Journal of Physics: Conference Series

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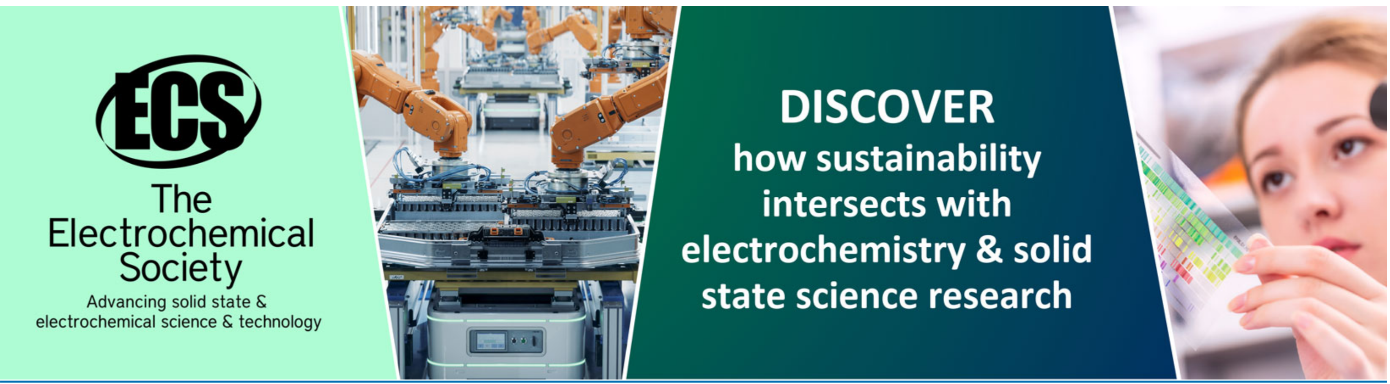
To cite this article: Oldřich Slavata *et al* 2013 *J. Phys.: Conf. Ser.* **459** 012059



Journal of Physics: Conference Series **459** (2013) 012059 doi:10.1088/1742-6596/459/1/012059

New Concept of Laboratory Exercise on Temperature Measurements Using Thermocouple

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Abstract: The proposed exercise is focused on the measurement of temperature using thermocouple, students acquire theoretical knowledge of the Seebeck effect, the design and application of thermocouples including the differences between their various types. The students measure the voltage at the thermocouple by various methods: directly with a compensation box, using operational amplifiers and USB module. The exercise explains also general principles of low voltage measurements, error compensation and uncertainty evaluation.

1. Introduction

1.1. Exercise positioning
Laboratory exercise thermocouple, measuring its voltage, junction temperature compensation is part of Labs on Sensors and Measurement. The course is compulsory for students of disciplines: Robotics, Sensors and Instrumentation and Control Systems and a Bachelor's degree Cybernetics and Robotics. Students of other disciplines may enroll as an optional subject.

1.2. Exercise history
Scope of Sensors and Measurements follows the past subject Sensors and Transducers. One of its laboratory exercises used to be the temperature measurement using thermocouples [4]. In this task, the students were asked to measure the temperature in a furnace in the range of 20-100 ° C using a K-type thermocouple. One thermocouple was connected to a transducer 101 XTR manufacturer Burr-Brown (USA), the converter converted the thermocouple voltage to current in the range of 4 - 18 mA. The task of the students was to suggest the resistor values so that the output current range corresponded to the range of measured temperatures. The second thermocouple was connected to the measuring module Janascard AD 232, module containing 18bit integrating AD converter and isothermal terminal block, the data were transmitted to a computer via RS232 bus.

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For the needs of a new course the laboratory exercise was substantially upgraded with emphasis on measurement of small voltages (tens of μV) and on the uncertainty calculation of such measurements. Also, multiple thermocouple types have been added.

2. Exercise description

The task of the students in this exercise is to measure the voltage at the thermocouple by different methods and to evaluate the accuracy and uncertainty of these measurements. List of thermocouples is given in Table 1.

Table. 1 List of thermocouples

Type	Sensitivity [μV/°C]	Temperature range	Material	Attachment
E	68	-100 - +1000	Chromel/Constantan	screw
J	55	0 - +760	Iron/Constatntan	sticker
K	40,8	-200 - +1370	Chromel/Alumel	screw
T	43	-160 - +400	Copper/Constantan	magnetic

The advantage over the previously taught exercise [4] is the use of multiple types of thermocouples with different mountings to the object to be measured. In similar tasks taught at the University at Buffalo [5], or the Polytechnic Institute of New York University [7] only one type of thermocouple is used. A similar exercise with multiple types of thermocouples is taught in Portland State University [6].

