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RESEARCHING THE POSSIBILITIES FOR CREATING AN AFFORDABLE PROJECT-ORIENTED LEARNING PROCESS IN THE FIELDS OF AUTOMATION AND INDUSTRIAL COMMUNICATIONS [8]

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Abstract: *The swift and dynamically changing world poses many challenges to the educational system and the engineering schools must be able to keep up with the development pace for the technological expansion to continue. The schools regularly need new more expensive equipment in order their students to develop the necessary operating skills, but their budgets are often over extended and clumsy to change. The science projects are solution, but they consume too much valuable time in bureaucracy and worsen the quality of education. This work presents the findings related to done research on the possibilities for creating an affordable project-oriented learning process in the field of automation, by creating effective setups with low price components. The real-world problem-based learning process is critical for students' development and future work success. The swift development of the microelectronics field allowed the mass production of multitude of affordable electronic devices, microchips, sensors, actuators and even ready to use control objects, but they work on lower operating voltages in comparison to the industrial programmable logic controllers (PLC). The solution is additional buffer circuit boards to be created and such electronic circuits are presented. The conclusion is that nowadays, there are many affordable solutions for the creation of the necessary close to real-world practical setups, but besides their low price, their development and creation consume a lot more work, effort and valuable time, which is deficient indeed.*

Keywords: *Education, Learning, Automation, PLC, Project, Setup.*

INTRODUCTION

Nowadays, we live in a swift and dynamically changing world, where technology develops fast (Schwab, K., 2017). The requirements towards the labour force are changing in all spheres of life (Schwab, K., & Samans, R., 2016; Schwab, K., 2018). The globalization and the resulting numerous processes in various public spheres undoubtedly pose many challenges to the educational system (Denchev, S., Yordanova, S., & Stoyanova, D., 2022). The further the science goes the more effort and resources are needed for lesser achievements. This leads to increasingly more expensive new technological goods and services. In order for the technological expansion to continue, the engineering schools must be able to keep up with the development pace, but often this costs too much money and requires a lot of working time and effort, which the schoolteachers, at least in Bulgaria, do not have available. The school budgets are often over extended and clumsy to change, but they regularly need new equipment because students must manually work with the studied equipment in order to develop the necessary operating skills (Baxter, G., Rooksby, J., Wang, Y., & Hosseini, A., 2012). The only available way for the needed additional financing often are scientific projects that require too much time and effort spent in bureaucracy in order certain financing for necessary equipment to be gained. This leaves engineering teachers without enough time to develop high quality education processes, which in turn is expected to stall the needed future industrial revolution.

The answer to these problems is hidden in the education policy of each separate country, which should assure proper financing for education development and with low level of bureaucracy. The high-quality education of the population is very important for every country

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economic development and for the prosperity of its people. It is a global responsibility for all individuals and governments (Neamtu, D., 2015). The automation engineering education is especially affected by these problems because everything developed for industrial environments is special and a lot more expensive. Affordable technological solutions are needed for the development of effective project-oriented education setups because the few available solutions on the market are too expensive. The automation and industrial communication departments must possess certain programmable logic controllers (PLC), but they also must create different objects for industrial control that develop different skills. The outcome-based education, which includes knowledge, skills and behavior, shows good results and that is why it is being adopted at a fast pace at technical institutions all over the world (Rathy, G., Sivasankar, P. & Gnanasambandhan, T., 2020). At the same time, a study concludes that most of the students are not aiming for high grades, but instead want to learn about the practical skills that they know would be useful after graduation, (Mohd-Yasin, F., 2021), and problem-solving skills are needed not only for their professional (work) life but also for their nonprofessional (everyday) life (Hämäläinen, R., De Wever B., Nissinen, K., & Cincinnato, S., 2019). The current technological revolution allows the creation of many free tools and services that anyone can start using now (Wallenius, L., & Tigerstedt, C., 2022), and while they might help in many subjects, they are not many useful such tools for the automation and industrial communication fields.

