120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013
Paper ID #6926

Remote Circuit Design Labs with Analog Discovery

Dr. Asad Yousuf, Savannah State University
Mr. Alex Wong, Digilent Inc.
Mr. Derek W. Edens

I am a Senior studying Electronics Engineering Technology at Savannah State University. I earned an Associates Degree from Savannah Technical College. Currently, I am the President of the IEEE Student Chapter at Savannah State College and served as the founding Chairman of Savannah Technical College's IEEE Student Chapter. Areas of interest include but are not limited to Autonomous Robotic Applications, UAV,Optics,and Electromechanical Security.

Remote Circuit Design Labs with Analog Discovery

Abstract

The limited resources in the traditional labs have restricted the effective and innovative circuit design projects from freshmen Circuits 1 class to Capstone ideas. The limited number of measuring and signal-generating instruments makes it difficult for students to engage in these projects when they need to share these instruments or schedule to use them at a specific time. Furthermore, it is a challenge for students to learn how to use various instruments including power supplies, multi-meters, oscilloscopes, and function-generators if not used in conjunction with each other. Likewise, it is also highly unlikely that students will acquire all of this rather expensive equipment and design a lab environment at their residence. Under such constraints, students cannot gain the necessary hands-on experience. Moreover, students have a tendency to play a minimal role in group-assigned projects, leading to minimal outcomes, which further weaken their accountability and curiosity. This will seriously reduce the students' aptitude for circuit designs and weaken a vast majority of other necessary engineering and technology based skills. A new approach, in which each student owns a circuit design station, is possible with a new compact device, which has incorporated many of these devices into one unit. Students can conduct many circuit designs spontaneously using their own remote lab. They can assemble and test various analog, digital, or mixed signal circuits including those from classroom textbooks. This paper will show that students can now set up a convenient remote laboratory to design and test low-power circuits. This lab environment is the newly launched Analog Discovery from Digilent. Analog Discovery is a low cost and portable test and measurement device, which provides various instruments including two oscilloscope probes, two arbitrary waveform generator, two power supplies, a voltmeter, a logic analyzer, and a pattern generator in a single module. This unit communicates with the WaveForms software and receives power from a standard USB port. This paper will introduce the course outline and present a very simple lab assignment, which students would typically test during the first few days of an introductory class. This example demonstrates the flexibility and ease-of-use while designing or testing a circuit with the Analog Discovery from any remote location.

Introduction

Traditionally, remote experimentation is the process of conducting real lab experiments without being physically in contact with lab devices. Recently, the development of Internet technologies promoted the spread of online virtual laboratories, and significant benefits of these laboratories helped establish remote experimentation as a potential substitute to hands-on experimentation. Internet-based experiments typically require very expensive hardware and dedicated high-speed internet connection, especially when a large number of students must share a limited set of devices [1]. Furthermore, the students cannot physically assemble the circuit.

A remote lab with the Analog Discovery station provides a unique opportunity for the students to overcome the limitations of a traditional laboratory experience. It can be defined as the process of conducting hands-on experiments while being physically located away from on-campus laboratory devices. The Digilent Analog Discovery™ design kit, developed in conjunction with

Analog Devices Inc., is the first in a new line of all-in-one analog design kits that will enable students to quickly and easily experiment with advanced technologies and build and test real-world, functional analog design circuits anytime, anywhere - right on their PCs. For the price of a textbook, students can purchase a low-cost analog hardware development platform and components, with access to downloadable teaching materials, reference designs and lab projects to design and implement analog circuits as a supplement to their core curriculum [2].

Freshman retention has been a critical issue for Electronics Engineering Technology programs over the last decade. Some State Universities have implemented many different approaches to improve the retention of freshmen. Some of these attempts include: creating basic Electronics Engineering Technology courses such as Electrical Circuit I in freshman year to give early hands-on experience to the students, and moving the ownership and maintenance of laboratory equipment from the university to the students. The concept of "engineering up-front" with hands-on, team-oriented introduction to engineering is the philosophy behind the course [3-6]. Introduction of Electrical Circuits I course in the freshman year of Electrical Engineering Technology program will enhance interest in Electrical Engineering Technology leading to higher matriculation rates, increased retention, and ultimately a higher graduation rate.

