New Laboratories for an Electrophysiology Lab Course in English and Spanish

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Abstract – Biomedical engineering and health sciences are two of the fastest growing fields for new job creation. Demographics demand new technologies and personnel to deal with an aging population. New innovative, affordable teaching tools are required to train a new generation of workers for these high-tech 21st Century jobs. An innovative laboratory course was developed to integrate wireless electrophysiology systems with a hands-on learning approach. The lab course is available in either Spanish or English.

Six new laboratory sessions were added since the PAHCE presentation in 2006, bringing the total to 31 laboratory sessions in four areas: basic data principles, basic physiology, advanced physiology, and clinical applications. In addition to the six new labs, this latest version of the educational laboratory course system, CleveLabs 6.0 by Cleveland Medical Devices Inc. (CleveMed), includes software upgrades and new transducer accessories.

CleveLabs is a lab course that, through hands-on experience with bioinstrumentation hardware and transducers, educates students on instrumentation, electrophysiology and clinical applications. Labs are designed for students at all levels from high school to the graduate level in biomedical engineering, the health sciences and basic science education. Students can perform each of the new labs using the medical-grade BioRadio® 150, a 12 channel data acquisition monitor that views and records physiological signs, such as electrocardiogram (ECG), electroencephalogram (EEG) and electromyogram (EMG), electro-oculogram (EOG), polysomnogram (PSG), as well as transducer inputs such as airflow, force, blood pressure, oximetry, and more.

Keywords – Biomedical Engineering, Health Sciences, Electrophysiology, Education, LabVIEW, Laboratory Course, Data Acquisition, Wireless

INTRODUCTION

The demand for health services (HS) workers and biomedical engineers (BME) reflects the large social and economic impact of the worlds aging demographic. The United States Department of Labor reports that the number of HS &BME jobs will increase much faster than the average for all occupations through 2014.[1] The demand for more sophisticated medical equipment and procedures and for people who can develop and operate the new technology will require a whole new generation of workers, trained in biology and electrophysiology.

BME & HS play an important role in affecting outcomes for medical disorders and rehabilitation needs. Thus, BME & HS education has a responsibility to effectively prepare students to approach and solve the health problems that come as a result of an aging society.

It is important for BME & HS students to first understand data acquisition and physiological fundamentals and application of these fundamentals to clinical problems. Utilizing the most advanced wireless electrophysiology equipment in a laboratory setting improves students' experience and interest in their field. As a consequence there is an increased need for applied learning focused on the latest clinical, industrial, and research applications. Once students understand how fundamentals can be applied to satisfy wide-ranging health and rehabilitation needs, they gain a better appreciation for biomedical theory.

Table 1 CleveLabs provides 31 laboratory sessions; schools may present or omit selected sessions to fit their curriculum. (*2007 new labs in italics.*)

Basic Data Principles	**Advanced Physiology**
Data Acquisition Basics	Blood Pressure
Digital Signal Processing	Electromyography II
Statistical Analysis	Electrocardiography II
Image Processing*	Electroencephalography II
Wireless Medical Telemetry	Polysomnography
Breadboard Circuit Design	*Pressure Based Airflow*
Accelerometry	*Pulse Oximetry*
Post-Processing Toolbox	Speech Recognition
	Spirometry
Basic Physiology	*Biomechanics*
Biopotential Basics	**Clinical Applications**
Electrocardiography	Alertness Detection
Electroencephalography	Biofeedback
Electromyography	Environmental Controls
Electrooculography	Gait Pattern Recognition
Respiration	Heart Rate Detection
	Motor Control
* Available as an option	Student Designed Lab

The National Science Foundation recently reported that engineering education should include “integrative laboratory experiences that promote inquiry, relevance, and hands-on experience.”[2] The Tulane BME study reported that students preferred to receive information visually (preferred by 88% of the student sample) rather than verbally, focus on sensory information (55%) instead of intuitive information, process information actively (66%) instead of reflectively, and understand information globally (59%) rather than sequentially.[3] The course was designed to incorporate all of these learning preferences.

