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Measurement and Instrumentation for Electrical and Mechanical Engineering Students

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ABSTRACT

Measurement and Instrumentation fundamentals are introduced to electrical and mechanical engineering students via unique joint course for Electrical and Mechanical Engineering Programs of Purdue University at Fort Wayne Campus. The course has a laboratory component that engages students with practice and illustrates how to apply theory. The students are grouped to conduct experiments in a multidisciplinary format. It has been observed that this type of unique joint course motivates students to solve engineering problems from different perspectives and improves teamwork.

General Terms

Multidisciplinary engineering course

Keywords

Measurement; instrumentation; electrical engineering; mechanical engineering; teamwork; multidisciplinary.

INTRODUCTION

Measurement and instrumentation in every engineering discipline provides a systematic method to measure and analyze the physical variables of interest [1-3]. As technology advances, it becomes a requirement for engineering students to be familiar with the measurement and instrumentation systems and equipment. A basic measurement and instrumentation system is illustrated in Fig, 1.

It is also a fact that many instrumentation tools are sensor and circuit based systems in mechanical and electrical engineering. This mandates mechanical engineering students to have basic knowledge in circuit theory and sensor modules. In addition, some of the mechanical engineering instrumentation tools such as pressure systems and vibration systems are widely used in electrical engineering applications. So, electrical engineering students need to understand the working mechanisms of these devices. It is then a need to have a joint course in measurement and instrumentation for electrical and mechanical engineering students.

ECE/ME 293 Measurement and Instrumentation course for the Electrical and Mechanical Engineering programs of Purdue University Fort Wayne Campus is developed to be the solution for the need in this area. The course is designed to provide the theory with lectures, practice with experiments and teamwork with multidisciplinary approach. Data acquisition systems and electrical circuits are integrated with sensors to measure the physical variables of interest. The measured data are analyzed using statistical methods to identify the measurement accuracy. Design of experiment is assigned to students as a project to work together in a team

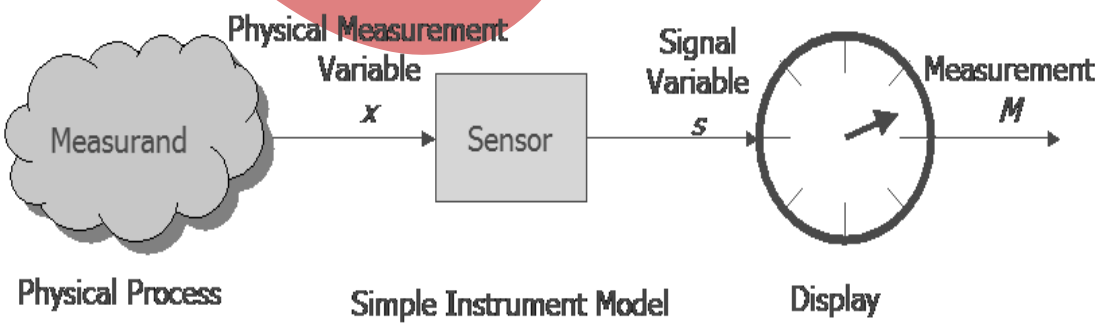

Fig. 1 – Basic measurement and instrumentation system

environment and design and implement their experiments. Students also find opportunity to give formal presentation about their results. This helps them improve their communication skills.

International Journal of Research in Education Methodology
Volume .. No.2 Issue 3 April 2013, ISSN:2278-7690

Overall, it has been observed that this type of joint course greatly improves the learning of the fundamentals in measurement and instrumentation among electrical and mechanical engineering students. Furthermore, it integrates the cutting edge technology by illustrating the applications of instrumentation tools in practice.

Implementation of the joint course

The course objectives of the joint course are identified as introduction to theory and application of sensors/devices and their instrumentation for measurement problems in electrical and mechanical engineering. In this course experiments utilizing basic circuits and sensors are performed. Methods for recording, interpretation, and presentation of experimental results are illustrated. Statistics and design of experiments are emphasized. The theory and analytical skills are introduced to students using lectures, homeworks, and quizzes. The application of the theory, use of sensors to measure physical variables/measurands are demonstrated via experiments.

The course in essence provides the ingredients needed to complete measurement and instrumentation cycle shown in Fig. 1. Students in electrical and mechanical engineering programs learn fundamental concepts and conduct experiments using sensors and devices with the measurement circuits that they build throughout the course. Students use LabView data acquisition systems to collect the data, and analyze it. They also use computing software such as Matlab and Mathcad to do the statistical analysis to determine the trends and errors in the measurement. They are then given assignment called Design of Experiment where they again work in a group setting to design an experiment to practice real engineering design problem.