The measured object is a table lamp shade in temperature range between 0-70 ° C.

2.1. Measurements using a digital multimeter

In this part of the task, students will gain awareness of the size of the output voltage of the thermocouple and the size and speed of change of output voltage with temperature changes. This is an advantage compared to tasks that use only measurements using the AD converter with subsequent data processing machine [5, 6]. Procedures for measuring low voltage that students learn are quite universal and applicable in other structures than the thermocouple measurements. A similar task using basic measuring instruments is taught at the Faculty of Engineering and Technology, University of Jodan [8].

2.1.1. Direct measurement. Task is to measure the voltage at the thermocouple directly using a multimeter manual Mastech MY-64 and laboratory Agilent U3401A multimeter. Wiring diagrams is shown in Figure 1. The junction temperature (the temperature in the laboratory) measured by means of bimetal thermometer must be taken into account when calculating the temperature.

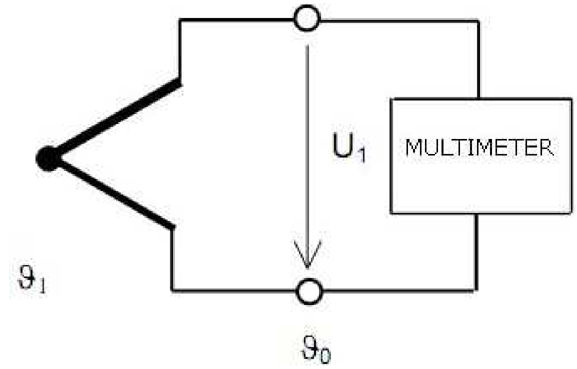

Figure 1. Wiring diagram of direct measurement

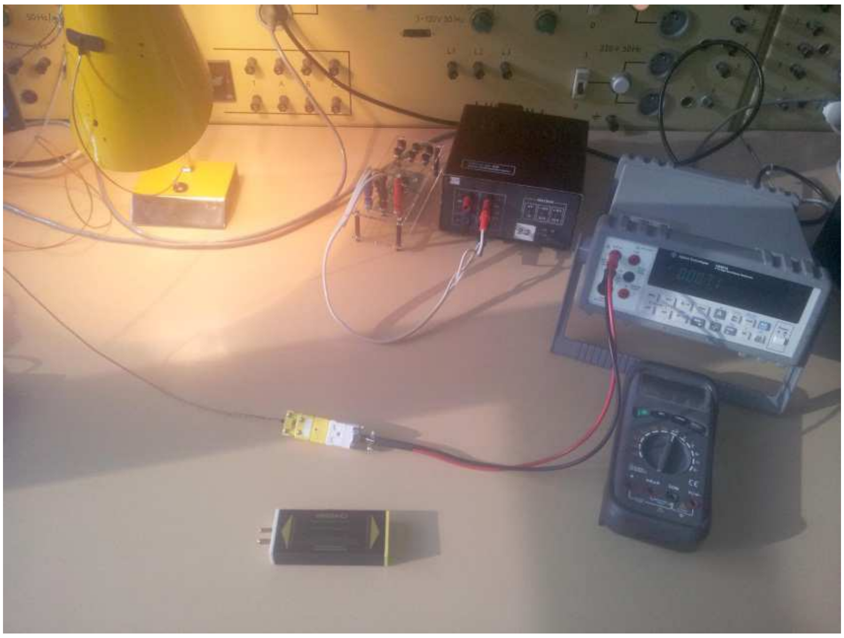

Figure 2. Direct measurement of the output voltage of the thermocouple with optional compensation box OMEGA CJ

2.1.2. Measurement with compensation box OMEGA CJ. Previous measurements are repeated but involving compensation box OMEGA CJ where the thermocouple output voltage corresponds to the comparator at the end of the temperature of 0 ° C. The diagram is shown in Figure 3.

