

THE MODERN CONTROL SYSTEM DESIGN TEST STAND FOR TEACHING ENGINEERING STUDENTS

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Abstract: In the following article a detailed description of a laboratory station which is used to broaden engineering students' knowledge of control system design is given. Exact construction details of the station have been presented along with its 3D model and wiring diagram. Multiple figures have been included in order to illustrate the whole process of developing the before mentioned laboratory stand in order to clarify the undertaken design approach. Also, students' skills and knowledge developed with use of the devised laboratory station are presented.

Keywords: teaching engineering students, control system, laboratory test stand, PID, dSPACE, Simulink.

Introduction

In everyday practice of automation or electrical engineer it is essential to be able to properly design and create control systems for various processes. This skill can be achieved by different methods of learning. The most effective is practice during laboratory classes.

In many cases it is impractical to teach students' on industrial objects which are controlling real processes. The best and commonly used solution of this problem is to build special laboratory test stand [1, 2] that requires the same treatment as the real process.

The main goal of developed laboratory stand was to introduce students to the thermal

processes control and increase their ability to solve real world problems in the field of automatics. Besides its didactical purposes, the plant can also be used in research of advanced control algorithms for thermal processes.

One of the requirements set for the laboratory station was its universal nature and capability to work with different control systems. Moreover, compact design and small size would ensure its portability and ease of installation. A very important issue is the safety of end-user from both thermal and electrical hazards. The first is ensured by operating temperature that minimizes the burn risk, the second by low system voltage. Other parameters (i.e. heat capacity, heater power, disturbance magnitude) have been selected in order to represent a behavior of real world process, while acknowledging the limited time allocated for the class.

The plant described in this article has been developed for the didactical purposes in West Pomeranian University of Technology in Szczecin for the students of Automatics and Robotics, Electrotechnics and Teleinformatics. The stand is used in many courses (e.g. Rapid Control Prototyping, Design of Discrete Systems, Fundamentals of Automatics) in order

to enhance the learning experience in the area of thermal process algorithm development. Previously, all students activities were focused around computer simulations as opposed to the real object interaction that is enabled by this station. Additionally, practical and manual skills are developed by letting the student connect the plant himself to the instrumentation and control equipment. This enables measuring thermal and electrical signals necessary to the successful completion of the exercise.

Laboratory station description

Block diagram of presented laboratory station is shown in fig. 1.

To obtain required functionality, the test stand consists of six basic elements:

- heat chamber where all actuators and sensors are placed,
- source of heat (30W halogen lamp),
- disturbance source (fan),
- temperature sensor (thermistor),
- power circuit with supplementary components,
- analog and digital I/O interface.

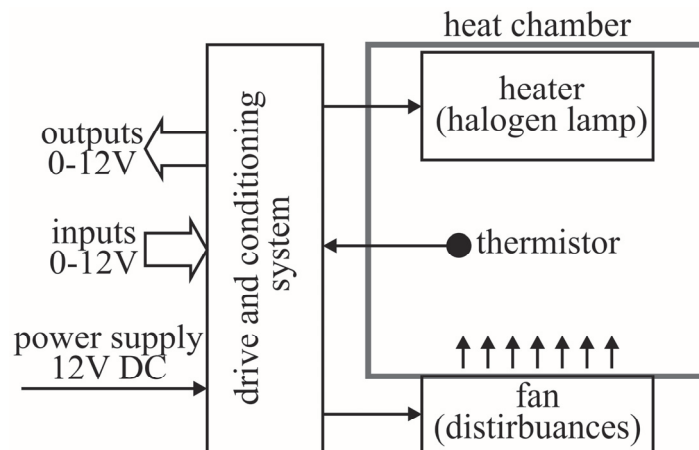


Fig. 1. Test stand block diagram.

The whole project saw an extensive use of computer aided design software (CAD) at practically every stage of its inception. Using *SolidWorks* a complete spatial visualization of the laboratory object has been achieved. Furthermore, using this software has enabled for precise allocation of the plant's elements in

regards to their size, shape and placement long before the plant's manufacturing. This approach has proven to be effective from an economic point of view: both time and material costs have been reduced.

Plexiglas has been used as a material of choice due to its relatively low weight, cost and ease of

machining. What is more important is its transparency which allows the continuous observation of the process. Figure 2 presents

3D view of the laboratory station project developed in *SolidWorks* software.