Table I – Deployment of the joint course

Week	ECE/ME 293 MEASUREMENTS AND INSTRUMENTATION Deployment of the Joint Course
I	Lecture I – Measurement Systems
	Lecture II – Basic Concepts in Measurement and Instrumentation
II	Lecture III – Statistical Analysis of Experimental Data
	Lecture IV – Probability Distribution Functions and Uncertainty Analysis
III	Lecture V–Curve Fitting
	Lecture VI–Basic Elec. Sys
IV	Lecture VII– Technical Report Writting
	Lecture VIII–LabView Introduction
V	Lab 1 –LabView Basics
	Lab 2 – Introduction Data Acquisition System with LabView
VI	Lecture IX - Basic Circuit Theory
	Exam
VII	Lab 3 – Basic Electrical Measurements
	Lab 4 – Circuit Laws
VIII	Lecture X–Design of Exp.
	Lecture XI – Oscilloscopes and Pressure Measurement Fundamentals
IX	Lab 5 – Introduction to Oscilloscopes
	Lab 6 – Fluid Pressure Measurement Fundamentals
X	Lecture XII –Temperature Measurement Fundamentals & Demonstration of Soldering on Components
	Soldering Practice
XI	Lab 7 - Temperature Measurement
	Lecture XIII –Strain and Vibration Measuerement Fundamentals
XII	Lab 8 - Strain Measurement
	Lab 9 – Vibration Measurement
XIII	Lecture XIV –Step Response & Freq Response of Electrical Circuits
	Lab 10 – Step Response of RL and RC Circuits
XIV	Lab 11 – Frequency Response of RL, RC and RLC Circuits
	Design of Experiment Hour
XV	Design of Experiment Presentation

International Journal of Research in Education Methodology
Volume .. No.2 Issue 3 April 2013, ISSN:2278-7690

Students write technical report and then make presentations to communicate their findings to other students and instructor.

The deployment of the joint course is illustrated in Table 1 week by week. This course is a 2 credit hour second year engineering course and offered every semester. It is a core course for both electrical and mechanical engineering students. The course is designed to have combination of lectures and experiments. There are total of eleven experiments throughout the course. At the beginning of the course fundamentals of measurement and instrumentation are presented. Students are prepared for the experiments by learning the theory of commonly used statistical methods, probability distribution functions, and curve fitting techniques. The basic theory of circuit analysis is also reviewed in the lectures. The prior knowledge of basic theory of circuit analysis is a pre-requisite for this joint course for both electrical and mechanical engineering students. Students are required to take ECE 201 Linear Circuit Analysis I before they enroll Measurement and Instrumentation course. Technical report writing techniques are also discussed and critical points in report writing are presented. LabView and data acquisition system constitute an important part for this course. LabView is extensively used in laboratory courses [4-7]. Students are introduced to data acquisition system and software in their program with this course for the first time. The background that they gain with this course can be later on used by other courses in their disciplines when design content exists. Measurement and Instrumentation course is specifically important for Senior Design Capstone projects for students where they heavily use the techniques, and devices that they were interfaced in ECE/ME 293 course. The data acquisition system used in the

