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Basic electrical engineering for non-majors: course design and implementation

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ABSTRACT: Introducing electrical engineering applications to non-majors is a challenge, especially since the technology in this field is rapidly accelerating. At King Abdulaziz University, and many others, non-major students face many problems in an electrical engineering course ranging from the topics taught to the methods by which they have been delivered. The aim of this article is to report on the design of a course that enables future engineers to develop the local industry with the latest technologies in their fields. In preparing for this project, a number of top international universities were searched to extract the course material they offer in this regard. Through discussions with professionals from academia and industry, a new course has been designed to suit the different engineering disciplines. The active learning environment has been adopted and developed for the different subjects in the course. Results of applying the course for the last five semesters showed an improvement in students' performance of about 8% from the first time the course was implemented. Detailed discussion on a sample section is reported to analyse the active learning effectiveness.

Keywords: Basis electrical engineering, engineering education, non-majors, active learning, education and industry

INTRODUCTION

The accelerated development in today's technology has largely contributed to advances in the field of electrical engineering, especially in the electronics discipline. Most of the industrial systems are integrated with some sort of electronic solutions for either monitoring or controlling purposes. In the very near future, increasing demand for development of such systems is expected [1-3]. Accordingly, universities need to pay special attention to their engineering students.

Most schools offer one or two service courses as an introduction to electrical engineering. However, many studies, old and recent, show that there are problems with such courses, mainly that the content and topics taught are irrelevant and impractical to the student's field in engineering [4-9].

A survey at Michigan University, for example, showed that more than 75% of the students faced problems with both the topics and the way of teaching, and that the course was a collection of pieces from other electrical engineering courses [5]. Additionally, many believe that the main objective of such a course for the non-EE students is for them to be prepared for the Fundamental of Engineering examination (FE), which covers a wide range of electrical engineering subjects [3].

In 2008, the Department of Electrical and Computer Engineering at King Abdulaziz University (KAU) decided to offer a different course that serves as an introduction to electrical engineering applications to the non-EE students. Previously, all engineering students shared the same circuit analysis course (EE251) that was actually intended for EE-majors. Nonetheless, 90% of the course topics were mapped from the old course and only few new topics were introduced for the non-EE students.

This article reports on an attempt to remedy the above situation by carefully developing an EE course for non EE-majors. Here, the authors discuss the following aspects of the underlying project:

- the content and topics;
- the experiments and projects;
- the learning experiences and environment;
- the electronic material and information.

In the following sections of the article, a discussion on the stages of this project is presented, along with the detailed tasks to achieve the abovementioned objectives. The implementation results of the course for five semesters are reported later; and finally, there are concluding remarks, along with suggested work to be carried out in the future.

DEVELOPMENT STAGES

Six stages in developing the course were considered; each stage consists of a number of detailed tasks to fulfil the mission. In the search stage, the top local and international universities in engineering, which are closely related to industry were investigated to obtain related course material. The next task was to analyse the different topics and material by consulting experts, and proposing a suitable content of the course, its learning objectives, and the corresponding levels of learning.

Laboratory experiments and term projects suitable for the course were then considered. The fourth stage was to design the learning experiences of the course units to be delivered. A Web site containing all necessary material and examination banks has to accompany the course. Finally, the designed course is to be implemented and delivered to all students at the College of Engineering of KAU for all disciplines for at least four semesters. The detailed tasks for each stage were as follows:

- 1.1 searching the local and global top universities;
- 1.2 acquiring material of similar courses taught;
- 1.3 acquiring the laboratory experiments and projects;
- 1.4 compiling a preliminary summary of the collected material;

- 2.1 consulting a number of professors and industry managers from different disciplines;
- 2.2 deciding what major units should be taught in the course;
- 2.3 suggesting the detailed topics of the course suitable for all engineering disciplines;
- 2.4 assigning the course learning objectives and their levels of learning;

- 3.1 assigning the laboratory experiments based on the course content;
- 3.2 describing the objectives of each experiment;
- 3.3 suggesting the laboratory equipment and setup needed;
- 3.4 outlining the possible practical projects of the course;

- 4.1 allocating time in weeks and lectures for various topics and subtopics;
- 4.2 assigning the learning experiences suitable for the different subjects;
- 4.3 suggesting the optimum classroom setup and arrangement;
- 4.4 recommending the assessment tools of the course;

- 5.1 categorising the Web site pages and elements;
- 5.2 developing the Web site structure and content;
- 5.3 reserving an address for publishing the Web site;

- 6.1 arranging for and preparing a classroom at the University;
- 6.2 training the instructors and assistances for the proposed course content and teaching methods;
- 6.3 delivering and implementing the course over four semesters.