Table 1 shows the 31 sessions for the BME & HS laboratory course platform that successfully integrated basic data principles, basic physiology, advanced physiology, and real world clinical applications to better train and challenge BME & HS students. This innovative laboratory course has been implemented into the curriculum at a score of universities.

The six new labs are in Biomechanics, Wireless Medical Telemetry, Breadboard Circuit Design, Accelerometry, Pressure Based Airflow, and Pulse Oximetry. Several features were also added to the software, including an upgrade to the save data features, making it easier to create lab reports. Additional transducers were added to the list of accessories, including a force plate and a breadboard design kit. The CD text can be purchased in either English or Spanish.

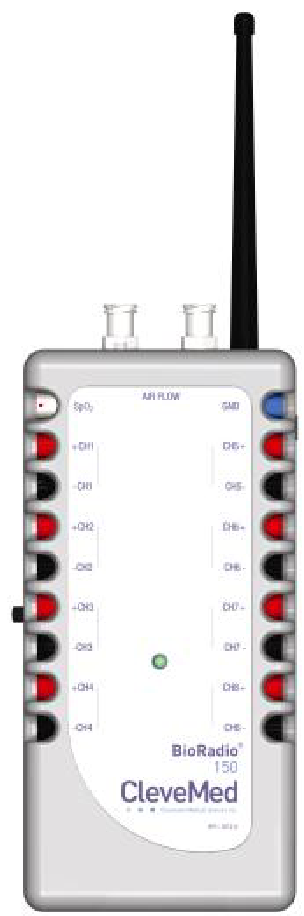

Figure 1 The BioRadio 150

A. CleveLabs Course Hardware

The BioRadio® 150 (**Figure 1**) is a lightweight, wireless physiological monitor with 12 channels. In addition to eight programmable electrophysiology channels, the device also has a digital input (usually used for a pulse oximeter), a DC input (frequently used for inputs such as a oral/nasal temperature thermistor, CO_2 sensor, respiratory effort belt, spirometer, blood pressure cuff, or other low-frequency sensor), an air pressure sensor, and a built-in accelerometer to determine body orientation or accelerations on the device.

The BioRadio 150 hardware was developed as the hardware platform for integration into the laboratory course system to meet the needs of, and to maximize flexibility for, different schools and their education focuses. Its small size saves laboratory space and allows any room with a computer to become a BME or HS laboratory. Additionally, its wireless design removes cumbersome tethered leads and increases the flexibility of potential locations and applications, allowing for studies to take place anywhere, from the sports field to the KC-135 "Vomit Comet" for zero gravity testing. With a laptop computer, the battery operation allows the lab to be performed even where there is no electric power.

Figure 2 CleveLabs Laboratory Course allows students to have hands-on experience acquiring biological data.

The subject-worn unit includes eight channels of programmable physiological inputs. Each channel can be programmed for a particular input range, sampling rate, resolution, and AC or DC coupling so that many types of signals can be monitored with the same device. For example, potential input signals for each channel include (but are not limited to) electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), and electro-oculography (EOG).

The subject-worn unit amplifies, digitizes, and telemeters data to a computer located up to 70 meters from the subject (or 25 meters though two walls indoors). A computer unit connected to the student computer via a USB port receives the telemetered data. The two-way communication protocol allows data packets to be retransmitted if necessary. This hardware platform exposes students to state-of-the-art technology compared to traditional rack- or bench-mounted amplifiers and filters.