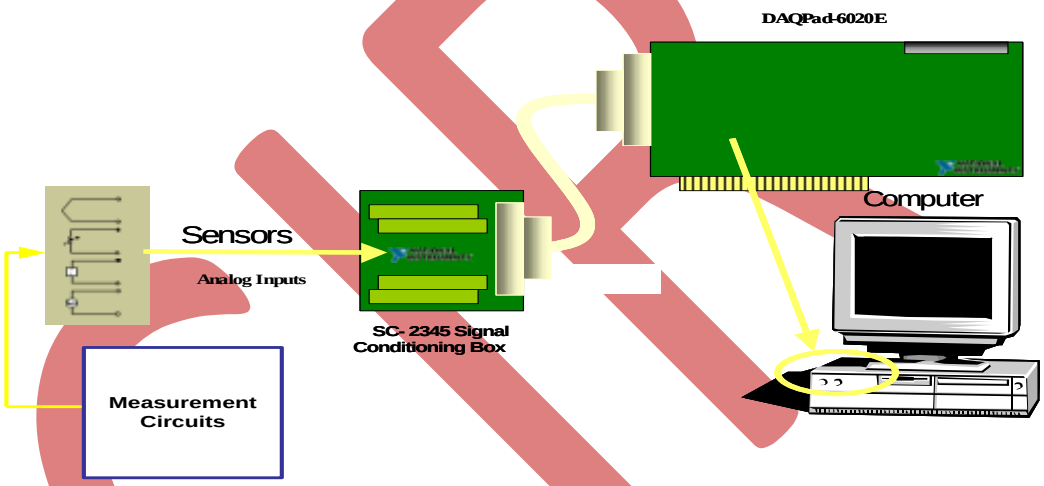

Fig. 2 –Measurement and instrumentation set up for each experiment

course include National Instruments DAQPad-6020E DAQ unit with National Instruments SC-2345 Signal Conditioning Box and corresponding sensors. The system with LabView software provides the functionality shown in Fig. 2. Every experiment uses the set up illustrated in Fig. 2 with the measurement circuit that is build by students. Sensors are interfaced with the data acquisition system and students design and calculate the circuit parameters using the theory they learn in the course. The structure of the course is to introduce students the theory of the experiment first and then do the experiment later. Students are also asked to do pre-laboratory work that enables them to calculate and design some of the circuit parameters prior to the experiment that they will be conducting.

The experiments are conducted in a group setting. Each group comprises of mechanical and electrical engineering students. This is aimed to motivate students to work as a member in a multidisciplinary engineering environment. This is typical in real engineering world where a team involving members from different disciplines brought together to work on the same project. This cannot be avoided in practice since every project has a requirement that may be part of different engineering discipline. For instance, when electrical engineer designs an amplifier, mechanical engineer works on its thermal issues, system engineer works on the integration of the components in the amplifier involving several different boards, and manufacturing engineer makes sure that the final product is manufacturable, repeatable, and meets the specifications.

Design of Experiment assignment in the course is another important tool for students to design an experiment to measure specific physical variable by considering several parameters to reduce the measurement error. Students again work in a multidisciplinary group setting to theoretically design, then implement, and measure, collect and analyze the data. This assignment also lets them use statistical method such as Chauvenet's Criteria and computing software such as Matlab. Students are also asked to write a technical report to present their findings. Technical report includes the analytical and numerical details about the experiment that they design and conduct. Each group then makes a presentation to communicate their findings to other teams and instructor. This gives students great experience in expressing their ideas in front of their colleagues, which is a great value in industry. Design of Experiment assigned to each group is evaluated by other students in different groups using the evaluation form shown below. This gives students self-confidence and shows them how to evaluate others' technical work.

International Journal of Research in Education Methodology
Volume .. No.2 Issue 3 April 2013, ISSN:2278-7690

DESIGNING AND PERFORMING THE EXPERIMENTS

The set up shown in Fig. 3 demonstrates the typical experimental set up used in this course for the laboratory experiments [1]. The specific experiment in Fig. 3 is designated as Lab 7 in Table 1 and conducted by students to measure the temparature at different conditions using thermistor, RTD, and thermocouple using data acquision system illustrated in Fig. 2. Temparature is the physical variable, and thermocuple, RTD and thermistor are the measurement devices used in this experiment as illustrated in Fig.1. Fig. 4 shows the measurement circuit build by students when RTD is used as a temperature measurement device. RTD can be replaced by thermistor or thermocouple in the circuit. Students calculate the component element values to measure temperature for each device in the circuit.

Design of Experiment Student Evaluation Form

Scores 1 represents less than average, 2 represents average, 3 represents over average, 4 represents very good. Please do not evaluate your own group.

1. Which group are you in?	1	2	3	4
			Score	
2. Problem definition	1	2	3	4
3. Experimenting design	1	2	3	4
4. Experiment construction and development	1	2	3	4
5. Data gathering	1	2	3	4
6. Analysis of data	1	2	3	4
7. Interpreting results and reporting	1	2	3	4
8. Oral Presentation	1	2	3	4