INVESTIGATED UNIVERSITIES

While this work is not intended to look for a specific ranking method in finding the world top universities and institutions, the authors mainly considered the Times Higher Education Supplement (THES) world university ranking for engineering [10]. The goal was to limit the search to good international schools, which have excellent relations to industry.

More than forty universities were searched with a comprehensive investigation for similar courses provided in their different engineering departments. The investigation included the course syllabus, description, all possible material found from the course home page, and whether or not the course was delivered specifically to non-majors. Some difficulties were faced by the authors at the search stage when trying to obtain information from some Asian universities due to the unavailability of such information on their Web sites.

CONTENT DEVELOPMENT

All topics taught in the investigated courses were classified and considered for review as shown in Table 1. In general, one could notice the diverse choices of topics considered by the different schools.

Table 1: A comprehensive list of topics taught.

Category	Topics
Concepts	Volt, Current, AC, DC, RMS, Energy, Power, Non-Ideal Sources
Components	Passive, Active, Semiconductors, Transducers, Relays, Solenoids, DC/DC Converters, AC/DC Converters, Switches
Circuit Theory	Ohm's Law, Impendence, Mesh, Node, Dividers, Equivalent, Matrix, Network Reduction, Superposition, Thevenin, Dependent Sources, Complex Numbers, Matrix
Communications	AM, FM, Transmission Lines, Impedance Matching, Transmitters/Receivers, Coding, Error Detection
Control Systems	Feedback, PID, Digital Control
Data Acquisition	ADC, DAC, Mixed Signals
Digital Systems	Numbers, Boolean Algebra, Logic Gates, Combinational, Sequential, Memories, FSM
Electronics	Diodes, MOS, BJT, Biasing
Filters	Passive, Active, Frequency Response, Resonance, Q, Bandwidth
Frequency	Transfer Function, Steady-State, Transient, Modulation
Instrumentations	Measurements, Accuracy, Tolerance, Limits
Op-Amps	Inverting, Non-Inverting, Adders, Integrators, Differentiators
Power Systems	3-Phase, Delta-Why, Motors, Machines, Generators, Breakers, Fuses, PF Correction
Processors	PIC, LabVIEW
Safety	IEE Regulations, Standards
Sensors	Temperature, Pressure, Flow Meters, Strain Gages
Simulators	Workbench, OrCad
Wiring	AWG, House Wiring, Grounding, Distribution

To ensure a proper selection of the subjects, a number of visits were made to some of the universities, as well as industries with the goal of meeting some professors and engineers and discussing with them their actual needs in either research in the different disciplines or in real engineering projects in industry.

The visits also included a tour to see the facilities and to meet the active research groups. Table 2 shows a list of the major local and international visits made. The discussions with the professors, engineers, industry managers and the research students included the following six common issues:

1. There is a problem with the current topics taught both in quantity and quality.
2. Teaching such a course must be done from an application-base point of view, not as pure theories.
3. There is a need to teach some multi-disciplinary systems in the course.
4. Students must be introduced to sensors and control systems.
5. *How things work* is the best way in teaching.
6. Students should know about new software applications and simulations.

Table 2: Departments and places visited.