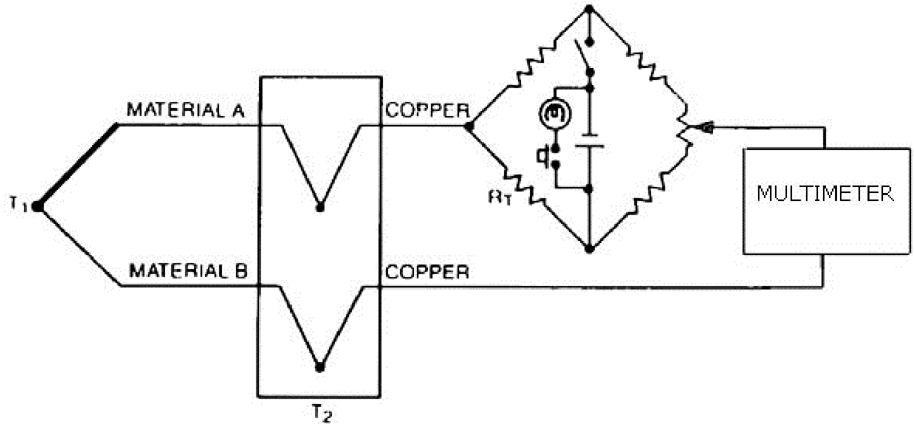

Figure 3. Wiring diagram of measurement with compensation box OMEGA CJ

2.2. Measurements using an operational amplifier

The student task in this part of the exercise is to design a circuit with operational amplifier (OA) that amplifies the thermocouple output voltage by the factor of 100. The circuit input resistance must take into account when designing the circuit type and feedback resistors value. The value of the feedback resistor also influences a thermal noise. Students will then verify and deploy their knowledge of other subjects. In comparison to converter U / I 101 XTR used in previously exercised role [4], the circuit with operational amplifier is easier for students to understand. The diagram is shown in Figure 3. The OA offset can be determined by commutating the thermocouple amplifier and compensated consequently.

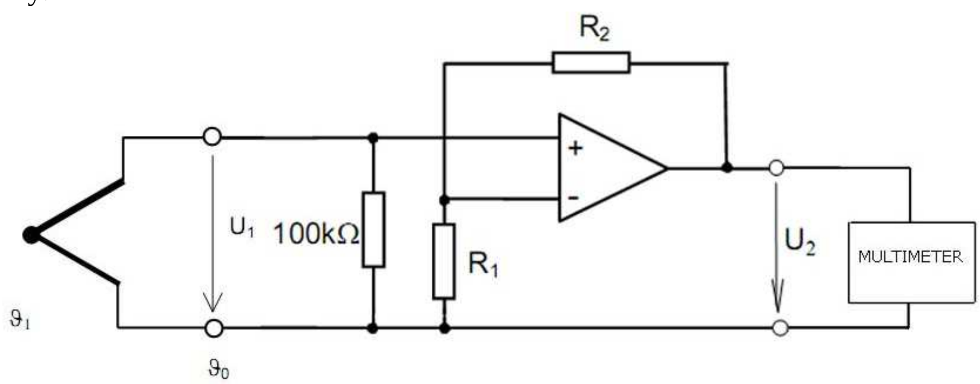

Figure 4. Wiring diagram of measurement with operational amplifier

2.3. Measurement with USB module with isothermal terminal block

Automatic measurement and data acquisition with post-processing on the computer plays an irreplaceable role in contemporary measurements. Usually, the part of the temperature measurement task is a measuring module connected to the computer via the bus. The measured data is then processed in Matlab [7], or other specialized software [5, 6].

New laboratory exercise replaced the outdated module Janascard AD 232 by Janascard AD24USB module (Figure 5.) that contains 24bit AD converter with 15nVpp noise which connects isothermal terminal block of 8 differential inputs with a range of 0 - 10V and semiconductor temperature sensor. The module is connected to the computer via the USB bus. Temperature compensation and linearization is performed in software program AD24control (figure 6.). The program allows you to set parameters of the connected sensor and different measurement and display of data.

The task of the students in this section is to record and display the temperature graphically on the screen when the lamp bulb is on or off. Measurements are repeated for different thermocouple types, and different locations on the lamp. Unlike [5, 8], students are not required to determine time constants of the thermocouples as it is part of the instruction in other subjects.