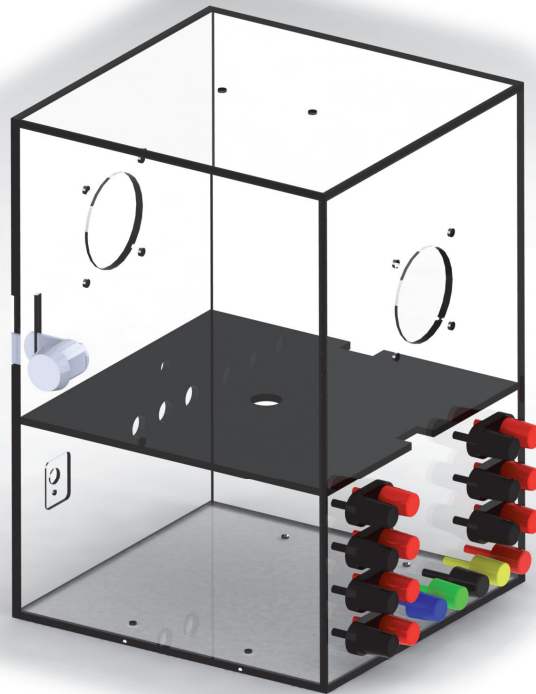


Fig. 2. 3D view of designed test stand.

The laboratory station has to be compatible with major industrial interfaces as to allow process control via different means. The station is powered from 12V DC, its inputs can accept signal from 0 V to 12 V. Output temperature

signal is also from 0 V to 12 V. To achieve that range of input and output signals drive (fig. 3.) and conditionings (fig. 4) circuits were designed. The same drive circuits are used for heater and fan control.

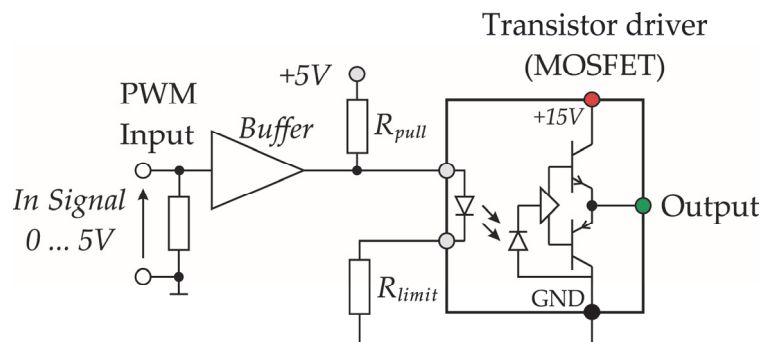


Fig. 3. Drive circuit.

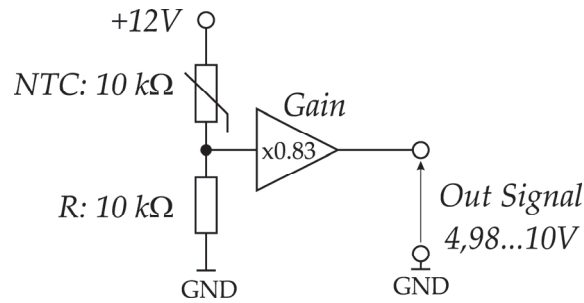


Fig. 4. Temperature conditioning circuit.

For schemes from fig. 3 and 4 development of an electronic circuit is necessary. The project of the circuitry was developed using EAGLE software dedicated for that purpose. This simplifies the process of meeting requirements that have been set for this part of the design process. User safety and resilience to user caused errors (e.g. reverse polarity, incorrect wiring of analog and digital I/Os) were both major issues in those considerations.

Case study

The overall method of operation of the described laboratory stand is based on controlling of the halogen lamp which is a heat source. Its activity or lack it is the source of temperature change inside the heat chamber. Control of the lamp is achieved using pulse-

width modulation (PWM) technique supplied through the electronic circuit. Temperature measurement is based on acquiring the resistance of the thermistor which is inside heat chamber and its temperature equals temperature inside chamber. The fan installed in the chamber is the source of disturbance and can be controlled using the same method as the halogen lamp (PWM). Its main purpose is the introduction of temperature fluctuation inside the chamber. This presents another difficulty for control system design.

Complete laboratory station including the before mentioned thermal object requires the usage of external control and measurement system. In the presented case, dSPACE1104 [3] is used which contains analog and digital I/O interface. Complete test stand, connected to the dSPACE system is presented in fig. 5.