Affiliation	Discipline
King Abdulaziz University, Saudi Arabia Former Chair, Thermal Engineering Department	Thermal
King Abdulaziz University, Saudi Arabia Chair, Aeronautical Engineering	Aeronautical
MIMOS Berhad, Malaysia Director, Microsystems and MEMS	Electrical
Advantest Europe GmbH, Germany Executive Officer and Managing Director	Process
Technical University of Munich, Germany Chair, Institute of Automatic Control Coordinator, DFG Excellence Research Cluster	Control
Technical University of Munich, Germany Institute of Automatic Control	Aeronautical
Swiss Federal Institute of Technology, Zurich Sensory-Motor Systems Laboratory	Biomedical
Swiss Federal Institute of Technology, Zurich Institute for Dynamic Systems and Control	Control
Swiss Federal Institute of Technology, Zurich Separation Processes Laboratory	Chemical

THE CONSIDERED COURSE CONTENT

What can be realised from the discussions is that the main objective of such a course is to enable students to understand the applications of electrical engineering in their own fields in a way that will help them to cope with future technologies. A mission like that is difficult to achieve, but the authors compiled a version of the course having four main parts as shown in Table 3. Each of the four parts has its own justifications and objectives as follows:

Part I (Electrical Engineering Basics): It is the essential basic part that must be known by every engineer; it is like the pre-knowledge to all the topics that follow in the course. The history of electricity and the general success stories in industry about working systems provide great learning motivation. When students see the different electronic components and handle them, they gain a clear vision of what is inside electrical instrumentation or a device they might see at work. Finally, the basic electrical measurements of simple voltages and currents, along with the associated safety are of a great importance in many projects at the work place.

Part II (Electric Circuits): Non-EE engineers do not need to analyse circuits on their own; however, they must at least know how different electronic modules interact when plugged into a system. For that, the basic laws of circuit theory are what they need to understand only. Later, a number of conventional units used in industry must be reviewed, such as the converters and filters, in terms of defining the required specifications and possibly designing them just as black boxes.

Part III (Electric Power Systems): This part deals with the generation and distribution of electric power, including the basic information and analysis of balanced 3-phase systems. For the generation part, only the simple and ideal DC machine topic is discussed to give the basic theory of electro-magnetism and electricity. The basic transformer circuit should also be discussed to provide an understanding of how to boost voltages while transmitting the same power. This part as a whole is used by many engineers in industry and even at home.

Part IV (Data Processing): This part discusses a great need in industry, as well as in research of a multi-disciplinary nature. Knowledge of sensors, including their specifications that make them suitable for an application, and the way processors deal with their signals is very useful. A good candidate for data acquisition and processing system is LabVIEW, which is a user-friendly interface and also is employed in industry [11].

Table 3: The considered course content.

Part I: Electrical Engineering Basics
1. Motivation, History, Non-Electrical Engineering Applications, Basic Concepts: Electricity, Electric Potential, Current, Closed Loop, DC and AC, Frequency, RMS, Power, Noise 2. Electric Components: Fundamental Elements, Electromechanical Components, Semiconductors, Integrated Circuits 3. Electrical Measurements & Instrumentation: Basic Concepts, Electric Instruments, Measurement Errors, Electric Simulators, Safety
Part II: Electric Circuits
4. Circuit Analysis: Ohm's Law, Equivalent Resistance, Voltage and Current Divider Rules, Kirchhoff's Laws, Current Sources, Complex Impedance, Reactive Power 5. Application-Specific Circuits: Oscillators, Converters, Protection Circuits, Math Circuits, Timer Circuits, Filters, Communication Units
Part III: Electric Power Systems
6. DC Machines: History, Basic Concepts, DC Motors and Generators 7. Three-Phase System: Generation, Star and Delta, Power Factor 8. Transmission and Distribution: Transformer Circuits, High Voltage Safety
Part IV: Data Processing
9. Sensors: Introduction, Passive Sensors, Temperature Sensors, Pressure Sensors, Motions Sensors, Other Sensors 10. Data Acquisition and Processing: Signals and Spectrum, Sampling and Quantisation, Data Acquisition, Analysis

COURSE EXPERIMENTS

The course laboratory experiments and projects provide the main support to the course content. It is an important ingredient for engineers to be able to relate practice to the theoretical content [12]. The proposed approach is to have hardware experiments, software circuit simulations and basic embedded system experiments, as well as team projects [11]. To overcome typical problems in laboratory sessions [13], Web-based laboratory tutorials should also be designed. Table 4 shows the proposed list of experiments, which are interleaved with the course lectures.

Table 4: Hardware and software course experiments.

