Full Paper: A First-Year Electronics Lab Project—Design of Basic Voltmeter plus Soldering Tutorial

Dr. Rod Blaine Foist, California Baptist University

Rod Foist Professor (and IEEE student club advisor), Electrical and Computer Engineering, Gordon & Jill Bourns College of Engineering, California Baptist University, rfoist@calbaptist.edu

Dr. Xuping Xu, California Baptist University

Dr. Xuping Xu is currently professor and chair of the Department of Electrical and Computer Engineering at California Baptist University. He received B.Sc. degrees in electrical engineering and applied mathematics from Shanghai Jiao Tong University, Shanghai, China, in 1995. He received M.Sc. degrees in electrical engineering and applied mathematics, and the Ph.D. degree in electrical engineering from the University of Notre Dame, Notre Dame, IN, in 1998, 1999, and 2001, respectively. In 2008, Dr. Xu joined the Gordon and Jill Bourns College of Engineering at California Baptist University. Between 2001 and 2008, he was an assistant professor and subsequently an associate professor in the Department of Electrical, Computer and Software Engineering at Penn State Erie, Erie, PA. His research interests include systems and control, hybrid and embedded systems, digital design, software/hardware enabled control applications, algorithms and optimization. He has published 18 journal papers, 39 conference papers, and 4 book reviews in the above areas. Since 2008, Dr. Xu has been serving as the assessment coordinator of the College of Engineering. He is a senior member of the IEEE and has been an associate editor on the Conference Editorial Board of the IEEE Control Systems Society. He also actively serves as a reviewer for a number of journals and conferences.

Mr. Timothy Gage, California Baptist University
Seth Truitt, California Baptist University
Mr. Matthias Hans Schmidt

A First-Year Electronics Lab Project—Design of Basic Voltmeter plus Soldering Tutorial

Rod Foist, Xuping Xu, Timothy Gage, Seth Truitt, and Matthias Schmidt
California Baptist University, rfoist@calbaptist.edu, xxu@ calbaptist.edu, MatthiasHans.Schmidt@calbaptist.edu, TimothyDean.Gage@calbaptist.edu, Seth.Truitt@calbaptist.edu

Abstract **- Recent National Science Foundation (NSF) research, aimed at improving the Electrical and Computer Engineering (ECE) curriculum across all four years, makes strategic use of laboratory projects. The "spiral model", adapted from other research, introduces certain lab component *themes* (in the freshman year) and revisits them with increased sophistication and interconnection in the following years. Thus, labs are used as a "cohesive framework" that connects and integrates individual courses. The three themes used in this research are centered on video (and image), sound, and touch sensors. In this paper, and a companion paper, we present our own design of two new lab projects (within the video/image theme). Specifically, this paper reports on the design of a microcontroller-based voltmeter with measured voltage values shown on a liquid crystal display (LCD). The companion paper presents the design of a Field-Programmable Gate Array (FPGA)-based embedded processor to control an LCD. Both projects can include a soldering tutorial/review session—and simple videos were made to illustrate soldering of the voltmeter components. The contribution of this paper is to provide a fully-working, easy-to-use, first-year lab project within the video/image theme of the spiral model approach to improving the ECE curriculum. The project design code will be made available for downloading on the internet, via the Bitbucket web-hosting service, and the soldering tutorial videos via YouTube.**

Index Terms – Electrical and Computer Engineering curriculum improvement, Electronics lab project, PSoC 4 microcontroller, Voltmeter with LCD.

INTRODUCTION—RECENT RESEARCH USING LABS

Recent National Science Foundation (NSF) research by Chu [1], aimed at improving the Electrical and Computer Engineering (ECE) curriculum across all four years, makes strategic use of laboratory projects—to enhance student learning and better prepare graduates for new challenges. The viewpoint given is that a good engineer must not only become knowledgeable in certain content areas (*components*, learned in individual courses), but also be able to apply and *integrate* that content to solve complex, real-world problems (or challenges).