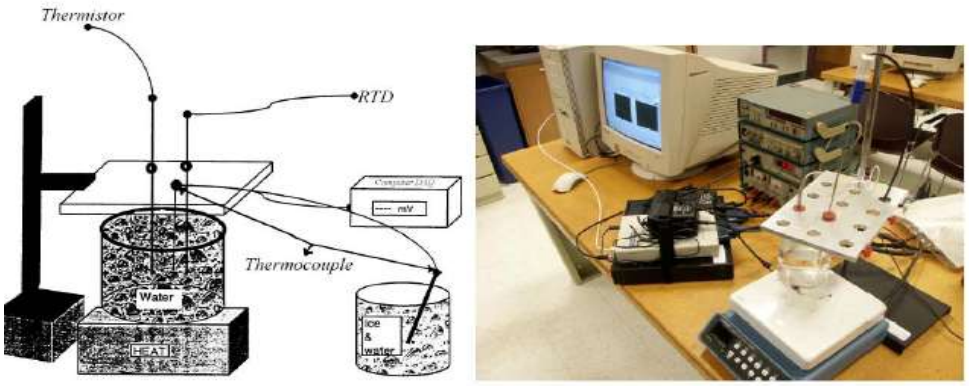

Fig. 3 –Typical experimental set up for the joint course

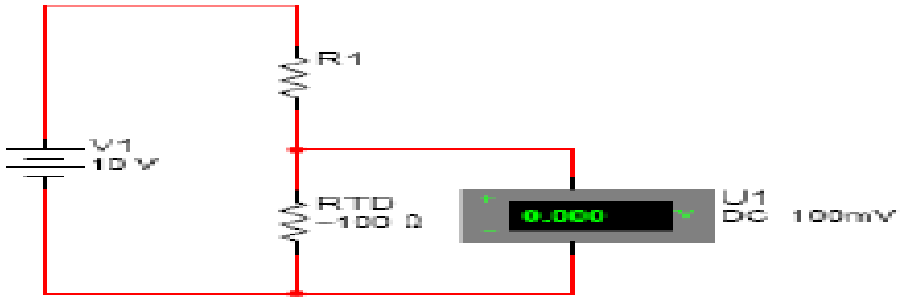

Fig. 4 –Measurement circuit for temperature

The voltage signal across the measurement device is sent to data acquisition system and correlated to the reference temperature, which might be a room temperature or ice temperature. The data acquisition system displays the measured temperature after processing the signal shown in Fig.5. Signal processing by data acquisition system include conditioning and converting the analog value of the signal to digital value and displaying it to the user.

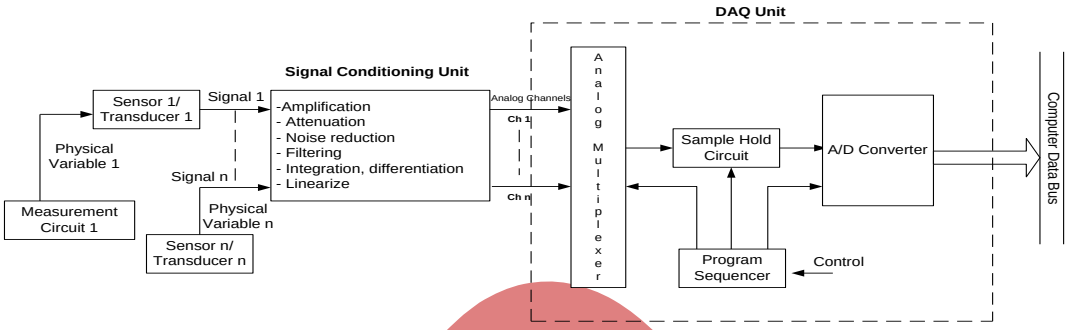

Fig. 5 –Measurement process for each physical variable using data acquisition.

Evaluation of the course objectives

Survey has been conducted over students who enrolled in this course to see if the course outcomes have been succeeded. Same survey has been applied for both electrical and mechanical engineering students just before end of the semester. Survey had seven questions and each question had four different ratings as answer. Rate 1 shows the weakest whereas Rate 4 indicates the strongest. The survey has been done to see mainly if

- Data acquisition system can be used for measurement of physical variables
- Statistical methods can be applied in measurement
- Sensors and transducers can be used in measurement of physical variables
- Students can work in a group setting increases interest and improves understanding
- Students can design an experiment and conduct it

The survey questions are illustrated in Table 2.

Table II - Measure of course outcomes

ECE/ME 293 Measurements and Instrumentation

Survey

Please rate the questions between 1- 4. Use 1 for weakest, 4 for strongest.

1 - An ability to use data acquisition hardware and software to obtain experimental data.

1 2 3 4

2 - An ability to use statistical methods and computer software to process experimental data.

1 2 3 4

3 – An ability to layout, wire and troubleshoot simply electrical circuits and apply circuits laws.

