REMOTE MONITORING OF CO-FIRING FURNACES

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Abstract. *This article deals with the software and hardware design of a measurement and logging system for two older co-firing furnaces PEO 601 and PEO 602, which are still in use at the Department of Technologies in Electronics and which need to be monitored remotely. The furnaces from the technological point of view matches the requirements of the laboratory experiments and technological processes provided at the department, but we need the ability to monitor and log the actual temperature in them, as well as to check, if the temperature during the co-firing process was in correspondence with the defined profile of it.*

Keywords: remote monitoring, remote sensing, microcontrollers

ZDALNY MONITORING KOTŁÓW DO WSPÓŁSPALANIA

Streszczenie. *W artykule opisano projekt oprogramowania i sprzętu systemu pomiaru i rejestracji dla dwóch starszych kotłów do współspalania PEO 601 i PEO 602, które są nadal w użyciu na Wydziale Technologii w Elektronice, i które powinny być monitorowane zdalnie. Kotły z technologicznego punktu widzenia odpowiadają wymogom badań laboratoryjnych i procesów technologicznych na Wydziale, ale wymagana jest możliwość monitorowania i rejestracji ich rzeczywistej temperatury, a także możliwość sprawdzenia, czy temperatura podczas współspalania jest zgodna ze zdefiniowanym profilem.*

Słowa kluczowe: zdalny monitoring, zdalny pomiar, mikrokontroler

Introduction

Every step of a laboratory experiment oriented on the field of technologies in electronics requires some technological equipment to be used. Different equipment is needed for preprocessing e.g. an LTCC structure, other for realization and other for post processing.

Evolution brings new features of laboratory equipment. Some of these features positively affects the result of the work (e.g. higher precision, higher speed of work, larger size of working area, etc.), other features increase the comfort of usage (comfortable user interface, ability of remote control, etc.).

Programmable co-firing furnaces PEO 601 and PEO 602 were made in 1992 and are still in use at our department. They are still working correctly and are able to ensure the predefined temperature in predefined time interval, what means, that we do not need to change them from the functional and results quality point of view. Only requirement, which they don't meet, is the ability of logging and remote monitoring. Because new types of LTCC material systems with longer co-firing process (e.g. DuPont Green Tape 9K7 with up to 26,5 hour co-fire profile (Fig. 1)) are used at the department, we need to monitor the whole co-firing process remotely. We also need to get information about the real co-firing profile to compare it with the predefined profile.
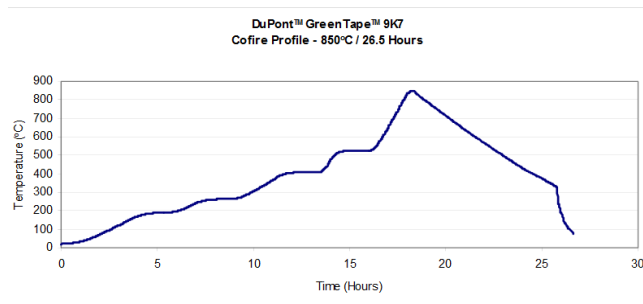

Fig. 1. Co-fire profile of the DuPont Green Tape 9K7 [4]

1. Monitoring system description

1.1. Communication interface of the furnaces

Both furnaces has a recorder output (GND and VCC), which provides information about the actual temperature in analogue form, represented by voltage in range from +0.01V to 1V, which is equal for temperature in range from +10 °C to +1000°C. This means, that the temperature can be measured by a voltmeter with accuracy of 1mV, while every 1mV represents 1°C

of temperature. We do not need this detail accuracy of the measurement; the measurement tolerance around 5°C is more than acceptable.

The hardware of the communication interface is represented by a 5 pin DIN 45322 connector. The pin output is the same for both furnaces. The GND is represented by pin 1, and the positive voltage is represented by pin 2 (Fig. 2).
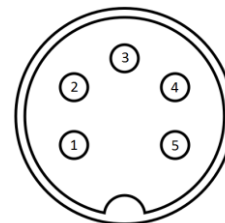

Fig. 2. 5 pin DIN connector - pin-out of the furnaces PEO 601 and PEO 602 [1]

To read remotely the accurate temperature inside the furnace, we need to remotely measure the voltage at the furnaces communication interface and provide the measured data through computer network.