Chu's work is motivated by an earlier 5-year study of engineering education [2] which found a deficiency in the curricula: subjects are taught in isolation, without proper context, and do not adequately prepare students to integrate that knowledge. In addition, labs were not used effectively. That study recommended a "spiral model" and effective use of labs (as design projects):

"… *the ideal learning trajectory is a spiral, with all components revisited at increasing levels of sophistication and interconnection. Learning in one area supports learning in another*." [1]-[2]

Brief "Book Highlights" of the study, available online, compares a "linear components" curricular model to their proposed "spiral model"—using two helpful diagrams [3].

Chu's work employs the spiral model by introducing certain lab component *themes* (in the freshman year) and lays out a plan to revisit them with increased sophistication and interconnection in the following years. Furthermore, it emphasizes design projects—because they can effectively "approximate professional practice", enhance knowledge synthesis, build teamwork, and even encourage student persistence. Thus, motivated by the spiral model, labs are used as a "cohesive framework" that connects and integrates individual courses. The three themes used in this research are centered on video (and image), sound, and touch sensors. Note that these are the main interface subsystems used in modern hand-held devices, such as smart phones.

The faculty authors acted as external collaborators for the principal investigator by implementing and testing new lab projects within two of our existing courses over a two-year period—a second year digital logic design course and a senior course in advanced digital design. In addition, some of this work has been used in our third-year microcontroller course and in our IEEE student club. That experience inspired us to see the benefit of creating lab projects which can be useful across the ECE curriculum to provide a cohesive framework and enhance learning. For example, students are exposed to lab projects using visual feedback (LEDs and LCDs) in all four years—but with more complexity introduced in each year.

In this paper, and a companion paper, we present our own design of two new (first-year) lab projects (within the video/image theme). Specifically, this paper reports on the design of a microcontroller-based voltmeter with measured voltage values shown on a liquid crystal display (LCD). The companion paper presents the design of a Field-Programmable Gate Array (FPGA)-based embedded processor to control an LCD. Both projects can include a soldering tutorial/review session—and simple videos were made to illustrate soldering of the voltmeter components.

Overall, we found that students really enjoyed creating hands-on lab projects that implement real-world electronic systems, and learning something of how the hardware and software components work together to create the desired functionality (a simplified voltmeter in this case). In addition, students indicated a lot of interest in learning and practicing soldering skills in building both of these projects.

The spiral model approach, in a broader sense, is also consistent with the growing interest in hands-on (or project-based) learning that is becoming widespread in engineering education. For example, The *STEM Lab Report* stated [4]:

"*Throughout higher education in engineering, colleges are requiring students to pull their gaze from a text-book to perform real-world, hands-on, team-based project learning. In short, they are teaching students to become engineers by having them work as engineers.*"

In a previous work [5], we concluded:

"…the key benefits of hands-*on approaches for students are better outcomes, seeing the relevance of math (and engineering) with real-world examples, deeper understanding, more enjoyment, and persistence in engineering.*"

VOLTMETER INTRODUCTION

The ability to measure voltage is a fundamental need within ECE and the engineering field in general. A digital multi-meter (or DMM), as shown in Figure 1, is a modern instrument (usually hand-held) that can measure voltage, current, and resistance, among other parameters. It is important for ECE students, in particular, to understand the basic analog and digital circuit concepts involved in the design of DMMs.

FIGURE 1
A DIGITAL MULTIMETER (THE FLUKE 115)—FOR MEASURING VOLTAGE, CURRENT, AND RESISTANCE.

Therefore, as a simple beginning, this paper presents a lab project for measuring only voltage—hence the name *voltmeter*—and only direct current (DC) voltage. Nevertheless, the design is based on the same key building blocks used within commercial DMMs—a *microcontroller* and an *analog-to-digital converter* (ADC) [6]. Figure 2, a block diagram of the overall voltmeter design project, shows these two blocks—labeled as "ADC" and "MCU" (microcontroller unit). In this paper, these blocks are implemented within the microcontroller-based Programmable System-on-Chip (PSoC) technology, described below.