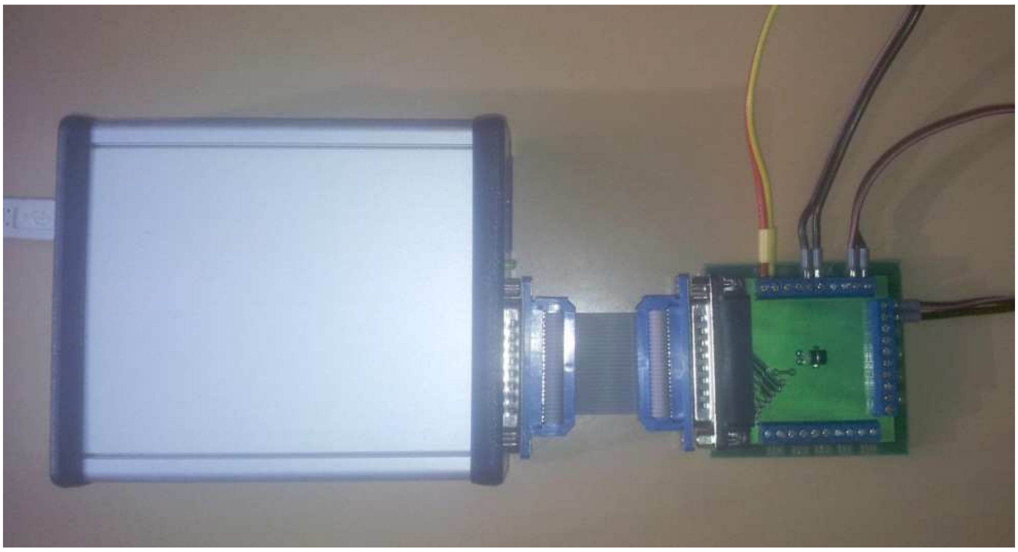

Figure 5. USB module with isothermal terminal block

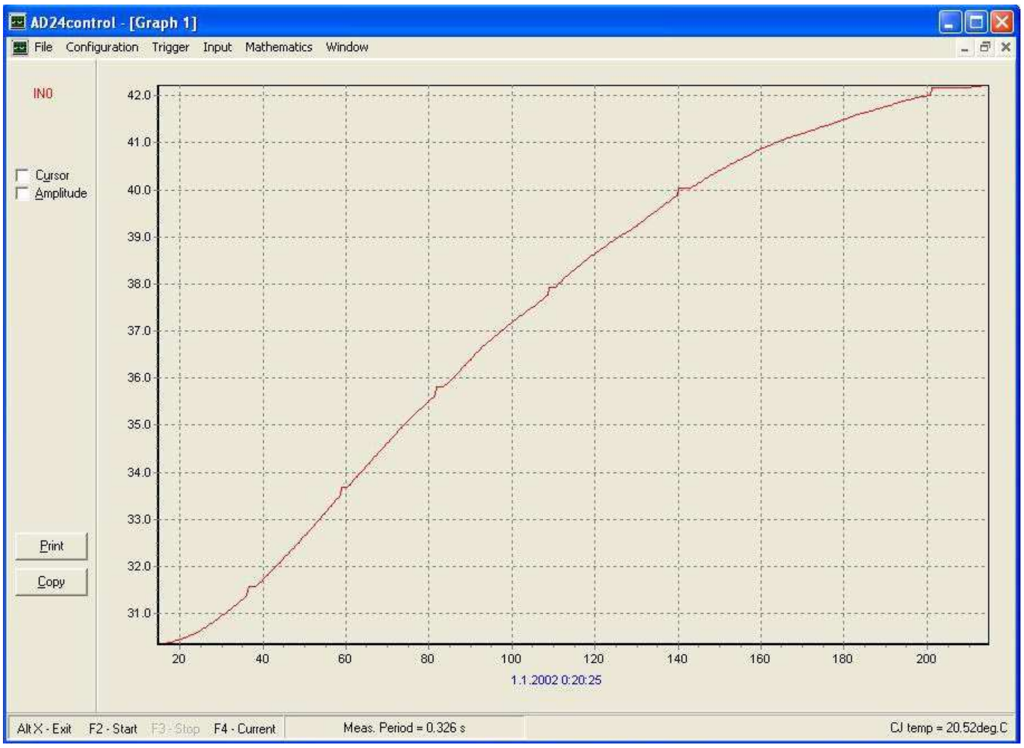

Figure 6. Software program AD24control

3. Summary

The task of the students in the exercise is to measure the thermocouple voltage using different methods and based on that, to calculate the object temperature. In the measurement protocol students are asked to compare different methods in terms of accuracy and to calculate the measurement uncertainty. The students make themselves acquaint with the theory of the Seebeck effect, the temperature dependence of the Seebeck coefficient and the basic compensation procedures. In comparison with the previous exercise version, methods of small voltage measurements and problems associated with this measurement are emphasized. The recap of operational amplifier and related feedback theory is another benefit of this exercise.

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