On the market there is available a huge number of multimeters or temperature meters, which can be controlled remotely through network. They are accurate, but high cost, as well. Using them for the described purposes is overmuch. Because the dedicated multimeters are mostly closed system, they are not extendable and cannot be used for monitoring the other parameters of the laboratory environment. They also do not meet our future plans for extending the monitoring system with the option of remote control as well as for automatically turn of the system in defined critical situations.

1.2. Hardware design of the remote measurement tool

For our purposes, we used the well-known and documented microcontroller platform, Arduino. Our selection was supplied by the huge number of examples available on the web for this platform, which increases the development process and shorten the time from scratch to real usage.

The Arduino platform is open-source, what means, that we can modify it without serious limitations. For the prototype of our application, we have used the Arduino Duemilanove compatible prototyping board, which contains an Atmel Atmega 328p microcontroller, 16MHz oscillator and implemented USB port, 6 analog and 13 input/output ports. The board can be supplied with DC in range between 7V and 12V.

The microcontroller embedded to this Arduino board has a built-in analog to digital converter (ADC) with 10 bit resolution. The microcontroller is able to measure voltage in specified range, mostly between 0V and +5V, which is represented by an analogue value between 0 and 1023. This provides us the resolution of 0.00488V (Fig. 3). The range of the represented voltage can be modified by the value of the reference voltage, which should be between 0V and +5V. A lower reference voltage increases the resolution of the measurement. In ideal case, a 1,023V reference voltage provides the most accurate measurement of the temperature in our co-firing furnaces, but this solution requires additional hardware to guarantee the accuracy of the reference voltage.

The on-chip Analog-to-Digital Converter of the selected microcontroller (Atmel Atmega 328p) have accurate integrated 1.1V ADC Reference Voltage.

$$Voltage = \frac{AnalogValue}{1023} \times ReferenceVoltage$$

Fig. 3. Equation for the Analog Value to Measured Voltage conversion

The internal reference voltage 1,1V is very close to the value, which would be ideal for us (1,023V), when each value of the Analog Value represents 1mV or 1°C. The internal reference voltage can provide us high measurement accuracy, which is sufficient for our need. The resolution using the internal reference voltage is 0.00107V.

To provide computer network connectivity for the Arduino board, there is a huge number of Ethernet controllers. We have selected the integrated network controller ENC28J60, which can provide 10Mbps network connectivity, are cheap and can be easily connected to the Arduino board through SPI interface. The limitation of this controller compared with other most used controllers is the bandwidth of the communication, which is not important for us, because we need to transfer only a few Bytes of data. One of the biggest advantages of its usage is the easiness of use. The chip is available in 28pin DIP package, and needs only a few additional peripheral components. Its big advantage is also the SPI interface, which can be easily used for communication.
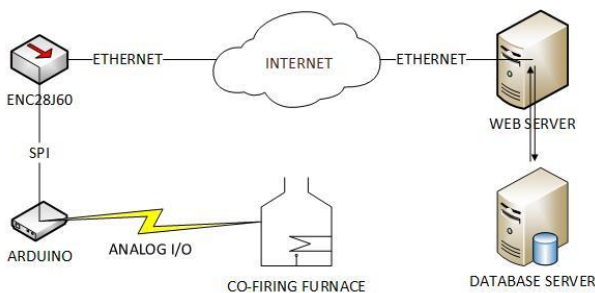

Fig. 4. Communication and data-flow during the temperature measurement

The selected Arduino board allows us to extend the measurement system in the future. Our solution uses only 5 digital I/O ports for the SPI communication and 1 analogue I/O port for the analogue input for voltage measurement. We have still a lot of free I/O ports for future extending of the measurement system with e.g. additional temperature sensor (to check the accuracy of the furnaces thermistors), safety remote turn off option, laboratory environment conditions monitoring (external temperature, barometric pressure and humidity), etc.

1.3. Software design of the remote measurement tool

As every electronics based on microcontrollers, the heart of our measurement system is its firmware. Our measurement and monitoring system can be described as a server-client application. The measurement hardware acts as a client, which is sending the measured data to the server, which is running in 24/7 regime, and is online always.

Generally, we have two options, how to provide the measured data through the computer network. The main difference between the two options is the role of the measurement sys-tem, if it acts as a server or a client. In the first case, the measurement system provides a HTML page, which contains information about the measured data. Because the microcontroller has limited performance, we need to interrupt the running process to handle the HTML request. This can affect the measurement and does not guarantee the accessibility of the measured data.