MICROCONTROLLERS

A microcontroller (MC) is essentially a small computer on a "chip" (a microelectronic integrated circuit) [6]-[7]. It contains digital logic circuits—including memory blocks and peripheral circuits plus inputs and outputs (I/O)—which enable it to run software programs that are designed to have the MC control something. For example, some electric toothbrushes contain an MC to run the motor, keep track of time (make the motor stumble every 30 seconds to notify the user to brush a new section of teeth), and monitor battery charge with an LED as indicator.

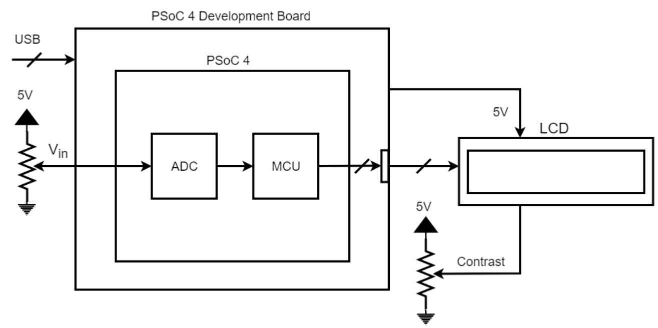

FIGURE 2
BLOCK DIAGRAM FOR DESIGN PROJECT: VOLTMETER + LCD.

I. Microcontrollers and Embedded Systems

Microcontrollers are often used as the *processor* within an *embedded system* [6]. An embedded system is "a computer system with a dedicated function" [8]. Thus, it requires an (embedded) computer (aka *embedded processor*) to control or implement the dedicated function. For example, the digital multimeter (mentioned above) is an embedded system—it contains a microcontroller that is programmed to measure voltage, current, and resistance [6]. In the broader context, embedded systems can control not only electrical, but also mechanical, chemical, and other types of devices.

In contrast to embedded systems, desktop (and laptop) computers are stand-alone, general-purpose computers with a *microprocessor* as the processor. Microprocessors are the original "computer-on-a-chip", but generally lack the peripheral circuit blocks which are built into a microcontroller especially for sensing and controlling other devices. Desktop systems—because they are physically large, relatively expensive, and general purpose (running almost any program)—cannot fulfill the needs of typical embedded systems (small, low-cost, single purpose, embedded processor).

Embedded systems are important to ECE because they impact all areas of modern life. For example, cell phones contain at least 5 MCs, automobiles have dozens, and homes may have hundreds [6]. Thus, the project presented here—as an embedded system, but also containing computer concepts—relates to important content within ECE.

ANALOG-TO-DIGITAL CONVERTERS

Analog-to-digital conversion is a widely-used technique for converting an analog signal to an accurate digital number that is proportional to the (voltage) amplitude of the signal, and vice versa [9]. An analog-to-digital converter (ADC) converts voltage to a digital number, whereas a digital-to-analog converter (DAC) constructs an analog voltage signal from a digital number.

PSOC—A MICROCONTROLLER PLUS MORE

As discussed in a previous FYEE paper [10], the Programmable System-on-Chip (PSoC) is a type of digital microelectronic circuit ("chip"), with a microcontroller core plus other special programmable electronic building blocks—both digital and analog. As shown in Figure 2, above, a *PSoC 4* device [11] is used in the lab project presented here. Note that the PSoC 4 provides both the MCU and ADC. Figure 3 is a photo of the small PSoC 4 circuit board used. See the Appendix for more details.

FIGURE 3
PSOC 4 CIRCUIT BOARD ("PROTOTYPING KIT").

HOW LCDS WORK

Liquid Crystal Displays (LCDs) are a type of "flat-panel display" which do not directly emit light [12]. Rather, they use a backlight or reflector to produce images using the light modulation capabilities of liquid crystals. Figure 4 shows a picture of a 16x2 (16-character by 2-row) LCD "character module"—as used in this project. LCDs are used in a wide variety of applications—as large screens (from LCD televisions to computer monitors), and as small screens (e.g. watches and calculators). They are useful for displaying information and images for electronic projects.

FIGURE 4
16X2 LIQUID CRYSTAL DISPLAY MODULE.