#	Experiment	Type	Objectives
L1	Measurement Techniques	HW	introduction to laboratory instruments and safety, measuring voltage, current, and resistance
L2	Ohm's Law	HW	Ohm's law, voltage and current dividers, power calculations
L3	Kirchhoff's Laws	HW	experimental analysis of two loop circuits
L4	AC Circuits	HW	RC circuits, frequency measurements with scopes
L5	Transformer Circuits	HW	transformer operation and turn ratio measurements
L6	Op-Amp Applications	HW	gain amplifier circuit with an op-amp
S1	DC Circuit Simulation	SW	simulating DC circuits with batteries and resistors only
S2	AC Circuit Simulation	SW	simulating AC circuits with R, L, C components, AC sources, power meters
S3	LabVIEW Basics	SW	introduction to LabVIEW package and VI components
S4	Basic NI USB-6009 IOs	SW	controlling inputs and outputs of a NI USB-6009 interface with LabVIEW
S5	Temperature Control	SW	reading, mathematical adjusting and controlling temperature level

TEACHING METHODS

An important step in any course design is how to deliver it to students. To them, the most important factor is for improved teaching [14]. The teaching methods, or learning experiences that should be designed to support the course were investigated. The authors mostly adopted the steps of integrated course design by Fink [15], and followed Richlin's learning blueprint in designing the assessment and documenting the course design [16]. First, the instructor's teaching goals were set, which are:

TG(1) understand how to use electrical engineering concepts and advanced technologies in their own engineering fields of specialisation;
TG(2) engage in life-long learning and discover new techniques in electrical engineering as they advance, as well as new tools and applications related to their field of specialisation;
TG(3) manage a group of engineers of required specialisations in real projects so that they fully understand their roles and tasks assigned;
TG(4) encourage engineering design, manufacturing and development in the local industry.

Having these goals in mind, the detailed course learning objectives were then set, based on the topics considered. A set of learning experiences have been adopted and developed in the course over the past five semesters, and finally, the course design per lecture has been approved as shown in the Appendix.

COURSE WEB SITE

A course Web site is built to support students as a learning experience directly. The items in the Web site include:

- Home Page: which consists of announcements and the term calendar.
- Syllabus Page: where all the course objectives and grading system are posted.
- Material Folder: consists of lecture notes, slides, previous quizzes and examinations and many solved problems.
- Laboratory Page: which has all the laboratory experiment sheets, both hardware and software, as well as the team project requirements and templates.
- Login Page: where students can see their grades once they have been posted by the graders. Student information and photographs can be posted by students for further electronic communications with the instructors.

IMPLEMENTATION RESULTS

The last stage in this first cycle of improvement was to apply both the new content and the teaching methods to a large sample of non-EE engineering students. With the chairman's approval, the new course design was first implemented in September 2009, the Fall Semester, 2010. The different sections accommodate all the non-EE students in the fields: aeronautical, chemical, civil, industrial, thermal, mechanical, mining and nuclear engineering.

The course content and topics have been adopted by all sections since that semester; however, the active teaching methods were first tried on some of the sections. Table 5 lists the number of enrolled students in the EE251 course at all different sections, along with their average grades and the percentage of the new active teaching implementation across the different semesters. One should note that the convention at King Abdulaziz University is to name the fall semester starting in September 2009 as Fall-2010, unlike most worldwide universities.

Table 5: Enrolled students in EE251 and their average grades.

	FL10	SP10	FL11	SP11	SM11
Total Students Enrolments	144	212	194	323	69
% Taught Actively	27%	69%	100%	61%	100%
Average Grade	73	82	77	76	76
Sample Section Enrolments	39	46	48	50	45
Sample Section Average Grade	76	80	78	81	83

Table 5 shows information about the sample section taught by the first author of this article in the last five semesters. This sample section was fully taught with the new proposed active learning experiences. The overall average grade of the sample section across the five semesters was around 80, with a trend of about +1.5 points per semester, while the overall average grades of all sections together maintain a constant grade around 77, as illustrated in Figure 1.

