JOURNAL OF CHEMICAL EDUCATION

Technology Report

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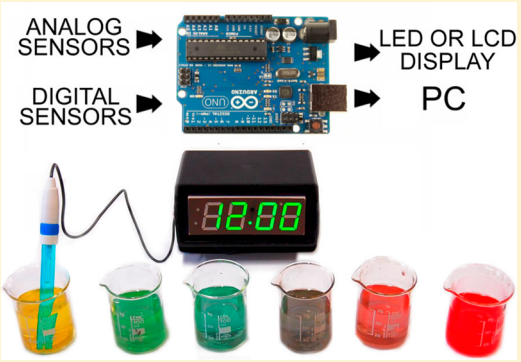
ChemDuino: Adapting Arduino for Low-Cost Chemical Measurements in Lecture and Laboratory

Štěpánka Kubínová and Jan Šlégr*

Department of Physics, Faculty of Science, University of Hradec Kralove, Hradec Kralove, Czech Republic 50002

Supporting Information

ABSTRACT: In everyday praxis, we often need demonstration measuring devices (thermometers, pH meters, etc.), with large enough displays to be easily readable from every point in the classroom. Here, we present some of the capabilities of the Arduino platform for the school environment. This microprocessor board can be used for inexpensive construction of measuring devices for demonstrations and experiments performed by students in chemistry.



KEYWORDS: *High School/Introductory Chemistry, Laboratory Instruction, Hands-On Learning/Manipulatives, Laboratory Equipment/Apparatus*

INTRODUCTION

When teaching chemistry we employ two kinds of experiments: demonstrations and student experiments. In the first case, teachers can use a measuring device, whether in connection with a computer (to display the results on a data projector, to see graphical representation of dependencies, further data processing, etc.) or without, in which case it is necessary to have a demonstration device with a large enough display: for example, a pH meter or thermometer. In the case of student experiments, pupils carry out experiments independently. In this case, the use of electronic measuring devices for measuring is also possible.

In this technology report, we introduce a device that can be used as a demonstration measuring device, as a computer interface, and as a basis for students to make measurements.

ARDUINO

Arduino[1] has recently become a quite popular microcontroller board based on the ATmega328 microprocessor with a variety of interfaces. The processor can be programmed using a very simple programming language called Wiring.

Owing to the popularity among enthusiasts, the price of this board is relatively low, which is a considerable advantage for school use. A wide range of input and output devices is also available.

Analog inputs of the board can process signals from sensors, whose output quantity is voltage (e.g., temperature sensors, pressure sensors). Digital inputs process data from digital sensors (e.g., thermocouple amplifiers with digital output, pH meters, etc.). A number of digital sensors are available for measuring various physical quantities. It is possible to purchase inexpensive "breakout" boards, which are usually small printed circuit boards containing the sensor itself and sometimes other circuits (signal amplifier, AD converter). These boards easily connect to the Arduino and circuitry to communicate via One-Wire or I2C bus.[2] The digital outputs of such cards can be used for demonstration purposes: the LED display with large (dot matrix) digits can be connected to the digital outputs of the card; for student experiments, an LCD display can be used. Data measurements can be stored on an SD card or sent to a PC via the USB port.

The possibilities of open source hardware and software are quite broad; recently published articles describe usage of the Arduino board in lab automation for the control of a thermal cycler for PCR[3] and construction of an inexpensive electronic buret.[4]

CHEMDUINO

By the term "ChemDuino" (portmanteau of "chemistry" and "Arduino") we mean the general practice of applying the Arduino hardware and software (e.g., Wiring and OneWire) to improve chemistry teaching and learning.

We have described elsewhere[2] the hardware required to build various instruments: thermometers with a range of −80 to 120 °C and −200 to 1400 °C; a pressure gauge; and a pH meter.