The Hitachi HD44780 [13], known as a "character LCD", has become a de facto industry standard LCD module which contains the LCD as well as a built-in controller and driver chips. The controller and driver components make the driving much simpler [14]. However, before sending character data to the display, a complicated initialization sequence—of electronic pulses and delays—must first be sent to the module to establish communication.

In our companion paper, mentioned above, an FPGA with embedded processor controls the LCD and handles the initialization process. In that case, the user (design engineer) must explicitly create the code for initialization (and that code was provided by the authors). In contrast, the PSoC 4 has a user-friendly and relatively simple way ("interface") to control HD44780-compatible LCDs, as will be described later.

THE "VOLTMETER + LCD" DESIGN PROJECT

I. Learning Objectives

The key learning objectives for this learn-by-doing project are:

- To understand basic microcontroller and PSoC 4 concepts—and see them in action.
- To understand the importance, usage, and basic control of an electronic display (LCD specifically).
- To understand that control of the LCD involves hardware (logic circuits) and software—thus a system (but that in using PSoC, the user only needs to manage the software).
- To gain preliminary experience in using the design software (*PSoC Creator*) which programs the PSoC 4 chip.
- To gain basic experience in building/connecting the PSoC 4 board and circuit components.
- To learn/practice soldering (of PSoC 4 and LCD headers).

II. Project Description

Figure 5 is a photograph of the completed and working project presented in this paper—indicating a voltage measurement of 4.998 V (displayed as milli-volts). Figure 2, above, is the block diagram for this design. The design consists of the PSoC 4 circuit board mounted on a breadboard and interconnected to an LCD and two potentiometers (variable resistors). Note that the PSoC 4 board does not have its own built-in LCD, but it can control an external one, with a few wires and components, and thus add a very useful display capability—for any project.

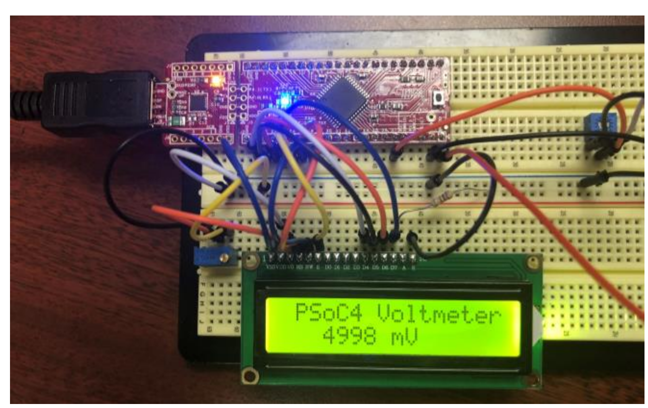

FIGURE 5

THE COMPLETE DESIGN PROJECT: PSOC-4 VOLTMETER + LCD.

In the upper left of the block diagram, a Universal Serial Bus (USB) connection provides the means to program the PSoC 4 board and supplies 5V power to it. This voltage is supplied in turn to the LCD and to both potentiometers. The left-hand potentiometer provides V_{in}, the "unknown voltage" (varies from 0-5V), which must be converted by the ADC into a digital number. The MCU processes that number and displays it on the LCD as shown.

The right-hand potentiometer provides a voltage to control the LCD's contrast. This contrast is necessary to make the letters "dark enough" to be seen against the general background. Please note that if the user does not set this properly, he/she may spend much time troubleshooting why the design is not working, only to find out that the potentiometer has not been "tuned" properly.

III. Lab Steps

- Instructor provides some sort of pre-lab tutorial information (could be the contents of this paper), and possibly some pre-project lab practice.
- Lab manual should list the steps to build this "kit" (on-line project code web-link is provided with this paper): 1) download and unzip the *PSoC Creator* project code, 2) assemble/connect the board and LCD circuitry, 3) open the *Creator* project and follow the steps to program the PSoC 4 chip, 4) Verify that the design is working—message appears on LCD (similar to Fig. 5), plus turning the proper potentiometer should cause the displayed voltage value to vary from 0V to 5V.
- Students can now make simple modifications to the C program (within the *Creator* editor) so as to change the message (such as put their name in it—"Jim's Voltmeter"), then re-program the board and verify.
- We like to have students work in teams of two, but each student must build their own project, while consulting their lab partner if desired.