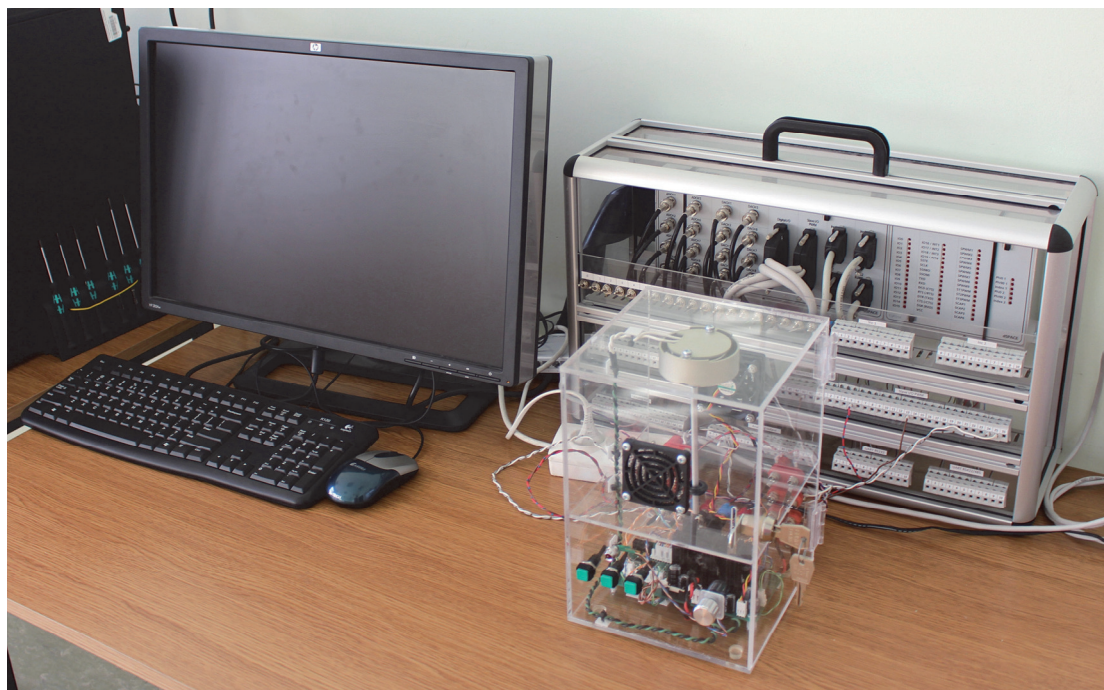


Fig. 5. View of test station connected to the dSPACE control system.

The student's task revolves around the creation of an appropriate control algorithm of thermal process [4, 5] with regards to requirements set out in the exercise card. In order to do so, the student must utilize the already acquired programming skills in Matlab/Simulink [6] environment where the process modeling takes place. This model is later transitioned to Control Desk software which controls the dSPACE interface. It is there, where the student has the ability to view all signals of the process (e.g. temperature, voltage, PWM value), modify them and save their values on the computer's hard drive. In this approach to the programming

of hardware platforms, known as Rapid Prototyping, the student can easily change the control system algorithm both in the software and hardware layer.

Commonly used in industry for control of the process temperature is proportional-integral-derivative controller (PID controller) [7, 8]. Block diagram of control loop that is used during didactic classes to control temperature inside test stand is shown in fig. 6. Use of Simulink software connected with dSPACE gives possibility to implement complex control algorithms that can have better parameters than typical PID controller.

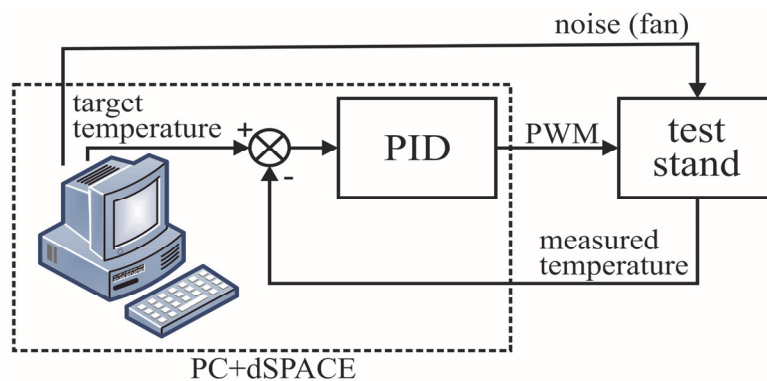


Fig. 6. Block diagram of control loop that can be used to control temperature.

Simulink diagram that is used for temperature control during laboratory classes is shown in fig. 7. Modification of this diagram gives

students' possibility of getting familiar with control systems prototyping and notice changes in controlled system responses.