To construct a demonstration measuring instrument requires an Arduino board (the least expensive version costs $10) and

DOI: 10.1021/ed5008102
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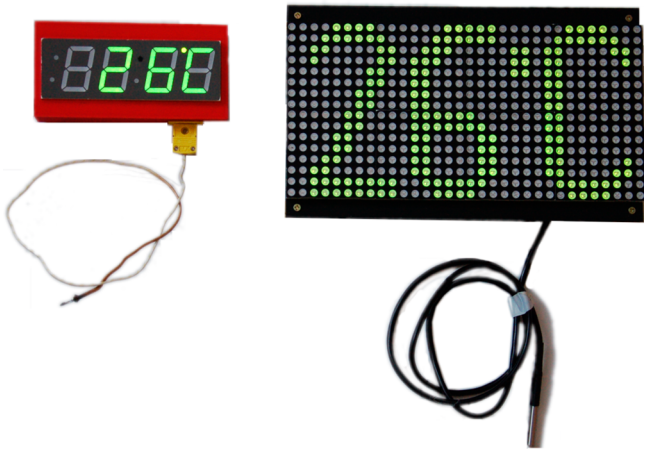

Figure 1. Two thermometers (to scale) with (left) thermocouple and 1.2 in. LED display, and (right) digital sensor and 5 in. dot matrix display.

Figure 2. Setup of a demonstration pH meter with LED display of pH values.

an LED display with digits 1.2 in. (3 cm) in height[5] or a 5 in. (12 cm) dot matrix display.

See Figure 1 for two digital thermometers built with ChemDuino. The left photograph shows a thermocouple thermometer with range of −200 to 1400 °C and a 1.2 in. (3 cm) LED display; pictured on the right is a thermometer with a digital sensor DS18B20 capable of indicating a temperature in the range of −80 to 120 °C and a 5 in. (12 cm) LED dot matrix display.

A demonstrational pH meter (Figure 2) can be used in various situations; for example, to measure pH values of color transitions in anthocyanin dye (a well-known pH indicator[6] that can be easily extracted from red cabbage and is usable from pH 2 to 12) or in tea. (Grandmothers told us that black tea with lemon is somewhat weaker, because it is lighter in color; with a few grains of baking soda of course it turns dark again.) This pH meter can be used also in a popular laboratory exercise: the determination of phosphoric acid in cola beverages.[7]

CONCLUSION

All described devices can be assembled easily. See Figure 3 for the wiring diagrams of the aforementioned thermocouple thermometer and pH meter. Students in a science or a technical club at school can readily construct, for example, a demonstration meter that the teacher will need next week, at a price significantly lower than the price of similar equipment from commercial suppliers.

Diagrams, photographs, and equipment program source codes in the Wiring programming language, as well as instructions on uploading code to the Arduino card are available.[2] We welcome comments from teachers and ideas for further demonstrations and student instruments.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/ed5008102.

Wiring diagrams and source codes for ChemDuino devices (PDF, DOCX)

AUTHOR INFORMATION

Corresponding Author

*E-mail: jan.slegr@uhk.cz.

Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

This work was supported by the SV PřF UHK nr. 2104/2014.

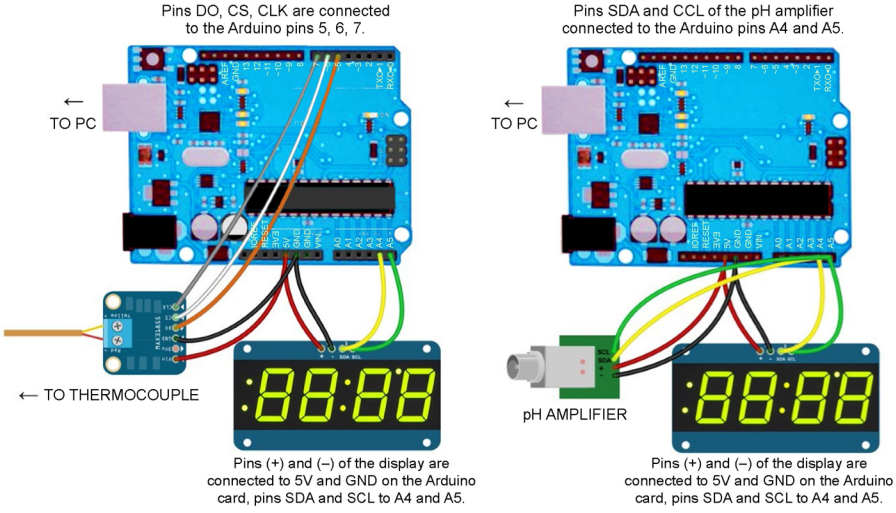

Figure 3. Wiring diagrams for a thermocouple thermometer and a pH meter.

DOI: 10.1021/ed5008102
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