IV. Revisiting the Project in Second to Fourth Year Courses

In freshman year, this project is mostly just the building of a "kit", and doesn't require much design work. But each year, course work (and labs) should give students more and more opportunity and responsibility to design additional functionality onto the original implementation—so as to train-by-doing into "professional practice". Here are some potential more sophisticated versions of the project—moving toward designing a roughly "full-featured" DMM:

- Sophomore year—learn to upgrade the original design so as to also measure current (like commercial DMMs).
- Junior year—upgrade the sophomore design so as to also measure resistance.
- Senior year—upgrade the junior design so as to make an auto-ranging capability for the "DMM"; and possibly also add the ability to measure negative voltages, as well as the original positive voltages.

SURVEY RESULTS AND STUDENT FEEDBACK

As mentioned above, the faculty authors acted as external collaborators for the principal investigator by testing some new lab projects within two of their existing courses (in 2016 and 2017). These labs employed aspects of the three themes (image, sound, touch) from the spiral model. One of the courses was a senior-level electronic design course using FPGAs. A special student survey was conducted at semester's end (only for the senior course). Six selected questions are analyzed here:
1) *The lab work I do for this course is relevant to my learning*,
2) *Learning the content in this course will help me get a good job*,
3) *The labs for this course show me how to problem-solve in Electrical and Computer Engineering*,
4) *The labs in this course make the content more understandable*,
5) *I enjoy doing the labs for this course*,
6) *Doing the labs shows me real life applications of the information*.
Possible responses (with numerical values) were: Strongly Agree (5), Agree (4), Undecided (3), Disagree (2), Strongly Disagree (1). Table 1 summarizes the data.

TABLE I
STUDENT SURVEY RESULTS: SELECTED QUESTIONS—AVERAGE SCORE
(FROM A SENIOR COURSE USING THE "SPIRAL APPROACH")

Question	2016 (10 students)	2017 (8 students)
1	4.4	4.4
2	4.2	4.3
3	4.6	4.3
4	4.5	3.9
5	4.0	4.1
6	4.7	4.3

Overall, the table shows that students generally *agree* or *strongly agree* with each of the six questions about course labs. For example, question 1 (*The lab work I do for this course is relevant to my learning*) got an average response/score of 4.4 (out of 5.0 maximum) for both years—calculated by adding student response values (5 to 1) and dividing by the number of students. Thus, per the questions, on the whole, students find these labs to be relevant, helpful, and enjoyable in their learning.

Now this data only reflects positive feelings for labs in a senior-level course that was partly re-designed to include some spiral model aspects/themes. However, from this apparent success in effective labs, we extrapolate that redesigning earlier-year labs with the spiral model's recurring themes (e.g., using an LCD)—that become more sophisticated year by year—will enhance learning. Hence, in this paper we offer a freshman version of the "Voltmeter + LCD" lab with reasonable confidence that it will be effective across the full ECE curriculum by forming part of the "cohesive framework" that connects and integrates individual courses.

OPTIONAL SOLDERING TUTORIAL

This voltmeter project was first used this academic year at an IEEE student club meeting (which included first-year and above students). Interestingly, it was advertised as a "Voltmeter design plus soldering tutorial", and had a noticeably stronger turn-out than usual for our club. Students indicated afterwards that they really enjoyed both aspects of the project—learning to make a voltmeter and learning to solder.

Later, the project was introduced (as the new first lab) in a third-year microcontrollers course, and simple soldering tutorial videos were created by one of the authors—as part of a pre-lab assignment. Following the initial lab session, anonymous written surveys were given to students which included the question, "How did you feel about…the PSoC 4 voltmeter soldering lab?" The response was unanimously positive, with selected comments as follows: "Never soldered before, so I thought it was good", "Good lab, very helpful", "Awesome, so glad we had it", "I love soldering", "I love it! Fun hands-on learning experience", "I enjoyed this very much since no other course teaches soldering".