1 2 3 4

4 - An understanding of the working mechanisms of sensors such as the strain gage, pressure transducer, accelerometer, thermocouple.

1 2 3 4

5 – An ability to write formal technical report and perform oral presentation to convey engineering message efficiently.

1 2 3 4

6 - An ability to engage in experiment design and execution

1 2 3 4

7 – An ability to work in a multidisciplinary group setting.

1 2 3 4

International Journal of Research in Education Methodology
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Survey results are shown in Fig. 6. Based on the results, 81.25% of the students believe that they are able to use data acquisition system in an experiment for measurement after they take course. Technical report writing seems to be the weakest area of students by 56.25%. It is also very positive that 87.5% of the students believe that they learned to work in a multidisciplinary team environment efficiently.

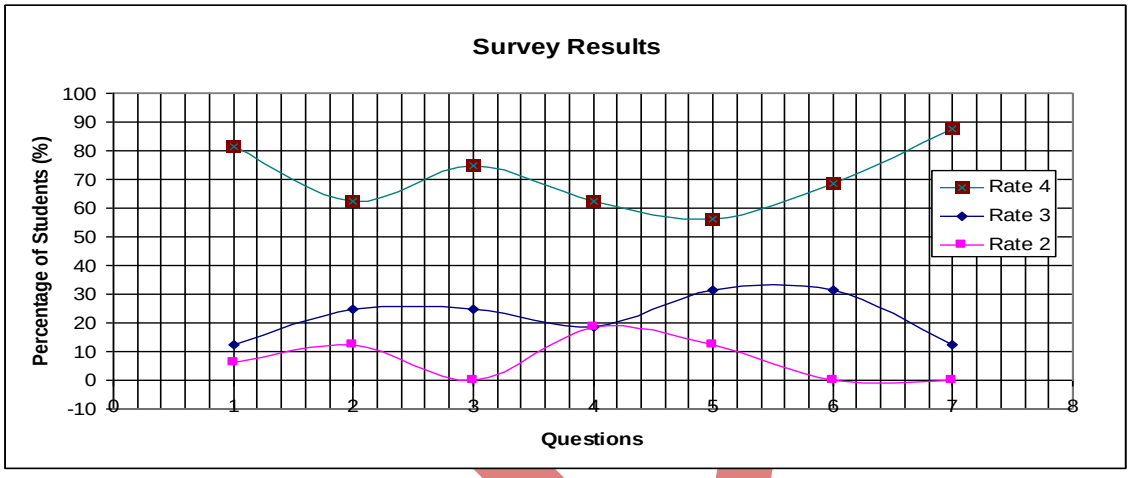

Fig. 6 –Survey results for ECE/ME 293 on course outcomes

Conclusion

Development and deployment of new joint course on measurements and instrumentation for electrical and mechanical engineering students are presented. The integration of laboratory experiments with theory for multidisciplinary engineering students has been detailed. The method to set up a multidisciplinary team comprising electrical and mechanical engineering students is discussed. The survey has been successfully conducted to measure the course outcomes. It has been shown that a joint course such as the one introduced in this paper motivates students to work together in a team setting, improves their presentation skills, and helps them to understand the challenging concepts in various disciplines with different perspective.

References

[1] A. Eroglu, Experimental Methods in Measurement and Instrumentation for Electrical and Mechanical Engineers, 1st Edition, Universal Publishers, ISBN : 978-1-5994-2814-7, November 2010.

[2] A. J. Wheeler and A. Ganji, Introduction to Engineering Experimentation, 2nd Ed., Prentice Hall, 2004.

[3] J. Dally, W. Riley, K. McConnel, Instrumentation for Engineering Measurements, Wiley 2nd Edition, 1993.

[4] J.E Globig, "An Interdisciplinary, LabVIEW Based, Data Acquisition and Measurements", *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*, Session 2147, 2003.

[5] C.V. Knight and G.H McDonald, "Modernization of A Mechanical Engineering Laboratory," *Proceedings of the 1998 American Society for Engineering Education Annual Conference & Exposition*, Session 2266, 1998.

[6] C.W. Lee, "LabVIEW Based Instrumentation and Experimental Methods Course," Proceedingsof the 2000 American Society for Engineering Education Annual Conference & Exposition, Session 2259, 2000.

[7] I.I. Orabi, "Application of LabVIEW for Undergraduate Lab Experiments On Materials Testing," Proceedings of the American Society for Engineering Education Annual Conference & Exposition, 2002.