B. CleveLabs Course Software

The BioRadio 150 hardware interfaces with National Instrument's LabVIEW™ graphical user interface software through a BioRadio LabVIEW driver. The driver utilizes a dynamically linked library to stream data from the computer serial port directly into LabVIEW, with no requirement to purchase LabVIEW. The LabVIEW programming language is a popular tool in education, research, and industry for data acquisition software and virtual lab system controls. Thus it provides a familiar environment for users to intuitively operate the course application software and also to design their own laboratories (**Figure 2**). Virtual instruments facilitate problem solving and decision-making. Sub virtual instruments (VIs) were designed for integration into the Windows-based programming language for starting, reading data, and stopping. The sub VIs were used in the course application software as well as in example development libraries to support student-designed software. In addition to the LabVIEW libraries, separate driver libraries were also created for use in MATLAB®.

C. CleveLabs Curriculum

Wide-ranging laboratory topics are available to introduce students to several areas of interest. These areas (basic data principles, basic physiology, advanced physiology, and clinical applications) allow each school and instructor, at each education level, to select the topics that are appropriate for them. Initial laboratory sessions introduce the basics of data acquisition and processing and the physiological mechanisms underlying the recorded signal, teach students how to acquire data from themselves, and demonstrate effective physiological signal processing. Intermediate sessions introduce abnormal clinical signals. Later sessions apply the signals in clinical applications. Each laboratory session incorporates detailed setup instructions and user-friendly features for saving, analyzing, and reporting results. Students process and analyze signals both in real-time and offline. The clinical labs allow students to be introduced to looking at clinical problems such as: using biofeedback as a mechanism to improve relaxation or sports performance, evaluating heart rate detection for diagnosing cardiac problems, and using gait pattern recognition to help diagnose disease. The labs also introduce the students to leading edge research such as motor control of robotics, and using human-computer interfaces to control a computer or the patient's environment.

The laboratory course minimizes overhead time associated with hardware setup, equipment troubleshooting, and data management, while maximizing the time spent critically analyzing and applying collected data. Finally, the course integrates learning styles shown effective for most BME & HS students including active, sensing, visual, and global learning.[3]

The CleveLabs system has been implemented at many US universities, including the University of Southern California, the University of Toronto, Case Western Reserve University, Bucknell University, Stevens Institute of Technology, and Lake Forest College (LFC). It is also being used in locations as diverse as New Zealand, Malaysia, South Africa, and the United Kingdom.

D. New CleveLabs Laboratories

The Wireless Medical Telemetry Lab: Wireless medical telemetry offers the advantage of obtaining accurate physiological signals from freely moving, un-tethered patients. Students are familiarized with the electromagnetic spectrum. A wireless medical telemetry device, as defined by the US Federal Communications Commission (FCC), is a device that transmits physiological signals via radio frequency (RF) from a transmitter worn by the patient to a remote receiver.

The Wireless Medical Telemetry lab illustrates basic wireless medical telemetry principles. Transmitter and receiver characteristics, data transmission, communications algorithms, and telemetry bands are discussed. The BioRadio 150 is used to scan for devices operating in the same Instrumentation, Scientific, and Medical (ISM) Band (**Figure 3**). Students learn the tradeoffs between fixed frequency and frequency hopping modes.

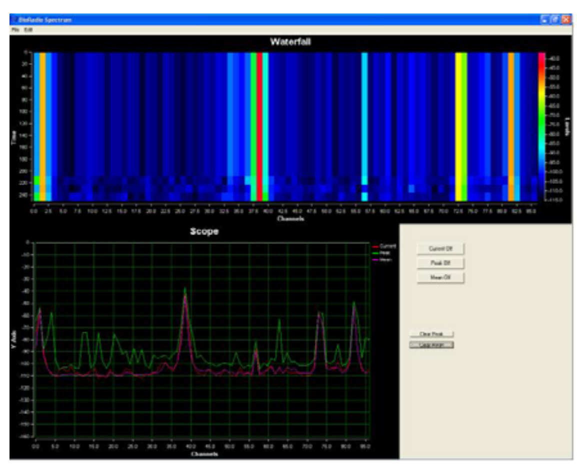

Figure 3 The BioRadio can be used as a spectrum analyzer. In the Wireless Medical Telemetry Lab, students determine which frequencies are being used in their area.