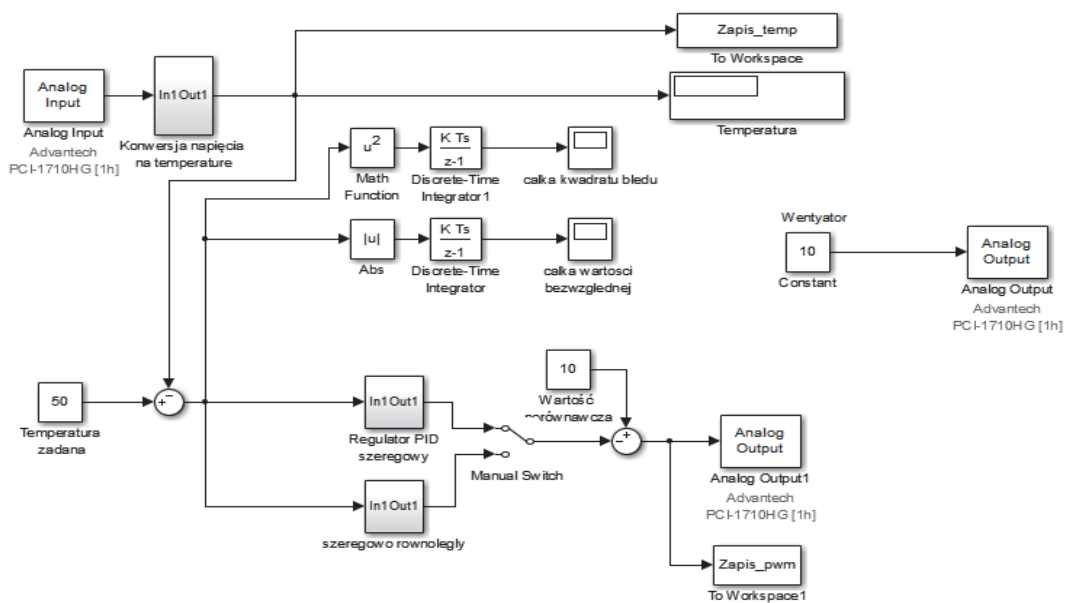


Fig. 7. Simulink diagram used in temperature control trough dSpace.

Example response of real object (test stand) and simulated response, for inertial object is shown

in fig. 8. There can be noticed difference between simulated and real response.

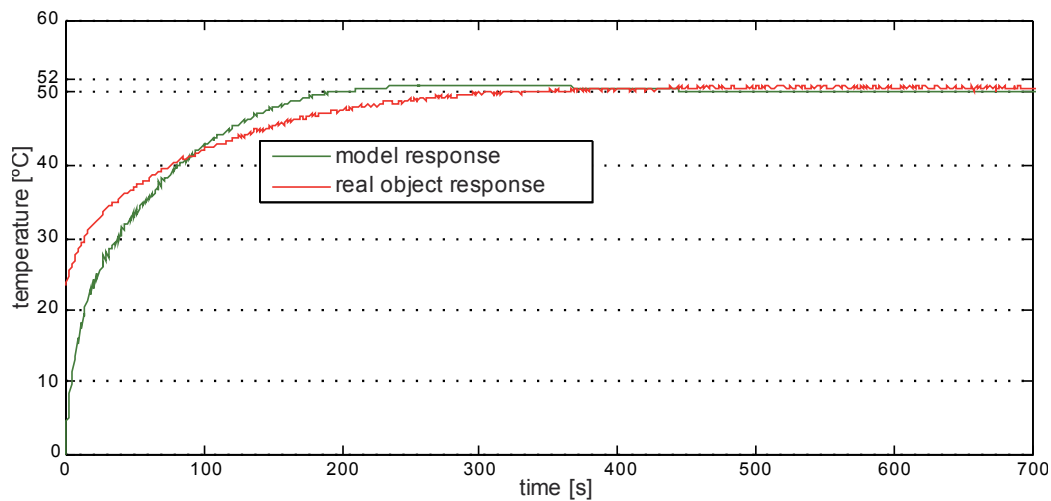


Fig. 8. Example of real object response and model response.

Learning Outcomes

The most basic skill acquired by student during the class, using presented laboratory station is the ability to design a control system for a thermal process. Moreover, the necessity to connect the control and measurement system to the object allows for development of practical and manual skills. The student should also acquire the knowledge in rapid control prototyping, its usage and design process.

During the class much of the work is done by interacting with modern software environments such as Matlab and Simulink. The development with these tools leads to increase in overall programming competence. Also noteworthy is the familiarization of students with modern industry tools and standards.

Not only the design of control system is learnt but a much broader insight into the problems of thermal object control is provided. This includes correct interpretation of received results. During the class students learn how to interpret and convert particular electrical quantities.

Verification of acquired knowledge is done by submitting a lab report in which student is

expected to describe the procedure of the exercise and analyze its outcome while providing and adequately presenting all crucial measurement data.

Conclusions

The laboratory stand described in the paper is successfully used for didactical purposes in Faculty of Electrical Engineering at West Pomeranian University of Technology in Szczecin, mainly for classes in industrial automation.

Due to its physical nature, the problems of process control are easily illustrated without referring to computer aided simulations. The learning process based on scaled down physical process allows for better understanding of complexity of process control as well as deepens students' immersion in the class. The fact of interaction with a real world problem provides a challenge in itself for students. Not only the interdisciplinary knowledge (i.e. automatics, mechanics and information technology) is required and tested but also its practical application which provides an invaluable experience.

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