The purpose of this work is to present the findings related to done research on the possibilities for creating an affordable project-oriented learning process in the field of automation and industrial communications, by creating effective setups with low price components. Such are needed because creativity and entrepreneurship are two interconnected competencies that are developed by students with work on activities that involve real-world problems solving (Weng, H., Chiu, T., & Tsang, Ch., 2022), and the problem-based learning process is critical for students' development and future work success (Akinoğlu, O., & Tandoğan, R., 2007; Boud, D., & Feletti, G., 1997).

EXPOSITION

Market Search for Affordable Sensors and Actuators

The microelectronics, microsensors, microactuators, and microcontrollers technological fields developed fast in the recent decades. This led to the creation of many comparatively cheap microcontroller development boards and different sensors, actuators, and complexly controlled objects for them, that are widely available today. While the cheapest industrial sensors usually cost over 50 euros, the microcontroller ones often cost about 1-2 euros. The market research led to the conclusion that there is multitude of cheap control devices, besides the common electronic components, as different led modules (Fig. 1), optical sensors (Fig. 2), RPM sensors, electric motors and drive modules for them, different types of relays controlled by sensors, as acoustic, photo, humidity, level relays and others, distance meters, RFID cards and readers, different types of indicators and displays, communication modules, movement detection sensors, compasses and gyroscopes, angle-meters, accelerometers, atmospheric pressure meters, water pumps, flow meters (Fig. 3), lasers and others. Some of these cheap devices are well built, but others are not. For example, the traffic light LED modules (Fig. 1) turned out to be with different resistors on the separate circuit boards, and the different color LEDs glow with significantly different intensities. In this case the different lighting intensities must be adjusted through the use of additional different current limiting resistors. Contrary, the infrared optical sensor (Fig. 2) seems to be quality built and fully functional. Affordable complete control objects are also found as robotic arms (Fig. 4), different types of robots, drones and 3D printers.

The wide range of affordable sensors and actuators allow the creation of the needed diverse project-oriented setups and exercises for a useful education process in the field of automation, but they work on different supply and signal voltages ranging from 3 to 24 *V*, the most common being 5 *V* and 12 *V*. The PLC power supply and operating voltages might be 24 *V* DC, 24 *V* AC, 110 *V* AC, and 240 *V* AC, but the most common is 24 *V* DC. For each standard PLC operating voltage, standard sensors and actuators are created, that connect directly to it without intermediary devices. This is to facilitate the engineers in the design process of the usually complex automation control systems and to ease the maintenance from inexperienced and unacquainted staff. The lower supply voltage of the affordable sensors and actuators require the use of additional power supplies and tailored buffer circuit boards, which complicates the design process of exercise mock-ups.

Fig. 1. Traffic light LED module

Fig. 2. Infrared optical sensor

Fig. 3. Liquid flow meter

Fig. 4. Robotic arm Arduino Tinkerkit Braccio

Buffer Electronic Circuit Design

An example buffer electronic circuit board for connection of low power sensors and light emitting diodes to Siemens S7-300 PLC is presented in Fig. 5. It is going to be integrated in currently developing exercise setup, representing a traffic light crossroad and smart street light control system, as part of a smart city. It will allow about 36 traffic lights and 8 sensors to be connected to the PLC and in addition the luminous intensity of all lights could be controlled in two steps. The designed buffer circuits are presented in Fig. 6.