In the Spring-2011 semester, a large number of students applied for the EE251 course, which required new staff members to assist in teaching. Therefore, the percentage of sections using active learning style was reduced to 61% before going back to 100% in the Summer-2011.

Analysis of the detailed grades of the sample section reveals that the increase in the total average grade over the semesters is due to the increases of the different assessment tools used. Noticeably, the average grade increase in the daily individual quizzes and the weekly team activities was about four points per semester each, as shown in Figure 2. These two tools were considered very effective since students have to be continuously prepared to take a daily 5-minute quiz and to solve a 40-minute weekly in-class team activity.

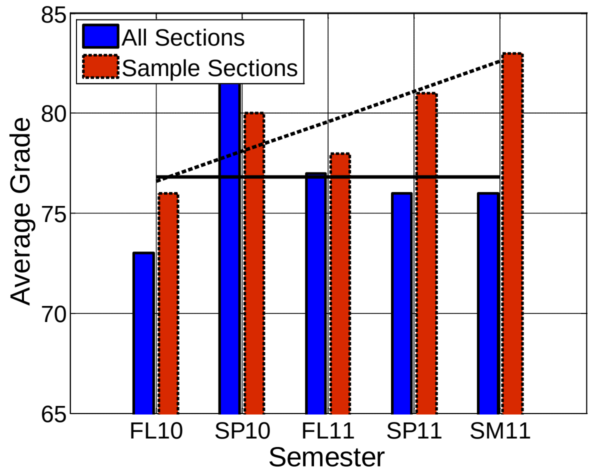

Figure 1: Average grades over the semesters.

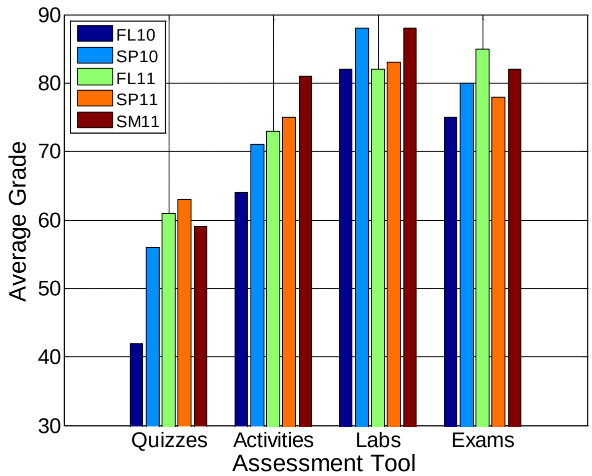

Figure 2: Detailed grade progress of the sample sections.

It is important to mention that at the first semester the course was taught, a deficiency in mathematics for most of the students was observed, especially in complex numbers. For that, immediate action was taken to introduce some extra tutorials on the subject to overcome the problem.

CONCLUSIONS

The authors designed and implemented an introductory course in electrical engineering applications for non-EE engineering students, which is presented in this article. The design process involved multiple stages, including information gathering and analysis of the suitable topics for inclusion in the course. A number of visits and consultations with professionals from both industry and academia have been made to ensure the usefulness and direct applicability of the subjects to be taught. Next was the design of the course experiments and projects to support the theoretical parts. In teaching the course, an active learning environment was adopted, where certain learning experiences are designed for higher perception and immediate application. The last stages of the project were to build a valuable course Web site for the students, before the real implementation of the new course.

In assessing the performance of the students with the new course design, the authors reported the last five semesters' grades for all sections and results show an average grade of 77 ranging from 73 to 82. A sample of a fully active class was also reported in detail to analyse the effect of the proposed active teaching experiences. The results show an increase of about +1.5 points per semester on average. The main factor contributing to this increase was the use of two assessment tools, namely, the daily quizzes and the weekly team activities. To continue the improvement cycle, detailed statistical investigations, along with indirect assessment methods, need to be considered in the future. This will have a direct impact on the learning experiences proposed and may result in the introduction of some modifications to the course content.