In the fall semester of 2012, the Electronics Engineering Technology department evaluated the Digilent Analog Discovery station, and advised the students to conduct basic laboratory experiments at random locations. This portable unit provides a unique opportunity for the students to perform many Electrical Circuit laboratory assignments 24/7 at their convenience. Students and faculty were very pleased with the enhancement in learning the basic concepts in Electrical Circuits based on hands on experience and "always-ready" instruments. After completing the lab experiments in a supervised environment equipped with Power Supplies, Function Generators, Multi-meters, Oscilloscopes, etc., students can reinforce the concepts by performing the same tasks using the Digilent Analogy Discovery station in their dormitory or any other location they desire. Typical results using standard lab equipment and the Analog Discovery have been included from a "Day-One" Electrical Circuits laboratory assignment.

The Electronics Engineering Technology programs at Some State Universities are in the process of restructuring their curriculum grid and changing the name of the program to Electrical Engineering Technology. Faculty executives at Some State Universities are even taking the initiative of creating and offering Electrical Circuit I in the first year to increase freshman retention. The rationale for creating this course developed based on student feedback and comments provided by many graduating seniors during their exit interviews. A growing number of students have expressed their concerns regarding how late the "Electronics Engineering Technology Laboratory Experience" is in the curriculum grid. The Electronics Engineering Technology faculty members and the Department Chairs of the Engineering Technology divisions made the decisions to help the Electrical Engineering Technology students by developing a course specifically designed for the students' freshman year for which the only pre-requisite is a Pre-Calculus course. The purpose of this course aims to introduce many of the basic Electrical Circuit concepts with hands on laboratory exercises. The students will also have a much better chance of becoming familiar with a wide variety of tools commonly used by most Electrical Engineering Technology students. An introduction to these instruments such as oscilloscopes, multi-meters, functions generators, and Analog Discovery stations early in the education process while the topics of study are relatively simple and easy to understand, will provide the much-needed first look at the equipment without being overwhelmed by more advanced circuit analysis techniques. These advanced techniques will require a working knowledge of such instruments.

The following paragraphs will introduce the course content, laboratory equipment, and lab exercises conducted, by using commonly available lab equipment and the Analog Discovery module.

Course Content

Electronics and Computer Science Technology students are introduced to Electrical Circuits I and II sequence courses at the sophomore level during fall and spring semesters respectively. Each course is a three-credit hour course consisting of two-hour lecture and a two-hour lab per week. Electrical Circuits I is designed to introduce the basic concepts in DC circuits, simulation and DC circuit labs, followed by Electrical Circuits II, which covers the advanced topics in AC, simulation and AC circuit labs [7].
Following topics are covered in Electrical Circuits I and II sequence courses:

1. Voltage and Current
2. Resistance
3. Ohm's Law, Power, and Energy
4. Series DC circuits
5. Parallel DC circuits
6. Network Theorems
7. Capacitors, Inductors and Magnetic Circuits
8. Sinusoidal Alternating Waveforms
9. The Basic Elements and Phasors
10. Series and Parallel AC circuits
11. Network theorems AC circuits
12. Power and Resonance
13. Transformers
14. Polyphase systems

The study of topics 1-7 occurs in Electrical Circuits I, with the remaining topics studied the following semester in Electrical Circuits II. As mentioned above the two-course sequence, once moved to the freshman year, will increase knowledge retention and graduation rates, and provide a solid foundation for the Electronics Engineering Technology students to build upon during their more advanced studies.

The prerequisite for the course is Pre-Calculus. It is highly recommended that the student have a basic knowledge of College Algebra and Physics. The knowledge in basic math skills and physics will provide the student not only an edge in solving circuit problems but will also provide the background to solve advanced design problems in Electrical Circuits II classes.

Laboratory Equipment

Typically, development tools and laboratory equipment needed for Electrical Circuits sequence course fall into two different categories: software and hardware. Software tools include Multisim, PSPICE, ELVIS, and systems integration environments to implement solutions. Although software solutions can be installed on personal computers and some handheld devices, hardware tools including Power Supplies (DC/AC), Digital Multi-meters, Function Generators, Oscilloscopes and other basic electronics components such as Resistors, Capacitors, Inductors, and Transformers are traditionally available to students for conducting the related labs only on campus during the lab time. However, at times, four-student groups form at each station due to the lack of equipment or the size of the class. Hence, many of the students lack an opportunity to perform the experiment. The department keeps the laboratory open for the students to come and practice individually to get the hands on experience when they can. However, it is quite difficult for the students to find time in a typical school day to return and complete the necessary hands on experience. Based on this information, and the "non-ideal" nature of the circumstances, an acquisition of a large number of these mobile Analog Discovery modules for an introductory class shall prove to be quite an "ideal" solution. This will give the students an opportunity to test and design circuits at a time and place of their own choosing. Students would typically receive a serialized Analog Discovery station for a given semester and return it back to the department fully tested and in working-condition. If the stations are not in working-condition then the student's school account will reflect charges for the replacement. Students may also choose to order their initial device and supplies directly from the manufacturer.

