often used ranges for the output quantities are:

- voltage - 0V to 10V, -10V to 10V;

- current - 0mA to 20mA, -20mA to 20mA, 4mA to 20mA.

4. SIMULATOR SYSTEM DEVELOPMENT

After studying the PLC input and output characteristics there have been decided that for the training purposes will be useful to give opportunities to acquaint with most of the submodules. Thus there is a need to generate input quantities for the digital and analog inputs, to indicate the action of the digital outputs and to measure the output quantities from the analog outputs.

The laboratory set-up for PLC programming training is shown on fig. 1. The simulator allows studying the operation of the PLC submodules.

For logical instructions studying there is a submodule consisting of switches connected to the PLC logical inputs. The action of the logical outputs will be indicated by LEDs.

For exercising the BCD to integer conversion there are digital switches setting the value of the decimal numbers in BCD code. The range of the numbers is from –999 to +999. The integer to BCD conversion will be experimented using 7-segment LED display and decoder. To harmonize the logic levels of the PLC outputs and the decoder inputs there are level shifting circuits.

To simulate connection of different sensors and transducers to the PLC are intended modules setting and measuring the input quantity – voltage, current, resistance and temperature in the most common used ranges.

The operation of the analog outputs is controlled by modules measuring DC voltage and current in the widest ranges used in the PLCs.

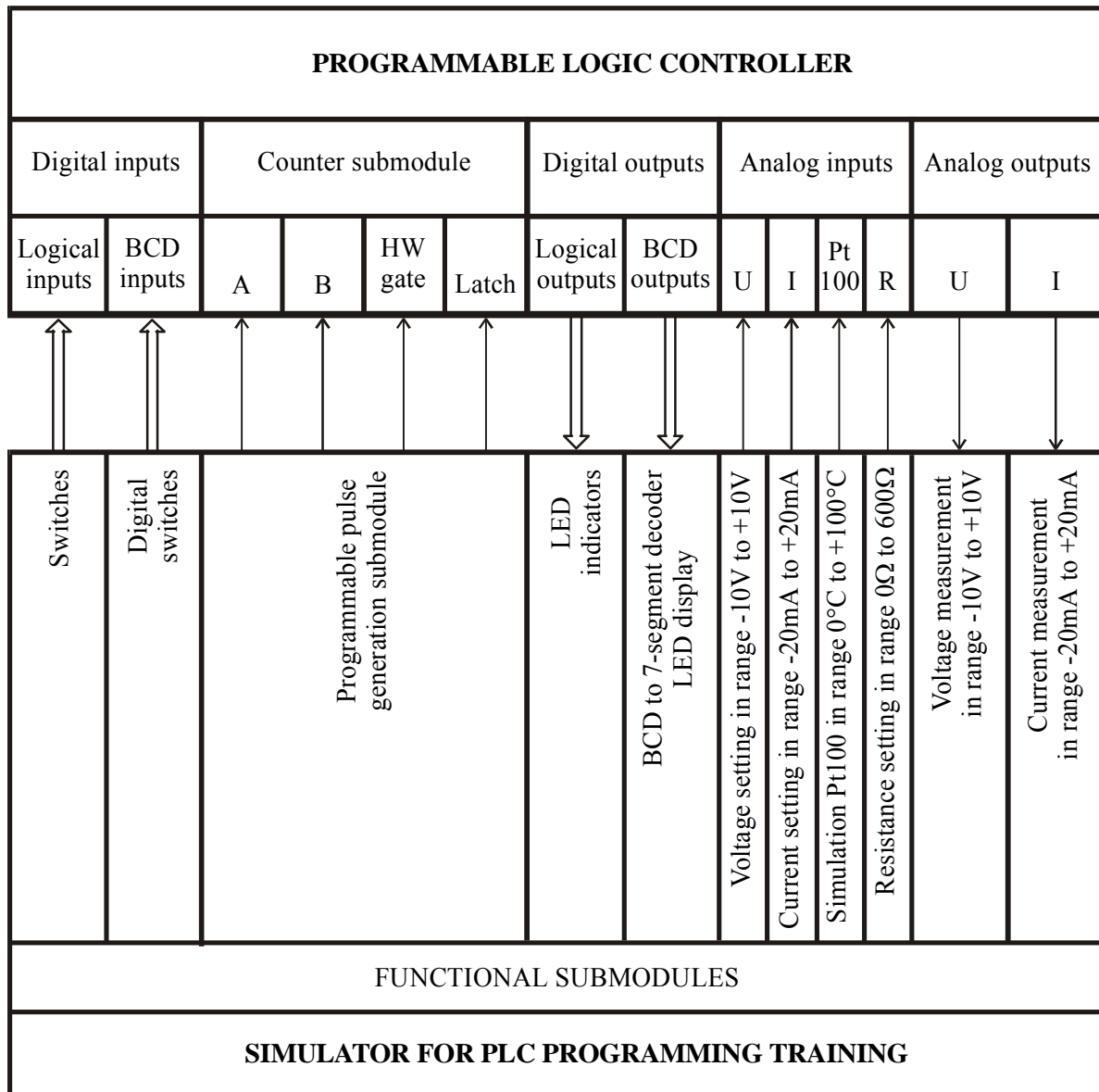| PROGRAMMABLE LOGIC CONTROLLER											
Digital inputs		Counter submodule				Digital outputs		Analog inputs			Analog outputs	
Logical inputs	BCD inputs	A	B	HW gate	Latch	Logical outputs	BCD outputs	U	I	Pt 100	R	U	I

