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PCB components for Simatic PLC portable education station

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***Abstract* — The paper's aim is to describe process of design a portable station. The station will be used to educating purposes of programming PLC devices from Siemens company. Before creating the design, it was necessary to get acquainted with the issue of industrial logic controllers. A description of the PLC 1200 performed and requirements for the portable education station is described. Then portable education station design on block level is described. Main focus of the paper is paid to PCB design of the specific blocks and at the end visualization of the education station is showed.**

***Keywords* — education station, PCB, PLC, printed circuit board, simulation, visualization**

I. Introduction

New industrial solutions require new education systems. The innovations in decentralization, visualization, and programming of programmable logic controllers according to uniform rules are just a few examples of changes in individual areas. From these requirements for automatization, there is a demand for modern, practically oriented training systems that provide students with the current technological level, the necessary knowledge and competencies. This article deals with the design and possible implementation of an educational workplace for PLC.

II. PLC SIMATIC S7-1200

The main part of the portable teaching workplace is the PLC of the S7-1200 series, which has a CPU 1215C with the product designation 6ES7215-1AG40-0XB0. Parameters such as: the number of inputs and outputs of this device and the voltage and current levels at the given inputs and outputs are important for this work. The PLC has 14 digital inputs, 10 digital outputs, 2 analog inputs and 2 analog outputs. The digital inputs operate at a voltage level of 24 V, with the manufacturer stating that the minimum value for logic 1 is 15 V DC at 2.5 mA. The output voltage at the digital outputs is at least 20 V for logic 1 and the maximum value of the current at the individual outputs is 0.5 A at the connected load. Input voltage ranges at the analog inputs (nominal values) are from 0 to 10 V. The output current range from 0 to 20 mA is defined at the analog outputs [1]. The Simatic PLC 1200 is shown in Fig.1

Fig. 1 Simatic PLC S7-1200 (CPU 1215C)

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III. PORTABLE EDUCATION STATION REQUIREMENTS

The station requirements can be grouped into the design requirements and I/O requirements. As a design requirements following requirements have been identified [3]:

- Usage of all inputs and outputs of the used PLC,
- Versatility - the device should be usable for testing a wide range of programs. It is necessary to ensure the possibility of connecting the station with external devices, which will increase the degree of universality of the resulting device.
- Robust - provide protection against damage due to improper use,
- Portable - ensure the possibility of relocating the teaching workplace,
- Stackable - ensure the possibility of storing individual workplaces,
- Define the space for future HMI connections,
- Choosing the right material and necessary components

I/O requirements describe the requirements for individual inputs and outputs of the PLC. Their common requirement is to design the possibility of connecting various external devices using IDC connectors. Another common requirement is to design a switch between internal and external signals as appropriate with a suitable switch. Furthermore, it is suitable to design a light signal to the positions of the signal switch. The last common feature is the creation of suitable descriptions for each I/O and the definition of space for the given descriptions. The requirements can be described as follow:

- Digital inputs - The first requirement is the ability to control all 14 DI using toggle switches and at the same time connect the buttons to at least five inputs in duplicate. The second requirement is to design a circuit containing a light signalling the status of the input signal, which would be active even when an external signal is connected.
- Digital outputs - It is necessary to design a light signal for all remote controllers. Another requirement is to ensure the possibility of setting the voltage level of digital outputs to 24 V, 5 V or the voltage level of an external device in the range of 5 to 24 V.
- Analog Inputs - Design a circuit containing a potentiometer to adjust the input voltage on both AIs and ensure that the voltage level of the input signal is displayed on a digital voltmeter.
- Analog outputs - Create a suitable design of the AO connection to display the analogue value of the current output.

IV. PORTABLE EDUCATION STATION BLOCK DIAGRAM

The portable education station block diagram is shown in Fig. 2. The block diagram also includes its possibilities of connection with external devices.

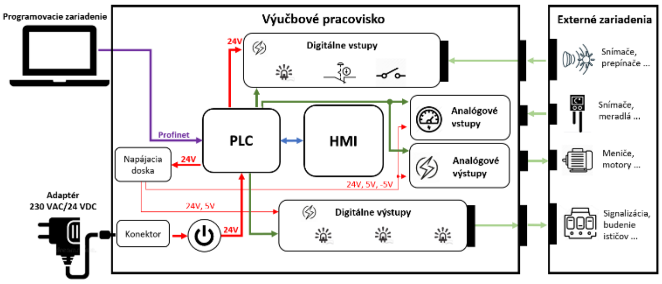

Fig. 2 Simatic PLC S7-1200 (CPU 1215C)

The programming device (PC) is connected to the PLC via the ProfiNet, which is intended for communication via industrial Ethernet. The power supply of the workplace is realized by means of an adapter, which converts the mains voltage to direct current, which is necessary for the power supply of the PLC and its peripherals. The adapter is connected to a connector whose terminals are connected to a switch. This switch can be used to interrupt or connect power from the adapter (Power button). The power supply is connected from the switch to the L + and M terminals on the PLC. The PLC is powered by a "power board", which is used to connect the peripheral countries to the PLC ground. The supply voltage and other voltage levels are also distributed using this board. As can be seen in the figure, the red arrows show the power supply to the peripherals and other components, and the other colours of the arrows show the signal transmission. Inside the teaching workplace block, it is possible to see the peripherals of the PLC for which the printed circuit boards were designed. Their arrangement in the block diagram is similar to the actually designed arrangement.