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BIOGRAPHIES

Amjad F. Hajjar was born in Medina, Kingdom of Saudi Arabia (1970). He received the BSc in electrical engineering from King Abdulaziz University, Jeddah, Saudi Arabia in 1992, and the MSc and PhD in VLSI design and verification from Colorado State University, Colorado, USA, in 1997 and 2001, respectively. He joined the Department of Electrical and Computer Engineering at King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia, in 2001 as an Assistant Professor. His field of interest includes analogue and mixed-signal design, FPGA and DSP optimisation techniques and statistical modelling of digital design algorithms.

Nebras M. Sobahi was born in Jeddah, Kingdom of Saudi Arabia (1982). He received the BSc in electrical engineering from King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia in 2006. Currently he is pursuing the MSc degree in electronics engineering at the same university. He joined the Department of Electrical and Computer Engineering at King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia in 2006 as a teaching assistant. His field of interest includes signal and image de-noising using wavelet transform.

APPENDIX

The Course Design

Lecture	Design		
0	CLO	Course Structure and Grading	
	LE	First Day Material, Syllabus, Course Web site	
	EP	Diagnostic Test	
1	CLO	CLO01:	recognise the role of electrical engineering in different disciplines
	LE	PPT01:	history of electricity, applications of EE
		VID01:	IC Manufacturing & Space Applications Video
	EP	PC01:	what do I need to know about EE in my field?
2	CLO	CLO02:	understand the basic concepts of electricity: motion of electrons, battery, electric potential, electric current, closed loop circuitry, AC versus DC currents
	LE	PPT02:	basic concepts
		EXP01:	can you see the flashing light bulb at higher frequencies?
	EP	JR01:	concepts team journal
3	CLO	CLO02:	understand the basic concepts of electricity: signal frequency, and RMS value
	LE	PPT02:	basic concepts
		PC02:	why RMS?
	EP	QZ01:	frequency calculation
4	CLO	CLO03:	understand the principles of the different electric components: resistors, capacitors, coils, diodes, transistors, fuses, circuit breakers, transformers, IC's, solenoid, component specifications and datasheets
	LE	PPT03:	electronic components
		ACT01:	applications and basic concepts
		PC03:	list other components you use in your field
	EP	QZ02:	RMS calculation
		JR02:	electronic components team journal
5	CLO	CLO04:	calculate the currents and voltages in simple resistive circuits using Ohm’s law
	LE	PPT04:	circuit analysis
		PC04:	check for the current drawn from the source
	EP	QZ03:	direction of the current in a diode circuit
6	CLO	CLO04:	calculate the currents and voltages in simple resistive circuits using voltage and current divisions
	LE	PPT04:	circuit analysis
		PC05:	can you generalise the divider to multiple branches?
	EP	QZ04:	Resistive Network Reduction
		JR03:	circuit analysis team journal
7	CLO	CLO04:	calculate the currents and voltages in simple resistive circuits using KCL and KVL
	LE	ACT02:	3-loop resistive circuit analysis
		PC06:	how many nodes, loops, branches in the circuit shown?