Fig. 1. Simulator system block diagram and connections to the PLC

The programmable pulse generation submodule (fig. 2) is intended to simulate different working regimes for the counter block of the PLC. It is based on the microcontroller PIC16F876A of Microchip. There are four pulse outputs which are connected to the inputs A, B, HW gate and latch. Using the transistors the level shifting between +5V logic and +24V logic is realized. The switches S1 to S4 set the modes of operation. Pushing the S1 switch starts the pulse generation. The switch S2 changes the mode in two ways – generation of pulses with defined frequency or generation a number of pulses. The switches S3 and S4 work in frequency generation mode. When S3 is pushed on "HW gate" output is generated time interval enabling

the PLC to measure the frequency of the pulses from "A" output. When S4 is pushed the signal generated from output "Latch" forces the PLC to store the count value. The pulses generated on outputs "A" and "B" have 90° phase offset to simulate encoder operation. The BCD digital switches set the number of pulses or the frequency in kHz depending on the working mode.
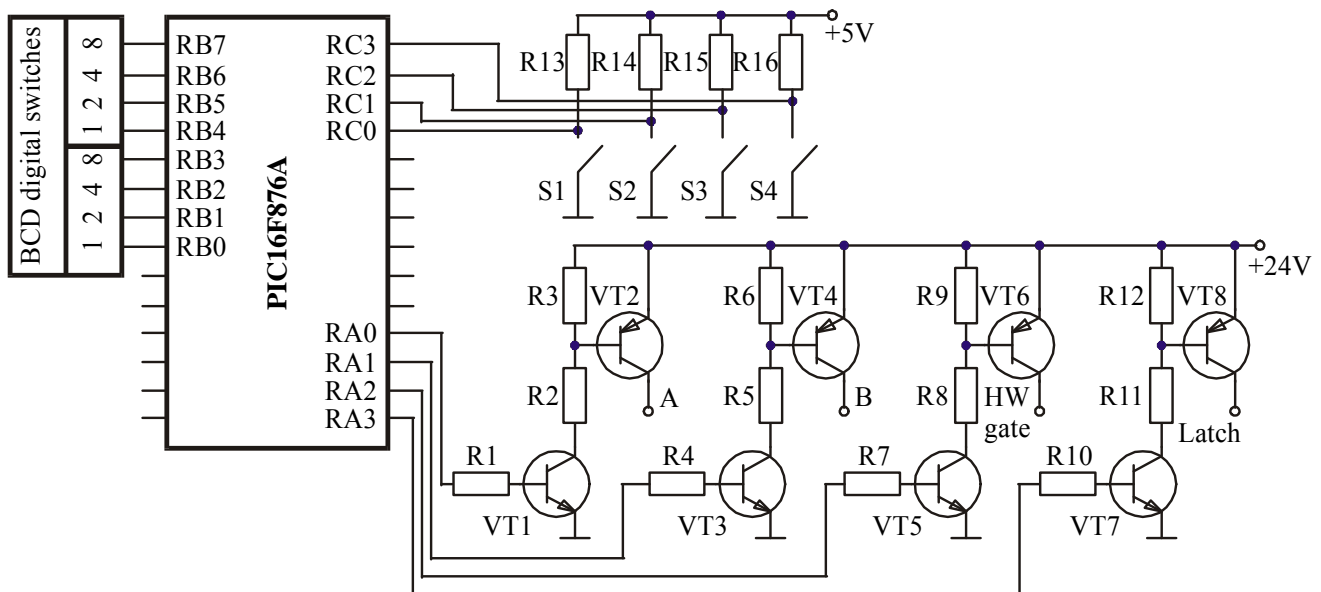

Fig. 2. Programmable pulse generation submodule

5. CONCLUSIONS

The developed simulator ensures conditions for studying and training the most of the PLC possibilities. It exceeds the resources of the system "FIELD DEVICE SIMULATOR PANEL 6ZB2 310-0BH00" of Siemens generating and measuring current, Pt100 simulating, resistance setting and counter module operation simulating. It can be used not only in the educational process but in the investigations and research as well.

6. ACKNOWLEDGMENT

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