The Breadboard Circuit Design lab: The Breadboard Circuit Design lab provides students with hands on design and breadboard fabrication experience. They build several types of signal generator outputs and use them as inputs into the BioRadio 150. Students examine the effect that changing components has on amplitude and frequency of the signal. **Figure 4** shows the output of their signal generator.

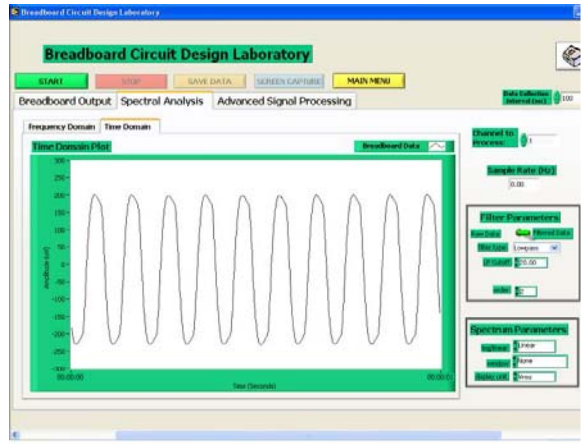

Figure 4 The output of the student fabricated bread-board signal generator is displayed and evaluated.

Biomechanics Lab: The Biomechanics lab explores the length-tension and force-velocity relationships of muscles. During this laboratory session, electromyography is be used to detect leg muscle contractions during jumping. A force plate quantifies the force generated during the different phases of a jump. Combining the two inputs, students see which leg muscles are active during the different phases of jumping, and how the different properties of muscle impact the ability to jump. (See **Figures 5 and 6**).

Accelerometry Lab: For this laboratory session, students use a two-axis Micro-Electrical-Mechanical Systems (MEMS) accelerometer that is embedded inside the BioRadio150. These accelerometers sense a change in electrical capacitance by the movement of a capacitor plate during applied accelerations. The displacement of the capacitor plate creates an output voltage that corresponds to the applied acceleration. In this lab session, students first measure the EMG activity of the carpi extensor (wrist extensor) and palmaris longus (wrist flexor) muscle groups during certain activities. Then students familiarize themselves with the accelerometer function of the BioRadio. Students then perform spectral analyses, and see data in both the time domain and frequency domain, observing the spectral content of the signal and understanding the relationship between the muscle activity and the axis and amplitude of acceleration.

Pressure Based Airflow: Measuring airflow is extremely important for many applications. For example, airflow measurements can provide important insight into sleep-disordered breathing.

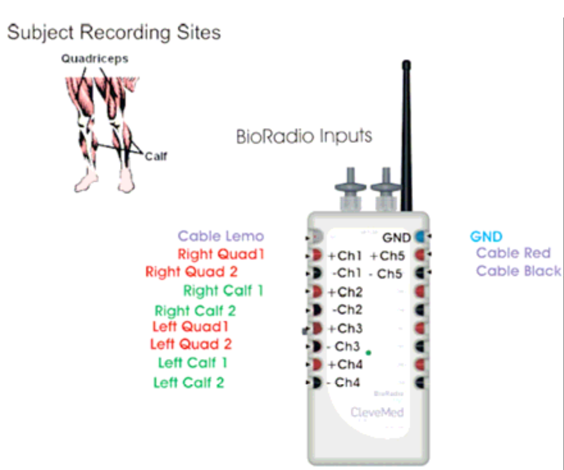

Figure 5 Every lab details the setup. The Biomechanics lab shows how to instrument leg muscles and a force plate to be able to show length-tension and force-velocity relationships of muscles during jumping.

