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Laboratory Experiments in Circuit Theory: Link between Theoretical Concepts and Practical Examples

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Introduction

The laboratory experiments in circuit theory course are dedicated for practical understanding of circuit theory concepts. Linking of the circuit theory with practice it is very important to motivate the students for learning theory and to encourage them to use this theory knowledge in practical activity. Thus the relation of theoretical circuit elements, circuit components and theoretical laws to understanding of circuit functioning is the main objective of the Circuit theory course [1, 2].

Curriculum of the Circuit theory course in the Faculty of Telecommunications and Electronics, Kaunas University of Technology (KUT) is designed to give a fundamental understanding on basic electric circuit laws in mathematical way, i.e. to give the background of relation of mathematical expressions to the electrical processes and the real electrical instrumentation to its circuit model. This course is the first one of an electrical engineering courses for the students and they usually do not have much understanding of electronics as such. The difficulty to link the circuit theory course to practical tasks usually is that the electronic instrumentation what students meet around and use is quite sophisticated nowadays. Following this situation it is a challenging task to link basic circuits and laws to the interesting practical examples that lead the whole physical process to be more comprehensible.

Electric circuits' laboratory in faculty of Telecommunications and electronics

Circuit theory is one of the basic courses in electronics engineering education [1–3]. The main aim of this course is to provide knowledge of the methods of mathematical modeling of the electric elements and circuits as well as to develop abilities and skills for practical applications.

Within the Faculty of Telecommunications and Electronics at the Kaunas University of Technology, the Circuit Theory course is run by the Department of Signal Processing. This course is a two-semester course. Since year 2009, the first part of the course is held on the first year of the studies, on the second semester. Every week students have classes for lectures, tutorials and laboratory (respectively 3, 2 and 1 hours in average). Duration of a laboratory experiment is four hours. Therefore students are attending the laboratory once a month that is four times in total per semester. Students usually work in groups of two, but separate reports have to be prepared and presented to the instructor for individual assessment.

In year 2006 the Department of Signal Processing received a grant for the purchase of teaching equipment for the Laboratory of the Circuit Theory. The grant was used for the purchase of equipment [4, 5]. The main equipment what is used in all laboratory experiments is listed in Table 1 (also see Fig. 1). The equipment is used in 7 working places of Laboratory of the Circuit Theory.

Table 1. Equipment of Laboratory of the Circuit Theory

Type	Model	Description
Digital Multimeter	GDM-8246, GW Instek	DC, AC voltage and current, resistance, diode, capacitance, frequency, continuity measurements; PC interface
Digital Storage Osciloscope	GDS-806C, GW Instek	60MHz bandwidth; color LCD display; PC interface; cursor and measurements modes
Function Generator	GFG-8219A, GW Instek	Frequency range 0.3Hz-3MHz; CMOS, TTL output; VCF; sweep operation; AM/FM modulation; frequency counter
Analogue terminal panel for laboratory work and experimentation	IDL-600, K&H	Solderless breadboard; 4 DC power supplies; function generator (1-100kHz); switches; jacks; potentiometers; speaker; voltmeter and ampermeter

The types and quantity of instruments meet the objectives of the laboratory, but the purchase was limited by funds available. Besides that, four computers and PC based oscilloscope and generator are available for analysis and processing of acquired data, as well as for demonstrations and some simple simulations.

Currently there are ten experiments prepared for laboratory instruction in the Laboratory of the Circuit Theory on the topics of the course.

1. Instrumentation and measurements – introduction.
2. Experiments with DC circuits.
3. Properties of circuit elements.
4. The resonance of a series RLC circuit.
5. The resonance of a parallel RLC circuit.
6. Two-port network frequency response.
7. Differentiation and integration circuits.
8. Transient response in RLC circuit.
9. Experiments with filters.
10. Transient response of transmission line.

The list of laboratory experiments is not fixed. The modernized laboratory is a challenge to the academic staff to develop new and more effective laboratory instructions.