To the right of the block diagram are the options for connecting external devices to the workplace. Connectors were placed on all PCBs for each I/O. It was advisable to design the location of the connectors so that the connection of external hardware was not complicated and so that it was possible to connect one device to all I/O. For these reasons, the connectors were located in the right part of the workplace. These connectors are shown in the diagram as black rectangles. Pairs of connectors have been designed for digital inputs and outputs. One connector from the pair is located on the PCB and the other on the right side of the board. They can be connected via a flat IDC cable. For analogue I/O, the connector was located on the right side of the PCB. Due to the location of the PCB, it is possible to connect external hardware directly to the AI and AO via the connector located on the PCB.

V. PCBs DESIGN

The control of individual I/O PLCs is divided into internal and external control. It was necessary to design the layout of the components on the PCB so that the components used to control the inputs and signal the outputs were far enough apart. Another important step was to create conductive paths between the components. These paths were created manually with a path thickness of 0.5 mm. In order to save production costs and simplify the design, a polygon was created on each PCB, which was connected to a common ground [4].

First, it was necessary to devise a suitable connection of all PCBs with the ground terminal on the PLC and also to bring voltage from the source to the individual PCBs, so the power supply board was designed, which serves the given purpose. It was also necessary to create voltage levels (5 V and -5 V), which are fed to other PCBs. In Fig. 3 shows the design of a given board with all the components located on it. First of all, it was necessary to bring power from the PLC source to the given board. A two-pin terminal block called "PLC_PWR" is used for this purpose. Furthermore, there are terminal blocks with the names "DO" and "AO_AI" on the board, which are used to supply power and the necessary voltage levels to the PCB. There are also two DC / DC converters on the board. The first converter converts a 24 V DC voltage to a voltage of 5 V. The second converter is used to invert the voltage polarity, converting 24 V to -5 V.

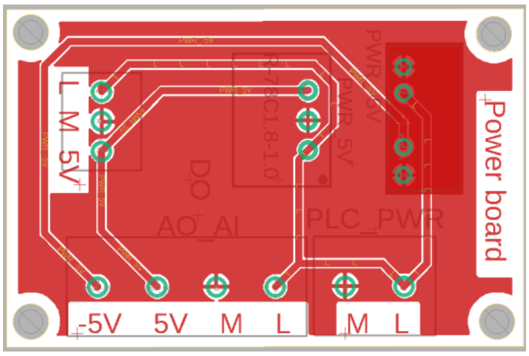

Fig. 3 Power board design

For digital inputs sections for internal and external control is designed. Internal control: In this section, the logic 1 or logic 0 signals are manually fed to the DI PLC. This can be done with 14 toggle switches or 5 buttons. A LED diode is connected to each input together with the switch to signal the status of the input signal. External control: A device that transmits digital signals can be connected via the 26-pin IDC connector. These signals are then processed in the PLC. When a logic 0 signal is applied to the input, it is possible to change this signal to the logic 1 level with an internal switch. In the DI part of the workplace, it is possible to monitor the status of input signals via LEDs even with external control. Digital inputs PCB design is shown in Fig. 4.

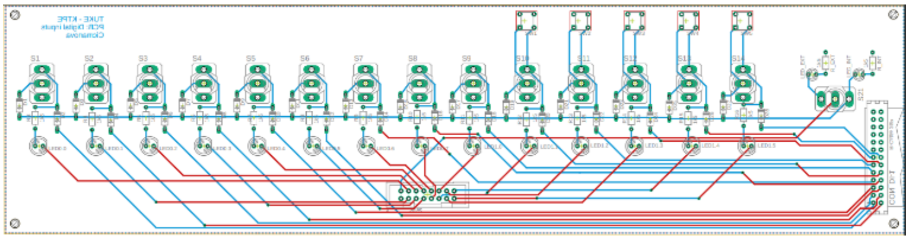

Fig. 4 Digital inputs PCB design

For digital outputs also sections for internal and external control is designed. Internal control: In this part it is possible to observe the change of the state of individual remote control via LED diodes. It is also possible to change the voltage level of the digital outputs. Primarily, this level would be 24 V. By switching the switch to the "5 V" position, a voltage level with a value of +5 V will be applied to the outputs. However, at this voltage level it is not possible to monitor the activity of the outputs on the LEDs. External control: A device that receives digital signals can be connected via the 26-pin IDC connector. It is also possible to supply external hardware via this connector or to supply the required voltage level from an external device to the PLC. As with the internal control, it is necessary to switch the switch when the voltage level changes from 24 V to 5 V. It is possible to supply power from an external device in the range of 5 to 15 V to the digital outputs of the PLC. The digital inputs and outputs PCB design is shown in Fig. 5.