In Electric Circuits I following labs are conducted:

1. Series/Parallel DC circuits
2. Superposition Theorem (DC)
3. Thevenin's and Norton's Theorem
4. RC, RL and RLC circuits

In Electric Circuits II following labs are conducted:

1. The Oscilloscope
2. R-L-C components
3. Frequency response of series RC, RL and RLC circuits
4. Superposition Theorem (AC)

Laboratory Experiment

The Digilent Analog Discovery™ design kit, developed in conjunction with Analog Devices Inc., is the first in a new line of all-in-one analog design kits that will enable students to quickly and easily experiment with advanced technologies and build and test real-world, functional analog design circuits anytime, anywhere - right on their PCs. For the price of a textbook, students can purchase a low-cost analog hardware development platform and components, with access to downloadable teaching materials, reference designs and lab projects to design and implement analog circuits as a supplement to their regular laboratory exercises.

Colleges have traditionally had to build and maintain centralized teaching labs. These labs, with their specialized equipment and trained lab assistants, are expensive and hard to maintain. With the Analog Discovery design kit, can help to build distributed labs - labs that can be found in dorm rooms, cafeterias, and libraries - anywhere students want to work. However, the importance of working with real laboratory equipment cannot be ignored. The Digital Analog Discovery station would therefore be used a supplemental lab station to enhance the concepts learned with on campus laboratory equipment and advisement.

The following paragraphs will discuss the "Resistors and Ohms Law- Voltage-Current Characteristics" lab conducted by using the Digilent Analog Discovery workstation, Digilent Analog Parts Kit, Digilent Digital Multi-meter, a bench power supply, a 100.4-ohm resistor, and a handheld Digital Multi-meter. A comparison of the results from the Analog Discovery workstation and the regular lab equipment has also been included.

The purpose of the lab is to measure several combinations of voltage and current for a resistor and plot the resulting voltage- current characteristic curve measured for the resistor. The resistance of the resistor will be estimated from the slope of the voltage-current characteristics. The slope of the curve will be estimated using linear regression techniques. Topic of linear regression will be explained in context of Ohm's Law. MATLAB commands are used to perform linear regression.

This laboratory exercise requires the following equipment and supplies:

Tek Power Supply
Digital Multi-meter
Breadboard
Analog Discovery Station
Digilent Analog Parts Kit
Waveform Generator software from Digilent
MATLAB.

The circuit shown schematically in Figure 1.0 is used to experimentally determine the current-voltage characteristic for the resistor.

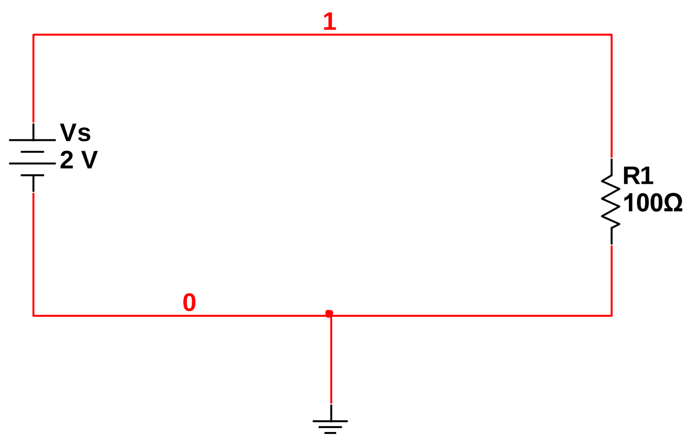

Figure 1.0 Circuit Schematic

Following are the steps to make the measurements with Analog Discovery workstation.

1. Connect the circuit shown in figure 1.0. Use a 100 ohms resistor and one of the Analog Waveform Generator (AWG) channels for the variable supply.
2. Vary the supply voltage Vs from 0V to approximately 2Vand record values of V_R and I_R in table 1.0.
3. Use the Arbitrary Waveform Generator to apply the voltage source Vs.
4. Measure the voltage across the resistor (V_R), and the current through the resistor (I_R) using the handheld digital multi-meter and the Digilent Voltmeter.