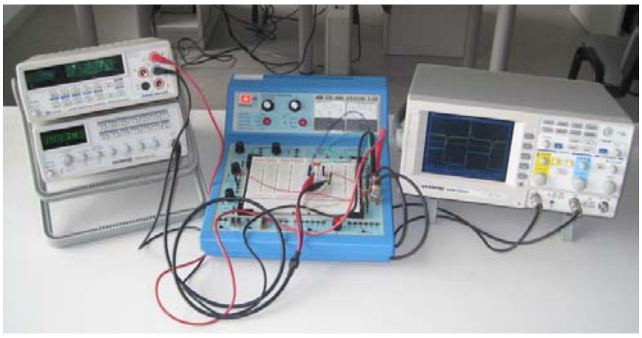

Fig. 1. Work place in the Laboratory of the Circuit Theory

Link between circuit theory and practical tasks

Understanding of circuit theory concepts and linking them with practical tasks sometimes is quite difficult. The student level of academic performance not always is a good predictor of fundamental understanding of circuit theory [3]. The best way should be to allow each student to discover compelling evidence that leads him to form a workable model. But the role of the teacher as guide can be challenging, since the teacher often must first identify misconceptions of the students about the material before he can point them toward experiments that directly contradict their erred beliefs about the topic [3].

One of the topics in linking theory and practical tasks is the design of a good study tools for students. In this field is very attractive kind of new laboratories – remote laboratories (one of many examples is presented in [6]). Also various interactive software based learning tools (one of many examples is presented in [7]) are used to stimulate and to practice theory learning and understanding of the key concepts. The approach of software tools for learning is feasible replacement of practical laboratory works with learning-by-doing principles in electronics engineering studies. We however are thinking that computer simulations today still cannot effectively replace hands-on experiments [1], but they can effectively complement them. For circuit theory simulations we use and recommend for students MicroCap SPICE based circuit simulation software by Spectrum Software (www.spectrum-soft.com). It is an integrated schematic editor and mixed analog/digital simulator that provides an interactive sketch and simulate environment for electronics engineers. The demo version of this software is limited only in functions (circuit size limited to 50 components, anywhere from 0 to 300% slower than the professional, limited component library, no Model program, and some of the advanced features are not available), but has enough functionality for circuit theory course.

The approach of the link between circuit theory and practical tasks can be outlined as follows:

- basic concepts of the circuit theory (Ohms, Kirchhofs Laws, etc.);
- application of the basic concepts by analyzing circuits by circuits simulation software;
- experimentation with real circuits, understanding of equipment usage, measurements;
- experimental data analysis;
- identification of strengths and limitations of theoretical models and practical circuits;
- design of circuits meeting requirements;
- learning from failure. Even failed experiment if analyzed appropriate can give useful understanding.

The good idea, especially for motivation of students is to integrate ground courses (mathematics, physics) with engineering course [2]. The mathematics in this way should be no more the separate course, but became a part of other courses: circuit theory, signals and systems, digital signal processing, programming, etc.

Practical projects, combining them with laboratory instructions could also link theory with practice. This should be an advanced process of learning, where the students have the responsibility for combining the theory and practical electric circuit design.

Example of laboratory instruction

As an example of laboratory exercise we present laboratory instruction in the topic of transmission lines. This topic is held on the second part of Circuit theory course in faculty of Telecommunications and electronics, KUT. This laboratory instruction is, in our opinion, good illustration of the link between theoretical concepts and practical examples.

Few years ago when Laboratory of the Circuit Theory had only old equipment, topic of transmission lines has practical work using a lumped circuit model of transmission line. Though such approach has some advantages (possibility to use low frequencies for experimental analysis of transmission line properties), it is not very related to the real transmission line and in this way this work do not attract students. After change of old equipment with the new one, Laboratory of the Circuit Theory lost this work on transmission lines. However, this topic is quite important and we were thinking on how to present it with good practical example. Limitations of possibilities of laboratory experiment implementation usually are two: available equipment for students and complexity of the experiment. With these thoughts we chose experimental investigation of transient voltages in coaxial cable.