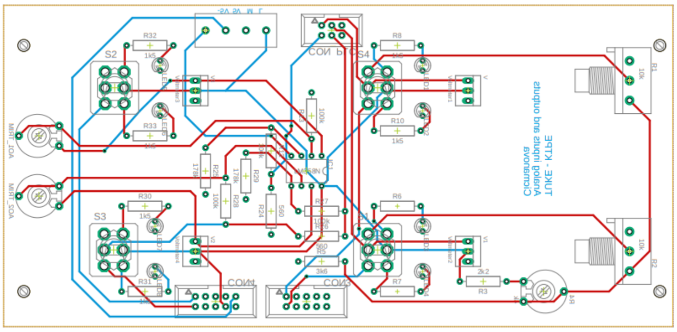

Fig. 5 Analog inputs and outputs PCB design

The analog outputs are current, with the output range from 0 to 20 mA. The current values at the outputs can be changed using potentiometers. It is possible to read voltage and current from the digital voltmeters. The value displayed on the voltmeter is the current value in mA and also the voltage value in V. A device that receives analog signals in the range 0 - 10 V can be connected via a 10-pin IDC connector. It is also possible to supply this device with either 24 V or 5 V via the connector.

VI. VISUALIZATION

After creating the printed circuit boards, it was possible to create a real visualization with the PCBs and other components. When creating PCBs in the Eagle program, these models were added gradually to individual parts and components that did not contain 3D models. It was also necessary to modify the footprint of some parts so that it agreed with the 3D model and, of course, with the real part [2]. The PCBs were placed under the designed worktop. The next step was to add 3D models of PLCs, HMIs and racks. Models of spacers, nuts and bolts have been added to visualize the attachment of the PCB to the worktop. Additionally, 3D models of voltmeters and buttons were created. The visualization model itself is shown in Fig. 6.

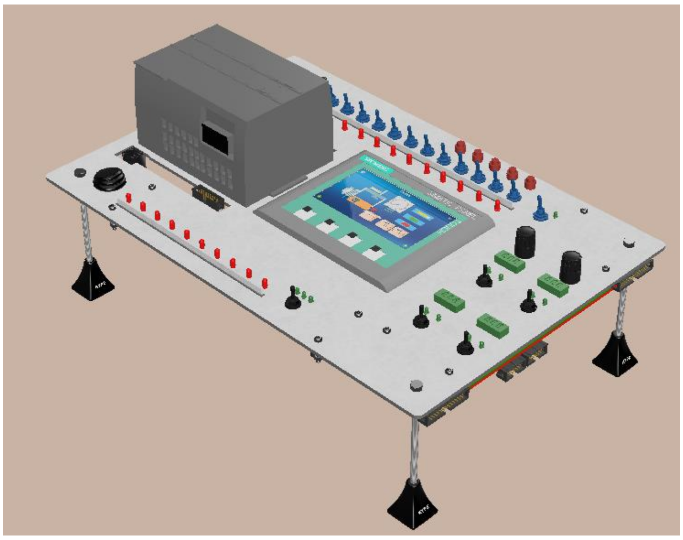

Fig. 6 Visualization of the proposed portable station

VII. Conclusion

This article describes part of the portable education station with PLC SIMATIC S7-1200 design focused to the PCB design. The proposed station is to serve as an educational aid at the Department of Theoretical and Industrial Electrical Engineering, which is part of the Technical University in Košice. The tool will serve as a universal simulator of PLC input/output peripherals. With the help of this workplace, students will be able to practically test their programs for PLC. There is also the possibility of creating additional teaching aids that could be compatible with the proposed workplace. As PLC devices are found in almost every industry, it is possible to create a number of different tools with which it will be possible to connect the proposed workplace. An example of such a tool is an existing device that creates a hardware feedback loop with a SIMATIC PLC. This tool with a microcontroller serves as a production line simulator. When designing the station, the possibility of connection with this external hardware was created. Other interesting tools could be simulators such as an intersection, a crane, a smart greenhouse or a system with renewable energy sources. Furthermore, they could be devices containing various sensors, the output signal of which is either digital (final, fire, motion, etc.) or analog (distances, level, temperature, etc.). Devices that are controlled by binary logic or devices that can be controlled continuously could be connected to the PLC output peripherals. Examples of such devices may be various drivers, e.g., circuit breakers or various drives and converters.

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