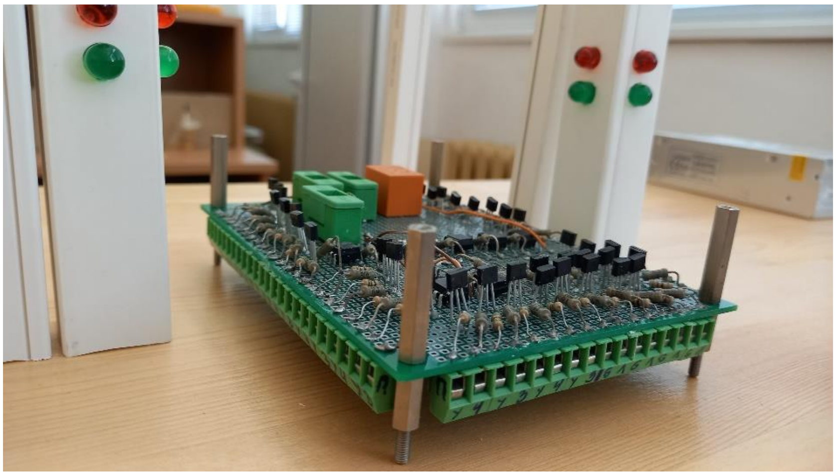

Fig. 5. Designed buffer electronic circuit board

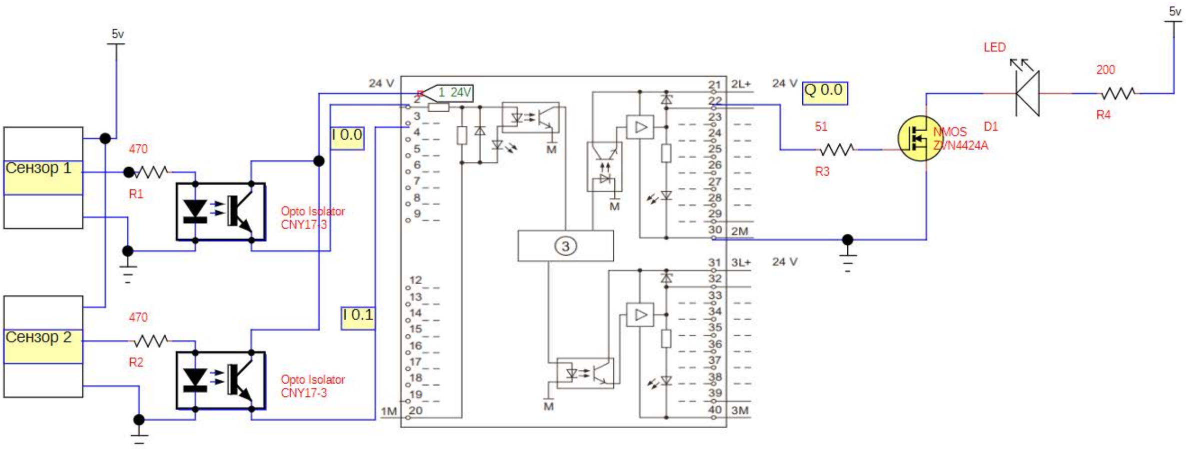

Fig. 6. Example buffer electronic circuits connected to inputs and outputs of Siemens S7-300 PLC

The sensors, powered by different power supplies, must be connected through optocouplers to prevent short circuit. For the connection of the LEDs, MOS transistors ZVN4424A with high Ugs voltage have been selected. The problem with this circuit is that in the initial design process it has been omitted that the Siemens PLC outputs require minimum load current of 2 *mA* for stable operation. This requirement leads to the conclusion that bipolar transistors would have been the better choice instead of the chosen MOS ones. In this case the board is already created and it will be modified by connecting additional resistors of 11 *k*Ω between the gates and the sources, which will provide the required minimum current.

CONCLUSION

This work presents the findings related to done research on the possibilities for creating an affordable project-oriented learning process in the field of automation, by creating effective setups with low price components. The real-world problem-based learning process is critical for students' development and future work success. The swift development of the microelectronics field allowed the mass production of multitude of affordable electronic devices, microchips, sensors, actuators and even ready to use control objects, but they work on lower operating voltages in comparison to the industrial PLC. The solution is additional buffer circuit boards to be created and such electronic circuits are presented. The conclusion is that nowadays, there are many affordable solutions for the creation of the necessary close to real-world practical setups, but besides their low price, their development and creation consume a lot more work, effort and valuable time, which is deficient indeed.

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