The theory of transmission lines is a significant concept when dealing with circuits where the wavelength of the signal is the same order of magnitude with the physical dimensions of the components of the circuits. In low frequencies or in pulsed circuits, there the pulse rise time is not important and is not specified, the wavelengths of the signals are much bigger than physical dimensions of the transmission medium. But the frequency of the signal from the TV signal source is hundreds of megahertz's, and the wavelength of signal is about one meter or less. A television can not be connected to the antenna or cable TV network by combining different types of cables. Every change in type of cable will cause a reflection, which will result as ghost images in an analogue TV and will disturb the quality of a digital TV signal. Such explanation is evident for students, us all them have these "domestic" transmission lines – coaxial TV cables and part of them have been seen the mentioned problems with cables.

For a discontinuity point on a transmission line, a reflection occurs and reflection coefficient can be calculated. The reflection coefficient is the ratio of the amplitude of the reflected wave to the amplitude of the incident wave. The analysis of transient response in coaxial cable is a good illustration and good practical example for the understanding of incident and reflected waves in the transmission lines.

For the implementation of laboratory experiment function generator GFG-8219A and digital storage oscilloscope GDS-806C were used. The frequency range of function generator is small enough – 0.3Hz-3MHz for sine wave and 0.3Hz-100kHz for square wave. On the front output of function generator the rise and fall time of square impulses are more than 100 ns and this parameter do not satisfy needs of experiment. For the experiment we use TTL output on the rear side of generator with square signal rise and fall time about 10 ns. In a case of absence of function generators with required output parameters, the ICL7667 MOSFET driver can be recommended to sharp edges of square wave. The output of this driver will deliver square wave with rising and falling fronts of about 15 ns. In this way IDL-600 analog lab experiments system can be adapted to the requirements of transmission line experiment without difficulty.

For the design of the laboratory experiment were used: coaxial TV cable of length of about 8 meters with characteristic impedance of 75 Ω; two T-connectors; termination connectors with: potentiometer, capacitor, inductor and 75 Ω termination.

Experimental assignments for students are:

- determination of the influence of coaxial cable termination on the waveform on the beginning of the cable;
- measurement of the time parameters of the waveforms;
- calculation of the reflection coefficient;
- relation of experimental results with transmission line theory: termination load impedance influence on reflections in cable; observed impulses time parameters relation with cable length.

Fig. 2 represents the view of the experimental setup and experimental waveforms obtained using different loads of the coaxial cable. Fig. 3 represents the same experiment using MicroCap simulator.

This laboratory experiment is newly implemented and has good response from students.

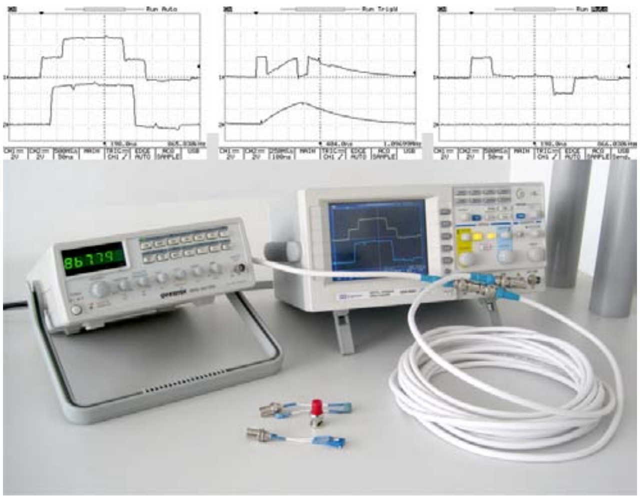

Fig. 2. Experimental setup of transmission line laboratory work and example of experimental oscilograms (top row)

