Low Cost Collaborative & Portable Electronics Lab Kit

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Abstract

The current growth in online program is exponential. However, undergraduate programs in engineering and engineering technology has not benefited from this growth as other programs. One of the main factors that encourage this disparity is the difficulty and infeasibility of incorporating the required laboratory experiences into an online/distance education program. In this paper, an attempt is made to provide a potential solution for this problem with the proposal of a conceptual framework for a low cost interactive and portable electronics lab kit. This lab kit could be utilized in distance education programs that require hands-on lab experience. The kit proposed is particular suited for courses in circuits and electronics at the undergraduate level. This stand-alone lab kit includes all of the necessary components and instruments to successfully conduct electrical circuits experiments remotely. In addition, the lab kit is retrofitted with multiple cameras and two-way communication devices to facilitate real-time interaction with lab partners and/or the lab instructor. This kit is intended to be used alongside online instruction in order to facilitate both the examination of the physical components of electronic circuits, and the theories that make them work.

Keywords— lab kit, circuit lab, portable lab, online courses

Introduction

As more and more courses are offered online it is a goal of many universities to try to provide a broad course selection for students who are exclusively distant learners. This poses a significant problem for lab intensive programs such as electrical engineering and electrical engineering technology. At the same time, there is a tremendous thrust to encourage students to pursue Science, Technology, Engineering and Mathematics (STEM) based careers. The National Science Foundation (NSF) actively, along with other federal and private entities, dedicates significant resources to encourage K-12 students to choose STEM careers. However, recruitment is only one side of the coin. In order to solve the projected shortage in STEM professionals, there needs to be greater focus on the expansion of access to qualified non-traditional students. Online/distant education is an appropriate vehicle to utilize in this expansion of access.

However, there are several challenges to offering an entire program in electrical engineering and/or electrical engineering technology online. One of the most significant of the challenges is the difficulty of offering high quality, instructor led, lab experiences over distance. Another challenge is to achieve this at a low cost. A solution to these problems would be a low cost, physical laboratory kit that each distant learning student would receive upon entry into the pertinent course/program. The utilization of laboratory kits to conduct electronics and or circuit labs is not a novel idea. In fact, several colleges and technical institutes have used this for years. The novelty of our approach is that the kits are retrofitted with miniaturize high quality instruments similar to the equipment in a typical undergraduate circuits lab. These instruments include oscilloscope, power supply, signal generator, and multimeter. In addition, the kit is equipped with video cameras (webcam) and audio communication devices to facilitate real-time interaction with student and instructor or with student and his/her lab partner. This portable stand-alone kit is able to connect to the Internet via Wi-Fi or ethernet cable. The novelty of this proposed lab kit is its ability to facilitate real-time interaction with multiple people as they conduct their experiments, and to enable this at a low cost. The proposed lab kit is a potential solution for achieving real-time lab group collaboration among electrical engineering and/or electrical engineering technology distant education students.

Background

There are typically four methods in which hands-on laboratory experience can be incorporated into the distant education curriculum. The first method is to supply the student with a laboratory kit via the postal system. The student then would be required, after limited assembling of the kit, to perform the experiments by his/herself, without interaction with others, based on written instructions. Assessment of learning is done through the evaluation of the results reported by the student, which is submitted to the instructor via snail mail or electronically. The main problems with this approach are: 1) the pedagogical approach does not encourage nor facilitate collaboration, hence the students have to conduct their experiments on their own with little or no interaction with other students or the instructor, 2) typically, the kits do not have advance instruments such as oscilloscope and if they do, the instruments are typically not custom-designed and optimized for the kit, and 3) from the instructor perspective there is no way to confirm whether the student actually conducted the reported experiment or it was done by someone else.

The second method allows students to gain laboratory experience by utilizing software tools. Students would be required to set up their circuits and conduct the experiments using simulation software such as LabView, MultiSim, and PSpice. Assessment is done by the evaluation of the results of the experiments reported by the student. The lab reports are usually submitted electronically via the Internet. As with the previous mentioned method, there is little interaction with other students or the instructor. There are many studies whose findings gives strong support for the pedagogical effectiveness of simulation software. There are even some that suggests that there are comparatively little or no difference in students' performance when a comparison is made between groups of students who conducted the lab with physical devices and those that used simulation. However, there are other studies that seem to suggest the opposite. Some researchers suggest that if labs are conducted using simulation only then the students will not develop important knowledge and skills. For instance, students who performed their labs in a physical electrical circuits laboratory gain valuable experience in wiring and troubleshooting circuits that cannot be gained through simulation[1,2] . In electrical engineering technology students are expected to develop practical skills during their undergraduate experience such as the ability to test concepts, prototype design, work in teams, operate electrical instruments, learn by trial and error, and perform analysis on experimental data[3]. It is difficulty, if not impossible, to accomplish all of this without physically interacting with equipment in a collaborative manner. Also, without the opportunity to develop these skills and gained these experiences the laboratory work would be rendered useless.