The soldering tutorial videos are available on YouTube [15]. Both the PSoC 4 board and LCD module are sold without the "headers" soldered in. These must be purchased for the board but may be included with the LCD. Altogether this involves having students solder about 50 pins.

Discussion and Conclusion

This paper presents a fully-working, relatively easy-to-use, first-year lab project within the video/image theme of the spiral model approach to improving the ECE curriculum. The project demonstrates a PSoC 4 microcontroller-based voltmeter design with measured voltage values displayed on an LCD. It includes simple soldering tutorial videos posted on YouTube. Design code and helpful documentation—which should help instructors to readily recreate this design—have been posted on the following Internet site:

https://bitbucket.org/CBUCoEFYEE2018

Although it is a relatively simple design project, its content addresses important material within the ECE curriculum—computers, microcontrollers, embedded systems, digital and analog circuits and a valuable system built upon them (a voltmeter). It also gives elementary experience with the software—both the tool to design the project (the PSoC 4 design software, called *Creator*) and the embedded C program (aka *firmware*).

Since we (the faculty authors) use microcontrollers and LCDs with both freshmen and senior students, we believe that this project makes a useful connection between first year introduction of "Microcontroller/Voltmeter + LCD" to more sophisticated versions of this design in second to fourth years of study. Since the project is based on the PSoC 4 microcontroller system, the topic could be easily "*revisited at increasing levels of sophistication and interconnection*" in the following years by extending the project into a full digital multimeter (DMM), as mentioned above. For example, the PSoC 4 could be used to measure current and resistance, and perhaps other parameters such as temperature.

Thus based on written student surveys and observing the general delight of students when building the projects, we believe this approach (spiral model plus themed labs across the four years), and this specific lab project, will be effective—in improving student learning and preparing graduates for new challenges.

Future Work

More first-year lab projects, within ECE, will be explored—drawing on all three themes of Chu's research: video/image, sound, and touch sensors.

Acknowledgment

We would like to acknowledge and thank our colleague, Dr. Pong P. Chu (Cleveland State University), for inviting us to participate in his National Science Foundation (NSF) research to improve the ECE curriculum. We also appreciate his excellent leadership, knowledge, and creativity—as an engineer, educator, and researcher. His work has greatly benefited us, and indirectly our students, we believe.

In addition, we thank the NSF for providing some funding to us in this work. Part of this material is based upon work supported by the IUSE program of the Division of Undergraduate Education of the National Science Foundation under Grant No. 504030. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Appendix: PSoC Details—For Setting Up The Project

As discussed, and shown in Fig. 2, the voltmeter design in this paper is implemented within the "PSoC 4" small prototyping circuit board made by Cypress [11]. Current price of this "kit" is $US 4. After soldering two sets of header pins (not part of kit) into the board, it can be mounted on a breadboard, as shown in Figure 5.

Cypress provides the (high quality, easy-to-use) design software (*PSoC Creator*) for free, downloadable from their website [16]. The PSoC 4 board can be directly connected to a PC's USB port, or by extension cable, to power the board and to allow the *Creator* software to program the actual PSoC 4 chip with the voltmeter design.

This PSoC 4 design (Creator schematic for Voltmeter shown in Fig. 6) was adapted from a Cypress Application Note: CE95280 [17]—which includes a zipped reference design file, to help a designer get started.

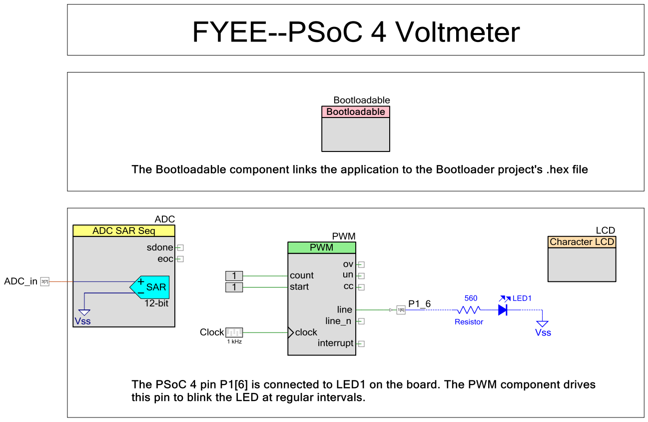

FIGURE 6
PSOC CREATOR (V. 3.3) SCHEMATIC FOR VOLTMETER DESIGN.