Lecture	Design		
	EP	QZ05:	current and voltage dividers
8	CLO	CLO05:	analyse circuits with electrical measuring devices: ohmmeter, ammeter and voltmeter
		CLO06:	calculate electric power in resistive networks
	LE	PPT04:	circuit analysis
		PC07:	why to disconnect the branch to measure the current?
	EP	QZ06:	KCL and KVL
		JR04:	voltage and current divider team journal
9	CLO	CLO07:	compute the RMS value for a given voltage (current) waveform
		CLO08:	transform a given sinusoidal signal into the phasor form
		CLO09:	calculate the impedances of the passive components: resistors, capacitors and inductors at a given frequency
	LE	PPT04:	circuit analysis
		PC08:	what is a complex number? And how to use it for circuit representations?
	EP	QZ07:	measurements
10	CLO	CLO10:	convert an AC steady-state circuit to a phasor circuit
		CLO11:	analyse a phasor circuit using Ohm’s law, KCL, KVL, and voltage and current divisions
	LE	PPT04:	circuit analysis
		ACT03:	AC circuit analysis
	EP	QZ07:	phasors
		JR05:	KCL and KVL team journal
11	CLO	CLO12:	calculate AC steady-state power dissipated by the circuit elements
	LE	PPT04:	circuit analysis
		PC09:	discuss increasing the voltage to decrease the current for the same power delivery
	EP	QZ08:	AC circuit analysis
12	CLO	CLO13:	solve a balanced three-phase system to calculate system voltages, currents and power
		CLO14:	understand and be able to use per phase analysis to solve simple three-phase systems
	LE	PPT05:	3-phase systems
		ACT04:	3-phase system analysis
	EP	QZ09:	AC power calculations
		JR06:	AC circuit analysis team journal
13	CLO	CLO15:	solve simple circuits for voltage, current and power containing ideal transformers
	LE	PPT06:	transformers
		PC10:	do you think transformers are perfect for power transfer? Why do we need so many coil turns in both sides of the transformer?
	EP	QZ10:	basic 3-phase system analysis
14	CLO	CLO16:	understand the basics operation of semiconductor diode and recognise its applications
		CLO17:	design multiple application-specific circuits according to given specifications using the engineering design equations which include: AC/DC converters, signal waveform and pulse generators
	LE	PPT07:	application specific circuits
		PC11:	how to use these design sheets, and where to find others?
	EP	QZ11:	transformer circuits analysis
		JR07:	3-phase systems team journal
15	CLO	CLO17:	design multiple application-specific circuits: voltage and current protection circuits, mathematical circuits: amplifiers, buffers, mixers, integrators and differentiator using op-amps, voltage/current converters, analogue/digital converters, timer circuits and filters
	LE	PPT07:	application specific circuits
		ACT05:	AC/DC converter design (integrated)
	EP	QZ11:	square wave generator design
16	CLO	CLO18:	understand the principals of electrical grounding and safety precautions
		CLO19:	understand the principals of rotating magnetic fields; the synchronous generator and the synchronous motor
	LE	PPT08:	power generation (machines)
		PC12:	think about magnetism, electricity and gravity as natural powers
	EP	QZ12:	pulse generator design
		JR08:	application specific circuits team journal
17	CLO	CLO20:	calculate the delivered mechanical power of DC motors and the delivered electrical power of DC generators
	LE	PPT08:	power generation (machines)
		ACT06:	DC machine analysis and design
	EP	QZ13:	motor equations

Lecture	Design		
18	CLO	CLO21:	understand the definition of sensors, actuators and transcendences
		CLO22:	recognise the different types of passive sensors: resistive, capacitive, inductive
	LE	PPT09:	sensors and actuators
		PC13:	do you think the temperature change in the circuit would affect the Wheatstone bridge? Prove it?
	EP	QZ14:	motor/generator power delivery
		JR09:	DC machines and transformers team journal
19	CLO	CLO23:	understand the principles of operation of the different sensors in the different engineering applications
		CLO24:	recognise the limitations of sensors and actuators
		CLO25:	be able to designate the best sensor based on the required specification
	LE	PPT09:	sensors and actuators
		ACT07:	Wheatstone bridge analysis
	EP	QZ15:	quator wheaston bridge
20	CLO	CLO26:	understand the concept of data acquisition and its applications
	LE	PPT10:	data acquisition
		PC14:	why do we need special processors for DAQ?
	EP	QZ15:	sensors limitations
		JR10:	sensors and Wheatstone bridge team journal
21	CLO	CLO27:	program simple applications using the LabVIEW package with NI USB-6008 interface card
	LE	PPT10:	data acquisition
		EXP02:	building temperature sensor interface circuit
	EP	QZ16:	data acquisition concept
22	CLO	CLO28:	recognise the safety principles and possible electric hazards at work
		CLO29:	recognise the different standards and earthling techniques
	LE	PPT11:	electric safety
	EP	ACT08:	safety multiple choice survey
23	CLO	CLO30:	work effectively in teams
	LE		team presentation for their projects and hardware products
	EP		presentation skills assessment, peer assessment

Keywords:

CLO: Course Learning Objective
LE: Learning Experience
EP: Evaluation Plan
PPT: Power Point Section
VID: Video Presentation
LAB: Laboratory Experiment
PC : In-Class Process Check
EXP: In-Class Experiment
ACT: In-Class Team Activity
JR: Team Weekly Journal
PR: Team Project
QZ: In-Class 5 Minute Quiz