The third method is to utilize strategically located remote (satellite) physical laboratories. This approach has limited use since it becomes very expensive if students are not densely located in a particular region. This may be a useful method for international outreach where the students have the opportunity to conduct their labs at a local college's physical facilities. Domestically it may require lots of paperwork to get agreement with multiple institutions to ensure that all the students have access to a nearby laboratory facility. This can be quite cumbersome administratively and very costly to execute efficiently.

The fourth method was introduced by MIT's iLAB- remote online laboratories. "iLab is dedicated to the proposition that online laboratories-real laboratories accessed through the Internet can enrich science and engineering education by greatly expanding the range of experiments that students are exposed to in the course of their education" [4] . This approach allows students all over the world to interact with real lab equipment via the Internet. Students are able to control the equipment and direct various cameras as they conduct experiments. The lab resources are limited; therefore, it is necessary to schedule students according to available time slots. This iLAB allows students the opportunity to interact with sophisticated equipment that under normal circumstances they would never be able to operate. This approach is useful, particularly because it provides an opportunity for students in developing regions such as Asia and Africa to be exposed to expensive cutting edge equipment. However, the inherent cost of this approach prohibits wide scale adoption. Also, more research is needed to assess the pedagogical effectiveness of this approach.

It is accepted that laboratory exercises are necessary for students in electrical engineering and electrical engineering technology to gain an understanding at the component level and how to troubleshoot [5]. To increase access to engineering, educators need to get more innovative in how and via what media these exercises are introduced. There are various home lab kits for college level courses that have been proposed. This includes lab kits that covers experiments in electrical circuits and solid-state electronics and uses devices such as operational amplifiers, diodes, BJTs, and MOSFETs [1]. With take home lab kits there is no need for a big lab room, it relaxes the schedule constraints of professors and students giving greater flexibility and allowing students more time to gain hands-on experience [6,7].

Improvements and desirably features for home-based kits have been documented in the literature. Some of these are listed as follows:

- A common suggestion was the addition of audio communication[3].
- It should be relatively inexpensive [8].
- Students should be trained in the proper use and maintenance of the kit [8].
- Should be designed such that students can easily replace certain parts if broken or lost [8].
- The major requirements for home lab kits are that they are able to demonstrate fundamental engineering principles, portable, relatively compact (small), user friendly, inexpensive and easily assembled [9,10].

Proposed Lab Kit

Guided by the documented recommendations in the literature a portable, collaborative, electronics lab kit suitable for electrical circuits and electronics courses in electrical engineering and electrical engineering technology is proposed. The proposed lab kit has the following features/characteristics.

- Inexpensive
- Easy to assemble

- Supplied with user training manual
- Equipped with bread-board for students to prototype and test circuits
- Retrofitted with high quality miniaturize test instruments and equipment, including oscilloscope, power supply, signal generator, and multimeters.
- Has audio and video capabilities to facilitate online collaboration with multiple people simultaneously
- Connects to the Internet via Wi-Fi or ethernet.
- Two webcams to enable the display of more than one views
- Enclosed in a sturdy briefcase-like metal casing for easy carry
- Electrical component storage area

The proposed lab kit was designed to minimize the cost for the learning institution as well as for the student [11]. A common fear expressed by educators about home-based lab kits is that they may not measure up pedagogically speaking to existing on-campus laboratories, especially in light of satisfying ABET accreditation requirements[7]. Primary expectations for any engineering/engineering technology program is that students learn how to use test instruments, develop problem-solving skills and demonstrate the ability to work in teams. Hence, the inclusion of video, audio and Internet capabilities in order to facilitate real-time collaboration with lab partners and/or instructor.

The distance learning lab kit facilitates real-time communication using Skype internet-based software platform. Skype was chosen because of the extensiveness of its current call features and its low cost (it is free for one-to-one communication over the internet). With the premium version of Skype more than two people can participate in a video conferencing session. With the Skype interface you can choose which webcam to select as well as mute your microphone. We envision several modes of collaboration among students and between students and instructor. For example, one scenario could be the students conduct the lab and display their results in real-time to the instructor. The lab instructor would have a webcam enabled as well as his microphone on. The lab instructor monitors the student's progress while watching their cameras that are streaming the video of inside their lab kit. While working the students will have their microphones muted so as not to disturb others or cause background noise. When a student has a question he or she will simply turn on the camera positioned towards his/her face and wait to be called upon and then unmute their microphone to be able to ask a question.