. By varying the supply voltage between 0-2V in increments of 200 milli-volts we obtain 10 different additional values for this range. We measured the values of the voltage (V_R) across, and the current (I_R) through the resistor. Table 1.0 shows the measured values for the voltage drop (V_R) and current (I_R) with input power provided by the Analog Discovery station. Table 1.0 also shows that the percent difference in measured values of V_R using the Analog Discovery meter and handheld multi-meter are well below 1% and insignificant. Table 2.0 shows the measured values of V_R and I_R with input power provided by the external power supply.

% Difference (V_R) = [V_R(Analog Discovery) – V_R(DMM)]/V_R(Analog Discovery) *100
Table 1.0: Analog Discovery Power Supply

V_S(Analog Discovery Power Supply)	V_R (Analog Discovery meter)	V_R (DMM)	I_R (DMM)	% Difference (V_R)
0	-0.0078	-0.0078	-0.00006	0
0.2	0.1918	0.1912	0.00167	.31
0.4	0.3915	0.3914	0.00342	.026
0.6	0.5908	0.589	0.00515	.30
0.8	0.7904	0.789	0.00689	.18
1.0	0.9906	0.988	0.00864	.25
1.2	1.1900	1.187	0.01037	.25
1.4	1.3901	1.386	0.01211	.29
1.6	1.5900	1.585	0.01384	.31
1.8	1.7900	1.785	0.01557	.28
2.0	1.9895	1.983	0.01727	.33

Table 2.0: External Power Supply

V_S(External Power Supply)	V_R (Analog Discovery meter)	V_R (DMM)	I_R(DMM)	% Difference (V_R)
0	0.0096	0.0091	0.00011	5.2
0.2	0.1975	0.1972	0.00194	.15
0.4	0.4015	0.401	0.00396	.12
0.6	0.5976	0.597	0.00590	.1
0.8	0.8012	0.801	0.00791	.025
1.0	0.9998	0.999	0.00987	.08
1.2	1.1974	1.197	0.01182	.033
1.4	1.4026	1.402	0.01384	.043
1.6	1.6022	1.600	0.01583	.14
1.8	1.8014	1.799	0.01779	.13
2.0	2.0045	2.002	0.01979	.12

The slope of the line that best fits the measured data can then be used to estimate the component's resistance.

Linear Regression

Experimental data will always contain some uncertainty, which is evident from the zero-readings on the previous tables. Hence, measured current-voltage data for resistor may not lie exactly on a straight line. One common approach toward determining a line which provides a best fit to the available data is least square method. To determine the least squares curve fit of the V_R versus I_R we can use the linear regression analysis. A basic explanation provides the basic concepts of least curve fitting method. A brief explanation of the following concepts has been included before examining the result obtained from MATLAB [8].

- If the correlation coefficient r=1 implies that the data lie exactly on a straight line with positive slope.
- If the correlation coefficient r=0 implies data which are entirely uncorrelated.
- If the correlation coefficient 0<r<1 then it represents the imperfect linear relationship.
- If the correlation coefficient r=-1 implies that there is a perfect negative relation which means that the data lie on a straight line with negative slope.

MATLAB is used for least squares curve fitting. MATLAB's "polyfit" function, which performs this procedure, is used. Syntax for the function is :

P= polyfit(x,y,n)

In the parenthesis, x and y are vectors containing the data to be fit. In our case $x=V_R$ and $Y=I_R$. "n" is the order of the polynomial since a straight line is a first order polynomial we set n=1. The function returns a vector containing the coefficients of the polynomial which provides a least square fit to the data. The first element of the vector will be the slope of the line (m=1/ R) and the second element will be the y-intercept of the line. The polyfit function returned the following values:
m=.0087 and b=0

MATLAB's "corrcoef" function can determine the correlation of two data sets. Possible syntax for using this function is:

r= corrcoef(x,y) where x and y are vectors containing data. The use of this function will return a 2 x 2 matrix, it will the following form:

$$r= \begin{matrix} rxx & rxy \\ ryx & ryy \end{matrix}$$

This matrix provides correlations between all possible combinations of the data provided to the function. rxx is the correlation between the x data and itself. Since data is perfectly correlated with itself then rxx=ryy =1 always. rxy is correlation between the x data and the y data, and ryx is the correlation between the y data and the x data. In our case x data is voltage V_R and y data is the current I_R. For this application rxy = ryx=1 which shows a perfect correlationship.