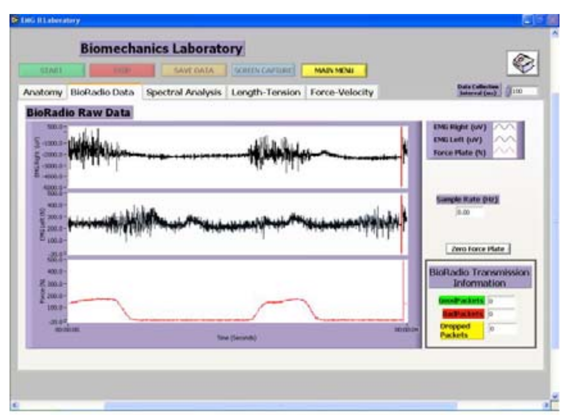

Figure 6 EMG is compared to the force plate readings in the Biomechanics lab.

This laboratory session uses pressure based airflow measurements. The BioRadio 150 unit has a small semiconductor based pressure sensor embedded inside the unit. The plastic outlet port at the top of the BioRadio (see Figure 1) is internally connected to the input of the pressure sensor. Air that the student inhales or exhales during respiration is routed to the pressure sensor via a plastic cannula. The change in pressure is output as a change in voltage recorded by the BioRadio. By monitoring the pressure, the student can determine her own breathing pattern.

Pulse Oximetry Lab: Measuring the arterial oxygen saturation (SpO_2) levels of patients is very beneficial to healthcare providers and has, in the past 20 years, become one of the most vital and easiest parameters to obtain and analyze. SpO_2 levels can provide valuable information including the efficiency of pulmonary gas exchange and the adequacy of alveolar ventilation, blood-gas transport, and tissue oxygenation. Pulse oximetry is a non-invasive method to determine SpO_2 by utilizing light emitting diode (LED) technology to measure the differences in red and infrared light absorption or reflection of oxygenated and deoxygenated hemoglobin. Since its inception, pulse oximetry has become a standard in the clinical environment because of its ease of use and the importance of the information it provides. In this laboratory session, students obtain heart rate, SpO_2, respiration effort, and one channel of electrocardiography (ECG) data in order to gain a better understanding of the basics of pulse oximetry.

CONCLUSION

A true 3rd generation[4] electrophysiology lab course has been created and now expanded with six new labs. It incorporates wireless biotechnology and programmable gain amplifiers; and it records signals on its 12 channels while integrating engineering & medical sensors. Its flexible design interface allows schools to use LabVIEW™ or MATLAB® drivers. Positive feedback was obtained after the course was inserted into the curriculum at a number of universities. "Advantages of CleveLabs include the scope of different modules and course design flexibility. Although many canned software sessions ranging from engineering principles to advanced physiology are provided, it is also flexible and offers an easy interface to MATLAB. You do not want to spend a lot of time on software issues; CleveLabs allows students to concentrate on the sensor and instrumentation content."[5] "I am a first year professor, and to have CleveLabs here is wonderful."[6] "The students appreciate the more general relevance of this experience for important aspects of their future in a technical world, including careers, medicine and graduate school."[7]

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[1] Bureau of Labor Statistics: **http://www.bls.gov/oco/cg/cgs035.htm** and **http://www.bls.gov/oco/ocos027.htm#emply**

[2] Meyers, C. and Ernst, E. "Restructuring engineering education" A focus on change, " Division of Undergraduate Education Directorate for Education and Human Resources, National Science Foundation, Report on NSF Workshop on Engineering Education., 1995.

[3] Dee, K.C., Nauman, E.A., Lievesay, G.A., and Rice, J. "Research Report: Learning Styles of Biomedical Engineering Students", Annals of Biomedical Engineering, Vol.30, pp.1100-1106, 2002.

[4] 1st generation being the development of instrumentation amplifiers to measure physiological signals; 2nd generation being the use of manufactured table-based electrophysiology equipment without inclusion of clinical applications.

[5] Patrick Craigo, PhD, Chairman, Biomedical Engineering, Case Western Reserve University.

[6] Joseph V Tranquillo, PhD, Biomedical & Electrical Engineering, Bucknell University.

[7] Robert Glassman, Ph.D., Chair, Psychology Lake Forest College.