REFERENCES

[1] Chu, P.P., "Integrating Computer Engineering Labs with a 'Sound Theme' ", *Proceedings 2016 ASEE Annual Conference & Exposition*, June 2016.

[2] Sheppard, S., et al., *Educating Engineers: Designing for the Future of the Field*. Jossey-Bass, 2009.

[3] Sheppard, S., et al., *Educating Engineers: Designing for the Future of the Field*. Jossey-Bass, 2009, Book Highlights, http://archive.carnegiefoundation.org/pdfs/elibrary/elibrary_pdf_769.pdf; see Figures 1 and 2 on pages 9-10.

[4] Author not given, "Engineering and Hands-On Learning: Examining the Importance of Project-Based Learning in STEM Fields ", *The STEM Lab Report*, Vol. 7, April 2011, https://powerofdiscovery.org/stem-lab-report

[5] Foist, R.B. and Donaldson, A., "An Intuitive Calculus Project, Using Electronic Filters, for a First-Year Engineering Math Laboratory", *Proceedings 2014 First Year Engineering Conference*, August 2014.

[6] Valvano, J., *Embedded Systems: Introduction to ARM Cortex Microcontrollers, 5th Edition*, 2017, Chapter 2: Introduction to Embedded Systems

[7] http://en.wikipedia.org/wiki/Microcontroller

[8] https://en.wikipedia.org/wiki/Embedded_system

[9] Horowitz, P. and Hill, H., *The Art of Electronics, Second Edition*, Cambridge University Press, 1989, pp. 612-628

[10] Foist, R.B. and Donaldson, A., "An *Improved* Intuitive Calculus Project, Using Electronic Filters, for a First-Year Engineering Math Laboratory", *Proceedings 2016 First Year Engineering Conference*, July 2016.

[11] http://www.cypress.com/documentation/development-kitsboards/psoc-4-cy8ckit-049-4xxx-prototyping-kits

[12] https://en.wikipedia.org/wiki/Liquid-crystal_display

[13] https://en.wikipedia.org/wiki/Hitachi_HD44780_LCD_controller

[14] https://web.stanford.edu/class/ee281/handouts/lcd_tutorial.pdf

[15] Soldering tutorial videos (1-4)
https://www.youtube.com/watch?v=s0KaFXxevxE,
https://www.youtube.com/watch?v=XxCQu7HJSWc,
https://www.youtube.com/watch?v=xnToOGiWWG8,
https://www.youtube.com/watch?v=-hbBXbL16PU

[16] http://www.cypress.com/products/psoc-creator-integrated-design-environment-ide

[17] http://www.cypress.com/documentation/code-examples/ce95280-bootloadable-project-psoc-4

AUTHOR INFORMATION

Rod Foist Professor (and IEEE student club advisor), Electrical and Computer Engineering, Gordon & Jill Bourns College of Engineering, California Baptist University, rfoist@calbaptist.edu

Xuping Xu Professor, Electrical and Computer Engineering, Gordon & Jill Bourns College of Engineering, California Baptist University, xxu@calbaptist.edu

Timothy Gage Student (and IEEE student club officer), Electrical and Computer Engineering, Gordon & Jill Bourns College of Engineering, California Baptist University, TimothyDean.Gage@calbaptist.edu

Seth Truitt Student (and IEEE student club officer), Electrical and Computer Engineering, Gordon & Jill Bourns College of Engineering, California Baptist University, Seth.Truitt@calbaptist.edu

Matthias Schmidt Student (and IEEE student club president), Electrical and Computer Engineering, Gordon & Jill Bourns College of Engineering, California Baptist University, MatthiasHans.Schmidt@calbaptist.edu