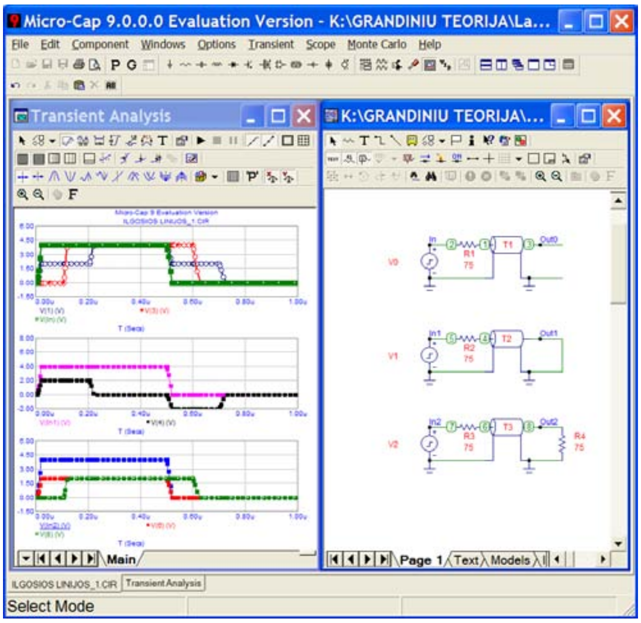

Fig. 3. Simulation of transmission line transient response with MicroCap

Conclusions

The laboratory experiments in circuit theory course are dedicated for practical understanding of circuit theory concepts. The link between circuit theory and electronic circuits practice is very important for the formation of student's understanding and also for the motivation of them.

We expect the students will improve their knowledge using our newly implemented laboratory experiments and will gain their understanding on practical things.

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The laboratory experiments in circuit theory course are dedicated for practical understanding of circuit theory concepts. In linking of Circuit theory with practice it is very important to motivate the students for learning theory and to encourage them to use this theory knowledge in practical activity. Following this situation it is a challenging task to link basic circuits and laws to the interesting practical examples that lead to be the whole physical process more comprehensible. Designing laboratory experiments of Circuit theory in the Faculty of Telecommunications and electronics, KTU simple practical examples have been complemented with some new hands-on laboratory experiments. Ill. 3, bibl. 7, tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

Д. Ягялявичюс, Д. Пагодинас, В. Думбрава. Лабораторные эксперименты по электрическим цепям: связь теоретических понятий и практических примеров // Электроника и электротехника. – Каунас: Технология, 2010. – № 6(102). – С. 107–110.

Лабораторные эксперименты по электрическим цепям предназначены для практического понимания теории электрических цепей очень важными. Для связи теории электрических цепей с практикой являются мотивация студентов и поощрение их, чтобы использовали эти знания теории в практической деятельности. Является сложной задачей увязать основные электрические цепи и законы с интересными практическими примерами, которые сделали бы весь физический процесс, происходящий в электрических цепях, более понятным. В статье показана разработка лабораторных экспериментов по теории электрических цепей в Факультете телекоммуникаций и электроники, используя простые практические примеры. Ил. 3, библ. 7, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

D. Jegelevičius, D. Pagodinas, V. Dumbrava. Laboratoriniai elektros grandinių teorijos darbai: sąsaja tarp teorinių sąvokų ir praktinių pavyzdžių // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 6(102). – P. 107–110.

Elektros grandinių teorijos kurso laboratoriniai darbai skirti praktiniam grandinių teorijos sąvokų supratimui. Susiejant elektros grandinių teoriją su praktika, labai svarbu motyvuoti studentus tam, kad jie studijuotų teoriją, ir padrąsinti juos panaudoti šias teorijos žinias praktinėje veikloje. Susieti pagrindines elektros grandinių elementų sąvokas ir dėsnius su įdomiais praktiniais pavyzdžiais, kurie padėtų geriau suprasti vykstančius fizikinius procesus, yra gana sunku. Straipsnyje pateiktas elektros grandinių teorijos laboratorinių darbų pavyzdys, sukurtas KTU Telekomunikacijų ir elektronikos fakultete, naudojantis paprastu praktiniu pavyzdžiu. Il. 3, bibl. 7, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).