The second option is to work as a client system. The hardware measures the temperature continually and at the end of the measurement cycle, the system sends it in form of HTML GET requests (Fig. 5) to the server on specified time interval. The interval of the request can be defined by the It is able to convert data at up to 15kSPS at Maximum Resolution [2].

http://kte.fei.tuke.sk/Vila/remote/PEO_602/
get_values.php?id=12&seq=56&seconds=2&
value=1024&pwd=password

Fig. 5. GET request providing data (id, sequence number, seconds, value, and password)

On the server side, there is a PHP script, which is called by the GET request and which parses out the strings containing data from it. The extracted data are loaded to a CSV with the actual timestamp, which can be used in the future for processing and generating outputs in different form.

This design of the application minimizes the delay between two measurement data processing, because the microcontroller does not need to be interrupted with any HTTP requests from external side. External HTTP requests are awaited only during the configuration of measurement device. Once the measurement is activated, it will run until the next reboot, or until the predefined time interval for the measurement expires.

The measurement device can be configured also through its USB port, in this time only by changing the static variables in the well documented source code.

Every measuring board has its own unique hardware number. There is also a counter stored in the EEPROM, which is incremented on every startup of the board. The combination of the unique board ID and the sequence number gives us a unique number, which can be used for identification the measurement.

The PHP script on the server side extract the board ID and the sequence number, and check, if any CSV file with this filename exists. If yes, the received data are stored to this file. If not, a new file is created with filename <board_id>_<sequence_number>.CSV. After the data are stored to the file, another script extracts the actual image from the connected IP camera, which provides overall view to the control panel of the furnace.

The actually received data are stored to a separate file, too. This file contains the actually measured values, as well as the filename of the actually used .CSV file.

For drawing interact line charts from the measured data, the libraries from [3] are used. As the input file, the script uses the actual .CSV file.

1.4. Monitoring of the furnaces

Because of high temperatures, the usage of the furnaces without keeping eyes on it is a potential security risk. For this reason, we have integrated to our system a control panel, which is accessible from any web browser and which contains the actual temperature in the furnace, the length of onetime of the system as well as a live video stream from an IP camera (Fig. 6), which is placed in front of the furnaces.

Fig. 6. Screenshot from the first part of the user interface – image from the attached IP camera with date and time information
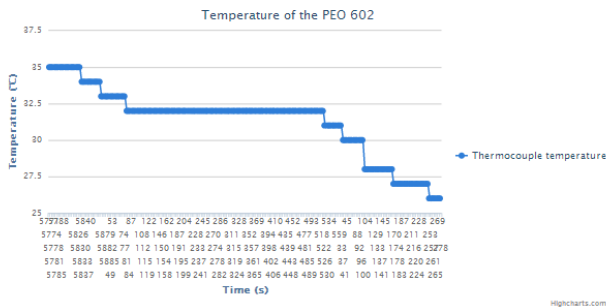

Fig. 7. Screen shot from the second part of the user interface – actual temperature, time counter and the line chart draw from the measured data

2. Logging feature and generation of output in graphical form

Every measurement is saved into separate log file in .CSV format. The filename of each log file is determined by the combination of the board ID and the sequence number, which is incremented during every startup. The saved log file can be post processed, imported to e.g. Microsoft Excel for future processing or processed in other ways.

3. Conclusion

The described remote measurement and logging system provides new facilities for the older laboratory equipment and allow us to integrate them to our virtual laboratory. The system allows to remotely monitoring the actual co-firing process. It can be easily extended by the ability of remote controlling the power supply of the furnaces, what should be useful in case of emergency or malfunction of the furnaces.

The generated output can be easily processed by any kind of software, which can import .CSV files, as well as the draw charts can be used for quick check, if the co-firing process was in correspondence with the predefined co-firing profile.

Bibliography

[1] 5 pin DIN connector, http://upload.wikimedia.org/wikipedia/commons/b/ba/DIN-5c_Diagram.svg
[2] Datasheet of the Atmel Atmega 328p, http://www.atmel.com/devices/atmega328p.aspx
[3] Highcharts JS – Interactive JavaScrip charts for your web projects, http://www.highcharts.com/
[4] Technical Data Sheet of DuPont™ Green Tape™ 9K7 Low Temperature Co-Fired Ceramic System, http://www2.dupont.com/MCM/en_US/assets/downloads/prodinfo/GreenTape9K7DataSheet.pdf

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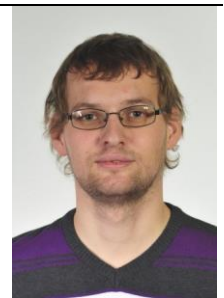
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