Particular attention was paid to the overall cost of building and maintaining the lab kit. In Table 1, a price list is provided with actual pricing as of the writing of this paper. It was a requirement that the lab was not costly to build or maintain, so that if an instrument got damaged it would be inexpensive to replace. Without the LCD displays and the necessary interface for Internet connectivity, we estimate the cost of the laboratory kit to be roughly three hundred dollars (Table 1). It is proposed that a microcontroller, for example an 8051 microcontroller or Arduino board, be used to facilitate Internet connectivity and interfacing among the respective webcams and display screens. Various devices exist commercially to allow 8051 microcontrollers and/or Arduino board to connect to the Internet via Wi-Fi or Ethernet. It is conservatively estimated that the devices required to allow real-time collaboration (microcontroller with Internet connectivity and properly interfaced display screens) will cost an additional $200 dollars. Thus, making the total cost of the lab kit to be approximately $500. This would satisfy the objective of providing an inexpensive lab kit.

It is intended that the lab kits be preassembled and the instruments properly tested before sending them to students, or designed in such a way as to keep the assembling required to a minimum. In addition, electrical components could be packaged and sent along with the kit as required to complete the set of labs.

Table 1: Price list for laboratory kit

Oscilloscope	$79.59
Digital Multimeter	$49.99
Breadboard (x2)	$36.95
Function Generator	$47.00
Wire Kit	$16.99
Probe Kit	$12.90
10Mp webcam	$29.99
Metal box	$20.00
Power Strip	$11.99
5 Piece Basic Soldering Kit	$10.99
Total	$305.40

Figure 1 shows a SketchUp drawing of the proposed laboratory kit. The dimension of this is approximately the size of a standard attaché case. All the miniaturized instruments included have dimensions so that they fit easily into the metal casing, with extra space for wire/components. The display would be integrated in such a way as to show the lab partner/instructor at the other end of the connection. It is assumed that the display would have split screen (picture-in-picture) capability. Note also that the webcams position is adjustable. Figure 2 shows a bird eye view of the lab kit.

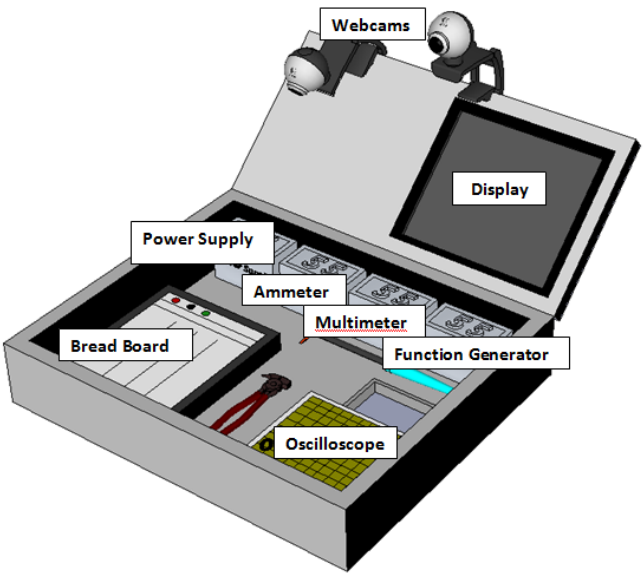

Figure 1: A view of the proposed lab kit

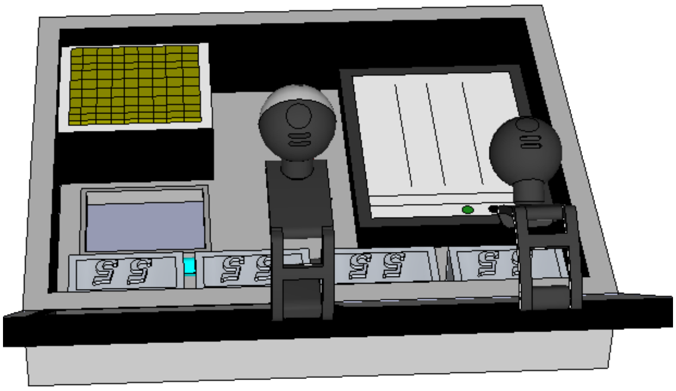

Figure 2: A bird's eye view of the lab kit

Conclusion & Future Work

The conceptual framework for a low cost, collaborative and portable electronics laboratory kit was presented. It possesses the features required for ease of use and pedagogical effectiveness. This can potentially facilitate rapid expansion of online electrical engineering/electrical engineering technology programs by providing a suitable collaborative distance education platform for conducting circuits and electronics experiments. It is the intention of the author to further investigate the feasibility of this lab kit through prototyping and testing.

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