Student Outreach

The Digilent Analog Discovery kit provides student outreach opportunities. Students can form a Student Led Outreach Group (SLOG). Specifically the responsibilities of SLOG are:

1. To disseminate Electronics Engineering Technology awareness to under-represented groups, local communities, precollege and postsecondary students, and teachers via outreach demonstration projects using the Analog Discovery kit.
2. To assist students who needs help at any location 24/7.

"SLOG has a vision to promote engineering and technology concepts and their relationship to science and math to a wide range of students, increasing the pool of students who will be both prepared for and interested in an engineering and technology career" [9]. Faculty at Some State Universities has recently embarked the school of education, which will soon offer a BS in Electronics Engineering Technology education. Curriculum is designed in such a way that these students will take courses in Electronics and Education. SLOG can then consist of team which will include students from engineering technology and education. SLOG with this strong partnership can focus on working on topics such as pedagogy of learning, the role of technology in education, assessment of student learning, as well as on specific disciplines such as math. "SLOG can help in bridging the gap in between high school and engineering technology education. The concept of hands on engineering education has been evolving over the last few decades as an emerging field of pedagogy within engineering technology curricula, and a focus on hands on helps to bridge the gap for high school students entering engineering technology education' [10].

Given the role of Electrical Circuits I as a fundamental grounding for other courses in the curriculum, the design of learning activities should include practical exercises in which the students implement circuits which will reinforce the theoretical concepts they have learned in the classroom. This hands-on approach concept differs from the typical lecture teaching where the instructor teaches fixed problems using common techniques. With hands on approach, the students' understanding of the material deepens by requiring them to apply the learned techniques to an open-ended task.

Conclusion

Introduction of the Electrical Circuits I course in the freshman year of Electrical Engineering Technology programs will enhance interest in Electrical Engineering Technology leading to higher matriculation rates, increased retention, and ultimately a higher graduation rate.

This paper emphasizes the evolution of the hands-on approach in Engineering Technology education and shows how this approach can be developed, taught, and shared with high school students. It also described how embedding this approach in the Electronics Engineering Technology program promotes Engineering Technology and Technology Education student teamwork when designing laboratory experiments. The paper highlights the importance of outreach programs. These programs give the students and faculty the opportunity to share their understanding, and promote interest with the high school student population. The variety of these hands-on laboratory exercises helps students realize the impact of math and science in the Electronics Engineering Technology environment, and their intrinsic relationships to each other. In addition, student involvement in this process promotes enhanced communication skills and develops the ability to function exceptionally well in a team-based environment.

Bibliography

1. Norbert Pachler, Christoph Pimmer, Judith Seipold (Editors). (2011). Work-Based Mobile Learning – Concepts and Cases. Peter Lang AG.
2. http://www.digilentinc.com/Products/Detail.cfm?NavPath=2,842,1018&Prod=ANALOG-DISCOVERY
3. H. Knickle, "Foundations of Engineering a First Year Course", Proceedings of the ASEE Annual Conference, Washington, DC 1996.
4. 2. J. W. Pierre, F. K. Tuffner, "A One-Credit Hands-On Introductory Course In Electrical and Computer Engineering Using a Variety of Topics Modules", IEEE Transactions on Education, vol.52, No. 2, May 2009.
5. 3. Ronald Roth, "Improving Freshman Retention Through an Introduction to Engineering Design Course", Proceedings of the ASEE Annual, 2001, Albuquerque, NM 2001.
6. Ruben Rojas-Oviedo, Dr. X. Cathy Qian, "Improving Retention of Undergraduate Students in Engineering through Freshman Courses", Proceedings of the ASEE Annual, Montréal, Quebec, Canada 2002.
7. Robert L. Boylestad, "Introductory Circuit Analysis", 12th edition, Prentice Hall.
8. http://www.mathworks.com/
9. M. Huang, D. Malicky, and S. Lord, "Choosing an optimal pedagogy: A design approach," in Proc. 35th Annu. ASSE/IEEE FIE Conf., San Diego, CA, Oct. 28–31, 2006, pp. 1–6.
10. E. Moesby, H. H. W. Johannsen, and L. Kornov, "Individual activities as an integrated part of project work: An innovative approach to project oriented and problem-based learning," World Trans. Eng. Tech. Educ., vol. 5, no. 1, pp. 11–17, 2006.